Atlantic States Marine Fisheries Commission

Horseshoe Crab Management Board

October 17, 2017
9:45 a.m. – 12:15 p.m.
Norfolk, 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 *(M. Rhodes)* — 9:45 a.m.

2. Board Consent — 9:45 a.m.
   - Approval of Agenda
   - Approval of Proceedings from October 2016

3. Public Comment — 9:50 a.m.

4. Review Results of Eel and Whelk Bait Practices Survey (*R. Sysak*) — 10:00 a.m.

5. Consider 2018 Benchmark Stock Assessment Terms of Reference (*K. Anstead*) — 10:30 a.m.
   Action
   - Assessment Timeline
   - Data Confidentiality Procedures for the Assessment
   - Advisory Panel (AP) Recommendations

6. Set 2018 Harvest Specifications **Final Action** — 11:10 a.m.
   - Review Horseshoe Crab and Red Knot Indices of Abundance for 2017 Adaptive Resource Management (ARM) Model Runs *(K. Anstead)*
   - Review Results of 2017 ARM Model Runs *(K. Anstead)*
   - Set 2018 Harvest Specifications *(M. Schmidtke)*

7. Review Results of ARM Model Runs Incorporating Biomedical Data and Recommendations from the ARM Subcommittee, Technical Committees, and AP (*K. Anstead & M. Schmidtke*) — 11:30 a.m.

8. Consider 2017 Fishery Management Plan Review and State Compliance Reports (*M. Schmidtke*) **Action** — 11:55 a.m.

9. Populate AP with Non-Traditional Stakeholders (*T. Berger*) — 12:05 p.m.
   Possible Action

10. Elect Vice-Chair **Action** — 12:10 p.m.

The meeting will be held at the Waterside Marriott Hotel, 235 East Main Street, Norfolk, Virginia 23510; 757.627.4200

MEETING OVERVIEW

Horseshoe Crab Management Board Meeting
Tuesday October 17, 2017
9:45 a.m. – 12:15 p.m.
Norfolk, Virginia

Chair: Dr. Malcolm Rhodes (SC) Assumed Chairmanship: 10/17	Horseshoe Crab Technical Committee Chair: Rachel Sysak (NY)	Stock Assessment Subcommittee Chair: Dr. John Sweka (FWS)
Vice Chair: Vacant	Horseshoe Crab Advisory Panel Chair: Dr. Jim Cooper (SC)	Law Enforcement Committee Representative: Doug Messeck (DE)
Shorebird Advisory Panel Chair: Dr. Sarah Karpanty (VA)	Delaware Bay Ecosystem Technical Committee Chair: Greg Breese (FWS)	Previous Board Meeting: October 26, 2016
Voting Members: MA, RI, CT, NY, NJ, DE, MD, DC, PRFC, VA, NC, SC, GA, FL, NMFS, USFWS (16 votes)		

2. Board Consent

- Approval of Agenda
- Approval of Proceedings from October 26, 2016 Board Meeting

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 Results of Eel and Whelk Bait Practices Survey (10:00 – 10:30 a.m.)

Background

- At the 2016 Annual Meeting, the Board tasked the Horseshoe Crab TC with conducting a survey of the channeled whelk and American eel fisheries to learn about baiting practices within these fisheries, particularly as they relate to horseshoe crab and manufactured alternative baits.
- The Horseshoe Crab TC conducted these surveys earlier in 2017 and developed a report summarizing the results. (**Briefing Materials**)

Presentations

- TC Report on Eel and Whelk Bait Practices Survey by R. Sysak

5. Consider 2018 Benchmark Stock Assessment Terms of Reference (10:30-11:10 a.m.) Action

Background

- In May, 2016, the Board moved to schedule a regional benchmark stock assessment, which was scheduled for completion in 2018.
- The Stock Assessment Subcommittee (SAS) has been populated and has developed Draft Terms of Reference and an approximate timeline for the Board's review. (**Briefing Materials**)
- The Board tasked the SAS with considering confidential data from the biomedical industry in this assessment. The Board will be updated on steps being taken to ensure confidentiality of these data during the assessment process.

Presentations

- Draft Terms of Reference and Assessment Timeline by K. Anstead
- Confidentiality Procedures for the Assessment by M. Schmidtke

Board actions for consideration at this meeting

- Consider Draft Stock Assessment Terms of Reference.

6. Set 2018 Delaware Bay Horseshoe Crab Fishery Specifications (11:10-11:30 a.m.) Final Action

Background

- The ARM Subcommittee met by conference call in August 2017.
- The Virginia Tech Trawl Survey was conducted in 2016, so the ARM Subcommittee used population estimates from this survey estimate horseshoe crab abundance in the Delaware Bay region.
- The ARM model was run using estimated abundances of horseshoe crabs in fall of 2016 and red knots in spring of 2017 to provide a recommendation for harvest specifications for Delaware Bay states in 2018. (**Briefing Materials**)

Presentations

- Horseshoe Crab and Red Knot Abundances and Results of 2017 ARM Model Runs by K. Anstead

Board actions for consideration at this meeting

- Consider ARM harvest recommendations and set specifications for the Delaware Bay states in 2018.

7. Review Results of ARM Model Runs Incorporating Biomedical Data (11:10-11:30 a.m.)

Background

- In October 2016, the Board tasked the ARM Subcommittee with conducting alternative runs of the ARM model that incorporated biomedical mortality.

- The ARM subcommittee met by conference call in August 2017 to review and discuss the results of these runs and a recommendation for management actions to be considered by the Board.
- The TCs and Advisory Panel also met to review these results and provide recommendations for management actions to be considered by the Board.

Presentations

- Results of ARM Model Runs Incorporating Biomedical Data by K. Anstead
- TC Recommendations by M. Schmidtke
- AP Recommendations by J. Cooper

8. Consider Approval of the 2017 FMP Review and State Compliance (11:55 a.m. -12:05 p.m.) Action

Background

- State Compliance Reports were due March 1, 2017.
- The Plan Review Team reviewed each state report and compiled the annual FMP Review. (**Briefing Materials**)
- The Potomac River Fisheries Commission, South Carolina, Georgia, and Florida have requested and meet the requirements of *de minimis* status.

Presentations

- Overview of the FMP Review by M. Schmidtke

Board actions for consideration at this meeting

- Accept 2017 FMP Review and State Compliance Reports.
- Approve *de minimis* requests.

9. Populate Horseshoe Crab AP with Non-Traditional Stakeholders (12:05 -12:10 p.m.) Possible Action

Background

- In October, 2016, the Board discussed addition of two non-traditional stakeholder positions to the AP.
- An announcement for nominations was sent out in September, 2017.

Board actions for consideration at this meeting

- Consider approval process for nominees.

10. Elect Vice-Chair (12:10 -12:15 p.m.) Action

Board actions for consideration at this meeting

- Elect Board Vice-Chair.

11. Other Business/Adjourn

11. Other Business/Adjourn 12:15 p.m.

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

HORSESHOE CRAB MANAGEMENT BOARD

The Harborside Hotel
Bar Harbor, Maine
October 26, 2016

These minutes are draft and subject to approval by the Horseshoe Crab Management Board
The Board will review the minutes during its next meeting

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ATTENDANCE

Board Members

Bill Adler, MA (GA)
Sarah Ferrara, MA, proxy for Rep. Peake (LA)
Dan McKiernan, MA, proxy for D. Pierce (AA)
Bob Ballou, RI, proxy for J. Coit (AA)
Eric Reid, RI, proxy for Sen. Sosnowski (LA)
David Borden, RI (GA)
Colleen Giannini, CT, proxy for D. Simpson (AA)
Rep. Melissa Ziobron, CT, proxy for Rep. Miner (LA)
James Gilmore, NY (AA)
Emerson Hasbrouck, NY (GA)
Brandon Muffley, NJ, proxy for D. Chanda (AA)
Tom Fote, NJ (GA)
Adam Nowalsky, NJ, proxy for Asm. Andrzejczak (LA)
Stewart Michels, DE, proxy for D. Saveikis (AA)
Craig Pugh, DE, proxy for Rep. Carson (LA)
Roy Miller, DE (GA)
Michael Luisi, MD, proxy for D. Blazer (AA)
Rachel Dean, MD (GA)
Ed O'Brien, MD, proxy for Del. Stein (LA)
Rob O'Reilly, VA, proxy for J. Bull (AA)
Catherine Davenport, VA (GA)
Michelle Duval, NC, proxy for B. Davis (AA)
David Bush, NC, proxy for Rep. Steinburg (LA)
Doug Brady, NC (GA)
Robert Boyles, Jr., SC (AA)
Malcolm Rhodes, SC (GA)
Sen. Ronnie Cromer, SC (LA)
Spud Woodward, GA (AA)
Nancy Addison, GA (GA)
Pat Geer, GA, proxy for Rep. Nimmer (LA)
James Estes, FL, proxy for J. McCawley (AA)
Mike Millard, USFWS
Chris Wright, NMFS
Martin Gary, PRFC

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

Ex-Officio Members

Steve Doctor, Technical Committee Chair
Doug Messeck, Law Enforcement Representative

Robert Beal
Toni Kerns
Kristin Anstead
Kirby Rootes-Murdy
Mike Schmidtke

Guests

convened in the Stotesbury Grand Ballroom of the Bar Harbor Club, Harborside Hotel, Bar Harbor, Maine, October 26, 2016, and was called to order at 8:00 o'clock a.m. by Chairman James J. Gilmore.

CALL TO ORDER

CHAIRMAN JAMES J. GILMORE: Welcome to the Horseshoe Crab board meeting. I would like to call the meeting to order. If you have important conversations, please take them out in the back. My name is Jim Gilmore; I am the Administrative Commissioner for New York, and I will be chairing the Horseshoe Crab Board meeting today.

We have a few things to go through in the agenda; but first before we get into that, and I know they're not here, but a shout out to the Maine delegation and the ASMFC staff for one of the best dinners I think I've ever had. I slept like a baby last night. I just hope they're going to repeat it again tonight, because I think it was really very popular.

Also, I would like to introduce Mike Schmidtke; he's a new ASMFC staff that is going to be working on horseshoe crabs and joining the team today. Welcome, Mike.

APPROVAL OF AGENDA

CHAIRMAN GILMORE: First order of business is approval of the agenda. Everyone has it in their briefing documents. Are there any changes to the agenda? Seeing none; we'll adopt those as in the briefing book.

APPROVAL OF PROCEEDINGS

CHAIRMAN GILMORE: The second order of business is the August, 2016 proceedings. Are there any changes to those proceedings? Seeing none; we will adopt those. Before each meeting we have public comment on issues not on the agenda. I did not have anybody sign up for making a comment, but is there anybody in the audience right now that would make a public comment on issues not on the agenda?

ARM SUBCOMMITTEE REPORT

CHAIRMAN GILMORE: Okay seeing none; we'll move right into our first order of business; which is the ARM Subcommittee report, and Kristen is going to give us a presentation on that.

MS. KRISTEN ANSTEAD: Good morning. This morning I'm going to update you on the activity of the ARM Subcommittee and the harvest recommendations for 2017 in the Bay. First I'll just remind you of the objective statement for the ARM model, which is to maximize the harvest of horseshoe crab while maintaining a population that can sustain the migrating birds, specifically the red knots.

This morning I would like to talk briefly about the red knot and horseshoe crab population thresholds in the ARM model. The abundance estimates for this year, the five harvest packages as they currently exist, and the recommendation for fishing for 2017. There are a couple thresholds in the ARM model that I think are important to review, one is female horseshoe crabs. That was set at 80 percent carrying capacity; and that turns out to be 11.2 million female crabs. For red knots it's 81,900 birds, and additionally you have to maintain an operational sex ratio of two males to one female, so that is on the spawning beaches; that is not out in the ocean. These two thresholds are important because this is how we understand when and how we get female harvest in the Bay, because that continues to sort of be an issue. I wanted to review these so that you understand when female harvest could be possible.

This is an either/or situation. If the birds hit their threshold, then there is the possibly for female harvest. Because regardless of how many female horseshoe crabs are there, they are sustaining the bird population. Conversely, if the crabs hit their threshold, even if the birds do not there is the possibility for female harvest; because there are enough horseshoe crabs to sustain the population where we want it to be.

Additionally, if that sex ratio falls below two-to-one, there would be no male harvest, but that hasn't happened, and it doesn't get close to that; but just a reminder that that is also a threshold that exists in the model. This is the red knot abundance for the last few years. The blue line is the mark-resight estimations of the abundance of the red knots in the Delaware Bay.

The red line is the threshold, so you can see how close or far we have been from it. Those are the 95 percent confidence intervals around their estimations. Fewer birds stopped in the Bay in 2016 than the previous year, but the estimates were very similar to 2014. The estimates were 47,300 birds, and that is below the bird threshold.

For the horseshoe crabs, we use the Virginia Tech Trawl Survey to make estimates of the population for horseshoe crabs. As you know, that doesn't run every year, so in lieu of the Virginia Tech Trawl Survey estimates, we have a composite index. It has been developed from a few surveys in the Bay.

The black lines up there are the Virginia Tech Trawl Survey estimates, and the top graph is for males and the bottom for females. You can see in the years that we have the trawl that they match pretty closely. When we don't have the trawl survey, which we did not have last year, we use the composite index.

The survey is underway this year, so next year we'll be able to use those results for the horseshoe crab abundance; as well as continue to tune the composite index with another year of data. The 2015 estimate for female horseshoe crabs was 8.1 million; that is also under the 11.2 threshold. But there was a slight uptick of crabs this year. That is a good sign.

These are the five harvest packages as they currently stand, from full moratorium to both male and female harvest. For the last several years, the ARM model has recommended Package 3; which is the 500,000 male only harvest. The way the ARM model works is we put this abundance in the season, and it goes through all possible states of the population; the juvenile abundances, birds, males, females and recommends a harvest package based on what would be best for both of those populations.

This is just a summary of the numbers we already went over, the male and the female horseshoe crab numbers for this year, as well as the bird estimates. Both are below threshold, and the harvest package recommendation is the same as it has been for the last several years, which is Harvest Package 3; the 500,000 male only harvest. I just want to talk briefly about some of the upcoming challenges the ARM Subcommittee has been discussing. As you know, we went under this short term review and we made several recommendations about how the ARM model could be fine-tuned. One of those was the incorporation of the biomedical data, which does prove to be the largest challenge moving forward. I'll just remind you that biomedical currently is not accounted for in the ARM.

The reason we feel like it should be, is because it accounts for 8 to 12 percent of the coastwide mortality; and we have put forward the preferred option and a minority opinion that we've already presented to you. But I will just briefly remind you, so that when Kirby talks about the Addendum, you'll remember what we were talking about.

The preferred option was to adjust the harvest packages to account for what the biomedical is already harvesting. These are made up numbers. On the left are the harvest packages is we've already talked about, and on the right is just an example of what that could look like. What we would do is take a three-to-five-year average of what the biomedical harvest in the bay and remove that from the current harvest packages.

This is not a quota for biomedical. We're not putting a cap on them or limiting them; we're just purely accounting for on average the mortality we're attributing to them. That number might be revised every six years or so. We don't want to

violate any data confidentiality, so we'll be using averages; adjusting it not every year but continuing to tune that number to reflect what is occurring in the Bay.

That was the preferred option as put forth by the ARM Subcommittee. The minority opinion or option was to incorporate it into the population dynamics model, using that 15 percent mortality, putting it in the kind of workings of the model rather than applying it to the harvest packages. The harvest packages would remain unchanged.

Exploring this option is time consuming, because the model goes through multiple iterations under different states of the population; and so it is a cumbersome process, and I will just show you briefly why that is. This is as simple as I could make the population dynamics model. You can see, you have the juvenile horseshoe crabs, and they can remain juvenile horseshoe crabs to the next year; or they can go on to the pre-breeding stage, or they can skip pre-breeding and go straight to being an adult male or an adult female or they can die.

Those are multiple steps just for the juveniles. For the pre-breeders, they can also remain a pre-breeder the next year or they can mature and become a breeding male or female; additionally, they can die. Then the adult males and females have the survivorship where they can remain in that stage. They are also feeding back to the juveniles, as well as being harvested.

When the ARM model is kind of balancing all these different states, the most simplistic way to think about it is that the horseshoe crabs available next year are the number of juveniles that go straight to adults, plus the pre-breeders that go straight to adults, plus the adults that survive minus the harvest.

What we would be suggesting in this minority opinion is sort of adding on to that red step, the amount that dies or gets harvested. We would be accounting for it in this stage. It would reduce the survivorship of those males or females in the adult stage and kind of be part of the harvest there rather than adjusting the actual harvest packages. While that sounds simple in theory, it is a time consuming step to kind of explore the sensitivity of the results to incorporating the biomedical. That is the population dynamics model. With that, I can take any questions about the ARM activities.

CHAIRMAN GILMORE: Great presentation. Questions for Kristen? Rob O'Reilly.

MR. ROB O'REILLY: I have two questions and they're old questions. The 15 percent mortality for the biomedical process, I think, last meeting we heard from one of the companies that it's much less. We've heard from others in the Technical Committee that it's more. I guess I'm just wondering, some of the sensitivity analyses that are going to be conducted.

Is it anticipated that that will also include varying that mortality rate a little bit? The reason I ask, I mean, we have a lot of discard mortality rates for fisheries where depending on the area, the time of year, and everything else, it might be just sort of pertinent to that particular study. But here we have a situation where the biomedical companies definitely have a handle on how much mortality there is. I don't know why there is such a mystery about it.

The second question, if I may, it will be a quick one. Kristi, you mentioned a six-year update. I'm just wondering, without violating any data confidentiality, in the last six years what has been the average change in the biomedical use of horseshoe crabs? I guess what I'm wondering really, is six years really something that is just thought about right now as an estimate and can be modified later on if there is information on a composite basis that the biomedical process is taking more horseshoe crabs.

MS. ANSTEAD: First, I'll answer your question about the 15 percent. We're going to do a benchmark stock assessment in 2018, so at that point we will have a great opportunity to reevaluate some of the studies, look back at the

literature, and work with biomedical to reevaluate that number. That is definitely something that's going to happen, and when that happens for the benchmark, the ARM will also adapt whatever they find to be the most appropriate number for the Delaware Bay region.

Also, when we do the benchmark, we're hoping to be able to do that on the regional basis; so if there is a study specific to the southeast, we can apply that biomedical mortality to that region as well as reevaluate that for the Delaware Bay. It may not have to be a flat percentage. If there is data specific to each region, we'll be able to use that at that time. As for the second question, I think Kirby is going to speak to that.

But yes, the six is just an example, the six-year average. Biomedical is pretty consistent, and so I think what we would look at is how often – I mean, we should reevaluate it every so often – but do we do that on a pre-chosen number of do we do that when there is some indication that it is changed? Then we would have to revise it in the ARM model, but I think Kirby has something to add.

MR. KIRBY ROOTES-MURDY: Yes, I was just going to offer, Rob, that in the supplemental materials we included the FMP review, and it lays out biomedical collection and bleeding over, I believe it's the last five to seven years or so. You can see trends there. But to what Kristen was mentioning, it has largely stayed pretty constant, in terms of the number of crabs that have been collected. The overall mortality coastwide has changed slightly year-to-year, but that trend hasn't moved either way significantly in recent years.

MR. BRANDON MUFFLEY: Just a question on the harvest information that goes into the ARM model. Does it assume, or do we provide, that it's just a 500,000 male harvest or we actually used harvest numbers from the prior year?

MS. ANSTEAD: We did talk about that recently, and it just assumes that that is what is being harvested. It has been discussed that maybe that is not the most appropriate thing to do, but that could be something else to look at as we revise the model. But right now, it assumes that harvest packages are what are being harvested in the Bay. I know that is not exactly true every year.

MR. ROBERT BALLOU: Kristen, excellent presentation, but if you could just turn back to the core issue and expound a bit on why the workload would increase so significantly by including the biomedical mortality; in addition to the bait harvest mortality. It just seems like a different number, a larger number as it were. Why does that make it such a – you talked about sensitivities, could you just expand on that a little bit?

MS. ANSTEAD: To explore kind of the sensitivity of both of these option, would this push us to moratorium? Would it most likely keep staying at 500,000? Changing the harvest packages is a little simpler to kind of explore. You just change that one number; and then when the model goes through this optimization routine, where it looks at all these possible states of the model based on all the years of data; along with all those probabilities of moving to another stage; or staying in the stage; or the survivorship at each of those stages; or the fecundity in that year or the male/female ratio, it doesn't need to go through all of those with a different mortality rate. Both of them would take time.

But doing the population dynamics one is just much more cumbersome. That's the lengthy process of the model, whether or not we change it. When Conor McGowan goes through the ARM model each year, it's that routine that is the time consuming routine. That is why adding mortality there would make that exploratory process a little longer.

CHAIRMAN GILMORE: Other questions? I actually have one, which I won't put Kristen on the spot, because it is more of an ornithology question, so maybe Mike will help out. I was impressed by, when I was reading the reports, of the difficulty in sampling red knots. I guess, when I looked at it, and what is equally important is not only the

horseshoe crab harvest, but the 89,000 number for the population that is fed into the model for the red knots.

Right now, I think 40 something thousand was the population estimate that is put into that. But how confident are we, because when I looked at the report on the sampling for that, it seems to be a real interesting way -- it is almost like a data poor species from a fisheries perspective. I mean, is there a lot of error with that or can you just expand on that a little bit?

MR. MIKE MILLARD: I would remind you, I am not an ornithologist. I think Jim Lyons' estimates from the mark-recapture does have error bars around it. I feel a lot more confident about those estimates than the old aerial surveys that the state of New Jersey was conducting. I don't have those numbers in front of me with the error bars, but I think it is about as good as we can do right now for a species like that. I feel pretty good about it myself.

CHAIRMAN GILMORE: Great, thanks, Mike. Bill Adler.

MR. WILLIAM A. ADLER: I remember when they were talking about red knots and where they are and where they're not that there was some concern that they were still around. But they weren't landing or coming to the place where we always thought they would be coming. I didn't know if any of that information has been added into the red knot population estimates; that there were other places where these things were landing. I think you remember all that. But I don't know if any of that got into the statistics as to the population size of the red knot. I don't know if they did anything on that.

MS. ANSTEAD: We talked about that a little bit at the TC meeting, because there were some concerns about how much the population had bounced around in the last three years. From 2014, and then it went up pretty high in 2015 and came back down. Many felt that that – well, fluctuation is natural – but that big of a leap couldn't be attributed to births and deaths alone.

We did talk a little bit about how maybe they didn't stop in the Bay at the same proportions that year as they usually do, or they stayed a different amount of time. That is definitely part of the estimation process, but it is not necessarily accounted for in the ARM, other than when we get that mark-resight abundance. Fluctuations can be explained by those things that you're talking about.

MR. MILLARD: Thanks for that report, Kristen. I have an observation, I think, followed by a question. In talking to some folks on the ARM Committee about the behavior of the model, I think there was a discussion in your meeting that because of the optimization routine and the way the model works, and because of the thresholds that you explained to us nicely at the beginning of your presentation, it is either going to want to go full open, wide open; once the females take value, harvest as many as you can until they no longer have value, according to that threshold; and then go to zero.

To drop into an analogy, it is like if you're in a car, it is either going to be in fifth gear, top speed or in neutral. It is never going to want to cruise along in third gear; is what I'm hearing. Now, I don't know if they've explored that rigorously with the model, but I guess that is my question to you. You mentioned it's time consuming, but I think the board, at least at the last meeting said, well, we would like to see more about how that behaves. Are they, in fact, going to undertake that analysis?

MS. ANSTEAD: Yes, I would say that's accurate that the model prefers Package 1, 3 and 5, which is moratorium, the highest male only harvest and then the highest male and female harvest; that those two other options aren't chosen as much. Exploring that, I think, was part of the long term review we suggested.

Maybe about a year ago we put forth what items could be accomplished on a short term review process, and what could be accomplished on a longer term. At that time we were tasked with doing the short term review. If we had the opportunity to do a long term review, certainly exploring what harvest packages might be more appropriate, or why those two aren't chosen would be part of that; as well as moving the ARM model into a different software program that would be more accessible for staff. Right now it is not run by us; it is run somewhere else. Those were two longer term goals, but yes, that is certainly a concern and a hope for moving forward.

UPDATE ON DRAFT ADDENDUM VIII

CHAIRMAN GILMORE: Okay, I think I'm going to move along and Kirby is now going to give us an update on Draft Addendum 8.

MR. ROOTES-MURDY: Kristen, I think, teed this up pretty nicely for me. I'm going to walk through kind of how we got to where we are today; the August, 2016 board meeting; trying to develop the Draft Addendum VIII coming out of that; some of the ARM Subcommittee comments we received; next steps, questions and considering board action today.

At the August, 2016 board meeting, as you all should remember, the ARM Subcommittee and TCs presented their recommendations on how to include biomedical mortality into the ARM framework. There were two options, as Kristen lay out. The preferred option reduced the bait harvest and accounted for biomedical mortality.

The second option, which we were calling a minority option, added biomedical mortality into the population dynamics model. Taking that into consideration, the board initiated an addendum to include biomedical mortality as well as bait harvest packages that allow for female harvest, and that was specifically outlined in Appendix C of one of the meeting materials we offered up for the August meeting.

In coming back to the addendum after the board meeting, staff sat down; we tried to think through logistically how this addendum could play out. One thought at first was an initial decision tree on how to deal with biomedical mortality. It is important to understand that from that you then would have to move down to figure out what harvest package would be the next option for someone to select.

We kind of coined it as a "choose your own adventure" in this way. When you do this, there is the possibility to have significant variation, depending on what biomedical mortality option is chosen initially. In this slide we have a breakdown of what the current harvest packages are, as Kristen presented, and then with that preferred option how they are slightly adjusted.

You start off with biomedical mortality, you have that decision point, whether to include it or not. It is pretty straightforward, no, you move to status quo. If yes, there are two options that are laid out, the preferred and the minority. The next step in that would be after you've chosen which of the options you would want to use to account for biomedical mortality; you would select a harvest package.

Again, we were guided to select, or at least include in the addendum, the options that were laid out in Appendix C. As I tried to explain, we have those two decision points in the decision tree; how to account for biomedical mortality, and then moving down to your harvest packages. When you start to look at this with the variations, you come up with multiple versions of harvest packages. The status quo would already get you at possibly two separate versions of the same sets of harvest packages. You add in Appendix C, you have four additional sets of harvest packages to look at. When you then times that by two, we would be looking at somewhere in the ballpark of 18 possible options that would be included in the addendum. From a staff standpoint, we expressed some concern that this may be possibly too many

for the public to consider and provide adequate comments on.

As Kristen laid out in her presentation, I believe the harvest packages have been evaluated and were evaluated by the ARM Subcommittee going into that August meeting, as part of the initial task way back, about a year ago; when the ARM Subcommittee was asked to look at how to get at female harvest in the bait industry.

The ARM Subcommittee looked at that and found that while there may be an interest in adding more options that have female harvest, unless you are above that threshold that Kristen laid out, you're not going to increase the likelihood of getting female harvest. So long as you're below that threshold, you can add as many harvest packages as you would like to have options for female harvest, but you won't get there.

With that in mind, this could possibly further confuse public comment for the draft addendum process in that we may be going out to the public with these 18 options, and asking them to provide us comment, when in actuality if they chose one of those options we couldn't necessarily tell them for sure that all the options that included female harvest would actually be selected in a given year.

With this information, we brought it back to some members of the board to further explain how to get guidance on how to move forward with this addendum. With this information, some of the board members asked us to look at whether it would be possible to do sensitivity analyses to get at how, say including biomedical mortality would have changed harvest package selections in previous years.

One of these ideas that were put forward was doing sensitivity analysis around the two versions of how to include biomedical mortality; going back between five to ten years, running the model with then these biomedical options in there. Again, the model inputs would be using the abundance index from the Virginia Tech Trawl Survey or the Composite Index and putting that in.

We would be keeping pretty much everything constant; it would just be seeing how the model would react with this new variation in it. In bringing this to the ARM Subcommittee in September, they expressed some concerns about the decision making process in this, and it being largely results driven versus making decisions that made the most sense, based on the information we have on the population and biological characteristic at each stage in the model.

As Kristen laid out, we have also talked with them about the sensitivity analysis work, and they expressed some concern that it would take some time. Anecdotally, the ARM Subcommittee members also offered that they thought that the approximate 34,000 mortality that may be coming out of the Delaware Bay, this is again a guestimate, not an actual number, would be a negligible amount.

It wouldn't necessarily change the optimized harvest package. The reason why is because the magnitude of the biomedical mortality there would be very small, compared to the magnitude of the abundance that we're using to set the harvest packages and specifications annually. You were just shown the graphs of what the male and female abundance estimates are in the Delaware Bay region, and so the magnitude between that abundance estimate and what these changes are in the mortality, they deem to be possibly negligible.

A separate note, harvesting female crabs, this is related to trying to put in more options that would possibly select female, so long as you're below the threshold. If you start to violate the rules of the ARM framework, you may be able to get at female harvest today. But it will actually push your timetable to getting at an optimized option for female harvest that is the model actually selecting it.

It will take a longer time to get to that; because, again, it is under the impression that it is still at a depleted state. We followed up with the ARM Subcommittee's members regarding specifically how long the timetable would be between getting these analyses done and presenting them to the board. The first one, as Kristen lay out, wouldn't take a tremendous amount of time; because of the lack of iterations that the model would have to go through.

The second one, after a little bit more conversation, we learned would possibly be able to be completed by summer of next year, 2017. For the reasons that have been laid out already that it would be time consuming, given the multiple iterations and the software availability and experienced limitations in trying to run it.

Some additional considerations for the board are that with this addendum having been initiated in August, and the benchmark stock assessment set to be started in 2017, and completed in 2018, there is a lot of work that the ARM Subcommittee will hopefully be contributing to the Technical Committee and Stock Assessment Subcommittees and completing the 2018 assessment.

There is potentially new information that would be coming out of that assessment to help inform this process. In having an addendum that would be at its earliest completed by mid or maybe even a year from now in 2017, the earliest it would be implementing harvest packages for would be 2018; therefore, we would be possibly going through the same process again once we had the results of the benchmark stock assessment.

There may be the possibility that it would be a redundant effort. Next steps, as staff we're looking for guidance from the board on whether to proceed in continuing development of this addendum, and also to consider possibly addressing this addendum after the 2018 benchmark stock assessment has been completed. With that, I'll take any questions.

MR. MICHAEL LUISI: I may be able to save you and the other commissioners around the table here a little time and quit with questions. I've got some thoughts, and I appreciate on the agenda that this presentation by Kirby was labeled as challenges with developing this addendum. I would argue that this is more than a challenge.

Challenges are things we can overcome, and there is more of a roadblock here as far as what we currently have as a framework for managing horseshoe crabs with the red knot, and trying to make adjustments as Mike alluded to kind of this third gear, rather than either neutral or in fifth gear.

For any of you who know me well, I can be a little stubborn when I get something in my mind. I just want to thank Kirby and Kristen for putting up with me the last few months, as we've communicated back and forth a number of times about how we could try to proceed with this addendum in accomplishing the goals that this board approved, as far as moving forward. The way that I see it now and where we currently stand is that we're going to set measures for 2017.

By the time an addendum would be finalized, we would be right at the base of a benchmark stock assessment. Given the comments that have already been made by staff, I think that it is probably in our best interest right now to hold off on any further development of this addendum until the benchmark is completed.

It sounds to me like the benchmark is the way we can maybe address some of the roadblocks, some of the walls that are within the model right now in moving forward. When you're ready, Mr. Chairman, I do have a motion I would like to make.

CHAIRMAN GILMORE: Okay, Mike, just let me see if there are other comments, along with where you're going and opposed to that and if we don't have that, I think we'll put your motion up. Any other questions or comments for Kirby or what

Mike just said? Okay Mike, go ahead, give us your motion.

MR. LUISI: I move to postpone development of Draft Addendum VIII until after the 2018 Benchmark Stock Assessment has been completed.

CHAIRMAN GILMORE: Okay, second by Roy Miller. Is there discussion on the motion? Rob O'Reilly.

MR. O'REILLY: The only comment I have, is I saw on one of the slides an indication that there is some experience needed and some software that needs to be mastered, perhaps, as part of this process. Even though I support the motion, it would seem that that also allows time for accomplishment of learning that software, the new software that might be needed and also getting the experience that is also needed. I wanted to make that comment.

CHARIMAN GILMORE: Any other questions? Brandon Muffley.

MR. MUFFLEY: I support the motion, as well. I guess my question is, do we think we will continue to work on some of these items that we talked about regarding the ARM model. Will we run sort of these sensitivity analyses with the two different biomedical methodologies and evaluating the actual harvest versus the assumed harvest of 500,000 crabs?

Will we continue to evaluate the model as we go forward, since we're going to kind of delay? I just want us to kind of be ready, once that stock assessment goes, that we've maybe kind of answered some of these questions within the ARM model that were ready to move forward.

MR. ROOTES-MURDY: That is definitely an option and a possibility for the ARM Subcommittee. I think it just needs to be clear coming out of this meeting that that is a request of the board that that analysis be carried forward. If this motion passes that it is kind of moving on two different time tables then. But if that is the pleasure of the board, then just making sure that's clearly tasked to them would be great.

MR. MUFFLEY: Do you think we need a motion then? I think that is the way we need to go. I support delaying and getting everything right and wait for the assessment. I think that's key. But I don't want to lose time on the work that we need to do on the ARM model.

CHAIRMAN GILMORE: I don't think we need a motion on it, Brandon, I think that's really well documented that is where we're going to go. I think we're okay on it. Mike, do you have a comment?

MR. MILLARD: I, too, support the motion, and I thank Mike for making it. My sense is after the benchmark, we can revisit the ARM in a sense that we were looking at these harvest packages, but those aren't the knobs that we want to tune with. We want to go back out to the threshold maybe and the value functions. Those would be the tuning knobs that the ARM would consider, I think, if I'm understanding correctly; after the benchmark assessment.

CHAIRMAN GILMORE: Yes, I agree Mike, I think that is correct. Any other discussion? Mike Luisi.

MR. LUISI: Just one more thing to add, not regarding the model but regarding the biomedical industry. In conversations that I've had with Kirby and Kristen, I think there may be things that we can do as states to help better understand the mortality associated with the biomedical companies. All the details aren't in my head right now, but Kirby, you and I have spoken about it, about what we might be able to do to capture the information that would help us all understand a little more clearly, the mortality associated with the biomedical industry.

Maybe that could be factored in at a later date, rather than incorporating that mortality now. After the benchmark we might have a better

understanding. I don't know if there is anything that you might be able to send out to the states, as far as a request for how we better those data, but I just ask maybe you could speak to that a little bit.

MR. ROOTES-MURDY: Sure thing. Hopefully, all the board members are aware, last week, prior to this meeting, Jim sent out an e-mail laying basically as a reminder that those states that have biomedical facilities that are bleeding crabs currently, are required to submit information on that; the number of males and the number of females that have been bled, because we have a process and a procedure for applying mortality to that.

As laid out in Jim's e-mail, we haven't necessarily been getting the best information on that recently. I'll be hitting on that point a little bit during my presentation for the FMP review. But just as a setup to that, it will be important for those states to keep in mind to give a better sense of what the mortality is at each stage from the collection through to those crabs that are bled and released; as well as those crabs that have been not used for bleeding, but discarded, as that can sometimes be a large category. That will help, not just for compliance components, but also for the upcoming benchmark stock assessment when we're going to be looking at how to best understand this data at a regional level.

CHAIRMAN GILMORE: Let me just go to the audience quickly; any public comment on the motion? Okay seeing none; back to the board. Any last discussion, before we vote? Okay, seeing none; is there any objection to this motion? Okay, so I guess we are going to vote. Call on Melissa on that.

MS. MELISSA ZIOBRON: I don't feel like I've sowed my oats here long enough to make a comment, this is only my second meeting. But in reading the letter from the Limuli Laboratories, my confusion really rests in the fact that it sounds like that there is reporting data available. I don't have the information of how that is relayed to whether it is the states or to this organization, but as a legislator I have seen firsthand putting off hard decisions, and I am very concerned, after attending the August meeting, hearing this. Once again, here we are postponing these kinds of tough decisions, and for that reason I oppose it.

CHAIRMAN GILMORE: Any other discussion before we vote? Okay, does anybody need to caucus? Two minutes for a caucus. Okay, we're ready to take the vote. Move to postpone development of Draft Addendum VII until after the 2018 Horseshoe Crab Benchmark Stock Assessment has been completed.

A motion by Mr. Luisi and seconded by Mr. Miller. All those in favor of the motion, please raise your hand. Fifteen in favor, all opposed. No opposed, any null votes; any abstentions? Motion passes 15-0-0-0. Thanks, we're ahead of schedule.

HORSESHOE CRAB
TECHNICAL COMMITTEE REPORT

Okay, next we're going to go into Technical Committee reports; and Steve Doctor has got a whole lot of great stuff to tell us.

MR. STEVE DOCTOR: Okay, we're going to look at a couple things here. We had a pretty productive Technical Committee meeting about a month ago. I'm going to try to go through some of the conclusions we came to. First, I'm going to go over the ARM framework and the recommendation for the optimal harvest, and then we're going to look at some horseshoe crab surveys.

We're going to do the shorebird survey; we're going to talk about alternative bait trials and then we're going to talk about the United States Fish and Wildlife Service response to the ESA listing. We were given Harvest Package 3, which is the 500 male only harvest. It was based on the composite index and red knot mark-resight population estimates that are the best available science at this point; and the Technical Committee was unanimous in recommending the ARM package at Package 3.

Now, we're going to go into some surveys here. The Delaware Bay Trawl Survey is one of the indexes that are going to the ARM model. Thanks to Jeff Brust, who is the Excel master of the coast, we have like male and female broken out, some nice graphs here from them. I'm going to go through these pretty quickly. They're basically showing pretty much the same trend.

This is the New Jersey Ocean Trawl Survey. When I say they are showing the same trend, they are all pretty much stable, is what I would say. Some of them are starting to show a little bit of increase in the tail end of the survey. This is the Ocean Trawl Survey, and it is also in the Composite Index; the Composite Index is made up of three surveys.

Then this is Delaware Bay Spawning Survey. The one survey that has a little bit of a significant trend is the Beach Delaware Bay Spawning Survey. It has a significant trend and a decline in females, but when we go further, you'll see that when you put them all together it doesn't show up. The next one is the Delaware Survey. I think Stew Michels has his hands in these maybe, John Clark too. These surveys are a 16 and a 30 foot trawl survey in Delaware Bay. This is the Maryland Offshore Trawl Survey. This is my survey, so I'll spend the most time on this one. You'll see that this is taken on commercial boats that go offshore and they're collecting horseshoe crabs for bait and biomedical. You'll see it goes along here real good until about 2008. I wish that was an increase in horseshoe crabs, but what they discovered is that you catch more horseshoe crabs at night, so they went to doing the survey at night.

Also, the Virginia Tech Trawl Survey discovered this, so it's been a learning experience going through this horseshoe crab stuff. You'll see this one index up here is really high. That year we were averaging 60 horseshoe crabs per minute. While in the 2008, you'll see a jump, it is still an upward trend. I really don't think that this index is going to go much higher, because you really can't cram more than 5,000 horseshoe crabs into the net in 40 minutes.

We'll probably plateau off there. But it did show an increase for a while. I've given you a bunch of surveys. What I would kind of like to do now is try to tie it all together for you. I've been involved with this since 1998. We started with horseshoe crabs and eels in '98. I met some great guys, Stew Michels and John Clark and Mike Millard.

We have been working on this ever since. Back then Stew and John, we used to go across the street to a gas station to get our lobster rolls, so we've evolved a little bit since then. What I would like to show you here is there is a paper by Sweka, Smith, and Millard that was done in 2007. What it did was a forward projection of the female abundance, using this model that they had. It is a stage-based model projection.

What you have down here on the X axis is years. What I want to show you here is that they started at like 3,000 females, but they didn't really know where it was. The population came up to like 6,000. The reason I'm showing you this, the stock seems to be acting like what the projections said it would do.

If you go to it, where we're at right now like 6 million 800 animals is like Year 37 of the projections. That isn't as important as what the projection does from there. To get to the threshold, this is actually where carrying capacity comes from, too. That's why I started looking at this, because the 80 percent carrying capacity is the threshold for female harvest.

It is going to be about 44 years before we get to those 11,000 animals, a carrying capacity where female harvest is going to be allowed. While we look forward to the index every year, where the male crabs are, where the females crabs are. I kind of want to temper your expectations that we're going to walk in here one day and we're going to have female harvest.

I mean it looks like about 2060 is where it's going to happen. The reason I have faith in this is I overlaid the projection to the estimates of abundance of female crabs from the composite index and also the Virginia Tech Survey. As a fisheries biologist, you live for stuff like this; where you can get a correlation that is that strong like that. It just matches beautifully. What this tells me is, I kind of almost believe the estimate of female abundance and where it's going. It's kind of interesting.

The reason I'm bringing this up is like I said, I don't want you to walk in here and think that we're going to go to Package 4 next year. It's probably going to be like 2060. That is why I wanted to let you know. Also, with the red knots, I talked with Jim Lyons who is the Fish and Wildlife -- he's a really excellent ornithologist with the Fish and Wildlife Service. I said, well, Jim, how are the other shore birds doing, because like red knots, we're trying to do this for red knots? But red knots you might want to think of more like a poster child for shorebirds; because there are like 15 different kinds of shorebirds.

There are plovers, Sanderlings, all up in Delaware Bay. While those horseshoe crab abundance eggs are affecting the red knots, they are affecting all of the shore birds. I said Jim, how are the shorebird populations doing up and down the coast? He says, "They're all declining, and he says and the ones that are declining the fastest are the ones that travel the furthest."

Well, do you know a bird that goes further than from Tierra del Fuego to Hudson Bay? I mean, that bird goes a long way, and there are a lot of things affecting that bird along that route. To see this population, which I think Jim Lyons answer is excellent, go from 40,000 to 80,000 birds, does anybody want to take some bets with me? I don't think it's going to happen next year.

I just wanted to give you that information. The shorebird stopover and winter population estimates are low but stable. The horseshoe crab estimates are low but stable. In the long term, where are we? Well, we've got this Package 5, and it is not really a bad thing. The market is kind of like stabled out.

Maryland had a really hard time. We've had the same harvest package for four years now. But the market kind of found itself. It worked itself out. The worst thing then a bad harvest is changing your harvest package. We left the harvest alone for four years. The market has kind of adapted to it, and I think we can kind of feel good that we're trying to do what we can for the red knots and the other shorebirds.

They might not come back. You know we might be here in 2060 or some of our offspring might be here in 2060. But we are doing what we can, and the market seems to have like found itself. I just wanted to give you that message on the population. Then I'm going to move on to alternative bait discussion.

We were going to go ahead and try some alternative bait from one supplier, and we sat together as a Technical Committee and we decided, you know, we can't get this product sometimes. We're not sure if it works. What we decided to do is step back a little bit and do a survey of what bait practices actually are right now, what the cost of the baits are, and then move forward from there.

There is a recommendation from the Technical Committee that all states evaluate the feasibility of conducting a survey to get bait bag ingredients and report back survey results by the beginning of 2017. That is where the Technical Committee is moving forward on that. The next thing is the red knot listing. I've got to be careful with my language here.

The service has kind of changed the way that they do threatened and endangered species. They are doing a species status assessment, and they're looking at critical habitat proposals for the red knot. It doesn't really affect us, because as long as the ARM model is in place, they are not considering

the harvest of horseshoe crabs as incidental take. That is something that I just wanted to let the board know that we're progressing on; I mean the Fish and Wildlife Service is progressing on, and it looks like we're in the green to make things short. The one last thing that I would like to add is that the ASMFC has brought on a guy buy the name of Mike Schmidtke; he is over here.

He's going to be our new coordinator for horseshoe crabs, and the guy is a stock assessment guru. He is really good. With Kristen on it, I'm really happy that ASMFC has stepped up and brought these really good stock assessment people to help with our 2018 exercise. With that, I conclude my report. If there are any questions, Mr. Chairman.

CHAIRMAN GILMORE: Thanks, Steve that was enlightening. Let's see, it is the 75th Anniversary so at the 118th Anniversary, we'll be having female harvest, Mike. How does that sit? Go ahead, Mike.

MR. LUISI: Steve, we ought to meet in my office when we get back in three days.

CHAIRMAN GILMORE: Questions for Steve. Bob Ballou.

MR. BALLOU: That was an awesome presentation. If you don't mind, I would like to circle back to the alternative bait portion of your presentation. It makes good sense to me that the survey work would be a logical next step before moving forward with additional trials. You want to get a good handle on what the needs are of the fishermen that rely upon bait.

Yet, I am not sure -- I think there was some bullet there, where it was sort of like the Rhode Island prospectus was discussed, and I don't know what phrase you used, but it didn't seem like it necessarily carried forward. For me, the prospectus, and it was frankly inspired by Toni Kerns, was all about trying to set some objectives; in terms of why we would even pursue alternative bait.

I think, as I remember, it was something along the lines of well there has to be some sort of conservation benefit. The bait has to prove that it's using less horseshoe crab than just using horseshoe crabs. The efficacy needs to be there. The cost needs to be reasonable and hopefully comparable, and the logistics and the handling need to be there.

Those seemed to be the factors that would drive us forward in our efforts to explore the use of alternative bait. Does the TC still identify with those issues, or is there some other perspective now that I'm missing, in terms of where the TC is on this issue? I just felt like those were key concepts to put forward, so that we knew what we were trying to do and what we were looking to evaluate. If it didn't meet those standards, if alternative bait wasn't as effective, wasn't as affordable and certainly didn't lead to a conservation benefit, i.e. use less horseshoe crabs than otherwise. No point in pursuing it. But I thought that was the whole point; to explore those issues. Are those issues still relevant?

MR. DOCTOR: Those issues are absolutely relevant, and it is because of those issues that we went forward with the action that we did.

MR. ROY W. MILLER: Steve, can you bring us up to speed on what alternative bait trials have been conducted, thus far? Were there any ongoing this year or is everything still in the planning stage in that regard; using the alternative baits, artificial baits, whatever you want to call them?

MR. DOCTOR: There was a study done last year, and I believe it was Rhode Island that did it. Was it Rhode Island that did the study last year?

MR. BALLOU: And Connecticut, I believe.

MR. DOCTOR: And Connecticut. It was a bait by one vendor, and there were a lot of problems getting the bait, number one, handling the bait, using the bait; and it seemed to have some

efficacy. There is a report available of it. It also used female horseshoe crab in the bait, which was kind of disconcerting for a lot of people, and also they were not specific on how much female horseshoe crab they were using, and the cost of the bait was a question.

The more we looked into it, the more questions we had. What we tried to do as a Technical Committee is identify what questions we have. One of the main questions we had was, what baits are people using, how much of it are they using, and what is the cost of it? We needed to know that information before we would be able to compare it to artificial bait.

CHAIRMAN GILMORE: Go ahead, Roy.

MR. MILLER: If I may just follow up on that. Was that bait that was tried in Rhode Island and Connecticut, was that the bait that University of Delaware worked on that contained roughly a tenth of a horseshoe crab that was marketed by LaMonica Foods, or was it something else?

MR. ROOTES-MURDY: I'm going to help Steve out on this just a little bit, because I was closer to it in the spring. Staff was instructed coming out of, I believe, the February meeting, to try to undertake this cost comparison between the bait that was used in those trials in Connecticut and Rhode Island, which was LaMonica Fine Foods product; and determine if it was the most cost effective alternative to what fishermen are doing currently, in terms of their mix or suite of ingredients they're using in the bait bags and pots.

What we found during those trials was that while the ratio for the pucks was anywhere between a tenth to a quarter of a crab, because it wasn't as effective in staying together, many times they would have to double up on the dosage. That could increase it up to anywhere between a quarter to a half, and in some instances even more.

What Steve was just mentioning is another concern that the TC had, which is the composition wasn't always clear how much of the females and males were in it. The idea was that you would need more males to be equivalent to females, in terms of it as an attractant. But we didn't have that breakdown for what each puck had, because that information wasn't available to us.

Additionally, we also didn't know where these crabs were coming from on the coast. When speaking with LaMonica Fine Foods about this, they go from purchasing this from dealers up and down the coast. If we're concerned or if the board is concerned, excuse me, about the populations in other parts of the coast that these crabs may be coming from, the conservation savings or benefits from it may be compromised in that way.

CHAIRMAN GILMORE: Other questions for Steve? Unless there is any more advice, I think the TC and staff are pretty well ready to go on the addendum. Unless there is anything else that we want to add to that, I think they'll be ready to move forward and then reporting back in the May, 2017 meeting. Is everybody good with that?

2017 DELAWARE BAY HORSESHOE CRAB SPECIFICATIONS

CHAIRMAN GILMORE: Okay. I think we'll move along now then to Item Number 6, which is the 2017 Delaware Bay Horseshoe Crab Specs, and Kirby is going to give us a presentation on that first.

MR. ROOTES-MURDY: This should be very straightforward, given the presentations we just walked through this morning so far. The 2017 harvest specifications for the Delaware Bay Region, there is the ARM recommendation for Harvest Package 3. It is the same as what's been in place the previous three years. Both the ARM Subcommittee and the Technical Committees together recommended this package be selected.

Just in terms of a breakdown of what that means, they are 500,000 male-only crabs, and the state quotas under that 500,000 male-only crabs is broken down as the following:

Delaware and New Jersey are proportioned 162,136; also understanding that New Jersey's bait fishery has been closed in recent years. Maryland's Delaware Bay origin quota would be 141,112 and Virginia's is 34,615 east of the COLREGS line for male-only harvest. With that, if there are any questions, I'm happy to take them, but this is for board consideration and action.

CHAIRMAN GILMORE: Questions for Kirby. Seeing none; we're going to need a motion to move forward on this. Go ahead, Mike.

MR. LUISI: I don't know if you guys prepared one already, but I guess what you're looking for is a motion, would be to move to select Harvest Package 3 for the 2017 Horseshoe Crab commercial fishery.

CHAIRMAN GILMORE: Perfect, Mike, second, Stew Michels; discussion on the motion. Emerson Hasbrouck.

MR. EMERSON HASBROUCK: Does that motion need to say for Delaware Bay?

CHAIRMAN GILMORE: **Yes, I think it does, is that okay Mike, friendly addition, some wordsmithing yes, for Delaware Bay.** Good point, Emerson.

MR. LUISI: I think we're going to be using this motion until 2060, so we should perfect it now.

CHAIRMAN GILMORE: That's a very good point. Other discussion on the motion, questions on the motion? This is a final action. Actually, we go to the audience first, are there any comments on the motion from the audience? Seeing none; back to the board. It is a final motion so we're going to need to do a roll call vote, unless there is no objection to the motion.

Let's start there. Is there any objection to the motion? Great, seeing none; we will approve the motion without objection. Okay, let me just read it just so we're really clear. Move to select Harvest Package 3 for 2017 Horseshoe crab harvest in Delaware Bay. A motion by Mr. Luisi, seconded by Mr. Michels, and that motion is adopted unanimously. We're on to other business right now. We actually have essentially some discussion on the advisory panel. Oh I'm sorry, I missed one. We're going to do the FMP review, and Kirby you're going to do that.

HORSESHOE CRAB FMP REVIEW

MR. ROOTES-MURDY: All right, if you guys will just bear with me a little bit longer on this. We're going to go through the Horseshoe Crab FMP Review fairly quickly. First, I want to show you, this is a chart we have been using in previous years to lay out how bait and biomedical harvest and collection have gone in recent years.

I just want to note that we've moved away from this graph, and later on in the PowerPoint I'm going to show you the new one that we've reusing for our outreach information; just to get at more accuracy from feedback we got from the Advisory Panel members on it. The 2015 bait fishery total coastwide harvest was approximately 583,000 crabs.

A majority of those crabs came from the states of Delaware, New York and Massachusetts. They combine for about 70 percent of the coastwide harvest. Overall though, it is a decrease in what the harvest levels were relative to 2014. Delaware through Virginia, as well as Georgia through Florida all decreased landings from 2014.

It is important, I guess, to note that the total coastwide landings are approximately 36 percent of the total coastwide quota. In terms of the number of crabs that are being harvested, relative to 1998 it has been a significant decrease and even relative to last year, it is also a decline. When moving on to talking about biomedical collection and bleeding, the reported number of crabs that were brought to biomedical facilities was about 559,000 crabs.

This is a 3 percent decrease from the previous five-year average. Crabs used as bait and those that

were bled was about 56,000 crabs, which is a 2 percent decrease from the past five-year average, and biomedical only mortality estimate is approximately 70,223. If you need more information on how that's broken down, why we're looking at biomedical only bled crabs, it's in part because those that are used for the bait fishery are also then given back and attributed as having completely died, no assumed post release mortality for those.

This is the new graph that we have on our website, and I just wanted to make sure the board was aware of it. It lays out what the commercial landings are, what the number of crabs that have been collected is, and then the additional bar is the estimated biomedical mortality. We had been given at least some advice and approached about needing to change the graphics we were having on the website, because people were concerned that it was misleading.

With some feedback from advisory panel members we did make this change. In going through the FMP review, it was noted by some of the PRT members that there is an interest in reporting out on some of the synthetic alternative LAL testing that's going on. We didn't have time to address that this year, due to some of the time constraints. But moving forward, this is something that the PRT would like to have included.

There is also concern on the number of crabs that are unidentified by sex from biomedical bleeding. I mentioned this earlier on in today's meeting about trying to get at this information better across the coast as noted. Those states that have a biomedical facility, and are bleeding crabs in their state, need to report out that those numbers, males and females that have been bled.

But what sometimes gets lost in translation is there are crabs that get to the facility and then are removed and not bled, and we get a total number for that. But we don't often get what that breakdown is by males and females. While we might be getting the number going in of the males and females, if we're subtracting a number that isn't attributing it to sex specific, then it starts to confuse how many of those males and females were actually bled, and what the mortality should be applied to those. It is important to note that the board did task the Stock Assessment Subcommittee with addressing biomedical mortality in the next stock assessment.

The sooner the states are able to better collect this information, and at least provide guidance on how to maybe apportion the sex ratio, if they aren't able to get at a specific number by males and females; it will help that process along significantly. The PRT recommends continuing to seek funding for the Virginia Tech Trawl Survey.

I will note, additionally, that during the Technical Committee's meeting there was discussion about, in the absence of the Virginia Tech Trawl Survey being able to be continued in future years if funding is not available, that the states of Delaware and New Jersey could possibly augment their current surveys to get at some of the biological sampling that we utilized through the Virginia Tech Trawl Survey.

State representatives from those states have indicated that that is a possibility and could be adjusted for future surveys; it just needs to be specified earlier on in the process. The PRT also considered a quota transfer from Virginia to North Carolina. This is a request that has come now two years in a row, and there were some concerns expressed by the PRT, just in terms of it being an occurrence that has happened more than once in recent years and whether that means the quota should be revisited for those states.

But because of the size of the quota transfer, which was approximately 900 crabs, it didn't raise significant concerns to the PRT about implications or impacts to that regional population. The PRT found, in summary, all the state management measures to be consistent with the FMP. It is important to note again that the District of Colombia did not submit a compliance report.

They still remain a member of this board, and so the PRT was not able to determine if they were in compliance with the FMP requirements. With that, an additional note, I walked you through how to best improve reporting numbers of males and females at bleeding facilities. The PRT finds all states in compliance with the FMP specifications.

In looking at requests for de minimis, the Potomac River Fisheries Commission, South Carolina, Georgia and Florida have all requested de minimis and qualify for 2017. New Jersey also qualifies, but did not request it. The PRT finds these states have met the requirements for de minimis. With that, I'll take any questions at this point.

CHAIRMAN GILMORE: Just to note the most important part of that slide was LAL, it means Limulus Amoeboctye Lysate, which may help you at Jeopardy some day. Rob O'Reilly.

MR. O'REILLY: Not a question, but Kirby, I heard you say the transfer from Virginia to North Carolina, it is Georgia to North Carolina.

MR. ROOTES-MURDY: Correct. The quota transfer and this was included, I believe, in your board meeting materials. It was a quota transfer from Georgia to North Carolina.

MR. MUFFLEY: Kirby, I just want to make sure I have it right. The bigger issue in regard to the sex information at the biomedical facility is sort of all of those crabs being collected and brought to the biomedical facility versus those crabs that are actually bled. You're getting more information by sex of crabs that are actually bled versus all of those that come to the facility. Is that the piece that we're missing more so? Is the total number of crabs coming to the facility versus what's actually being bled?

MR. ROOTES-MURDY: I think, just to clarify, what we get many times from the states is a breakdown that you have X number of crabs have been brought to the facility, males and females. From the point in which they're brought to the facility to then when they're bled, there is a determination that some of those crabs aren't fit to be bled.

Those crabs are then removed; there hasn't been sex information attributed to them. Then they said X number of crabs is then bled, and we don't necessarily know after the other ones have been removed what that sex ratio is for bled crabs; and that is where we start to have some confusion on the total number of males and females that have been bled.

For more clarity, if the states can work with the facilities to get better information on the numbers of males and females that, once they are brought to the facility are determined not fit to be bled, that information will help us with getting at post release mortality for those bled crabs by sex.

MR. MILLARD: Thanks for the presentation, Kirby. Regarding the graphic on the biomedical collection, I can see the footnote says this pertains to crabs that are brought to the bleeding facility. That 15 percent mortality is applied to those crabs that are brought into the facility, maybe a question for Steve, who is more on the ground.

I haven't been on one of these biomedical collection trawls, but I have it in my head that there is a fair amount of onboard culling that goes, because the biomeds don't want crabs that are damaged or puncture. They want pretty much pristine condition crabs brought into their facility. Again, it is in my head that there is a fair amount of mortality that is not being accounted for then in that process, because of the onboard culling that doesn't go into the facility. Can you comment on that?

MR. DOCTOR: I can start from the Maryland perspective. We have a chain of custody form that follows the crabs from the point of collection all the way to release again. On that form they actually list the number of crabs that are rejected because of death or injury; and we report that to

ASMFC when we report the total number bled by male and female. It is reported.

MR. MILLARD: This terminology on here about crabs brought to the facility is really a little broader than that? Crabs that come up in the trawl is what the 15 percent is being accounted for, is what I think I just heard.

MR. DOCTOR: Okay, so Kirby says that we're reporting mortality on the number that are bled, not the total number collected.

MR. MILLARD: My point is, that bears directly on this sort of ongoing back and forth we're having with the biomedical companies about, is it 15 percent or is it a lot less. I'm suggesting there is a large, I don't know how large, but there is a component that is not being accounted for that are coming up in the trawl damaged, going right back overboard. We don't know. That's a mortality segment that we're not accounting for.

MR. DOCTOR: I just want to reiterate that I do report the number that are injured and dead at the time of collection and also at the time of release, and also the rejected because of death at the biomedical. We're in the middle somewhere is the best way I can answer that.

CHAIRMAN GILMORE: I'm not sure what the other states do either, so it is a good point, Mike, it could be higher.

DR. MICHELLE DUVAL: I just wanted to -- if you read the materials you probably saw this, but just in regards to the PRTs concern about sort of an annual request from North Carolina to Georgia to transfer horseshoe crabs. I just wanted to note that we did actually shorten our harvest season for 2016 by a month to constrain harvest to within our quota, and so we issue a proclamation prior to the beginning of the year that establishes the seasons start date and end date.

We shorten that by a month and all of the harvest that was legally pursued during that open season was actually underneath the quota, it was actually illegal harvest that occurred after the season was closed that led to the overage; so enforcement action has been taken, and I think we feel pretty confident about next year. Thank you again to Spud and Pat for helping us out.

CHAIRMAN GILMORE: That was clear in the briefing materials. You guys are definitely managing it and putting a lot of effort into it. Any other questions? Colleen.

MS. COLLEEN CALLAHAN: Kirby, do we have an idea on the percentage of crabs that are brought to the facility and ultimately not bled?

MR. ROOTES-MURDY: Yes, we have that information. I will offer that, for the FMP Review, we have to aggregate this information right now on a coastwide level. We could drill down and try to provide that, if needed, through the benchmark stock assessment, but right now we have to aggregate it at the coastwide level. I can go back and look at the FMP review a little bit more closely, and if you would like I can work at trying to get at that amount that are brought to the facility and not bled coastwide and report back to the board on that.

MS. CALLAHAN: I didn't mean to create more work. I was just trying to get a handle on how large a problem it is, since we're trying to apply mortality by sex; and that is a group that is unaccounted for.

CHAIRMAN GILMORE: Okay, any other questions? All right, we need a couple of motions here. We've actually got four things we want to cover. I think the first motion, if we combine it into one, which would be accepting the FMP review with the compliance reports and the de minimis as one motion would be efficient, and then we'll do the North Carolina/Georgia transfer as a separate one. Does anyone have a motion for the first three that they would like to offer?

MR. ROBERT H. BOYLES JR.: I would move that the board accept the 2016 FMP Review and

approve the de minimis request from the Potomac River Fisheries Commission, Georgia, Florida, and South Carolina or whatever order is preferred.

CHAIRMAN GILMORE: Do we have a second to that motion? Bill Adler. Mike Luisi.

MR. LUISI: Would you want to add state compliance reports to that too; tackle all three?

CHAIRMAN GILMORE: Is that okay with you, Robert?

MR. BOYLES: Yes, sir.

CHAIRMAN GILMORE: Bill. Amy is going to get that up there. We want to add the state compliance reports. While we're fixing it, is there any discussion on the motion? Okay, I think we've got the motion up there, everybody can see it. Any discussion on the motion? Okay, let me read it into the record.

Move to accept the Horseshoe Crab 2016 FMP Review and State Compliance Reports and approve de minimis requests for the Potomac River Fisheries Commission, South Carolina, Georgia and Florida. Motion by Mr. Boyles and seconded by Mr. Adler. Is there any objection to the motion? Okay, seeing none; we will approve that adopted unanimously. Okay, we're going to need a second motion now for the transfer between North Carolina and Georgia. Michelle.

DR. DUVAL: I move that the board approve the request for transfer of quota from Georgia to North Carolina.

CHAIRMAN GILMORE: Do we have a second to that motion? Pat Geer. Discussion on the motion. Michelle, go ahead. Michelle, you have black gloves on, I can't see your hands.

DR. DUVAL: I'll put my shiny gloves on next time. Perhaps, we should just add the amount of the transfer, which is 1,250 crabs to the motion; just to be clear.

CHAIRMAN GILMORE: Okay, we'll put that up; 1,250 was the number? Okay. Further discussion on the motion? Let me read this before we take a vote. **Move that the board approve the request of transfer of quota, 1,250 crabs, from Georgia to North Carolina; a motion by Dr. Duval, seconded by Mr. Geer. Is there any objection to the motion? Seeing none; we will adopt that unanimously**. Bill Adler.

MR. ADLER: Just to the previous motion that passed about the de minimis and the compliance. Wasn't it to approve the FMP report, the de minimis status and the compliance things? Did it say all three in that motion?

CHAIRMAN GILMORE: Yes.

MR. ADLER: All right, thank you.

OTHER BUSINESS

CHAIRMAN GILMORE: Okay, we're on to other business now, we have one item, which is involved with the AP, and Kirby, do you want to take that?

MR. ROOTES-MURDY: One other thing that the Technical Committee did talk about when they met earlier this month was regarding the Shorebird Advisory Panel. There has been some discussion at times amongst staff on how best to engage this group, as they have not been very active in the last four years or so. Technical Committee members recommended that the Shorebird Advisory Panel should be reinvigorated, repopulated and engaged in the commission's process for reviewing any management actions and decisions. One of the unique challenges, just in terms of the dynamics we have with horseshoe crabs, is that the Shorebird Advisory Panel would be providing additional input into the process.

That would be separate from what the state agency and federal agency partners who have shorebird biologists on the ARM Subcommittee and the Delaware Bay Ecosystem Technical

Committee. Staff did make this clear to the Technical Committees that it was not apparent what additional input would be needed from those groups.

But a suggested way of moving forward would be that the current Horseshoe Crab Advisory Panel be adjusted to accommodate two nontraditional stakeholder positions that would be occupied by shorebird, essentially AP members, or to represent the shorebird conservation interest groups, as needed, to accommodate the interest of the Technical Committees to have that representation in the process. This is a suggestion from staff moving forward. Tina Berger is up at the microphone, as well.

What we're looking for, moving forward from the states, would be collectively we would be adding two more positions to the Horseshoe Crab Advisory Panel that would be specific to shorebird conservation interest and possibly interest groups. I can take any questions on that at this point. There doesn't need to be nominations made at this meeting, but to follow up with staff on who you would recommend having join that; and again, it is two more positions for the entire coast not per state.

CHAIRMAN GILMORE: Any comments on that or questions for Kirby? It appears we're all good then with just expanding the AP by the two members, and then we'll come up with recommendations for the next meeting in February, and we'll vote on them at that point. Okay, seeing no more on that, is there any other business to come before the Horseshoe Crab Board? Oh Tina, go ahead.

MS. TINA BERGER: Just one more point. We will be sending out the AP list to folks, and if you could look at your membership, there seems to be less activity by the actual bait harvesters, so we would like their voice heard to balance AP input. If you could look at that for your next meeting, that would be great.

ADJOURNMENT

CHAIRMAN GILMORE: Thanks, Tina, great homework. Okay, any other items to come before the Horseshoe Crab Board? If not we will adjourn, thank you everyone.

(Whereupon the meeting adjourned at 9:34 o'clock a.m. on October 26, 2016)

Atlantic States Marine Fisheries Commission

Horseshoe Crab Technical Committee Report

Bait Use Surveys of the American Eel and Channeled Whelk Fisheries

Participants:

Rachel Sysak (NY), Chair	Jeff Dobbs (NC)
Derek Perry (MA)	Jeff Brunson (SC)
Scott Olszewski (RI)	Lindsey Aubart (GA)
Natalie Ameral (RI)	Tiffany Black (FL)
Colleen Giannini (CT)	Mike Millard (USFWS)
Jeff Brust (NJ)	Dr. John Sweka (USFWS)
Jordy Zimmerman (DE)	Dr. Joanna Burger (Rutgers)
Steve Doctor (MD)	Dr. Kristen Anstead (ASMFC)
Adam Kenyon (VA)	Michael Schmidtke (ASMFC)

Introduction

The Horseshoe Crab Technical Committee conducted a survey of American eel and channeled whelk fishermen along the US Atlantic coast. The intents of this survey were to: a) characterize the preference, prevalence, and performance of horseshoe crab as bait in these fisheries, b) provide information on the relative amounts and costs of horseshoe crab bait use that could be used to assess the viability of manufactured baits with reduced amounts of horseshoe crab, and c) provide information on the fishery's current impression of manufactured baits. The surveys for the American eel and channeled whelk fisheries can be found in Appendices I and II, respectively.

State Survey Distribution Methods and Response Rates

Mail surveys were sent by state fisheries departments to American eel and channeled whelk trap/pot fishermen during January-February, 2017. All states except New York sent surveys to all current permit holders; New York only sent surveys to permit holders who were active in the past two years. Responses were voluntary in all states except for Massachusetts, where survey completion was required for permit renewal.

Harvest of horseshoe crabs for bait, or the use of horseshoe crabs as bait in any fishery in South Carolina, is prohibited, pursuant to Code of Laws of South Carolina, Title 50, Chapter 5, Article and Section 1330. The only allowable harvest of horseshoe crabs in South Carolina is for biomedical bleeding, or for research and scientific purposes, and is limited to harvest by hand. Therefore, while phone interviews were conducted with blue crab fishermen that encounter whelk as bycatch (summarized in Appendix III), data from South Carolina were not included in survey analyses.

Of 548 eel surveys mailed, coastwide, 163 voluntary responses were received, for a 30% response rate. Of 822 whelk surveys mailed, coastwide, 260 responses were received (32% response rate). Massachusetts sent 150 whelk surveys and received 133 responses, which were required for permit renewal. In states from Rhode Island through Florida, where responses were not required for permit renewal, 630 whelk surveys were mailed, and 127 responses were received, for a 20% voluntary response rate. Response rates for individual states are shown in Table 1.

Table 1. State response rates for the American eel and channeled whelk bait surveys. Coastwide response rates are shown for all states (Total) and states where survey completion was not a condition of permit renewal (Voluntary).

State	American Eel			Channeled Whelk		
	Surveys Sent	Responses Received	Response Rate	Surveys Sent	Responses Received	Response Rate
MA	0	0		150	133	88.7%
RI	6	2	33.3%	138	39	28.3%
CT	0	0		131	29	22.1%
NY	14	9	64.3%	28	14	50.0%
NJ	100	22	22.0%	200*	13	6.5%
DE	65	12	18.5%	64	9	14.1%
MD	40	12	30.0%	13	4	30.8%
VA	216	76	35.2%	82	18	22.0%
NC	55	6	10.9%	16	1	6.3%
GA	28	10	35.7%	0	0	
FL	24	14	58.3%	0	0	
Total	**548**	**163**	**29.7%**	**822**	**260**	**31.6%**
Voluntary	**548**	**163**	**29.7%**	**672**	**127**	**18.9%**

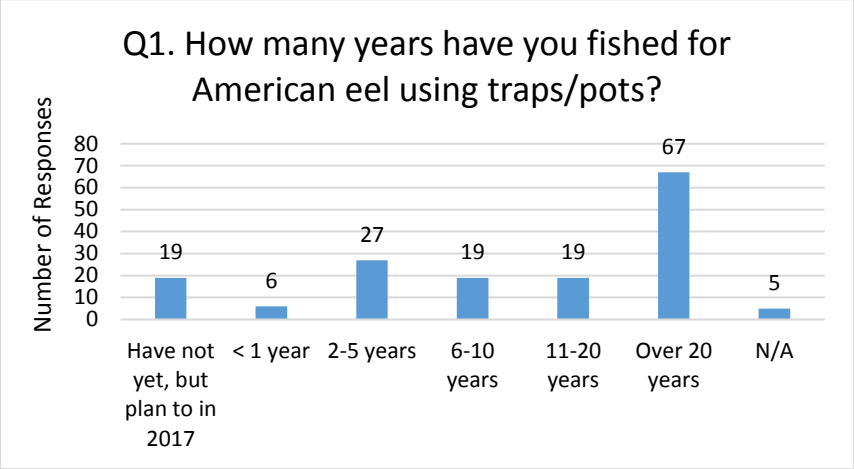
*New Jersey sent whelk surveys to crab fishermen, as New Jersey does not currently manage whelk, but whelk are caught in New Jersey by crab fishermen.

Results and Discussion

Eel

Characterization of the American Eel Fishery

Figure 1. Respondents' years of experience in the American eel trap/pot fishery (N=162). (Q1)



For all analyses presented, only data from respondents that fished for American eel in 2016 were used, unless otherwise indicated with "all respondents".

Figure 2. Percentages of respondents who did or did not fish for American eel in 2016 with traps/pots (N=161). (Q2)

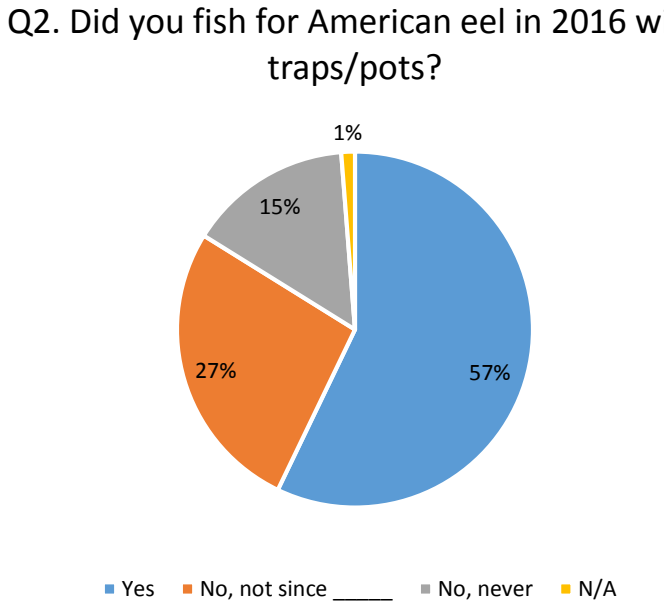


Table 2. Most recent year fished for fishermen who are no longer active in the American eel fishery. (Q2)

Last Year Fished	No. of Responses
1990	1
1995	1
2000	1
2005	1
2008	1
2010	1
2011	3
2012	4
2013	1
2014	8
2015	11
No Response	10

Table 3. Months fished in the American eel fishery using traps/pots, by state, in numbers of responses. Month(s) of greatest fishing activity for each state and all states combined is highlighted. (Q4)

Month	All States	RI	NY	NJ	DE	MD	VA	NC	GA	FL
Jan	15	0	0	1	0	0	0	0	3	11
Feb	13	0	0	1	0	0	1	1	3	7
Mar	49	0	3	6	4	10	15	1	3	7
Apr	75	1	5	9	5	10	40	1	4	0
May	82	1	7	11	7	10	41	0	5	0
June	49	1	5	7	3	7	21	1	3	1
July	27	1	3	2	0	4	13	1	2	1
Aug	35	1	3	3	3	5	15	2	2	1
Sept	79	1	6	11	8	10	36	3	3	1
Oct	89	1	8	15	9	10	36	5	2	3
Nov	74	1	7	10	10	7	26	4	2	7
Dec	33	0	0	2	4	5	6	3	2	11
Total	620	8	47	78	53	78	250	22	34	50

Fishing Practices of the American Eel Fishery

Figure 3. Use of single and trawl/longline methods for traps/pots in the American eel fishery in percentages of responses (N=140). (Q5)

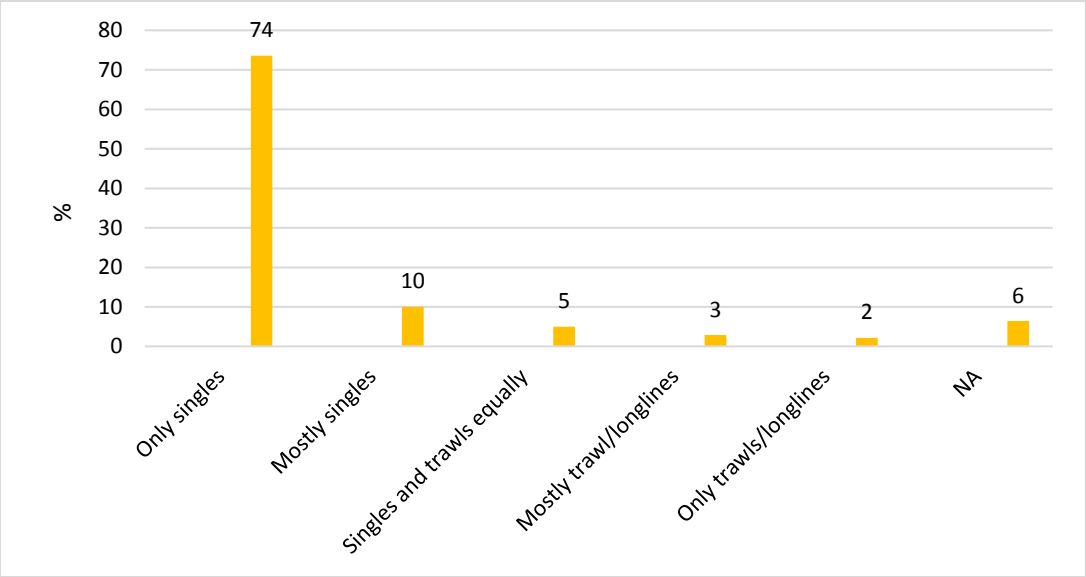
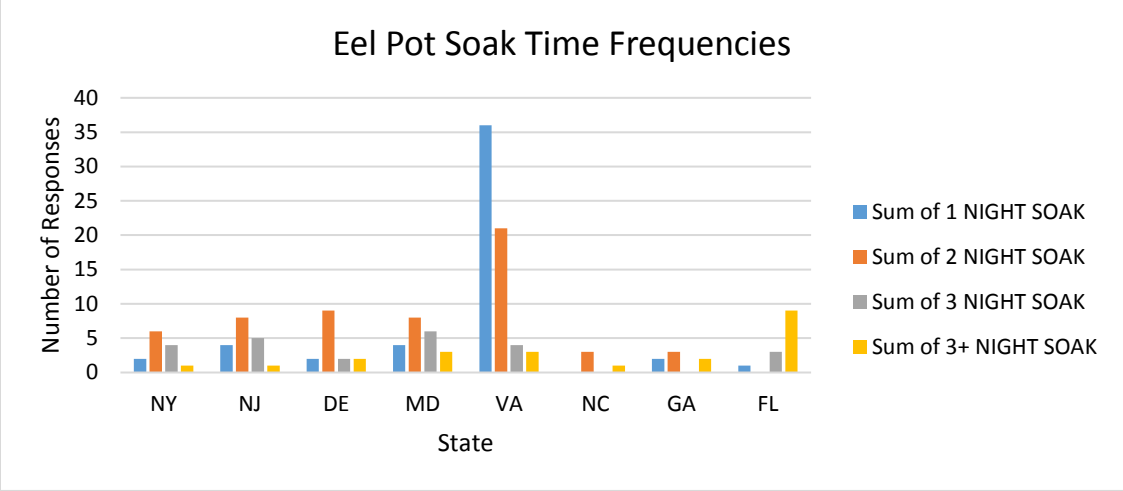


Figure 4. Soak time frequencies by state for traps/pots in the American eel fishery (all respondents). (Q6)



From the survey responses, eel trap/pot usage was considerably variable. With the exception of Maryland, average traps/pots per trip ranged from 31 – 190 and average max traps/pots ranged from 48 – 220 (Table 4). Maryland reported an average of 411 traps/pots per trip and an average of 1024 max traps/pots.

Table 4. Numbers of traps/pots used per trip, by state, in the American eel fishery (all respondents). (Q7-8)

State	n	Average of Max Traps/Pots	stdDev of Max Traps/Pots	Min Traps/ Pots	Max Traps/ Pots	Average Traps/Pots per Trip	stdDev of Traps/Pots per Trip
NY	8	92	47	35	150	70	40
NJ	16	89	86	6	250	78	80
DE	11	137	105	30	400	104	66
MD	10	1024	956	35	3000	411	239
VA	60	79	91	1	500	72	86
NC	5	220	110	100	300	190	102
GA	7	48	36	8	100	31	25
FL	12	105	71	15	300	92	75

Bait Use in the American Eel Fishery

Of 90 respondents to the American eel survey, 30 (22.56%) typically use horseshoe crab as bait. The most prominent bait in the American eel fishery is blue crab, with 54 (40.60%) respondents typically using blue crab as bait. Numbers and percentages of respondents that typically use different types of bait in the eel fishery are shown in Table 5. About half of respondents (52.2%) reported typical use of multiple bait types. Fish are the second most prominent bait in the American eel fishery (27.07%), with menhaden being the most common identified species within this bait type. Of 28 responses that identified fish to the species level, 26 identified menhaden as a typical bait used.

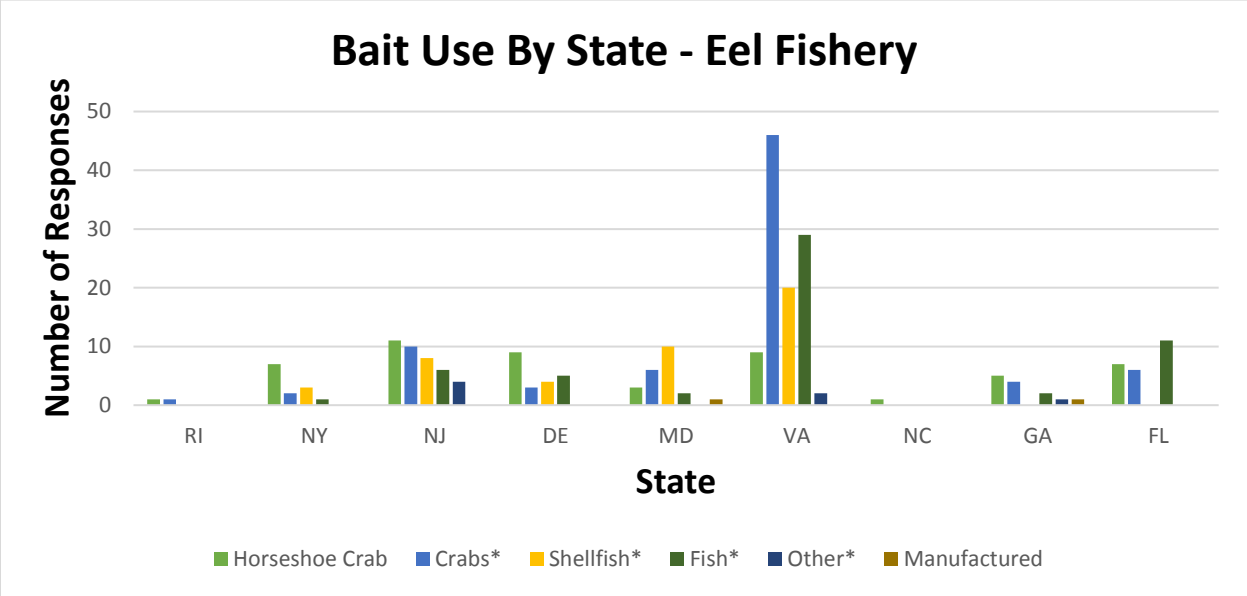
Table 5. Bait types typically used by American eel fishermen in 2016 shown in numbers and percentages of responses to eel bait surveys. Fishermen may typically use multiple bait types, so percentages do not sum to 100%. (Q9-10)

Bait Type	**Eel (N=90)**	
	Responses	Use Percentage
Blue crabs	54	40.60%
Fish racks or whole	36	27.07%
Horseshoe crab	30	22.56%
Shellfish	27	20.30%
Other**	9	6.77%
Razor Clams	7	5.26%
Green crabs	1	0.75%
Manufactured bait	1	0.75%
Rock crabs	1	0.75%
Jonah crabs	1	0.75%
Sharks/Skates/Dogfish	0	0.00%

**No individual bait type included in Other had a use percentage greater than 5% for the American eel trap/pot fishery.

Figure 5 contains data representing 241 individual responses to bait use surveys in the eel fishery. 32% of the responses designate “crab” use, 23% designate “fish” use, 22% designate “horseshoe crab” use, 19% designate “shellfish” use, 3% designate “other”, and only 1% designate “manufactured” bait use. This demonstrates the minor role of manufactured bait in the industry. Although horseshoe crabs are not the most frequently used bait under current fishing practices, it is the only bait being employed in every state. It is worth noting that many of these responses were from the same individuals as the survey allowed users to select up to 5 bait types and over 75% of responses exemplified the roles of other bait sources in the fishery.

Figure 5. Numbers of respondents who use each bait type in the American eel fishery. Does not include amount used. Number after bait type represents sum of all state responses (all respondents). (Q9-10)



*Crabs column compiled individual responses for: green crab, rock crab, blue crab, Jonah crab, and shrimp heads.
*Shellfish column compiled individual responses for: shellfish and razor clams
*Fish column compiled individual responses for: fish racks or whole, menhaden, herring, and porgy
*Other column compiled individual responses for: other, road kill, and chicken scraps

Soak time (Figure 4) and bait longevity (Figure 6) varied from state to state, however within each state soak time and bait longevity correlated very well. Overall, most states had 2 nights of soak and bait time as their most frequent responses. Most eel fishermen (83%) do not use bait saving devices such as cups or bags (Table 6), and use of these devices is not required by current state regulations.

Figure 6. Bait longevity, by state, in the trap/pot American eel fishery (all respondents). (Q13)

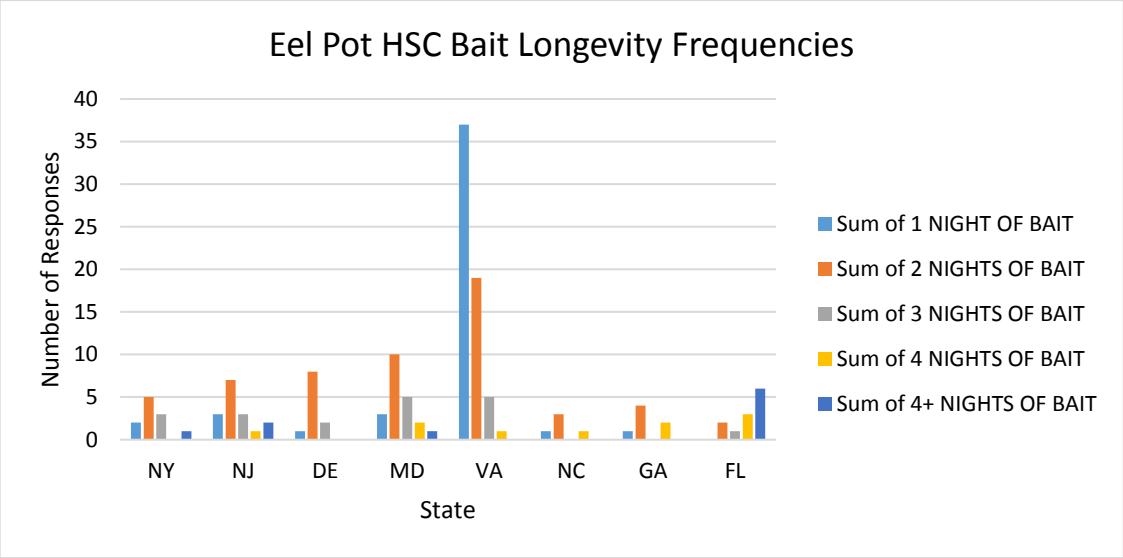
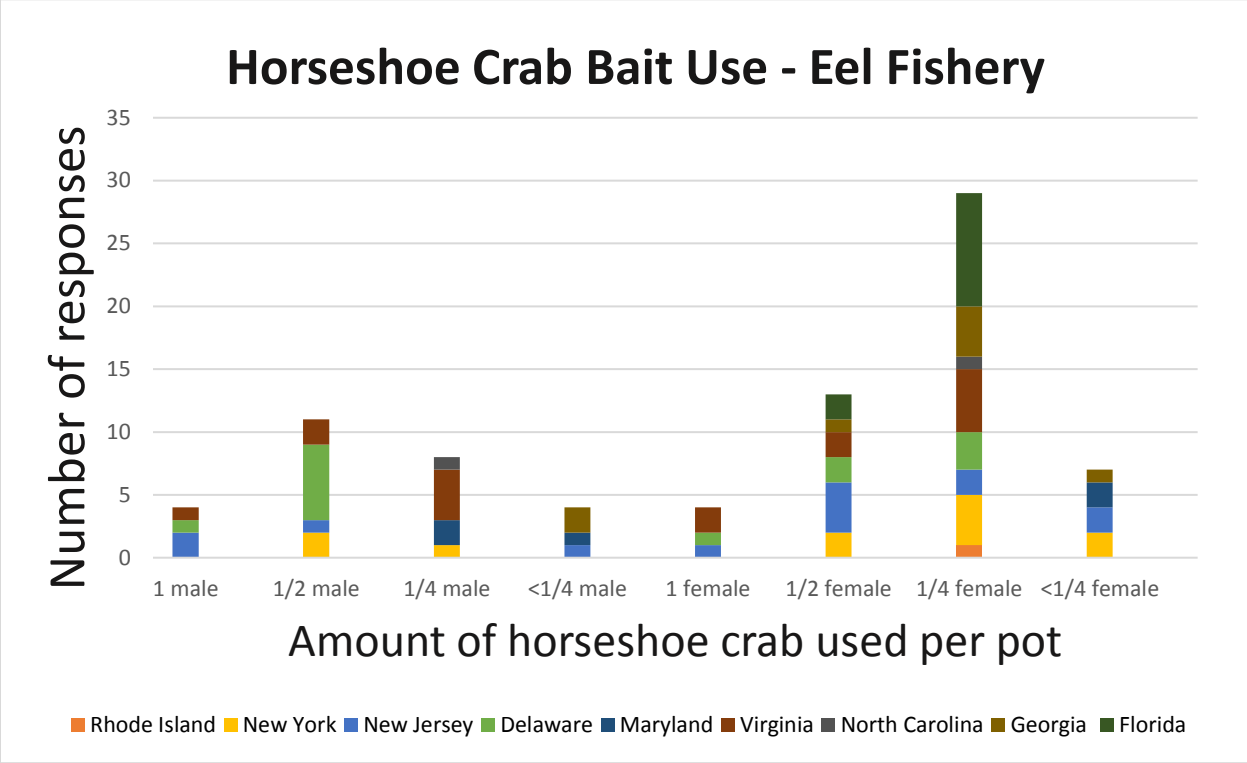


Table 6. Use of bait-saving devices in the American eel fishery. Bait-saving devices are required in the American eel trap/pot fishery in Delaware, but not in other states. (Q14)

	All States	**RI**	**NY**	**NJ**	**DE**	**MD**	**VA**	**NC**	**GA**	**FL**
Yes, HSC only	3	0	1	1	0	0	1	0	0	0
Yes, mix	14	0	2	4	3	1	4	0	0	0
No	62	1	5	4	3	0	36	4	3	6
NA	3	0	0	1	0	0	1	0	0	1

66% of respondents who use horseshoe crabs typically use females (Figure 7). The most common amount of female horseshoe crab used per trap/pot was one fourth of a female crab (36% of respondents who use horseshoe crabs). 34% of the respondents who use horseshoe crabs typically use males. The most common amount of male horseshoe crab used per trap/pot was one half of a male crab. Of respondents who typically use male horseshoe crabs, 40% use one half of a male crab per trap/pot. The sexual dimorphism of horseshoe crabs (with females growing larger than males) may explain the difference in the relative amounts of male and female crab used. Additionally, considering sexually dimorphic size differences, the amount of horseshoe crab in volume per trap/pot is likely similar between one fourth of a male crab and one half of a female crab.

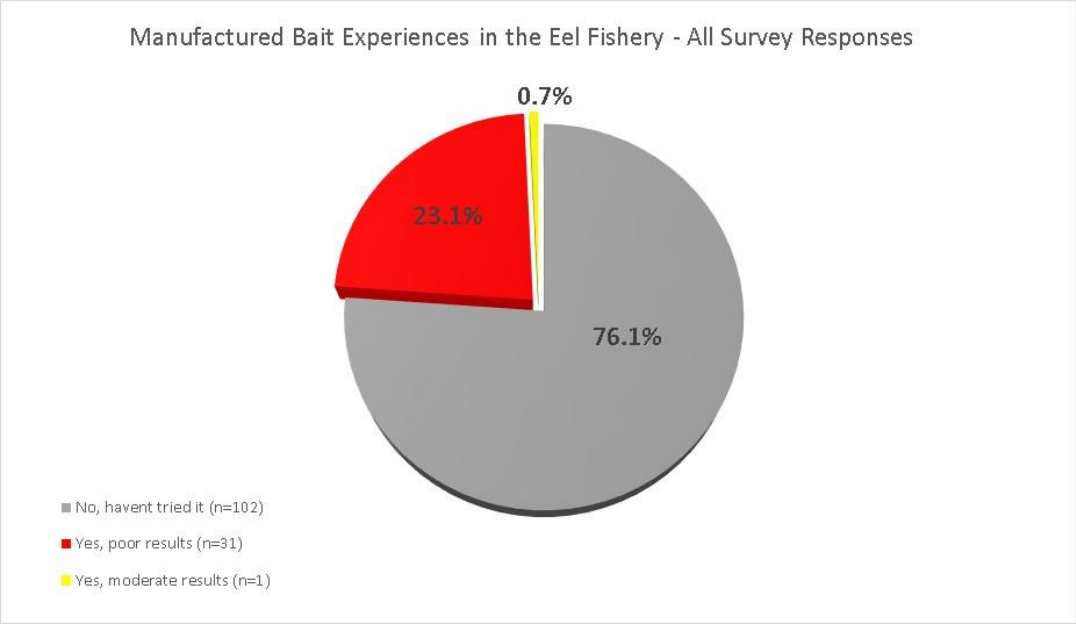
Figure 7. Typical amounts of horseshoe crab used per trap/pot, by state, in the American eel fishery. (Q17)



Use and Impression of Manufactured Bait in the Eel Fishery

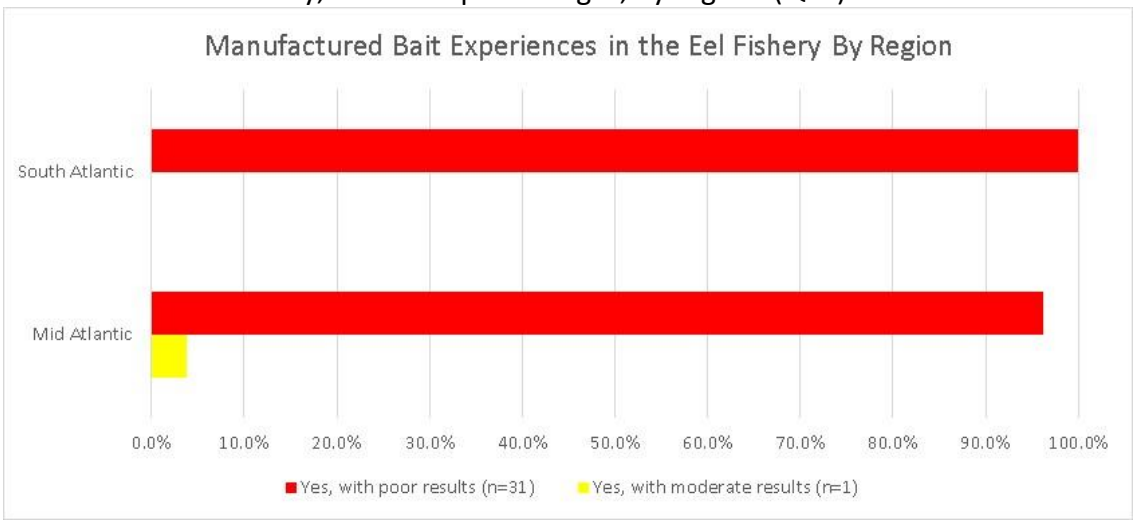
Looking at all survey responses for the eel fishery the majority (76.1%) of respondents indicated they had never used manufactured bait (Figure 8). Less than 24% of survey responders had used manufactured bait with the majority (97.1% of respondents who have used manufactured bait; 23.1% of all respondents) reporting poor results. It is important to note there were no responses for the eel fishery in the surveys received from Massachusetts or Connecticut and only one survey was received from an active eel fisherman in Rhode Island.

Figure 8. Experiences with manufactured bait in the American eel fishery, shown as percentages. (Q11)



When looking at responses by region for those who had used manufactured bait in the past, the same pattern develops. The majority (average 98%) of fishermen in both the Mid Atlantic (New York to North Carolina) and the South Atlantic (Georgia and Florida) reported poor results with the product, with a single responder (4%) in the Mid Atlantic indicating having positive results using the product (Figure 9). The single survey received from Rhode Island indicated they had not used manufactured bait and therefore is not included in these analyses.

Figure 9. Moderate and poor experiences with manufactured bait for fishermen who have used it in the American eel fishery, shown as percentages, by region. (Q11)



Bait costs in the American Eel Fishery

Greater than 53% of eel fishermen using only non-HSC bait paid less than $1.00 per trap/pot for bait, and nearly 89.3% paid $1.50 or less (Table 7). Among those eel fishermen that used HSC in combination with other types of bait, 47% paid $1.50 or less, and 58.8% paid less than $2.00 per trap/pot for bait. Only one fisherman used exclusively HSC, at an average cost of $1.00 to $1.50 per trap/pot for bait.

Table 7. Costs to bait American eel traps/pots using baits that include only horseshoe crab (HSC Only), horseshoe crab and other bait (HSC Plus), and no horseshoe crab (Non-HSC). (Q12)

	Percent of Respondents			
Cost to Bait Eel Trap/Pot	**Non-HSC (n=56)**	**HSC Plus (n=17)**	**HSC Only (n=1)**	**All Baits (N=74)**
< $1.00	53.6	29.4	0	47.3
$1.00 - $1.50	35.7	17.6	100	32.4
$1.51 - $2.00	8.9	11.8	0	9.5
$2.00 or more	0.0	17.6	0	4.1
$2.00-$2.50	1.8	11.8	0	4.1
> $2.50	0.0	11.8	0	2.7

Channeled whelk

Table 8. Number of total respondents by state by number of years fishing for channeled whelk with traps/pots. (Q1)

	Q1. How many years have you fished for whelk using traps/pots?									
	All States	MA	RI	CT	NY	NJ	DE	MD	VA	NC
Yet to fish	21	10	4	2	1	2	0	1	1	0
≤1 year	9	4	2	1	1	0	1	0	0	0
2-5 years	42	23	10	2	2	1	1	1	2	0
6-10 years	46	23	8	6	3	0	1	0	4	1
11-20 years	51	25	6	4	4	3	2	1	6	0
>20 years	75	37	9	13	3	5	2	1	5	0
No response	16	11	0	1	0	2	2	0	0	0

For all analyses presented, only data from respondents that fished for channeled whelk in 2016 were used, unless otherwise indicated with “all respondents”.

Figure 10. Percentages of respondents who did or did not fish for channeled whelk in 2016 with traps/pots (N=260). (Q2)

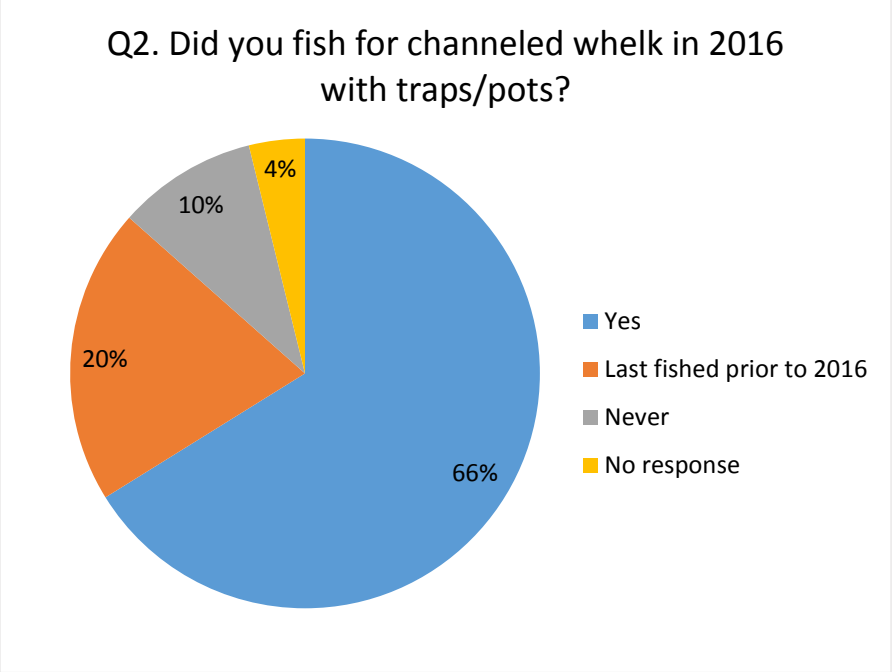


Table 9. Fishing activity by month by state for respondents that reported fishing channeled whelk traps/pots in 2016. Month(s) of greatest fishing activity for each state and all states combined is highlighted. (Q4)

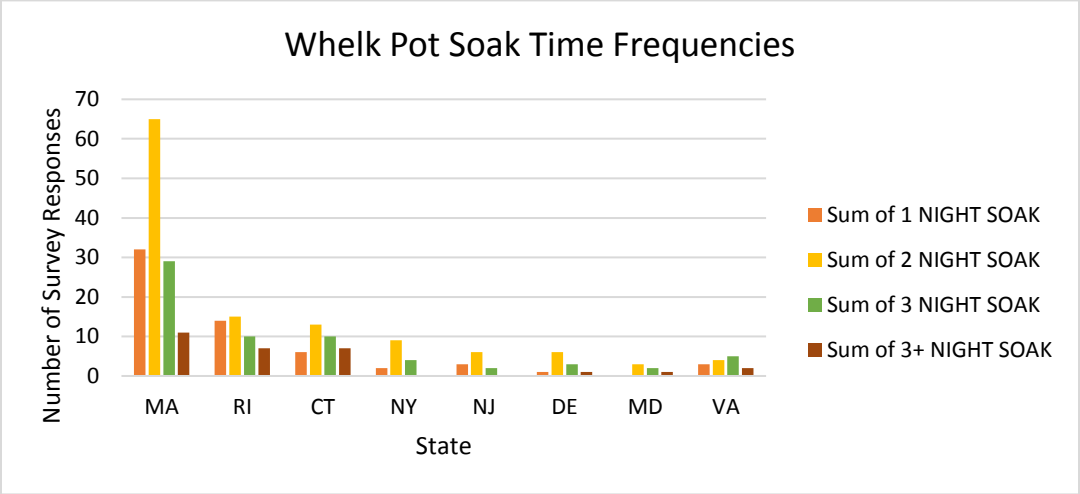
	Q4. What months do you fish whelk traps/pots?								
	All States	MA	RI	CT	NY	NJ	DE	MD	VA
Jan	14	0	2	1	1	1	1	2	6
Feb	2	0	0	0	0	0	0	0	2
Mar	4	0	2	0	1	0	0	0	1
Apr	61	28	13	8	5	2	0	2	3
May	119	50	27	19	11	6	0	3	3
June	127	63	23	22	10	5	1	2	1
July	106	57	18	21	6	3	0	1	0
Aug	73	41	8	16	6	2	0	0	0
Sept	121	68	22	14	9	5	1	1	1
Oct	156	81	26	20	11	8	3	3	4
Nov	154	79	22	20	11	8	4	3	7
Dec	115	56	15	18	7	6	4	2	7

Fishing Practices of the Channeled Whelk Fishery

Table 10. Gear configuration by state for all respondents that reported fishing channeled whelk traps/pots in 2016.

	Q5. In 2016, did you fish your whelk traps/pots as singles or trawls/longlines?								
	All States	MA	RI	CT	NY	NJ	DE	MD	VA
Only singles	82 (52.9%)	46	4	6	8	3	3	3	8
Mostly singles	20 (12.9%)	7	4	4	3	2	0	0	0
Both about equally	0 (0%)	0	0	0	0	0	0	0	0
Mostly trawl/longlines	24 (15.5%)	7	9	4	2	2	0	0	0
Only trawls/longlines	28 (18.1%)	19	7	2	0	0	0	0	0
No response	1(0.6%)	0	0	1	0	0	0	0	0

Figure 11. Soak time frequencies by state for traps/pots using all bait types in the channeled whelk fishery (all respondents). (Q6)



From the survey responses, MA through NY use less traps/pots per trip on average (107 – 139), they also reported lower averages of max traps/pots fished (133 – 239). NJ – VA used more traps/pots per trip on average (225 – 269) and had higher averages of max traps/pots fished (436 – 738) (Table 11).

Table 11. Numbers of traps/pots used per trip, by state, in the channeled whelk fishery (all respondents. (Q7-8)

State	N	Average of Max Traps/Pots	stdDev of Max Traps/Pots	Min Traps/Pots	Max Traps/Pots	Average Traps/Pots per Trip	stdDev of Traps/Pots per Trip
MA	104	153	61	1	240	139	59
RI	32	133	90	35	300	107	74
CT	27	239	203	12	1000	116	53
NY	13	216	151	35	500	113	59
NJ	7	454	688	80	2000	269	247
DE	7	436	358	180	1200	229	48
MD	4	738	565	50	1200	225	140
VA	14	389	193	200	800	259	136

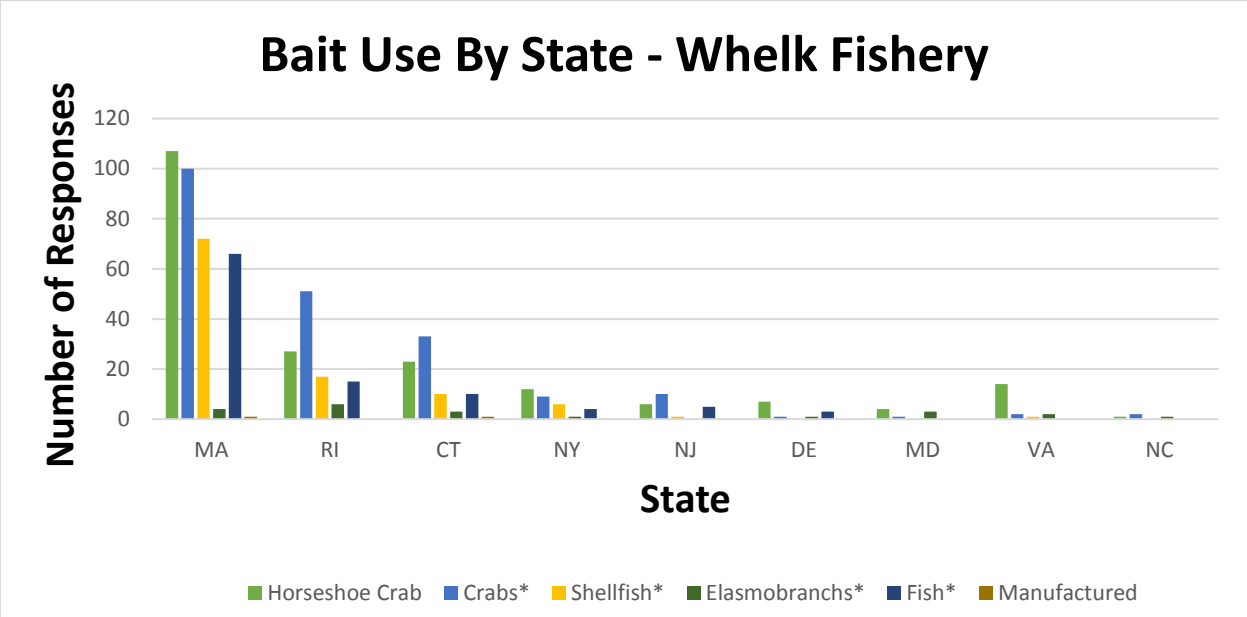
Bait Use in the Channeled Whelk Fishery

Horseshoe crabs are the most prominent bait in the channeled whelk fishery, with 91.2% of 172 coastwide respondents to the whelk survey typically using horseshoe crab as bait (Table 12). Most respondents reported typical use of multiple bait types. Prominent baits other than horseshoe crab include shellfish (typically used by 54.4% of respondents), green crabs (typically used by 50.3% of respondents), and fish (typically used by 50.3% of respondents), and. Of 19 responses that identified fish to the species level, 10 identified Atlantic herring and 8 identified menhaden as typical baits used.

Table 12. Bait preferences by state for all respondents that reporting fishing for channeled whelk in 2016. NA's responded to survey but left this question blank. Percentages are based on the number of respondents that fished in 2016 and answered the question. Fishermen may typically use multiple bait types, so percentages do not sum to 100%. (Q9-10)

	All States	MA	RI	CT	NY	NJ	DE	MD	VA
Number	172	85	28	23	13	8	4	3	8
NA	1	0	0	0	0	1	0	0	0
Horseshoe crab	91.2%	91.8%	82.1%	91.3%	100.0%	85.7%	100.0%	100.0%	100.0%
Shellfish	54.4%	72.9%	57.1%	34.8%	46.2%	14.3%	0.0%	0.0%	0.0%
Green crabs	50.3%	64.7%	75.0%	34.8%	15.4%	0.0%	0.0%	0.0%	0.0%
Fish racks/whole	50.3%	65.9%	46.4%	17.4%	46.2%	71.4%	25.0%	33.3%	0.0%
Manufactured bait	5.3%	0.0%	0.0%	39.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Rock crabs	17.0%	10.6%	21.4%	47.8%	15.4%	14.3%	0.0%	0.0%	0.0%
Jonah crabs	14.6%	7.1%	14.3%	43.5%	15.4%	28.6%	0.0%	33.3%	0.0%
Blue crabs	21.1%	14.1%	28.6%	0.0%	38.5%	100.0%	25.0%	33.3%	25.0%
Other*	13.5%	0.0%	35.7%	21.7%	7.7%	28.6%	25.0%	66.7%	25.0%
-Dogfish	5.3%	0.0%	21.4%	0.0%	7.7%	0.0%	0.0%	0.0%	25.0%
-Skates	1.2%	0.0%	0.0%	4.3%	0.0%	0.0%	0.0%	33.3%	0.0%
-Spider crabs	4.1%	0.0%	10.7%	17.4%	0.0%	0.0%	0.0%	0.0%	0.0%
-Chicken	0.6%	0.0%	3.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
-Sharks	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	0.0%
-Other	1.8%	0.0%	0.0%	0.0%	0.0%	28.6%	25.0%	0.0%	0.0%
Horseshoe crab only	9.9%	5.9%	3.6%	8.7%	23.1%	0.0%	25.0%	33.3%	50.0%

Figure 12. Numbers of respondents who use each bait type in the channeled whelk fishery (all respondents). Does not include amount used. (Q9-10)



*Crabs column compiled individual responses for: green crab, rock crab, blue crab, spider crab, spider crab/starfish, spring crab, and Jonah crab.
*Shellfish column compiled individual responses for: shellfish, clam bellies, and surf clams
*Elasmobranchs column compiled individual responses for: sharks, skates, and dogfish
*Fish column compiled individual responses for: fish racks or whole, menhaden, bluefish, cod, pollock, herring, and mackerel

Soak time (Figure 11) and bait longevity (Figure 13) correlated fairly well. The most frequent responses were 2 nights of both bait longevity and soak time. Most whelk fishermen (94%) use bait saving devices such as cups or bags (Table 13), and use of these devices is only required by current state regulations in Delaware. Use of these devices is not required in the states with the largest annual whelk harvests (MA-CT).

Figure 13. Soak time frequencies by state for traps/pots including horseshoe crab as bait in the channeled whelk fishery (all respondents). (Q10 & 13)

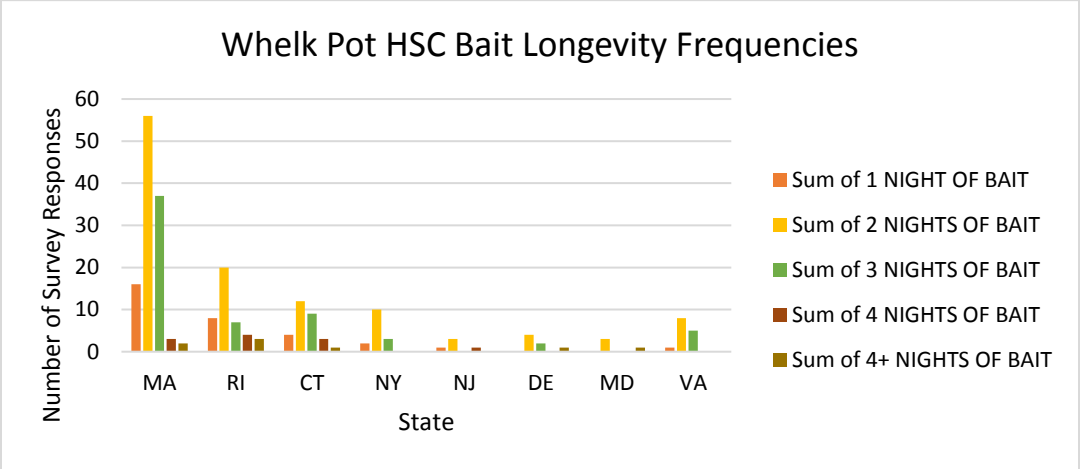
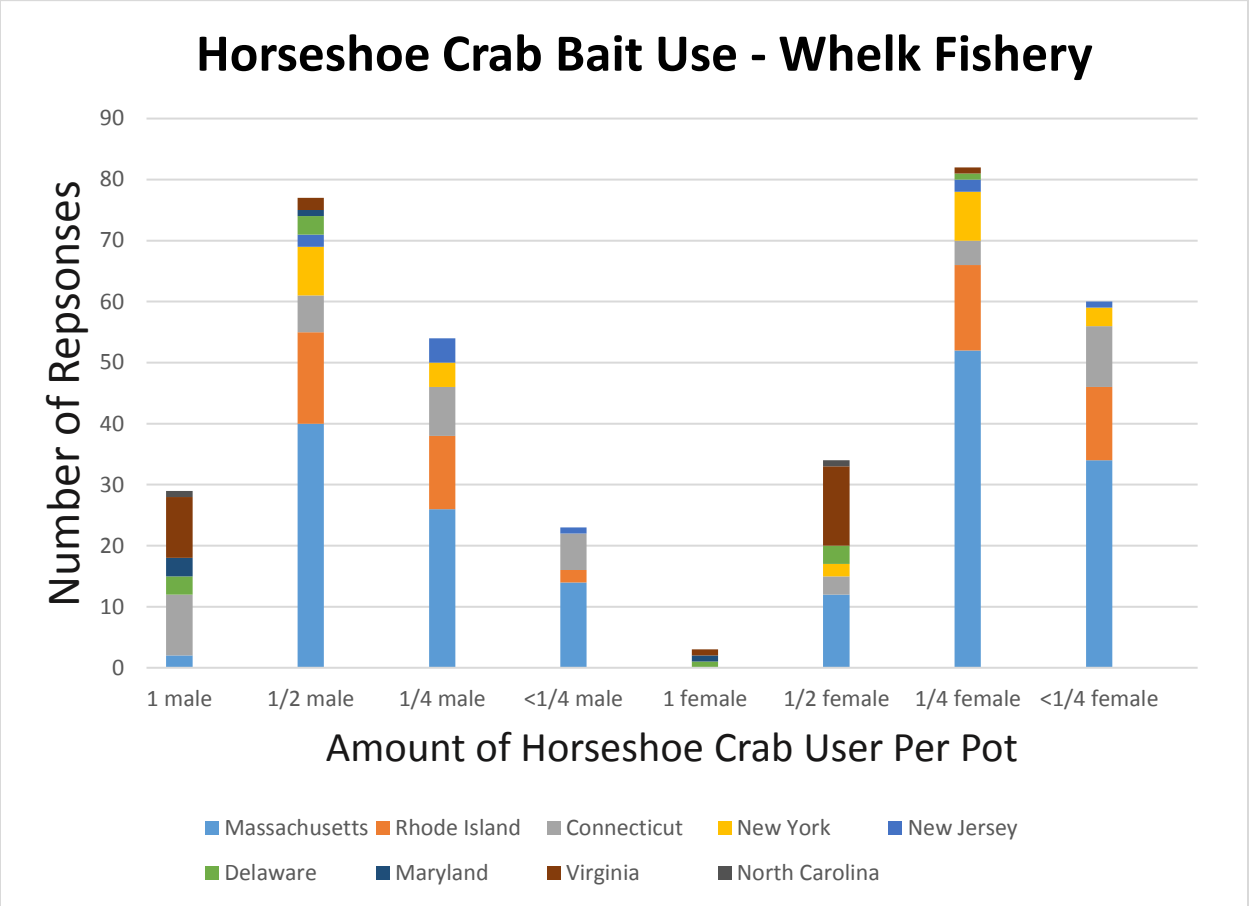


Table 13. Use of bait saving devices in the channeled whelk fishery, by state. Bait-saving devices are required in the whelk trap/pot fishery in Delaware, but not in other states. (Q14)

	All States	CT	MA	RI	NY	NJ	DE	MD	VA
Yes, HSC only	14	2	3	3	2	1	1	0	2
Yes, mix	144	20	75	24	10	5	3	2	5
No	10	1	6	0	1	0	0	1	1
NA	4	0	1	1	0	2	0	0	0

As seen with the eel fishery survey results, the most popular responses for amounts of horseshoe crab used as bait were for half of a male and a quarter female. Of the 362 responses (respondents could select more than one option), 23% were for one quarter female and 21% were for half of a male. The divide between male and female responses were almost exactly even with female responses at 49% and male responses at 51%. This may speak to the possibility of fishermen in the eel fishery favoring female crabs as a better, more successful bait, while whelk fishermen find males and females equally successful.

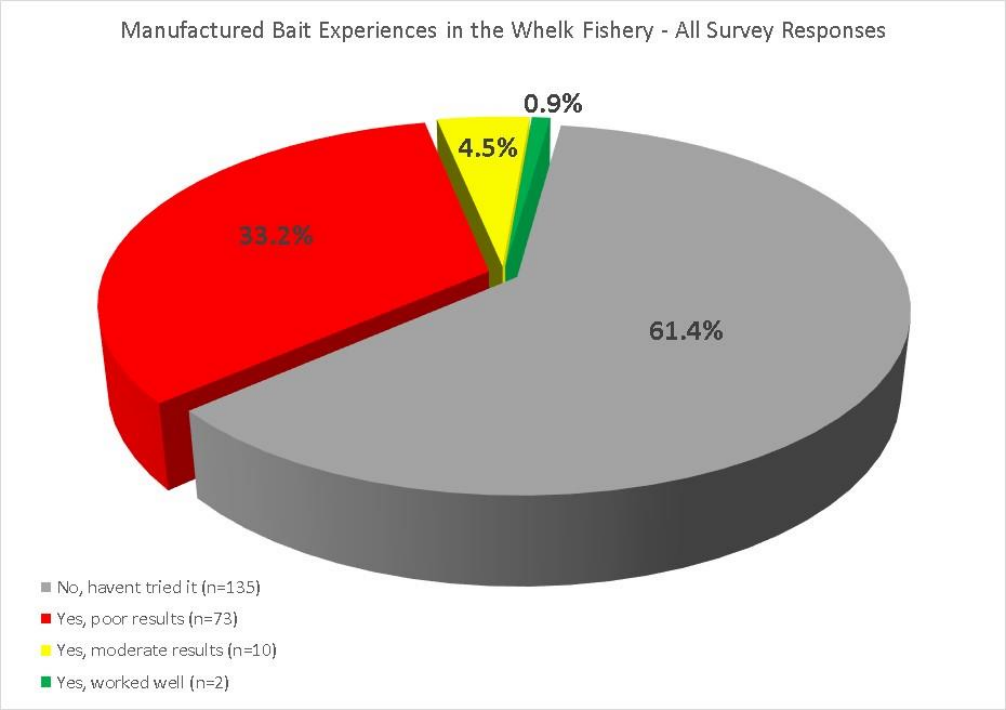
Figure 14. Typical amounts of horseshoe crab used per trap/pot, by state, in the channeled whelk fishery. (Q17)



Use and Impression of Manufactured Bait in the Channeled Whelk Fishery

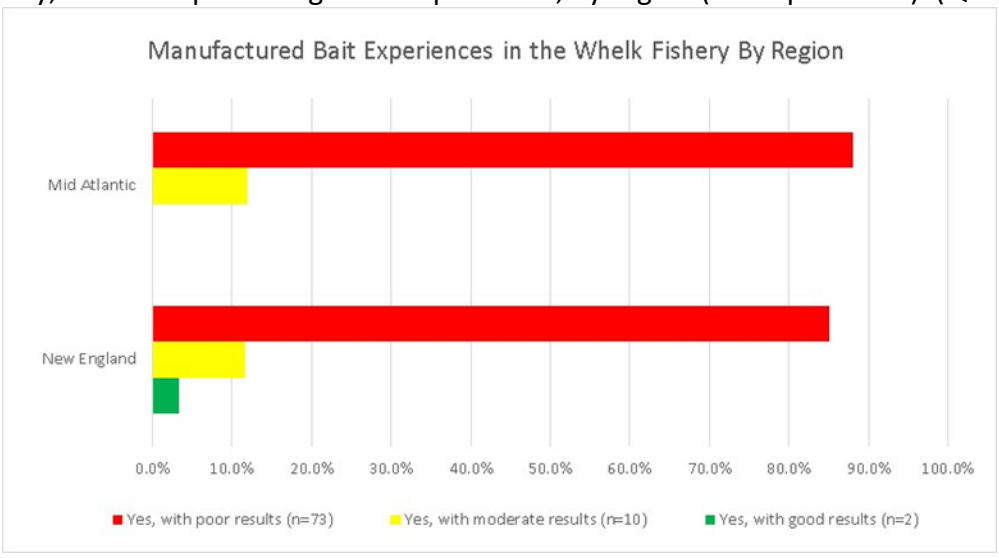
Considering all survey responses for the channeled whelk fishery (there were no responses for the channeled whelk fishery from Georgia or Florida), the majority (61.4%) of respondents indicated they had never used manufactured bait (Figure 15). A third of survey responders had used manufactured bait and observed poor results (33.2%). Just over 5% had also used manufactured bait and reported moderate to good results.

Figure 15. Experiences with manufactured bait in the channeled whelk fishery, shown as percentages (all respondents). (Q11)



Considering responses by region for those who had used manufactured bait in the past, the same pattern develops as seen coastwide (Figure 16). The majority of fishermen in both New England (Massachusetts to Connecticut) and the Mid Atlantic (New York to North Carolina) reported poor results with the product, with less than 5% in each region having had positive results (Figure 16).

Figure 16. Experiences with manufactured bait for fishermen who have used it in the channeled whelk fishery, shown as percentages of respondents, by region (all respondents). (Q11)



Bait Costs in the Channeled Whelk Fishery

Among channeled whelk fishermen using only non-HSC bait, 61.5% paid less than $1.00 to bait a trap/pot, and all paid $1.50 or less (Table 14). Among those respondents that used a combination of HSC and non-HSC bait, 54.7% paid $1.50 or less, and 71.8% paid $2.00 or less. Similarly, among those respondents that used exclusively HSC for bait, 50% paid $1.50 or less, and 85.7% paid $2.00 or less.

Table 14. Costs to bait channeled whelk traps/pots using baits that include only horseshoe crab (HSC Only), horseshoe crab and other bait (HSC Plus), and no horseshoe crab (Non-HSC). (Q12)

	Percent of respondents			
Cost to Bait Whelk Traps/Pots	**Non-HSC (n=13)**	**HSC Plus (n=117)**	**HSC Only (n=14)**	**All Bait Types (N=144)**
< $1.00	61.5	15.4	7.1	18.8
$1.00 - $1.50	38.5	39.3	42.9	39.6
$1.51 - $2.00	0.0	17.1	35.7	17.4
$2.00-$2.50	0.0	17.9	7.1	15.3
> $2.50	0.0	10.3	7.1	9.0

Conclusions

- **Roughly half of the respondents have fished for over 10 years, so they are experienced.**
- **Channeled whelk trap/pot fishermen generally use a bait medley including horseshoe crabs and other baits.**
- **The American eel fishery uses a mix of horseshoe crab and non-horseshoe crab bait, with zero responses stating they only use horseshoe crab.**
- **Overall, the channeled whelk fishery uses more horseshoe crabs for bait than the American eel fishery.**
    - Reported use of Horseshoe crab as bait is 91% in the whelk fishery vs 23% in the eel fishery.
    - The whelk fishery has higher averages of maximum traps/pots fished and traps/pots per trip: 212 and 147 vs 165 and 80 in the eel fishery (across all respondents regardless of whether they fished in 2016). Regional differences exist. MA – NY fish less traps/pots on average than NJ – VA in the whelk fishery. For the eel fishery MD had several fishers that reported extremely high traps/pots per trip and max traps.
    - The coastwide whelk fishery occurs in a more defined seasonal pattern, occurring from April through December, while the coastwide eel fishery occurs more continuously with definite peaks in March-June and September-November.
    - Most states, including those with the greatest whelk harvests (MA-CT), do not require the use of bait-saving devices in the trap/pot fishery. These devices are required in Delaware.
- **The American eel fishery uses more female crabs than male crabs.**
- **Both fisheries use larger proportions of male crabs than female crabs – this could be related to the fact that male crabs are smaller than female crabs.**

- **Bait saving devices, like bait bags, are more prevalent in the channeled whelk fishery than in the American eel fishery with 92% of respondents reporting some type of use versus 21%, respectively.**
- **Important Information for future manufactured baits:**
  - For both fisheries and all current bait practices, the bait typically lasts for 2 days.
  - Both fisheries had low percentages of participants who had tried manufactured baits, and most of the fishers who tried them reported poor results. Based on Technical Committee discussions of previous manufactured bait trials[1], poor results may not necessarily be solely indicative of poor performance, as fishers reported issues of cost and availability of manufactured bait.
  - Most fishers in both fisheries typically pay $1.50 or less per trap/pot, with cost per trap/pot being generally more expensive in the whelk fishery than the eel fishery.

[1] ASMFC Horseshoe Crab Alternative Bait Working Group Call Summary. March, 2016.

Appendix I

American Eel Bait Use Survey

Please answer the following questions by circling or writing in your response(s) as requested.

1. How many years have you fished for American eel using traps/pots?
    a. Have not yet, but plan to in 2017
    b. 1 month - 1 year
    c. 2 - 5 years
    d. 6 - 10 years
    e. 11 - 20 years
    f. Over 20 years

2. Did you fish for American eel in 2016 with traps/pots?
    a. Yes
    b. No, I last fished for American eel in _____. (Please answer the rest of the survey based on the last year you fished.)
    c. No, I have not fished for American eel. (Thank you for your time. Please discontinue and submit the survey.)

3. To identify region fished, in 2016 which area did the majority of your American eel catch come from (trap/pot only)?

4. What months do you fish American eel traps/pots? *(Circle all that apply)*

    a. January
    b. February
    c. March
    d. April
    e. May
    f. June
    g. July
    h. August
    i. September
    j. October
    k. November
    l. December

5. In 2016, did you fish your American eel traps/pots as singles or trawls/longlines?
    a. Only singles
    b. Mostly singles
    c. Both about equally
    d. Mostly trawls/longlines
    e. Only trawls/longlines

6. How long do you let your traps/pots soak?
    a. 1 night
    b. 2 nights

c. 3 nights
d. More than 3 nights

7. What was the maximum number of American eel traps/pots you fished in 2016? _____

8. How many traps/pots do you haul per trip, on average? _____

9. Which of the following do you primarily use as bait for your American eel traps/pots (select all that apply)?
    a. Horseshoe crab
    b. Shellfish
    c. Green crabs
    d. Fish racks/whole
    e. Manufactured alternative bait (artificial bait)
    f. Rock crabs
    g. Jonah crabs
    h. Blue crabs
    i. Other: _____

10. On average, how many of each type of bait do you use per trip? *(Please provide approximate quantity and circle bushel or tote where applicable)*
    a. _____Horseshoe crab: total # of crabs **(*if >0 please answer questions 15-17)**
    b. _____Shellfish: bushels or totes
    c. _____Green crabs: bushels or totes
    d. _____Fish (Species: _____): bushels or totes
    e. _____Manufactured alternative bait (artificial bait): premade pieces
    f. _____Rock crabs: bushels or totes
    g. _____Jonah crabs: bushels or totes
    h. _____Blue crabs: bushels or totes
    i. _____Other: _____
    j. _____Other: _____

11. Have you ever tried a manufactured alternative bait for American eel, and if so, was it effective?
    a. No, I have never tried it
    b. Yes, I tried it but it performed poorly
    c. Yes, I tried it with moderate success
    d. Yes, I tried it and it worked well

12. In 2016, what was your average cost to bait an American eel trap (per trap/pot)?
    a. Less than a dollar
    b. $1.00 - $1.50

c. $1.51 - $2.00
d. $2.00 - $2.50
e. More than $2.50

13. How long do your baits typically last?
    a. 1 night
    b. 2 nights
    c. 3 nights
    d. 4 nights
    e. More than 4 nights

14. Do you use bait-saving devices, such as cups or bags?
    a. Yes, with horseshoe crab only
    b. Yes, with horseshoe crab and other types of bait
    c. No

(*Please answer questions 15-17 if your response to 10a was greater than 0)

15. How much, on average, do you pay per crab for female horseshoe crabs?
    a. Price: $_____
    b. I harvest my own.

16. How much, on average, do you pay per crab for male horseshoe crabs?
    a. Price: $_____
    b. I harvest my own.

17. In a typical trap/pot, do you use *(circle all that apply)*:
    a. A whole female horseshoe crab
    b. Half of a female horseshoe crab
    c. ¼ of a female horseshoe crab
    d. Less than a ¼ of a female horseshoe crab
    e. A whole male horseshoe crab
    f. Half of a male horseshoe crab
    g. ¼ of a male horseshoe crab
    h. Less than a ¼ of a male horseshoe crab

Appendix II

Channeled whelk Bait Use Survey

Please answer the following questions by circling or writing in your response(s) as requested.

1. How many years have you fished for channeled whelk using traps/pots?
    a. Have not yet, but plan to in 2017
    b. 1 month - 1 year
    c. 2 - 5 years
    d. 6 - 10 years
    e. 11 - 20 years
    f. Over 20 years

2. Did you fish for channeled whelk in 2016 with traps/pots?
    a. Yes
    b. No, I last fished for channeled whelk in _____. (Please answer the rest of the survey based on the last year you fished.)
    c. No, I have not fished for channeled whelk. (Thank you for your time. Please discontinue and submit the survey.)

3. To identify region fished, in 2016 which area did the majority of your channeled whelk catch come from (trap/pot only)?

4. What months do you fish channeled whelk traps/pots? *(Circle all that apply)*
    a. January
    b. February
    c. March
    d. April
    e. May
    f. June
    g. July
    h. August
    i. September
    j. October
    k. November
    l. December

5. In 2016, did you fish your channeled whelk traps/pots as singles or trawls/longlines?
    a. Only singles
    b. Mostly singles
    c. Both about equally
    d. Mostly trawls/longlines
    e. Only trawls/longlines

6. How long do you let your traps/pots soak?
    e. 1 night
    f. 2 nights
    g. 3 nights
    h. More than 3 nights

7. What was the maximum number of channeled whelk traps/pots you fished in 2016? _____

8. How many traps/pots do you haul per trip, on average? _____

9. Which of the following do you primarily use as bait for your channeled whelk traps/pots (select all that apply)?
    a. Horseshoe crab
    b. Shellfish
    c. Green crabs
    d. Fish racks/whole
    e. Manufactured alternative bait (artificial bait)
    f. Rock crabs
    g. Jonah crabs
    h. Blue crabs
    i. Other: _____

10. On average, how many of each type of bait do you use per trip? *(Please provide approximate quantity and circle bushel or tote where applicable)*
    a. _____Horseshoe crab: total # of crabs **(*if >0 please answer questions 15-17)**
    b. _____Shellfish: bushels or totes
    c. _____Green crabs: bushels or totes
    d. _____Fish (Species: _____): bushels or totes
    e. _____Manufactured alternative bait (artificial bait): premade pieces
    f. _____Rock crabs: bushels or totes
    g. _____Jonah crabs: bushels or totes
    h. _____Blue crabs: bushels or totes
    i. _____Other: _____
    j. _____Other: _____

11. Have you ever tried a manufactured alternative bait for channeled whelk, and if so, was it effective?
    a. No, I have never tried it
    b. Yes, I tried it but it performed poorly
    c. Yes, I tried it with moderate success
    d. Yes, I tried it and it worked well

12. In 2016, what was your average cost to bait a channeled whelk trap (per trap/pot)?
    a. Less than a dollar
    b. $1.00 - $1.50
    c. $1.51 - $2.00
    d. $2.00 - $2.50

e. More than $2.50

13. How long do your baits typically last?
    a. 1 night
    b. 2 nights
    c. 3 nights
    d. 4 nights
    e. More than 4 nights

14. Do you use bait-saving devices, such as cups or bags?
    a. Yes, with horseshoe crab only
    b. Yes, with horseshoe crab and other types of bait
    c. No

(*Please answer questions 15-17 if your response to 10a was greater than 0)

15. How much, on average, do you pay per crab for female horseshoe crabs?
    a. Price: $_____
    b. I harvest my own.

16. How much, on average, do you pay per crab for male horseshoe crabs?
    a. Price: $_____
    b. I harvest my own.

17. In a typical trap/pot, do you use *(circle all that apply)*:
    a. A whole female horseshoe crab
    b. Half of a female horseshoe crab
    c. ¼ of a female horseshoe crab
    d. Less than a ¼ of a female horseshoe crab
    e. A whole male horseshoe crab
    f. Half of a male horseshoe crab
    g. ¼ of a male horseshoe crab
    h. Less than a ¼ of a male horseshoe crab

Appendix III

A Brief Synopsis of the Commercial Whelk Fishery in South Carolina

Prepared by Jeff Brunson, South Carolina Department of Natural Resources
February 2017

The whelk fishery in South Carolina is small relative to those fisheries in the mid-Atlantic states. The South Carolina Department of Natural Resources does issue a small number of whelk trawling permits occasionally, but those landings data are minimal and confidential. Commercial hand-harvest of whelk is allowed, and requires a commercial saltwater license. Whelk harvested in this manner are reported to wholesale dealers. By far, most of the reported commercial whelk landings come in the form of crab trip ticket reports from commercial blue crab fishermen, and it has been speculated that such harvest is simply bycatch. Since 2004, mean annual whelk harvest reported on crab trip tickets was 6962 shell on pounds, and ranged from 1370 to 22,104 pounds. In order to validate the assumption that reported whelk landings by commercial crabbers were as bycatch, the nine commercial crabbers with the highest reported whelk landings were identified. Phone interviews were then attempted to determine if whelk were targeted by commercial crab fishermen, and if so, what type of bait was used. Below are the general conclusions from conversations with seven of those nine identified crab fishermen:

1) Harvest of whelk by blue crab fishermen was characterized as "bycatch."
2) Whelk landings are dominated by channeled whelk (*Busycotypus canaliculatus*), with harvest primarily occurring "off the beach."
3) In some cases, whelk were actually avoided, because they compete with crabs for bait.
4) In other cases, "targeting" of whelk meant that crabbers may set extra commercial crab pots in an area where whelk are being caught in larger numbers. However, this practice occurs while the fishermen adhere to their normal blue crab harvest practices.
5) Crab traps are primarily baited with menhaden, even when the expectation is to increase the catch of whelk. Little, if any, effort is made to use an alternative bait to target whelk.
6) Interestingly, one respondent suggested that when in the process of trawling for shrimp, he had encountered a number of open top traps, similar to those used for whelk harvest, in the waters off the northern coast of the state. However, that report could not be substantiated

It should be noted that the harvest of horseshoe crabs for bait, or the use of horseshoe crabs as bait in any fishery in South Carolina, is prohibited, pursuant to Code of Laws of South Carolina, Title 50, Chapter 5, Article and Section 1330. The only allowable harvest of horseshoe crabs in South Carolina is for biomedical bleeding, or for research and scientific purposes, and is limited to harvest by hand.

Horseshoe Crab Draft Terms of Reference

1. Define population structure based on available data. If alternative population structures are used in the models (e.g., coast-wide, regional, sub-regional or estuary-specific), justify use of each population structure.
2. Characterize precision and accuracy of fishery-dependent and fishery-independent data, including biomedical data, that are used in the assessment, including the following but not limited to:
    a. Provide descriptions of each data source (e.g., geographic location, sampling methodology, potential explanation for outlying or anomalous data)
    b. Describe calculation and potential standardization of abundance indices.
    c. Discuss trends and associated estimates of uncertainty (e.g., standard errors)
    d. Justify inclusion or elimination of available data sources.
    e. Discuss the effects of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, aging accuracy, sample size) on model inputs and outputs.
3. Develop models used to estimate population parameters (e.g., F, biomass, abundance) and biological reference points, and analyze model performance.
    a. Describe stability of model (e.g., ability to find a stable solution, invert Hessian)
    b. Justify choice of CVs, effective sample sizes, or likelihood weighting schemes.
    c. Perform sensitivity analyses for starting parameter values, priors, etc. and conduct other model diagnostics as necessary.
    d. Clearly and thoroughly explain model strengths and limitations.
    e. Briefly describe history of model usage, its theory and framework, and document associated peer-reviewed literature. If using a new model, test using simulated data.
    f. If multiple models were considered, justify the choice of preferred model and the explanation of any differences in results among models.
    g. State assumptions made for all models and explain the likely effects of assumption violations on synthesis of input data and model outputs.
    h. Incorporate biomedical data into the models used. Reassess associated mortality of bled crabs coast-wide, or regionally.

4. Characterize uncertainty of model estimates and biological or empirical reference points.

5. Perform retrospective analyses, assess magnitude and direction of retrospective patterns detected, and discuss implications of any observed retrospective pattern for uncertainty in population parameters (e.g., F, SSB), reference points, and/or

management measures.

6. Recommend stock status as related to reference points (if available). For example:
    a. Is the stock below the biomass threshold?
    b. Is F above the threshold?
7. Other potential scientific issues:
    a. Compare trends in population parameters and reference points with current and proposed modeling approaches, including the results of the ARM model for the Delaware Bay. If outcomes differ, discuss potential causes of observed discrepancies.
    b. Compare reference points derived in this assessment with what is known about the general life history of the exploited stock. Explain any inconsistencies.
8. If a minority report has been filed, explain majority reasoning against adopting approach suggested in that report. The minority report should explain reasoning against adopting approach suggested by the majority.
9. Develop detailed short and long-term prioritized lists of recommendations for future research, data collection, and assessment methodology. Highlight improvements to be made by next benchmark review.
10. Recommend timing of next benchmark assessment and intermediate updates, if necessary relative to biology and current management of the species.

Generic ASMFC Terms of Reference for External Peer Review

1. Evaluate the thoroughness of data collection and the presentation and treatment of fishery-dependent and fishery-independent data in the assessment, including the following but not limited to:
    a. Presentation of data source variance (e.g., standard errors).
    b. Justification for inclusion or elimination of available data sources,
    c. Consideration of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, aging accuracy, sample size),
    d. Calculation and/or standardization of abundance indices.

2. Evaluate the methods and models used to estimate population parameters (e.g., F, biomass, abundance) and biological reference points, including but not limited to:
    a. Evaluate the choice and justification of the preferred model(s). Was the most appropriate model (or model averaging approach) chosen given available data and life history of the species?
    b. If multiple models were considered, evaluate the analysts' explanation of any differences in results.
    c. Evaluate model parameterization and specification (e.g., choice of CVs, effective

sample sizes, likelihood weighting schemes, calculation/specification of M, stock-recruitment relationship, choice of time-varying parameters, plus group treatment).

3. Evaluate the diagnostic analyses performed, including but not limited to:
    a. Sensitivity analyses to determine model stability and potential consequences of major model assumptions
    b. Retrospective analysis

4. Evaluate the methods used to characterize uncertainty in estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.

5. If a minority report has been filed, review minority opinion and any associated analyses. If possible, make recommendation on current or future use of alternative assessment approach presented in minority report.

6. Recommend best estimates of stock biomass, abundance, and exploitation from the assessment for use in management, if possible, or specify alternative estimation methods.

7. Evaluate the choice of reference points and the methods used to estimate them. Recommend stock status determination from the assessment, or, if appropriate, specify alternative methods/measures.

8. Review the research, data collection, and assessment methodology recommendations provided by the TC and make any additional recommendations warranted. Clearly prioritize the activities needed to inform and maintain the current assessment, and provide recommendations to improve the reliability of future assessments.

9. Recommend timing of the next benchmark assessment and updates, if necessary, relative to the life history and current management of the species.

10. Prepare a peer review panel terms of reference and advisory report summarizing the panel's evaluation of the stock assessment and addressing each peer review term of reference. Develop a list of tasks to be completed following the workshop. Complete and submit the report within 4 weeks of workshop conclusion.

2018 Horseshoe Crab Benchmark Stock Assessment Timeline			
What	**Who**	**When**	**Why**
Pre-Assessment Webinar	Rachel Sysak (TC Chair,), Michael Schmidtke (FMP Coordinator), Kristen Anstead (Stock Assessment Scientist), SAS	Early September 2017	Develop timeline, draft ToRs, roles & responsibilities, and develop a data submission form and needs
Obtain Data Confidentiality	ASFMC Staff, State partners	Early September 2017	May need to contact each state with biomedical facilities individually to resolve confidentiality issues
Pre-Assessment TC Meeting	TC, SAS, ASMFC staff	September 2017	Review timeline and ToRs for Board Approval, identify data sources & availability, develop assignments & due dates for TC, SAS, and staff members, review previous assessment (2009), review data confidentiality
Data Workshop Preparation	TC, SAS, ASMFC staff	September-December 2017	Circulate data submission workbooks, presentation needs for the data workshop, clear instructions & expectations to TC and SAS members; Stock assessment scientist compiles data as it is submitted, ASMFC staff develops & distributes data workshop agenda, FMP coordinator forwards ToRs & timeline to the Board
Board Approval of ToRs, timeline	HSC Board	October 2017	
Data Workshop	TC, SAS, ASMFC staff, invited data holders (university, biomedical, etc.)	January 2018? (at least 2-3 months after TC meeting)	Review previous assessments, summary of literature review (life history, habitat, etc), all data sets; Develop list of data analysis and report writing assignments and due dates; Determine data analyses to conduct and possible approaches for assessing stock, finalize date of assessment workshop
Assessment Workshop Preparation	Rachel Sysak (TC Chair,) SAS Chair, Michael Schmidtke (FMP Coordinator), Kristen	January-February 2018	FMP coordinator sends data workshop report, assignments, due dates to SAS

	Anstead (Stock Assessment Scientist)		
Assessment Workshop	SAS, ASMFC Staff	March 2018	Review report sections, data analyses, ToRs; Determine best approach for assessing stock, conduct model runs, sensitivity analyses, consensus recommendation of stock status, research recommendations
Assessment Workshop II??		*May 2018*	**if needed and the budget allows??*
TC Review of Stock Assessment	TC, SAS Chair, ASMFC Staff	July 2018	Sweka presents the ToRs and stock assessment, TC reviews it and approves it for peer review (or not)
Preparation for Peer Review	ASMFC Staff, SAS	July-August 2018	Report revisions as needed following TC review; **report goes to the peer review panel one month before review meeting**
Peer Review Workshop	ASFMC Staff, Peer Review Panel, SAS members	Mid/late August 2018 (Note: AFS is Aug 19-23rd)	Present assessment to peer review panel and conduct additional analyses as needed
Post-Review Workshop	ASFMC Staff, Peer Review Panel, SAS members	August-September 2018	SAS and Peer Review Panel prepare presentations for the Board; FMP Coordinator finalizes report; follow up TC call held if needed; Stock Assessment Scientist drafts species overview document
Board Meeting	Board, ASMFC Staff, SAS Chair	October 2018	SAS chair presents the assessment to the Board; Science Director presents peer review report; Board accepts or rejects assessment for management

Horseshoe Crab Harvest Recommendations Based on Adaptive Resource Management (ARM) Framework and Most Recent Monitoring Data

Report to the Delaware Bay Ecosystem Technical Committee by the ARM Subcommittee

September 2017

This report summarizes annual harvest recommendations. Detailed background on the ARM framework and data sources can be found in previous technical reports[1].

Objective statement

Manage harvest of horseshoe crabs in the Delaware Bay to maximize harvest but also to maintain ecosystem integrity and provide adequate stopover habitat for migrating shorebirds.

Alternative harvest packages

These harvest packages were compared to determine which will best meet the above objective given the most recent monitoring data. Harvest is of adult horseshoe crabs of Delaware Bay origin.

Harvest package	Male harvest (×1,000)	Female harvest (×1,000)
1	0	0
2	250	0
3	500	0
4	280	140
5	420	210

Population models

Population dynamics models that link horseshoe crabs and red knots were used to predict the effect of harvest packages. Three variations in the models represent the amount and type of dependence between horseshoe crabs and red knots. Stochastic dynamic programming was used to create a decision matrix to identify the optimal harvest package given the most recent monitoring data.

Monitoring data

In 2015, and 2016, sources of data for horseshoe crab abundance were a set of trawl surveys conducted by Delaware and New Jersey.[2] Historic data from the independent surveys were compiled into a composite index and correlated with past VT trawl survey data. In the fall of 2016 the VT trawl survey was reinstated and the abundance estimates were reported to the ARM team[5]. The regression coefficients from that survey were used to estimate 2016 abundance from 2016 indices[2]. Red Knot abundance estimates are taken from a mark-resight estimate for red knot abundance[3].

Horseshoe crab abundance (millions)			Red knot abundance (×1,000)	
Year	Male	Female	Year	Male and female
2016 (Fall)	25.4	7.7	2017 (Spring)	49.405

Harvest recommendations

Decision matrix was optimized incorporating recommendations on red knot stopover population estimates and associated calibration of red knot threshold[4].

Recommended harvest package	Male harvest (×1,000)	Female harvest (×1,000)
3	500	0

Quota of horseshoe crab harvest for Delaware Bay region states. Allocation of allowable harvest under ARM package 3 (500K males, 0 females) was conducted in accordance with management board approved methodology in *Addendum VII to the Interstate Fishery Management Plan for Horseshoe Crabs*. Note: Maryland and Virginia total quota refer to that east of the COLREGS line.

	Delaware Bay Origin HSC Quota		**Total Quota**	
State	**Male**	**Female**	**Male**	**Female**
Delaware	162,136	0	162,136	0
New Jersey	162,136	0	162,136	0
Maryland	141,112	0	255,980	0
Virginia	34,615	0	81,331	0

References

[1] McGowan, C. P., D. R. Smith, J. D. Nichols, J. Martin, J. A. Sweka, J. E. Lyons, L. J. Niles, K. Kalasz, R. Wong, J. Brust, M. Davis. 2009. A framework for the adaptive management of horseshoe crab harvests in the Delaware Bay constrained by Red Knot conservation. Report to the Atlantic States Marine Fisheries Commission Horseshoe Crab Technical Committee.

ASMFC Horseshoe Crab Stock Assessment Subcommittee. 2009. Horseshoe crab 2009 stock assessment report. Report to the Atlantic States Marine Fisheries Commission Horseshoe Crab Technical Committee.

ASMFC 2009. Terms of Reference and Advisory Report to the Horseshoe Crab Stock Assessment Peer Review. Stock Assessment Report No. 09-02.

[2] John Sweka's August, 2017 Memo

[3] Jim Lyons' 2017 estimate in the August, 2017 email

[4] ARM's recommendations for improved estimates of red knot stopover population size and associated calibration of red knot threshold

5 Hata and Hallerman, June 2016, Horseshe Crab Trawl Survey Report to the ASMFC

Results of the 2016 Horseshoe Crab Trawl Survey:

Report to the Atlantic States Marine Fisheries Commission Horseshoe Crab and Delaware Bay Ecology Technical Committees

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March 20, 2017

Abstract

To properly manage the mid-Atlantic horseshoe crab (*Limulus polyphemus*) fishery, a time-series of data on relative abundance of all demographic groups is needed. We conducted a trawl survey in the coastal Delaware Bay area and the lower Delaware Bay, quantifying mean catch per 15-minute tow and comparing the results with those of previous years. Mean catch-per-tow of mature males were higher than in previous years, although the confidence interval was large; mean catches of mature females were higher than in most previous years, but still lower than in 2008. Mean catch-per-tow of immature horseshoe crabs in the coastal Delaware Bay area has been variable since 2002 with no trend, and remained below the peak of 2009. Our findings will be used to parameterize the Adaptive Resource Management model used to set harvest levels for horseshoe crabs.

Introduction

To properly manage the mid-Atlantic horseshoe crab (*Limulus polyphemus*) fishery, accurate information on abundance levels and trends is needed. The Adaptive Resource Management model adopted by the ASMFC requires annual, fishery-independent indices of newly-mature recruit and adult abundance. The purpose of this

project was to conduct a horseshoe crab trawl survey along the Mid-Atlantic coast in order to: (1) determine horseshoe crab relative abundance, (2) describe horseshoe crab population demographics, and (3) track inter-annual changes in horseshoe crab abundance and demographics. Here, we report our cumulative results through the fall 2016 trawl survey.

Methods

The 2016 horseshoe crab trawl survey was conducted in two areas (Figure 1). The coastal Delaware Bay area (DBA) survey extended in the Atlantic Ocean from shore out to 22.2 km (12 nautical miles), and from 39º 20' N (Atlantic City, NJ) to 37º 40' N (slightly north of Wachapreague, VA). This area was previously sampled from 2002 to 2011. The lower Delaware Bay (LDB) survey area extended from the Bay mouth to a line between Egg Island Point, New Jersey and Kitts Hummock, Delaware. The LDB was previously sampled from 2010 to 2012. The surveys were conducted from 17 September to 27 October 2016.

The DBA survey area was stratified by distance from shore (0-3 nm, 3-12 nm) and bottom topography (trough, nontrough) as in previous years. The LDB survey area was stratified by bottom topography only, as in previous years. Sampling was conducted aboard a 16.8-m chartered commercial fishing vessel operated out of Ocean City, MD. We used a two-seam flounder trawl with a 18.3-m headrope and 24.4-m footrope, rigged with a Texas Sweep of 13-mm link chain and a tickler chain. The net body consisted of 15.2-cm (6-in) stretched mesh, and the bag consisted of 14.3-cm (5 5/8-in) stretched mesh. Tows were usually 15-minutes bottom time, but were occasionally shorter to avoid fishing gear (e.g., gill nets, crab and whelk pots) or vessel traffic, or when the net unexpectedly hit an underwater obstruction. Bottom water temperature was recorded for each tow. We sampled 41 stations in the DBA survey and 10 stations in the LDB.

Horseshoe crabs were culled from the catch, and either all individuals or a subsample were examined for prosomal width (millimeters) and identified for sex and maturity. Maturity classifications were: immature, newly mature - those that are capable of spawning but have not yet spawned, and mature - those that are have previously spawned. Newly mature and mature males are morphologically distinct, and are believed

to be classifiable without error. However, some error is associated with distinguishing newly mature from immature females. All examined females that were not obviously mature (i.e., bearing rub marks) or immature (too small or soft-shelled) were probed with an awl to determine presence or absence of eggs. Females with eggs but without rub marks were considered newly mature. Females with both eggs and rub marks were considered mature. Initial sorting classifications were: presumed adult males (newly mature and mature), presumed adult females, and all immature. Up to 25 adult males, 25 adult females, and 50 immatures were retained for examination. The remainder were counted separately by classification and released. Characteristics of the examined subsamples were then extrapolated to the counted portions of the catch.

In each stratum, the mean catch per 15-minute tow and associated variance were calculated using two methods, i.e., either assuming a normal-distribution model or a lognormal delta-distribution model (Pennington, 1983). Stratum mean and variance estimates were combined using formulas for a stratified random sampling design (Cochran, 1977). The approximate 95% confidence intervals were calculated using the effective degrees of freedom (Cochran, 1977). Annual means were considered significantly different if 95% confidence limits did not overlap. Stratified means calculated using the lognormal delta-distribution model are not additive - i.e., means calculated for each demographic group do not sum to the mean calculated using all crabs. Likewise, stratified means from survey subregions do not sum to the means calculated using the entire survey area. Means calculated using the normal-distribution model are additive, within rounding errors.

Inter-annual comparisons for the main DBA survey used the entire area from 39º 20' N to 37º 40' N (Figure 1). This area has been subdivided in previous reports to include the core region that was sampled in the 2001 pilot study. The core region was sampled from 2001 to 2011 and again in 2016 and extends from 39º 10' N to 38º 10' N. Catch means using the core region allow extension of the time-series for that region by one year. However, sample sizes and random station selection since 2002 are based on the entire survey area. Therefore, sample sizes within the core region are small and variable year to year, resulting in large variances. In addition, because station selection is based on the entire survey area, strata within the core region may have insufficient

sample sizes, necessitating merging strata in some years. When strata were merged, weighted mean catch and variance were calculated for the combined stratum, with observations weighted by the probability of selection in the combined stratum.

Annual size-frequency distributions, in intervals of 10-mm prosomal width, were calculated for each sex/maturity category by pooling size-frequency distributions of all stations (adjusted for tow duration if necessary) in a stratum in a year to calculate the relative proportions for each size interval. Those proportions then were multiplied by the stratum mean catch per tow that year to produce a stratum size-frequency distribution. Stratum size-frequency distributions then were multiplied by the stratum weights and added in the same manner as calculating the stratified mean catch per tow. Areas under the distribution curves then would represent the stratified mean catch per tow at each size interval.

Size-frequency distributions of newly mature and mature horseshoe crabs were examined for approximate mean prosomal width to look for changes in size over time. Mean prosomal widths and standard deviations were calculated using the NORMSEP method of modal progression analysis in FiSAT II (version 1.2.2) analytical software (Guyanilo et al., 2005) fitted to the 10-mm size intervals calculated above.

Results

Delaware Bay area

Stratified mean catches per tow for immature females and males in 2016 were nearly twice those in 2011 but were not significantly higher, based on non-overlapping confidence limits (Tables 1 and 2; Figure 2). However, mean catches in 2016 remained lower than in 2009, when the largest mean catches in the time-series were observed. Likewise, stratified mean catches of newly mature females and males in 2016 were nearly twice those in 2011, but not significantly higher. Mean catches of mature females and males have been variable over the time-series, but are significantly correlated ($r = 0.954$; $T = 9.59$; $p < 0.001$; $n = 11$). Mean catches of mature males appear to be increasing over the time-series ($r = 0.630$; $T = 2.43$; $p = 0.038$), but mature females do not ($r = 0.485$; $T = 1.66$; $p = 0.131$). Yearly trends from the delta- and normal-distribution models followed similar patterns for all demographic groups.

Stratified mean catches of immature crabs within the DBA core region have remained generally consistent over the time-series, and typically have been comparable to mean catches in the entire DBA region, with the exception of 2009 (Tables 3 and 4; Figure 3). The large mean catches of immature crabs for the entire DBA in 2009 were due to catches outside the core region. Mean catches of newly mature and mature crabs in the core region followed similar trends to those in the entire survey area, although mean catches of mature crabs in the core region were typically larger, indicating the relative importance of the core region to the distribution of mature horseshoe crabs. As in the entire DBA, mean catches of mature females and males are significantly correlated ($r = 0.654$; $T = 2.73$; $p = 0.021$; $n = 12$). Mean catches of mature males appear to be increasing over time ($r = 0.833$; $T = 4.77$; $p = 0.001$), but of mature females do not ($r = 0.346$; $T = 1.17$; $p = 0.271$). Yearly trends from the delta- and normal-distribution models followed similar patterns for all demographic groups.

Lower Delaware Bay

This was the fourth year of sampling within the Delaware Bay. Stratified mean catches of immature crabs in 2016 were the largest observed, and were significantly higher than in 2011 but similar to 2012, based on non-overlapping confidence limits (Tables 5 and 6; Figure 4). Mean catches of mature females were consistent over time, but catches of mature males were higher in 2016 than in 2012. Mean catches of immature crabs were significantly higher within the Delaware Bay than in the coastal survey in 2010 and 2016 (Figure 4). Mean catches of mature crabs were also larger within the Bay, but only males in 2016 were significantly so.

Sex ratios

Mature males were typically more than twice as numerous as mature females throughout the survey time-series. Sex ratios from mean catch per tow (M:F) in the DBA surveys ranged from 2.18 in 2008 to 3.08 in 2011, and averaged 2.44 over all years. Although the sex ratio of mature crabs appeared to increase over time, the increase was not significant at $\alpha = 0.05$ ($r = 0.597$; $T = 2.234$; $p = 0.052$; $n = 11$). In contrast, the ratio of newly mature males to females was highly variable, ranging from 0.38 in 2008 to 1.70

in 2004, and averaged 1.08. This may reflect temporal variability in recruitment to the newly mature class relative to survey period, or differences in year-class abundance because females are believed to mature a year later than males.

Sex ratios of mature horseshoe crabs were higher within the Delaware Bay than on the coast. Sex ratios (M:F) ranged from 2.67 in 2010 to 6.17 in 2016, averaging 4.05. Over the four survey years within the Delaware Bay, the ratio of mature males to females significantly increased ($r = 0.989$; $T = 9.574$; $p = 0.011$; $n = 4$). As on the coast, sex ratios of newly mature crabs within the Bay were variable, and ranged from 0.44 to 9.43, averaging 3.61. The higher sex ratios within Delaware Bay may reflect a tendency for mature male horseshoe crabs to remain near the spawning beaches later than females.

Size distributions

Size-frequency distributions of immature horseshoe crabs in the DBA survey display a considerable variability (Figure 5). Modal groups are generally indistinct, except for one large group of both females and males in 2009. However, that modal group, which would presumably be larger in size the following year, becomes indistinct again in 2010. Size-frequency distributions from the lower Delaware Bay do not reflect that modal group in 2010 either (Figure 6).

Mean prosomal widths of mature and newly mature horseshoe crabs remained consistent in both survey areas through the time-series. Mature females in the Delaware Bay area averaged 258 to 270 mm PW, compared to the 245 to 271 mm average for newly mature females there (Table 7). Mature females in the lower Delaware Bay averaged 255 to 265 mm PW, while newly mature females averaged 246 to 265 mm. Mean widths of mature males averaged 196 to 212 mm in the Delaware Bay area, and of newly mature males averaged 202 to 212 mm. Mature males in the lower Delaware Bay averaged 198 to 203 mm, and newly mature males averaged 184 to 203 mm.

Mean prosomal widths of mature male and female crabs in the DBA survey displayed slight but detectable decreases over time (Table 8; Figure 7). The smallest means were observed in 2016, but those decreases remained significant only when the 2002-2011 data are included.

Effects of sampling period

The 2016 DBA survey was conducted from mid-September to late October. The average bottom water temperature in 2016 was the highest in the time series (Table 9; Figure 8). Mean bottom water temperature was inversely correlated with mean ordinal sampling date over the survey time-series (r = -0.796; T = -3.94; p = 0.003; n = 11). When comparing survey time-frames and water temperatures, it appears that the mean catches of immature crabs are correlated with mean sampling dates but not with water temperature (Table 10). In contrast, mean catches of mature males were correlated with mean water temperatures.

The lower Delaware Bay surveys were each completed within one or two days, and all four surveys were conducted within the month of October (Table 9; Figure 8). Mean water temperatures were cooler than mean temperatures in the coastal surveys, and the 2016 mean was the highest in the time series. Immature horseshoe crab catches within Delaware Bay were not correlated with ordinal sampling date, but mature male catches were correlated with sampling date (Table 10).

Key findings

1. Mean catch-per-tow of immature horseshoe crabs in the coastal Delaware Bay area has been variable since 2002 with no trend, and remains below the peak of 2009.
2. Mean catch-per-tow of newly mature crabs in the coastal Delaware Bay area have remained below peaks in 2007 (males) or 2008 (females) and show no long-term trend.
3. Mean catch-per-tow of mature males in the coastal Delaware Bay area has been variable throughout the time-series, but shows an increasing trend since 2002.
4. Mean catch-per-tow of immature horseshoe crabs and mature males in the lower Delaware Bay proper were higher than in the coastal Delaware Bay area.
5. Mean sizes of mature male and female horseshoe crabs appear to have decreased slightly since 2002.
6. Mean catch-per-tow of immature crabs, at least in the coastal Delaware Bay area, may be related to sampling date. Mean catch-per-tow of mature males may be related to water temperature.

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Table 1. Stratified mean catch per tow of horseshoe crabs in the coastal **Delaware Bay area** survey, 2002-2016, with standard deviation (sd) and coefficient of variation (CV), calculated using the **delta distribution** model, by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

	mean	UCL	LCL	CV	sd		mean	UCL	LCL	CV	sd
Immature females						Immature males					
2002	24.7	42.6	6.9	0.34	8.5	2002	14.3	25.7	2.9	0.38	5.5
2003	7.3	12.8	1.8	0.35	2.6	2003	3.8	6.2	1.3	0.32	1.2
2004	21.5	33.4	9.7	0.26	5.6	2004	17.3	27.3	7.4	0.27	4.7
2005	28.2	49.1	7.2	0.36	10.2	2005	24.5	45.4	3.6	0.41	10.1
2006	32.0	48.5	15.6	0.24	7.5	2006	24.1	41.2	7.0	0.29	7.0
2007	42.9	87.0	-1.3	0.40	17.2	2007	32.3	66.4	-1.8	0.43	13.9
2008	29.0	50.6	7.4	0.33	9.7	2008	20.4	35.2	5.7	0.32	6.6
2009	76.5	127.1	25.9	0.32	24.3	2009	76.4	133.0	19.8	0.34	25.7
2010	8.6	11.2	6.0	0.15	1.3	2010	5.7	8.4	3.0	0.23	1.3
2011	11.2	15.3	7.1	0.17	1.9	2011	6.9	9.7	4.1	0.19	1.3
2016	23.9	46.3	1.5	0.34	8.1	2016	17.8	35.7	-0.1	0.36	6.5
Mature females						Mature males					
2002	10.8	16.0	5.6	0.23	2.5	2002	25.5	36.7	14.4	0.21	5.5
2003	7.8	11.8	3.8	0.24	1.9	2003	17.9	29.0	6.9	0.29	5.1
2004	6.5	9.9	3.2	0.25	1.6	2004	14.7	23.9	5.6	0.30	4.4
2005	9.6	15.7	3.5	0.28	2.6	2005	21.2	33.7	8.7	0.28	5.9
2006	14.7	26.5	3.0	0.35	5.1	2006	37.4	58.7	16.1	0.27	10.0
2007	18.9	30.1	7.7	0.29	5.5	2007	43.9	69.0	18.9	0.28	12.4
2008	17.3	27.0	7.6	0.27	4.7	2008	37.8	56.8	18.8	0.25	9.4
2009	7.5	12.1	2.9	0.30	2.2	2009	16.4	26.0	6.9	0.28	4.6
2010	11.0	15.9	6.0	0.22	2.4	2010	29.0	43.6	14.4	0.25	7.1
2011	10.3	16.4	4.2	0.27	2.8	2011	36.3	67.8	4.8	0.38	13.7
2016	17.9	29.2	6.6	0.30	5.4	2016	48.7	87.8	9.6	0.29	14.1
Newly mature females						Newly mature males					
2002	3.2	4.7	1.7	0.23	0.7	2002	1.6	2.5	0.6	0.28	0.4
2003	1.4	2.9	-0.1	0.51	0.7	2003	0.2	0.5	-0.1	0.74	0.1
2004	1.2	1.9	0.4	0.32	0.4	2004	2.0	2.9	1.0	0.23	0.4
2005	1.7	2.8	0.6	0.29	0.5	2005	2.5	4.5	0.6	0.37	0.9
2006	5.5	9.9	1.2	0.32	1.8	2006	7.5	12.7	2.2	0.38	3.0
2007	5.6	9.8	1.3	0.36	2.0	2007	8.6	13.8	3.3	0.29	2.5
2008	7.0	12.2	1.8	0.36	2.5	2008	2.6	4.3	1.0	0.30	0.8
2009	2.1	3.2	1.0	0.25	0.5	2009	1.7	2.8	0.5	0.32	0.5
2010	2.6	5.1	0.1	0.47	1.2	2010	3.0	6.5	-0.6	0.58	1.7
2011	2.0	3.2	0.8	0.30	0.6	2011	2.3	4.2	0.3	0.41	0.9
2016	3.4	5.0	1.8	0.22	0.7	2016	5.7	12.4	-1.0	0.42	2.4

Table 1 continued.

	mean	UCL	LCL	CV	sd
Total					
2002	76.5	108.2	44.7	0.20	15.4
2003	41.8	66.1	17.5	0.27	11.4
2004	68.2	105.8	30.6	0.27	18.2
2005	95.6	157.5	33.6	0.32	30.3
2006	118.0	173.4	62.6	0.21	24.9
2007	172.5	288.9	56.1	0.32	55.4
2008	115.1	170.0	60.2	0.23	26.5
2009	226.4	404.9	47.9	0.36	81.9
2010	58.9	83.4	34.5	0.20	12.0
2011	72.6	111.9	33.2	0.24	17.7
2016	113.6	197.9	29.4	0.27	30.3

Table 2. Stratified mean catch per tow of horseshoe crabs in the coastal **Delaware Bay area** survey, 2002-2016, with standard deviation (sd) and coefficient of variation (CV), calculated using the **normal distribution** model, by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

	mean	UCL	LCL	CV	sd		mean	UCL	LCL	CV	sd
Immature females						Immature males					
2002	21.3	31.5	11.0	0.23	4.9	2002	12.6	19.3	5.8	0.26	3.3
2003	7.3	12.8	1.7	0.36	2.6	2003	3.7	6.0	1.4	0.29	1.1
2004	18.8	26.1	11.5	0.19	3.6	2004	15.3	21.4	9.1	0.20	3.0
2005	25.6	43.7	7.4	0.34	8.7	2005	26.8	56.0	-2.4	0.52	13.8
2006	32.8	49.6	15.9	0.24	8.0	2006	22.0	32.7	11.4	0.23	5.1
2007	39.4	76.6	2.1	0.39	15.2	2007	34.5	68.5	0.5	0.46	15.8
2008	27.5	42.2	12.7	0.25	7.0	2008	18.9	29.0	8.8	0.26	4.8
2009	62.2	93.5	30.9	0.24	15.1	2009	60.4	90.7	30.1	0.24	14.5
2010	8.9	12.2	5.6	0.18	1.6	2010	5.9	9.2	2.6	0.27	1.6
2011	11.5	15.9	7.2	0.18	2.1	2011	7.0	9.9	4.1	0.20	1.4
2016	23.6	40.2	7.0	0.31	7.3	2016	16.8	28.3	5.4	0.31	5.2
Mature females						Mature males					
2002	10.3	14.9	5.8	0.21	2.2	2002	22.9	31.2	14.7	0.17	4.0
2003	7.7	11.3	4.1	0.22	1.7	2003	16.7	24.7	8.6	0.23	3.8
2004	6.5	9.6	3.4	0.23	1.5	2004	15.2	24.7	5.8	0.30	4.5
2005	10.3	17.1	3.4	0.32	3.3	2005	18.9	28.0	9.8	0.23	4.3
2006	16.0	27.7	4.2	0.33	5.3	2006	36.5	54.9	18.2	0.24	8.6
2007	17.0	25.7	8.3	0.25	4.3	2007	35.7	49.9	21.6	0.19	7.0
2008	19.2	32.5	5.9	0.34	6.5	2008	39.7	63.5	16.0	0.29	11.6
2009	8.0	13.0	3.0	0.30	2.4	2009	16.2	24.8	7.6	0.26	4.1
2010	11.8	18.2	5.4	0.26	3.1	2010	30.8	47.5	14.1	0.26	8.0
2011	10.1	15.7	4.5	0.26	2.6	2011	35.7	61.6	9.8	0.32	11.4
2016	16.7	25.1	8.2	0.25	4.1	2016	57.6	118.7	-3.4	0.38	22.0
Newly mature females						Newly mature males					
2002	3.1	4.6	1.7	0.22	0.7	2002	1.6	2.6	0.6	0.30	0.5
2003	1.4	3.0	-0.1	0.50	0.7	2003	0.2	0.5	-0.1	0.74	0.1
2004	1.2	1.9	0.4	0.32	0.4	2004	2.0	2.9	1.1	0.22	0.4
2005	1.8	3.2	0.5	0.33	0.6	2005	2.6	4.7	0.6	0.37	1.0
2006	5.6	9.2	2.0	0.29	1.6	2006	7.8	14.1	1.6	0.38	3.0
2007	4.9	7.5	2.2	0.26	1.3	2007	7.7	11.6	3.7	0.25	1.9
2008	7.6	12.6	2.6	0.32	2.4	2008	2.8	4.4	1.1	0.29	0.8
2009	2.1	3.1	1.0	0.25	0.5	2009	1.6	2.6	0.6	0.29	0.5
2010	3.8	9.4	-1.8	0.71	2.7	2010	3.0	6.5	-0.5	0.56	1.7
2011	2.2	3.8	0.6	0.36	0.8	2011	2.2	3.8	0.6	0.36	0.8
2016	3.3	4.7	1.9	0.20	0.7	2016	6.3	12.2	0.5	0.43	2.7

Table 2 continued.

	mean	UCL	LCL	CV	sd
Total					
2002	71.9	94.4	49.4	0.15	10.9
2003	37.0	52.1	21.9	0.19	7.2
2004	59.0	82.2	35.7	0.19	11.3
2005	86.0	140.0	32.0	0.30	26.0
2006	120.7	172.3	69.1	0.21	24.9
2007	139.1	219.6	58.6	0.27	37.3
2008	115.7	169.8	61.7	0.23	26.4
2009	150.5	213.9	87.1	0.20	30.5
2010	64.2	98.9	29.5	0.26	16.7
2011	70.8	104.9	36.7	0.22	15.5
2016	120.8	216.2	25.4	0.31	37.1

Table 3. Stratified mean catch per tow of horseshoe crabs in the coastal **Delaware Bay area** survey **core region**, 2001-2016, with standard deviation (sd) and coefficient of variation (CV), calculated using the **delta distribution** model, by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

	mean	UCL	LCL	CV	sd		mean	UCL	LCL	CV	sd
Immature females						Immature males					
2001	10.3	16.0	4.6	0.26	2.7	2001	5.3	8.4	2.1	0.28	1.5
2002	17.8	34.1	1.5	0.39	6.9	2002	9.8	20.2	-0.5	0.43	4.2
2003	5.6	19.9	-8.6	0.59	3.3	2003	2.3	6.2	-1.7	0.40	0.9
2004	18.1	29.7	6.6	0.29	5.3	2004	14.5	26.4	2.5	0.32	4.6
2005	28.9	50.8	6.9	0.36	10.5	2005	33.7	72.0	-4.6	0.53	17.9
2006	32.2	57.8	6.7	0.34	10.8	2006	23.7	54.3	-6.9	0.41	9.6
2007	44.7	100.8	-11.4	0.45	20.2	2007	36.0	80.2	-8.3	0.50	18.1
2008	24.4	47.2	1.7	0.38	9.3	2008	16.7	32.0	1.4	0.39	6.5
2009	22.5	49.9	-4.9	0.47	10.7	2009	23.8	60.3	-12.7	0.55	13.2
2010	9.9	15.1	4.7	0.22	2.1	2010	5.8	11.2	0.3	0.44	2.6
2011	12.3	17.8	6.8	0.19	2.4	2011	7.5	11.6	3.3	0.23	1.7
2016	34.9	230.5	-160.7	0.44	15.4	2016	25.7	169.6	-118.3	0.44	11.3
Mature females						Mature males					
2001	10.4	14.5	6.3	0.19	2.0	2001	19.7	29.7	9.6	0.24	4.8
2002	11.2	16.6	5.9	0.22	2.5	2002	24.2	34.2	14.1	0.20	4.8
2003	11.7	19.9	3.4	0.27	3.2	2003	25.9	46.5	5.2	0.33	8.4
2004	8.2	12.9	3.5	0.27	2.2	2004	22.3	38.4	6.2	0.34	7.6
2005	12.8	23.4	2.2	0.39	4.9	2005	24.7	38.2	11.2	0.26	6.3
2006	24.6	45.6	3.5	0.27	6.6	2006	47.9	77.5	18.4	0.24	11.5
2007	29.1	47.9	10.3	0.31	8.9	2007	63.3	104.7	21.9	0.31	19.4
2008	21.9	34.5	9.4	0.27	6.0	2008	48.1	73.7	22.5	0.25	12.1
2009	9.8	19.7	-0.1	0.45	4.4	2009	21.2	40.7	1.6	0.41	8.6
2010	17.5	26.3	8.7	0.24	4.1	2010	49.4	76.9	22.0	0.26	12.8
2011	16.4	34.4	-1.6	0.39	6.5	2011	63.6	136.4	-9.2	0.41	26.2
2016	17.2	76.7	-42.4	0.27	4.7	2016	91.0	640.7	-458.7	0.48	43.3
Newly mature females						Newly mature males					
2001	1.6	2.3	0.9	0.21	0.3	2001	1.3	2.4	0.3	0.37	0.5
2002	2.2	3.6	0.8	0.29	0.6	2002	0.9	1.6	0.2	0.39	0.3
2003	0.2	0.5	-0.1	0.31	0.1	2003	0.1	0.3	-0.1	0.85	0.1
2004	1.7	2.9	0.5	0.32	0.5	2004	1.5	2.7	0.3	0.37	0.6
2005	1.5	3.9	-0.9	0.51	0.8	2005	2.6	5.5	-0.4	0.51	1.3
2006	4.1	9.2	-0.9	0.38	1.6	2006	10.5	24.2	-3.2	0.57	5.9
2007	4.6	9.2	0.0	0.45	2.1	2007	10.6	18.8	2.4	0.35	3.7
2008	6.3	11.7	1.0	0.40	2.5	2008	2.3	4.1	0.6	0.35	0.8
2009	1.2	2.3	0.1	0.42	0.5	2009	0.3	0.8	-0.2	0.49	0.1
2010	4.0	9.8	-1.8	0.67	2.7	2010	4.6	10.8	-1.7	0.64	2.9
2011	2.1	3.5	0.8	0.28	0.6	2011	2.5	5.7	-0.8	0.51	1.2
2016	4.3	6.6	1.9	0.23	1.0	2016	9.5	66.3	-47.4	0.47	4.5

Table 3 continued.

	mean	UCL	LCL	cv	sd
Total					
2001	51.7	75.4	28.1	0.22	11.4
2002	67.2	103.8	30.5	0.25	16.5
2003	48.9	86.7	11.1	0.30	14.7
2004	66.5	103.8	29.2	0.26	17.5
2005	105.9	184.8	27.0	0.36	37.7
2006	139.3	240.6	38.1	0.26	36.5
2007	208.4	365.6	51.2	0.35	73.7
2008	119.1	182.8	55.3	0.25	29.9
2009	103.6	224.1	-16.9	0.48	49.2
2010	92.0	142.3	41.6	0.26	23.7
2011	108.8	194.3	23.2	0.31	33.3
2016	179.7	1126.1	-766.6	0.41	74.5

Table 4. Stratified mean catch per tow of horseshoe crabs in the coastal **Delaware Bay area** survey **core region**, 2001-2016, with standard deviation (sd) and coefficient of variation (CV), calculated using the **normal distribution** model, by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

	mean	UCL	LCL	CV	sd		mean	UCL	LCL	CV	sd
Immature females						Immature males					
2001	9.2	12.2	6.1	0.16	1.5	2001	4.7	6.7	2.8	0.20	1.0
2002	16.3	28.3	4.3	0.33	5.3	2002	9.8	18.6	1.1	0.41	4.1
2003	6.6	21.1	-7.8	0.51	3.4	2003	2.2	5.1	-0.6	0.40	0.9
2004	18.3	28.3	8.4	0.25	4.6	2004	13.6	21.2	6.1	0.25	3.4
2005	31.4	59.0	3.8	0.41	12.9	2005	36.2	81.7	-9.2	0.58	21.1
2006	35.5	68.4	2.7	0.40	14.3	2006	23.0	41.6	4.4	0.36	8.2
2007	43.6	93.6	-6.5	0.45	19.5	2007	44.7	101.6	-12.2	0.58	26.1
2008	24.1	42.8	5.5	0.33	7.9	2008	15.7	27.3	4.1	0.31	4.9
2009	23.2	57.7	-11.2	0.53	12.4	2009	22.3	56.7	-12.0	0.55	12.4
2010	10.3	16.0	4.6	0.26	2.7	2010	5.8	11.3	0.3	0.44	2.6
2011	12.4	18.0	6.7	0.20	2.4	2011	7.5	11.4	3.6	0.23	1.7
2016	32.4	90.8	-26.0	0.42	13.6	2016	22.9	63.2	-17.3	0.41	9.4
Mature females						Mature males					
2001	11.0	15.7	6.3	0.21	2.3	2001	19.6	28.0	11.2	0.21	4.1
2002	11.5	17.8	5.2	0.25	2.9	2002	24.5	35.4	13.6	0.21	5.1
2003	11.3	17.8	4.9	0.24	2.7	2003	23.8	38.3	9.3	0.26	6.1
2004	8.9	13.7	4.1	0.25	2.2	2004	22.4	37.0	7.8	0.30	6.8
2005	13.6	25.5	1.8	0.40	5.5	2005	24.3	36.8	11.8	0.24	5.9
2006	25.1	49.2	1.0	0.30	7.6	2006	48.3	78.3	18.2	0.25	12.3
2007	25.7	40.1	11.4	0.26	6.7	2007	52.3	74.7	29.9	0.20	10.4
2008	26.3	46.6	6.0	0.37	9.7	2008	54.7	91.5	17.8	0.32	17.4
2009	9.7	19.3	0.1	0.43	4.2	2009	20.6	36.8	4.4	0.35	7.2
2010	18.2	28.6	7.8	0.26	4.8	2010	48.9	75.6	22.1	0.25	12.3
2011	14.2	24.6	3.8	0.28	4.0	2011	57.4	105.0	9.8	0.30	17.2
2016	16.1	34.0	-1.7	0.26	4.1	2016	90.7	636.1	-454.7	0.47	42.9
Newly mature females						Newly mature males					
2001	1.7	2.5	0.9	0.23	0.4	2001	1.3	2.2	0.4	0.34	0.4
2002	2.2	3.7	0.8	0.29	0.7	2002	0.9	1.7	0.1	0.41	0.4
2003	0.2	0.5	0.0	0.32	0.1	2003	0.1	0.3	-0.1	0.85	0.1
2004	1.7	2.9	0.6	0.30	0.5	2004	1.7	2.9	0.5	0.33	0.6
2005	1.5	3.6	-0.6	0.51	0.8	2005	2.5	5.1	-0.1	0.47	1.2
2006	4.2	8.7	-0.3	0.39	1.6	2006	9.6	22.7	-3.6	0.58	5.5
2007	4.4	8.2	0.6	0.38	1.7	2007	9.7	16.1	3.4	0.31	3.0
2008	7.9	15.0	0.8	0.42	3.3	2008	2.4	4.4	0.5	0.38	0.9
2009	1.2	2.3	0.1	0.41	0.5	2009	0.3	0.6	0.0	0.49	0.1
2010	5.6	15.7	-4.5	0.82	4.6	2010	4.6	10.8	-1.6	0.62	2.9
2011	2.2	3.6	0.8	0.28	0.6	2011	2.3	4.6	0.0	0.40	0.9
2016	4.1	5.9	2.3	0.21	0.9	2016	10.1	25.3	-5.0	0.47	4.8

Table 4 continued.

	mean	UCL	LCL	cv	sd
Total					
2001	47.5	62.8	32.2	0.16	7.6
2002	65.2	94.4	36.1	0.21	13.6
2003	44.3	71.3	17.4	0.24	10.5
2004	66.7	101.1	32.3	0.24	16.0
2005	109.6	191.7	27.4	0.35	38.6
2006	145.6	240.2	51.0	0.29	41.8
2007	180.3	302.2	58.5	0.31	55.9
2008	131.1	209.0	53.2	0.28	37.4
2009	78.0	144.6	11.4	0.36	28.2
2010	93.4	151.5	35.3	0.29	26.7
2011	98.4	158.6	38.1	0.24	23.4
2016	176.5	1098.9	-745.9	0.41	72.6

Table 5. Stratified mean catch per tow of horseshoe crabs in the **lower Delaware Bay** survey area in 2010-2016, with standard deviation (sd) and coefficient of variation (CV), calculated using the **delta distribution** model, by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

	mean	UCL	LCL	CV	sd		mean	UCL	LCL	CV	sd
Immature females						Immature males					
2010	86.2	137.9	34.5	0.25	21.9	2010	65.6	113.8	17.4	0.32	21.3
2011	20.8	44.2	-2.6	0.44	9.1	2011	21.3	44.9	-2.3	0.43	9.2
2012	173.1	320.9	25.2	0.33	57.5	2012	182.5	356.8	8.2	0.37	67.8
2016	211.3	363.3	59.3	0.26	54.7	2016	191.9	312.8	71.0	0.25	47.0
Mature females						Mature males					
2010	45.4	88.1	2.7	0.38	17.4	2010	121.1	209.1	33.2	0.31	37.2
2011	25.9	45.6	6.2	0.30	7.7	2011	94.2	174.1	14.2	0.33	31.1
2012	17.2	33.0	1.3	0.29	5.0	2012	63.7	113.9	13.5	0.31	19.5
2016	27.2	37.1	17.3	0.14	3.8	2016	167.8	201.2	134.3	0.08	13.7
Newly mature females						Newly mature males					
2010	9.7	25.8	-6.4	0.68	6.6	2010	4.3	9.6	-1.0	0.50	2.2
2011	1.3	3.3	-0.6	0.57	0.8	2011	1.3	4.0	-1.4	0.83	1.0
2012	0.7	1.7	-0.4	0.58	0.4	2012	6.6	17.9	-4.7	0.54	3.6
2016	5.3	9.2	1.4	0.27	1.4	2016	18.8	32.6	4.9	0.27	5.0
						Total					
						2010	327.3	530.2	124.5	0.25	82.9
						2011	172.5	316.1	28.9	0.32	55.9
						2012	434.0	762.2	105.7	0.29	127.7
						2016	609.1	825.7	392.5	0.13	78.0

Table 6. Stratified mean catch per tow of horseshoe crabs in the **lower Delaware Bay** survey area in 2010-2016, with standard deviation (sd) and coefficient of variation (CV), calculated using the **normal distribution** model, by demographic group. Also included are the estimated upper and lower 95% confidence limits (UCL, LCL).

	mean	UCL	LCL	CV	sd		mean	UCL	LCL	CV	sd
Immature females						Immature males					
2010	86.9	141.7	32.0	0.26	22.4	2010	64.1	104.1	24.1	0.28	17.7
2011	21.4	46.3	-3.6	0.45	9.7	2011	22.2	48.6	-4.2	0.46	10.3
2012	171.5	321.8	21.1	0.32	54.1	2012	178.4	326.3	30.6	0.34	60.4
2016	204.4	305.6	103.1	0.19	39.4	2016	184.1	263.6	104.7	0.17	30.9
Mature females						Mature males					
2010	52.2	121.4	-17.0	0.54	28.3	2010	131.7	267.8	-4.4	0.42	55.6
2011	28.8	42.8	14.8	0.20	5.7	2011	92.2	158.1	26.3	0.28	25.6
2012	17.1	32.6	1.6	0.28	4.9	2012	62.5	104.9	20.1	0.26	16.5
2016	27.0	35.9	18.2	0.13	3.4	2016	167.7	199.5	135.8	0.08	13.0
Newly mature females						Newly mature males					
2010	11.5	33.4	-10.4	0.78	8.9	2010	4.5	10.4	-1.5	0.55	2.4
2011	1.3	3.1	-0.5	0.53	0.7	2011	1.3	4.0	-1.4	0.83	1.0
2012	0.7	1.7	-0.4	0.58	0.4	2012	6.6	17.8	-4.6	0.53	3.5
2016	5.2	8.9	1.6	0.25	1.3	2016	18.6	31.2	6.1	0.24	4.5
						Total					
						2010	350.9	656.8	44.9	0.36	125.0
						2011	167.1	279.7	54.4	0.26	43.8
						2012	436.8	767.1	106.4	0.29	128.5
						2016	607.1	783.3	430.8	0.11	68.6

Table 7. Mean prosomal widths (mm) and standard deviations (sd) of newly mature and mature males and females from the Delaware Bay area and lower Delaware Bay trawl surveys, 2002-2016, calculated using the FiSAT II program's NORMSEP method of modal progression analysis.

	Delaware Bay area		Lower Delaware Bay			Delaware Bay area		Lower Delaware Bay	
Year	Mean	sd	Mean	sd	Year	Mean	sd	Mean	sd
Mature females					Mature males				
2002	267	18.7	-	-	2002	212	14.1	-	-
2003	268	18.2	-	-	2003	210	15.6	-	-
2004	270	19.2	-	-	2004	210	14.1	-	-
2005	268	18.5	-	-	2005	210	13.0	-	-
2006	268	20.5	-	-	2006	209	13.2	-	-
2007	267	19.7	-	-	2007	208	13.6	-	-
2008	268	20.0	-	-	2008	207	12.5	-	-
2009	267	18.9	-	-	2009	206	14.8	-	-
2010	264	17.9	259	15.9	2010	206	14.0	203	11.3
2011	263	18.7	265	17.6	2011	208	14.2	203	13.0
2012	-	-	262	17.8	2012	-	-	202	14.5
2016	258	20.0	255	16.3	2016	196	15.1	198	14.2
Newly mature females					Newly mature males				
2002	262	15.2	-	-	2002	202	13.4	-	-
2003	271	16.2	-	-	2003	202	8.2	-	-
2004	257	19.9	-	-	2004	209	13.8	-	-
2005	258	13.4	-	-	2005	209	12.7	-	-
2006	264	17.9	-	-	2006	207	10.6	-	-
2007	260	15.8	-	-	2007	211	14.4	-	-
2008	261	16.9	-	-	2008	212	12.0	-	-
2009	271	20.3	-	-	2009	206	12.5	-	-
2010	260	15.1	265	21.1	2010	203	15.1	184	17.4
2011	259	24.4	257	5.7	2011	204	14.7	188	3.3
2012	-	-	250	15.7	2012	-	-	203	14.6
2016	245	19.0	246	19.6	2016	204	13.1	195	12.2

Table 8. Results of regression analyses of mean prosomal width (mm) on survey year for newly mature and mature males and females from the Delaware Bay area survey. Mean widths are listed in Table 7. Statistics presented are number of years included, *n*; *T*-score; probability, *p*; and correlation coefficient, *r*. A negative correlation coefficient indicates a decreasing regression slope.

Maturity group	*n*	*T*	*p*	*r*
2002-2016				
Mature females	11	-5.26	<0.001	-0.869
Newly mature females	11	-2.10	0.065	-0.574
Mature males	11	-6.53	<0.001	-0.909
Newly mature males	11	-0.21	0.839	-0.069
2002-2011				
Mature females	10	-2.89	0.020	-0.714
Newly mature females	10	-0.30	0.769	-0.107
Mature males	10	-5.30	<0.001	-0.882
Newly mature males	10	0.33	0.753	0.114

Table 9. Mean, minimum (min) and maximum (max) bottom water temperature (C°) and ordinal sampling date (numerical calendar date from 1 January) for survey collections in the Delaware Bay area and Lower Delaware Bay. For reference, 1 September is ordinal date 243 in non-leap years.

	Water temperature			Ordinal date		
	mean	min	max	mean	min	max
Delaware Bay area						
2002	19.6	15.0	23.5	289	274	301
2003	17.4	13.5	20.0	288	279	297
2004	16.7	14.5	20.5	294	278	303
2005	20.8	14.0	24.5	261	251	307
2006	17.4	13.0	22.3	287	247	315
2007	19.5	14.3	23.3	297	283	312
2008	20.1	19.3	22.6	278	273	288
2009	15.6	14.3	17.0	315	307	324
2010	19.3	12.3	24.1	284	265	331
2011	21.5	18.6	23.8	265	254	296
2016	22.5	18.6	24.8	276	260	299
Lower Delaware Bay						
2010	17.2	16.7	17.7	295	295	296
2011	18.3	18.0	18.6	294	294	295
2012	18.0	17.9	18.0	299	299	299
2016	19.6	19.0	20.1	289	288	289

Table 10. Correlations between annual mean catches per tow of horseshoe crabs with mean bottom water temperature and ordinal sampling date in the Delaware Bay area survey and the lower Delaware Bay survey, by demographic group. The Delaware Bay area surveys included 11 years, and the lower Delaware Bay surveys included four years. Statistics presented include correlation coefficient, *r*; *T*-score; and probability, *p*. Data are from Tables 1, 5 and 9.

	Water temperature			Ordinal date		
	r	*T*	*p*	*r*	*T*	*p*
Delaware Bay area						
Immature females	-0.435	-1.45	0.181	0.644	2.53	0.032
Immature males	-0.478	-1.63	0.137	0.642	2.51	0.033
Mature females	0.578	2.13	0.063	-0.215	-0.66	0.525
Mature males	0.674	2.74	0.023	-0.315	-0.99	0.346
Newly mature females	0.183	0.56	0.589	0.027	0.08	0.938
Newly mature males	0.218	0.67	0.519	0.036	0.11	0.917
Lower Delaware Bay						
Immature females	0.537	0.90	0.463	0.072	0.10	0.928
Immature males	0.515	0.85	0.485	-0.078	-0.11	0.922
Mature females	-0.461	-0.73	0.539	0.500	0.82	0.500
Mature males	0.594	1.04	0.406	0.956	4.62	0.044
Newly mature females	-0.275	-0.40	0.725	0.577	1.00	0.423
Newly mature males	0.802	1.90	0.198	0.542	0.91	0.458

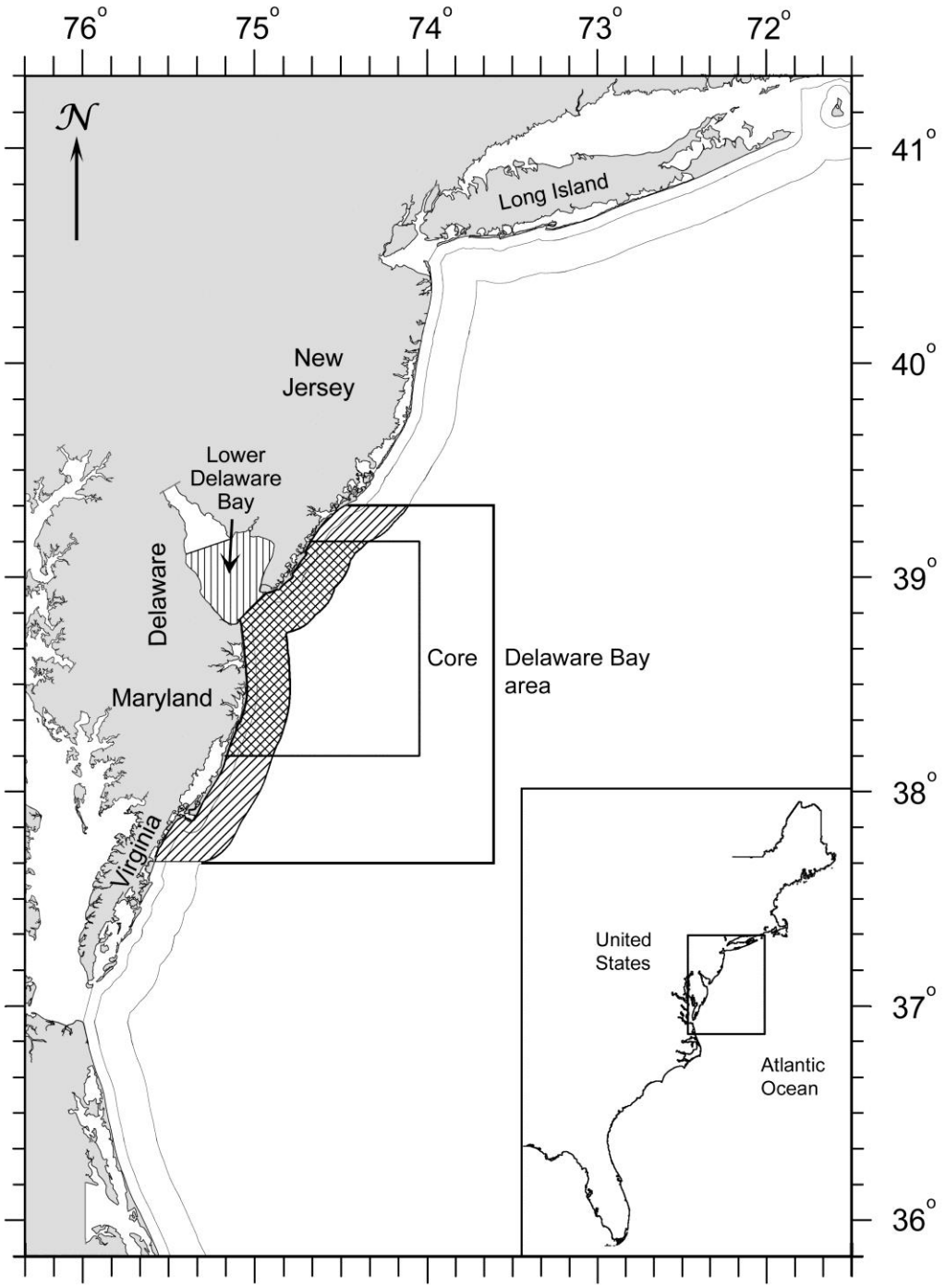


Figure 1. Fall 2016 horseshoe crab trawl survey sampling area. The coastal Delaware Bay area (DBA) and Lower Delaware Bay (LDB) survey areas are indicated. Mean catches among years were compared using stations within the shaded portions of the survey areas. The core DBA survey region, indicated by crossed lines, was surveyed from 2001 to 2011, and again in 2016. The Lower Delaware Bay was sampled from 2010 to 2012, and again in 2016.

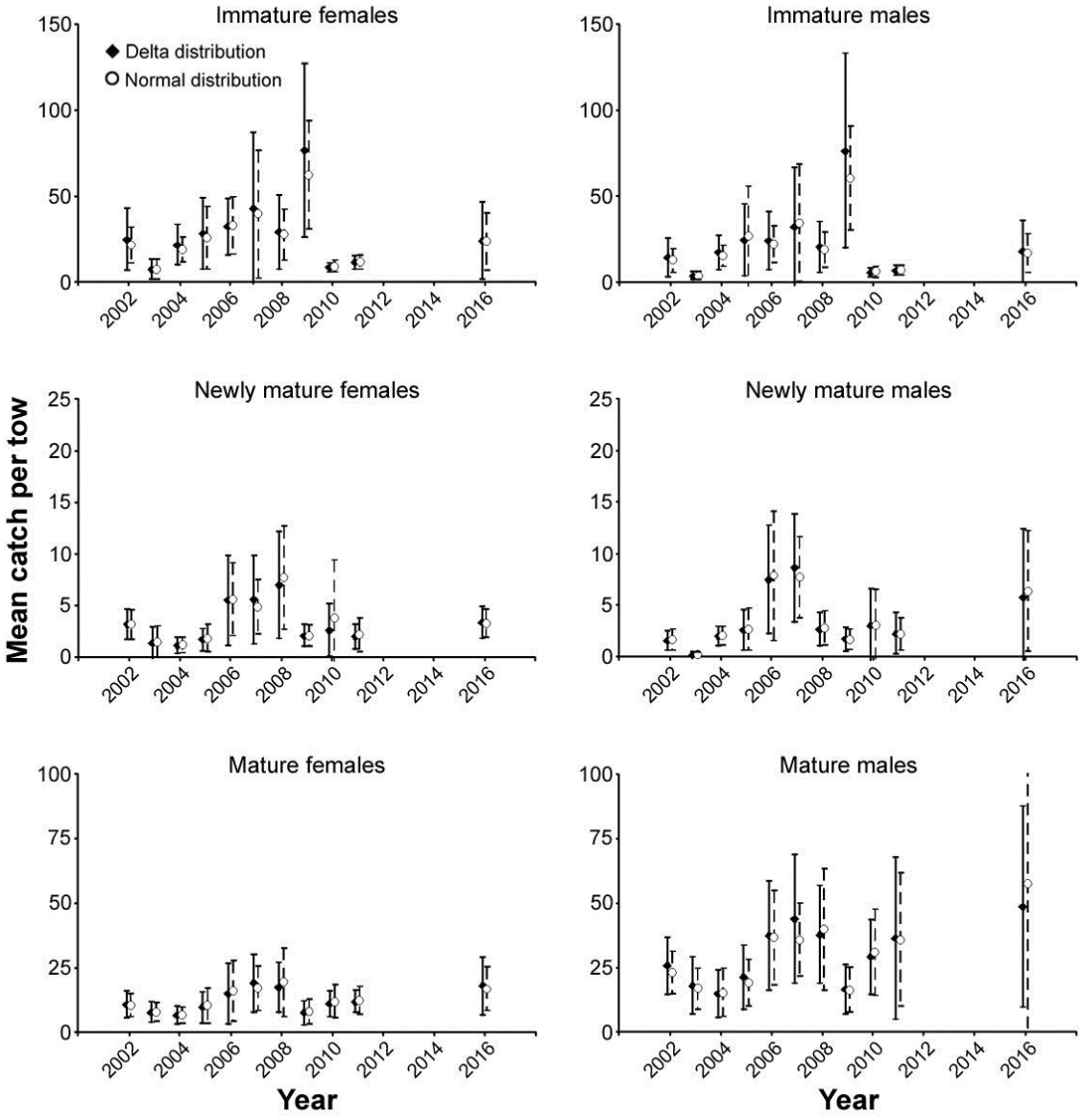


Figure 2. Plots of stratified mean catches per 15-minute tow of horseshoe crabs in the coastal **Delaware Bay area** survey by demographic group. Vertical lines indicate 95% confidence limits. Solid symbols and lines indicate the **delta distribution** model. Open symbols and dashed lines indicate the **normal distribution** model. Data are from Tables 1 and 2. Note differences in *y*-axis scales.

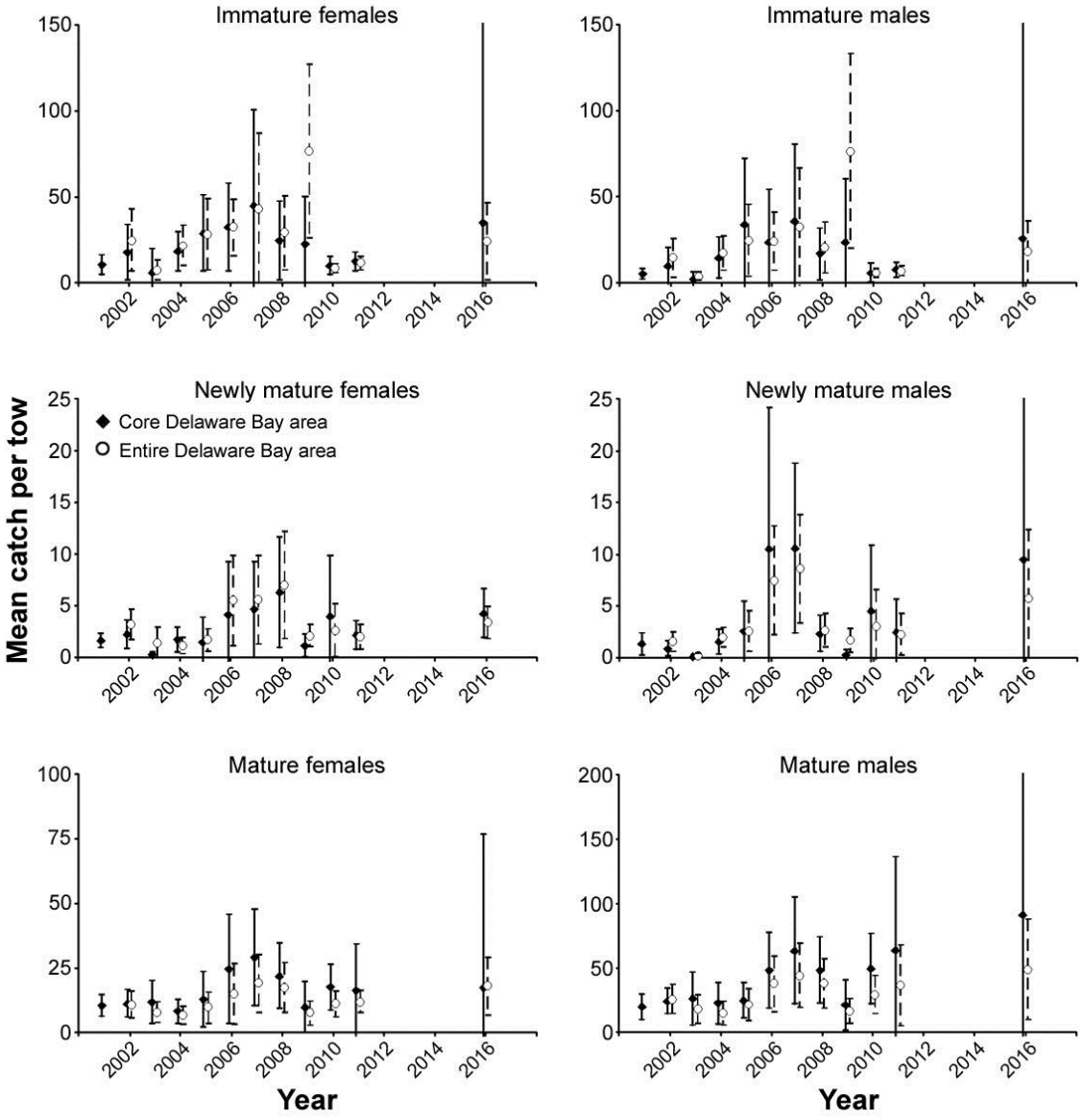


Figure 3. Plots of stratified mean catches per tow of horseshoe crabs in the **core region** of the coastal **Delaware Bay area** survey by demographic group. Vertical lines indicate 95% confidence limits. Catches in the **entire Delaware Bay area** are shown for comparison. Only **delta distribution** means are illustrated for the sake of clarity. Solid symbols and lines indicate the **core region**. Open symbols and dashed lines indicate the **entire survey region**. Data are from Tables 1 and 3. Note differences in y-axis scales.

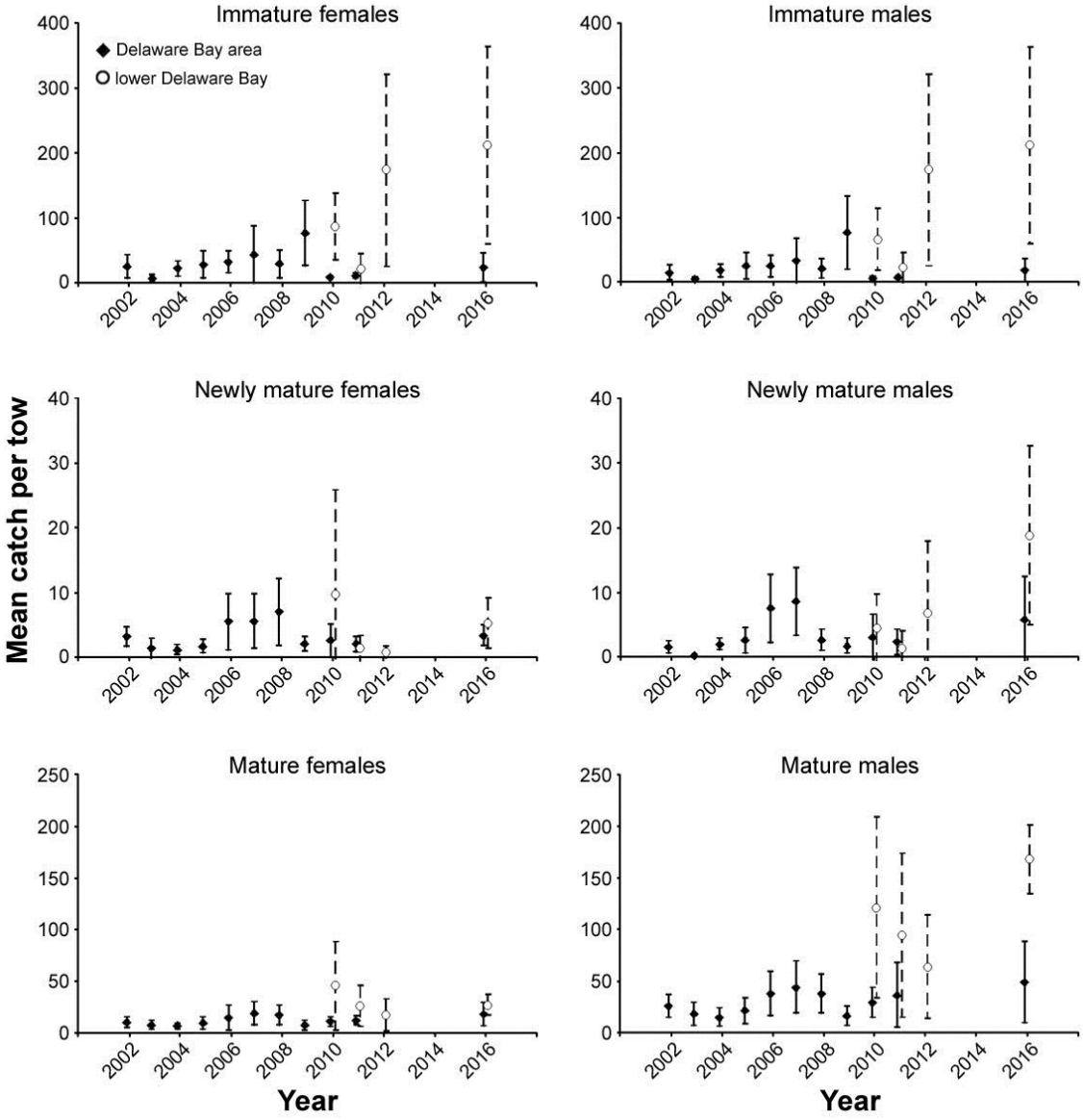


Figure 4. Stratified mean catches per tow of horseshoe crabs in the **lower Delaware Bay** survey by demographic group, 2010-2011, with coastal **Delaware Bay area** survey means for comparison. Vertical lines indicate 95% confidence limits. Only the **delta distribution** model means are presented for clarity. Solid symbols and lines indicate the coastal Delaware Bay area survey. Open symbols and dashed lines indicate the lower Delaware Bay survey. Note differences in *y*-axis scales.

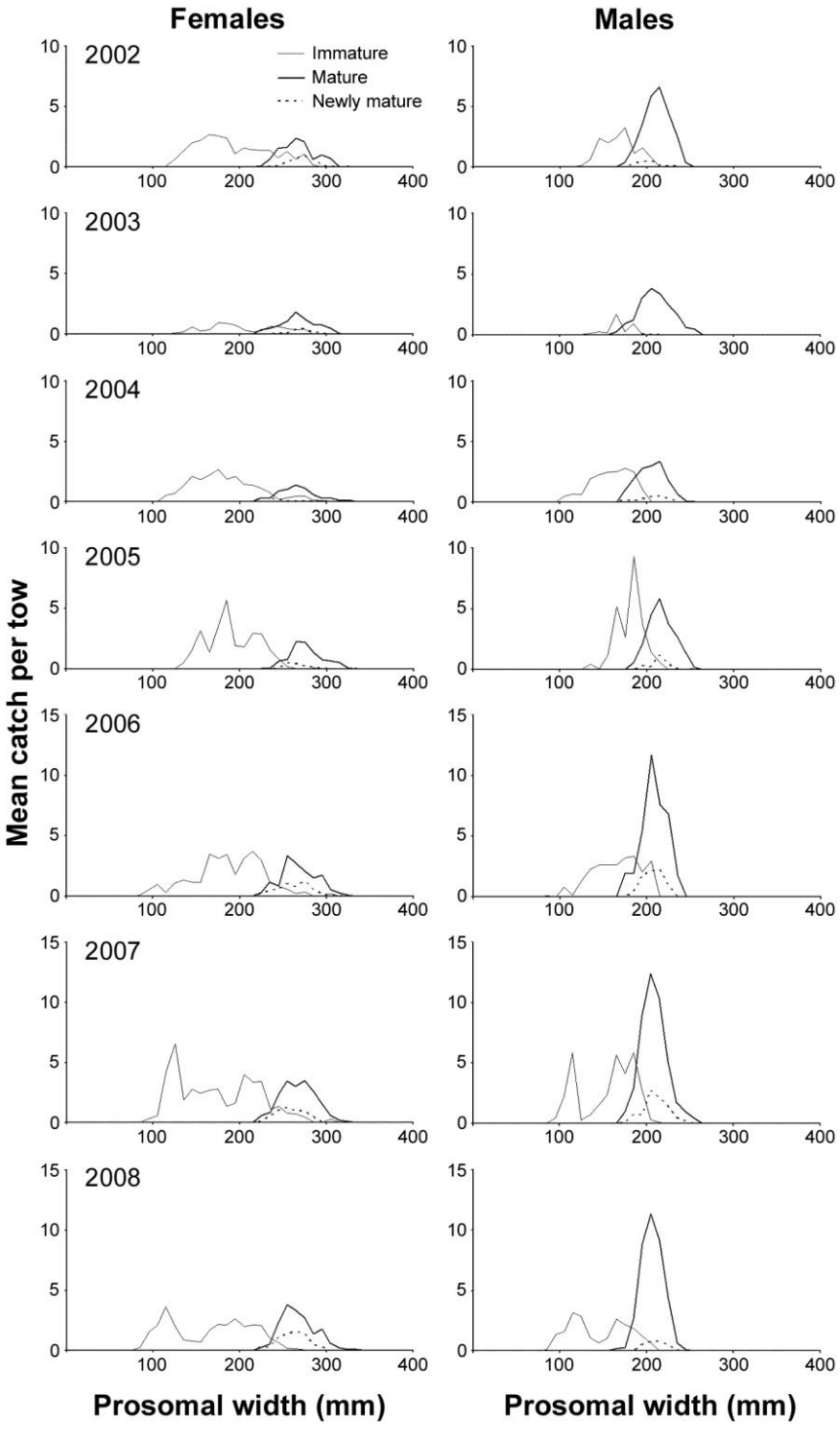


Figure 5. Relative size-frequency distributions of horseshoe crabs, by demographic group and year, in the coastal **Delaware Bay area** trawl survey. Relative frequencies are scaled to represent stratified mean catches in Table 1.

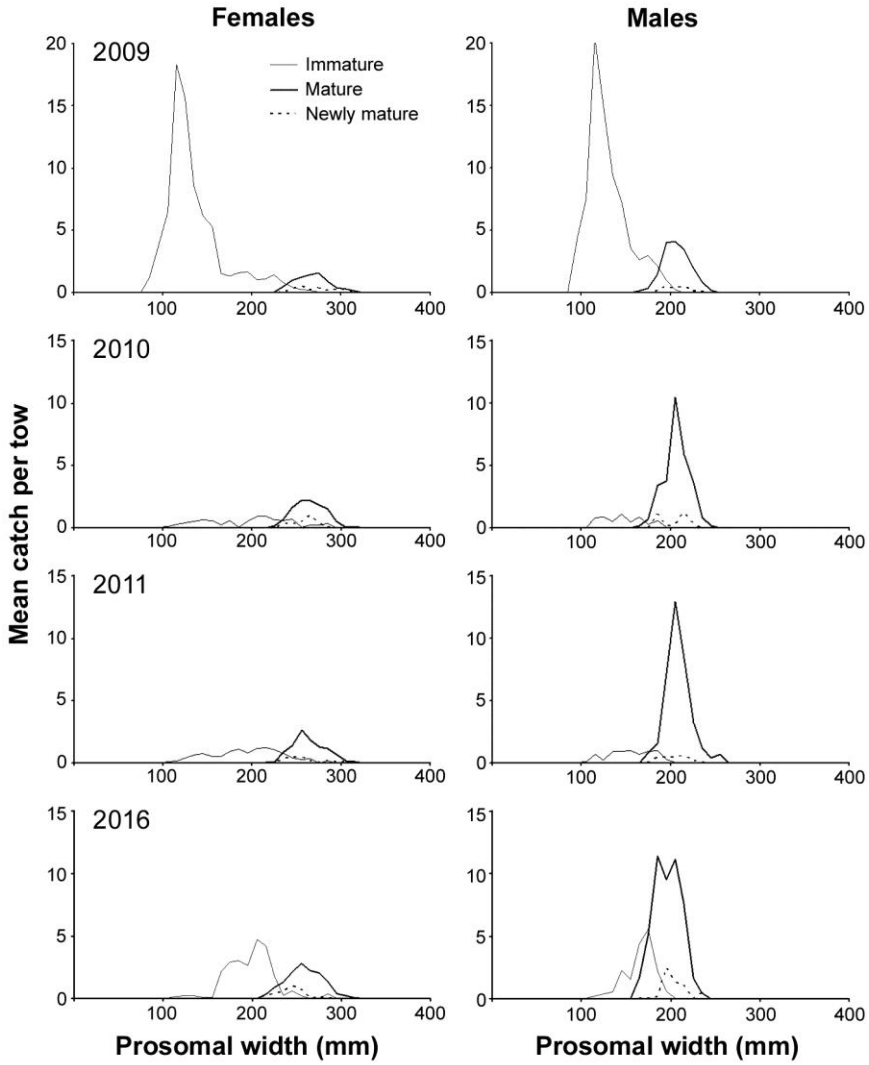


Figure 5 (continued).

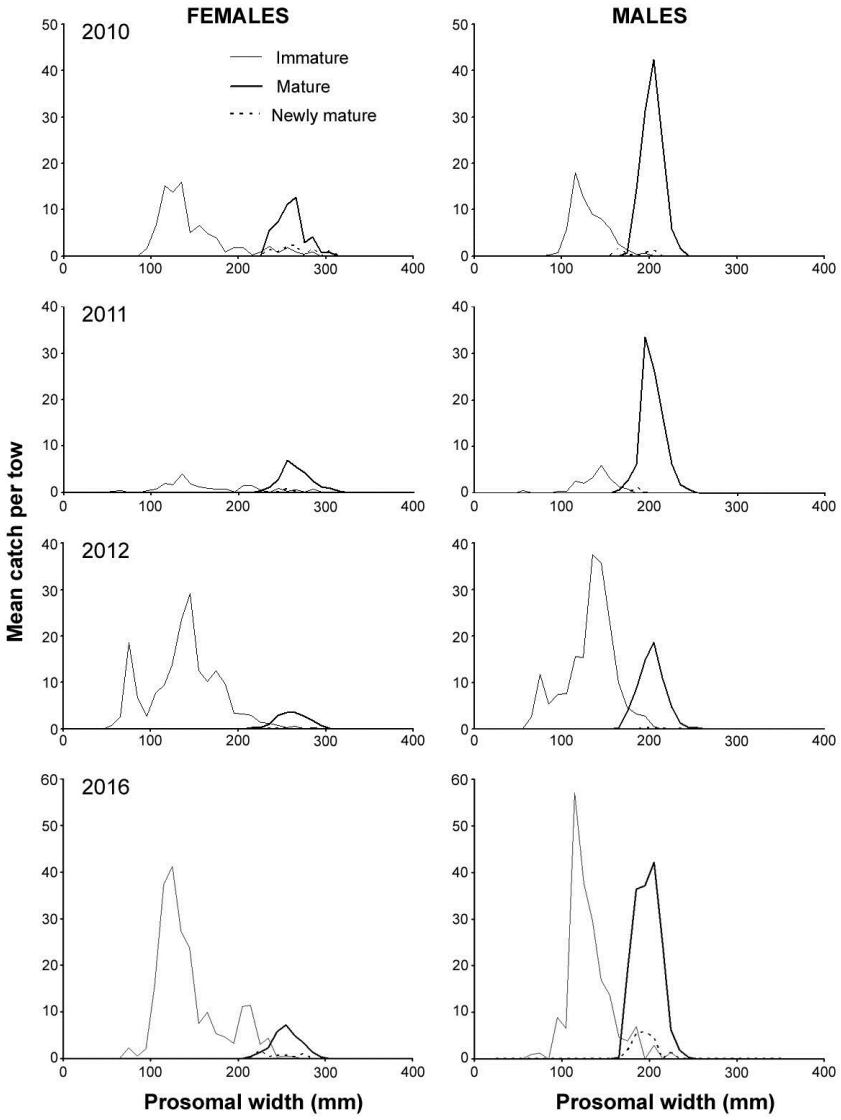


Figure 6. Relative size-frequency distributions of horseshoe crabs, by demographic group and year, in the **lower Delaware Bay** trawl survey. Relative frequencies are scaled to represent stratified mean catches in Table 7.

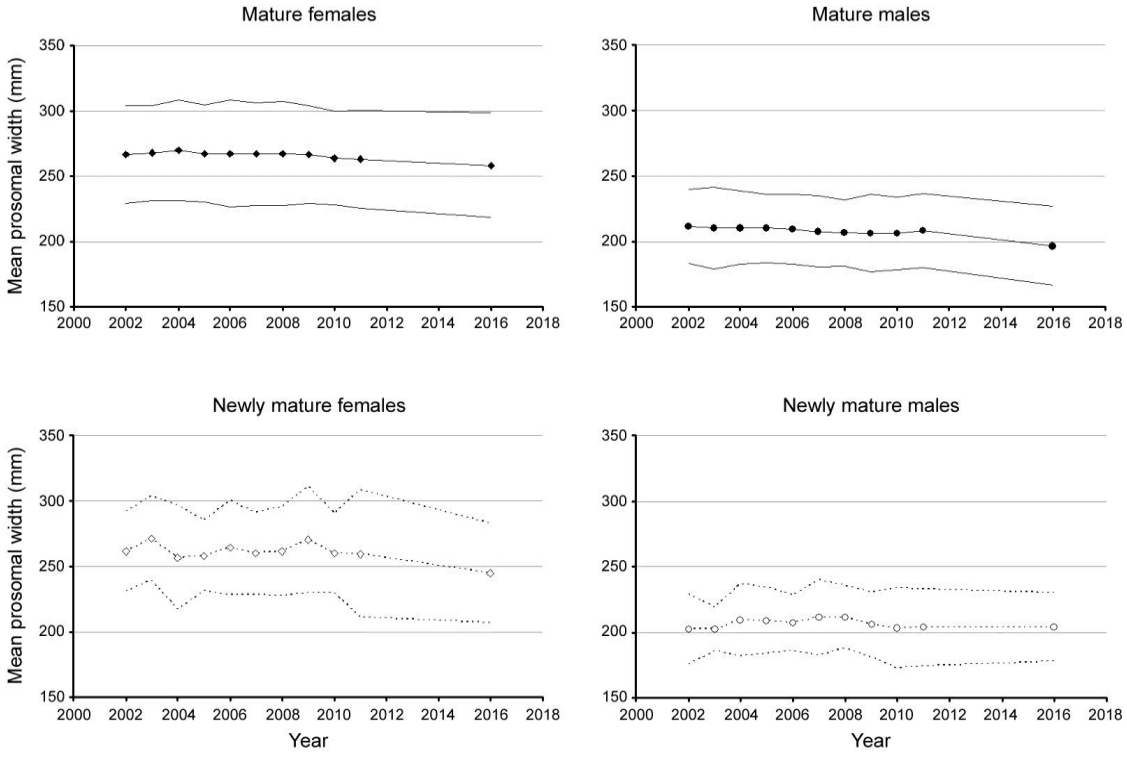


Figure 7. Mean prosomal widths (mm) (± 2 standard deviations) of mature and newly mature female and male horseshoe crabs in the Delaware Bay area survey, 2002-2016. Means and standard deviations were calculated using the FiSAT II program's NORMSEP method of modal progression analysis. Values are from Table 9.

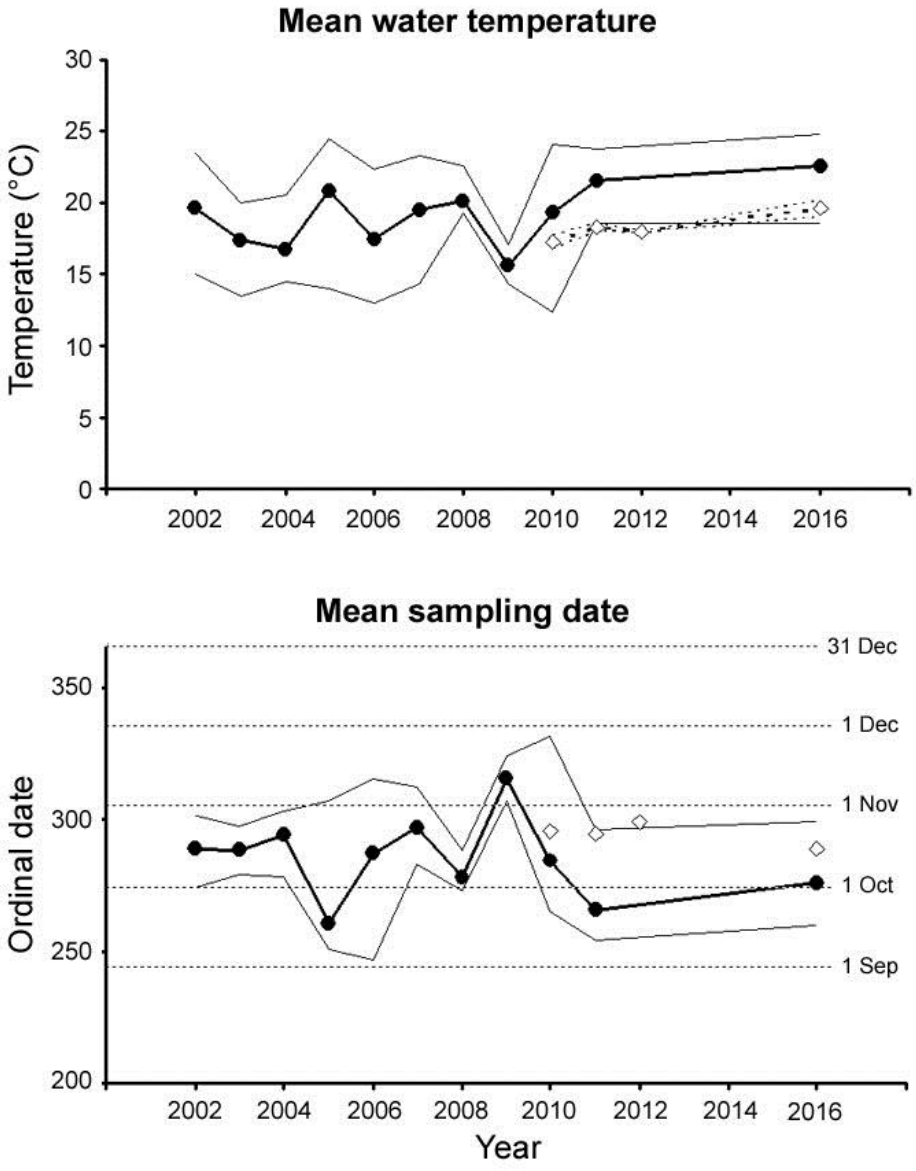


Figure 8. Plots of mean bottom water temperatures and ordinal sampling dates (days since 1 January) in the coastal Delaware Bay area and lower Delaware Bay trawl surveys. Solid symbols and heavy lines indicate means, and light lines indicate ranges for the coastal DBA survey. Open diamonds indicate means for the lower Delaware Bay survey. Approximate calendar dates are indicated by dashed lines for reference (ordinal dates are shifted by one day for leap years).

Adult Horseshoe Crab Abundance in the Delaware Bay

Delaware Bay ARM Workgroup

Report to the Delaware Bay Ecosystem Technical Committee

July 31, 2017

Introduction

In 2015, the Adaptive Resource Management (ARM) workgroup developed a horseshoe crab abundance index based on three trawl surveys in the Delaware Bay region: Delaware 30 foot trawl survey, the New Jersey Delaware Bay trawl survey, and the New Jersey Ocean trawl survey. This composite index was developed because the Virginia Tech trawl survey, which was used to estimate horseshoe crab abundance, lost funding and did not occur. The ARM workgroup showed that the composite index from the three other trawl surveys correlated well with the Virginia Tech Trawl survey for years in which data overlapped and could be used as a substitute for the Virginia Tech Trawl survey when estimating the abundance of male and female horseshoe crabs. The Virginia Tech Trawl Survey was funded and occurred in 2016. This report adds data collected in 2016, updates the composite index, updates the correlation between the composite index and the Virginia Tech Trawl Survey and extrapolates the composite index to horseshoe crab abundance.

Methods

Relative abundance data from the Delaware 30 foot trawl survey, the New Jersey Delaware Bay trawl survey, and the New Jersey Ocean trawl survey were used as input to a linear mixed random effects model to generate the composite index for each year from 1998 – 2016. In this model, each individual survey within a year represented the random effect. The model was fit using the "lme" function from the package "nlme" in R 3.0.2 and was specified as a non-intercept model to allow for year specific estimates of abundance rather than differences for each year from the intercept. Index values from each survey were ln + 0.01 transformed prior to model fitting and final yearly indices of abundance from the model were back-transformed.

Estimates of mean horseshoe crab density were calculated based on the swept area of the Virginia Tech trawl. Mean density estimates were then expanded by the total area included in the trawl survey to calculate a total abundance estimate (Dave Hata, VA Tech, personal communication). Linear regression models were then developed to relate the composite indices of abundance for each sex to the total abundance estimates from the Virginia Tech Trawl Survey. These models were then used to infer total horseshoe crab abundance for years in which the Virginia Tech Trawl Survey did not occur.

Results

The relative abundance indices for both males and females increased in all trawl surveys from 2015 to 2016. These increases translated into an increase in the composite index of abundance of 54% for males and 63% for females over the 2015 values (Table 1, Figure 1).

Sex ratios (males:females) from the compsosite index have varied through the time series and were lowest in the first two years (1998 – 1999). Since 2000, the sex ratio has ranged between 1.07 and 1.70 (Table 2).

Regression of population estimates of male horseshoe crabs from the Virginia Tech Trawl Survey on the composite index of abundance showed a strong positive relationship ($p = 0.002$) with 66% of the variation in abundance explained by the composite index. However, the relationship for female horseshoe crabs was much weaker ($p = 0.252$) and only 14% of the variation in abundance was explained by the composite index (Figure 2).

Final estimates of total abundance for each sex are shown in Table 4 and Figure 3. Abundance of male horseshoe crabs was 24.4 million in 2016 as estimated directly from the Virginia Tech Trawl Survey and was 25.4 million as estimated from the composite index. Abundance of female horseshoe crabs was 7.7 million in 2016 as estimated directly from the Virginia Tech Trawl Survey and was 9.2 million as estimated from the composite index.

Table 1. Relative abundance index values from three trawl surveys in the Delaware Bay region and the composite abundance index derived from the three trawl surveys.

Sex	Year	Delaware 30 ft. trawl	NJ DE Bay trawl	NJ ocean trawl	Composite Index
Male	1998	0.34	0.29		**0.32**
	1999	0.42	0.17	0.50	**0.33**
	2000	0.75	0.33	0.45	**0.48**
	2001	0.57	0.18	0.27	**0.31**
	2002	0.07	0.25	0.32	**0.18**
	2003	0.82	0.18	0.44	**0.41**
	2004	0.02	0.19	0.47	**0.13**
	2005	0.06	0.46	0.56	**0.26**
	2006	0.68	0.30	0.47	**0.46**
	2007	1.04	0.58	0.27	**0.55**
	2008	0.20	0.42	0.24	**0.27**
	2009	0.41	0.21	0.28	**0.29**
	2010	0.36	0.53	0.21	**0.34**
	2011	0.43	0.42	0.39	**0.41**
	2012	0.23	0.34	0.32	**0.29**
	2013	0.09	0.47	0.53	**0.29**
	2014	1.19	0.18	0.44	**0.46**
	2015	0.68	0.32	0.55	**0.49**
	2016	0.84	0.84	0.62	**0.76**
Female	1998	0.47	0.21		**0.39**
	1999	0.63	0.11	0.51	**0.33**
	2000	0.65	0.19	0.46	**0.39**
	2001	0.89	0.10	0.25	**0.28**
	2002	0.08	0.11	0.43	**0.16**
	2003	0.71	0.05	0.45	**0.25**
	2004	0.04	0.07	0.57	**0.12**
	2005	0.10	0.24	0.49	**0.23**
	2006	0.75	0.08	0.47	**0.31**
	2007	0.83	0.24	0.28	**0.39**
	2008	0.18	0.09	0.30	**0.17**
	2009	0.27	0.11	0.29	**0.20**
	2010	0.12	0.26	0.26	**0.20**
	2011	0.19	0.18	0.52	**0.26**
	2012	0.23	0.16	0.41	**0.25**
	2013	0.02	0.27	0.65	**0.17**
	2014	0.83	0.15	0.48	**0.39**
	2015	0.47	0.18	0.68	**0.39**
	2016	0.95	0.34	0.76	**0.63**

Table 2. Sex ratios (male:female) of horseshoe crabs from the composite index in the Delaware Bay region.

Year	Male Index	Female Index	Sex Ratio
1998	0.32	0.39	0.80
1999	0.33	0.33	1.00
2000	0.48	0.39	1.24
2001	0.31	0.28	1.09
2002	0.18	0.16	1.11
2003	0.41	0.25	1.59
2004	0.13	0.12	1.07
2005	0.26	0.23	1.10
2006	0.46	0.31	1.49
2007	0.55	0.39	1.42
2008	0.27	0.17	1.59
2009	0.29	0.20	1.43
2010	0.34	0.20	1.69
2011	0.41	0.26	1.59
2012	0.29	0.25	1.17
2013	0.29	0.17	1.70
2014	0.46	0.39	1.18
2015	0.49	0.39	1.28
2016	0.76	0.63	1.20

Table 3. Regression parameters relating the composite index of abundance to the estimated abundance from the Virginia Tech trawl survey (2002 – 2011 and 2016).

Regression parameter	Males	Females
Intercept	5148537 (SE = 2580195)	4893345 (SE = 1665635)
Slope	26690987(SE = 6354514)	6833214 (SE = 5584816)
p-value (Slope)	0.002	0.252
R^2	0.662	0.143

Table 4. Estimates of total abundance of horseshoe crabs in the Delaware Bay region derived from the composite index (1998 – 2015) of abundance and the Virginia Tech trawl survey (2002 – 2011).

Sex	Year	Composite Index	Virginia Tech
Male	1998	13,588,007	
	1999	13,874,719	
	2000	18,032,348	
	2001	13,336,277	
	2002	9,898,773	11,790,000
	2003	15,965,536	8,430,000
	2004	8,637,182	7,500,000
	2005	11,979,533	10,630,000
	2006	17,464,019	19,660,000
	2007	19,779,029	23,900,000
	2008	12,454,844	17,490,000
	2009	12,921,627	11,080,000
	2010	14,271,647	14,150,000
	2011	16,206,318	15,940,000
	2012	12,897,153	
	2013	12,764,117	
	2014	17,413,356	
	2015	18,257,908	
	2016	25,361,492	24,370,000
Female	1998	7,583,681	
	1999	7,135,592	
	2000	7,549,384	
	2001	6,816,421	
	2002	5,986,253	6,060,000
	2003	6,634,723	3,810,000
	2004	5,724,920	3,490,000
	2005	6,481,016	4,950,000
	2006	7,008,727	8,820,000
	2007	7,524,205	11,110,000
	2008	6,068,302	10,590,000
	2009	6,287,533	5,510,000
	2010	6,272,055	5,950,000
	2011	6,672,283	5,890,000
	2012	6,586,019	
	2013	6,042,921	
	2014	7,546,041	
	2015	7,524,505	
	2016	9,189,983	7,670,000

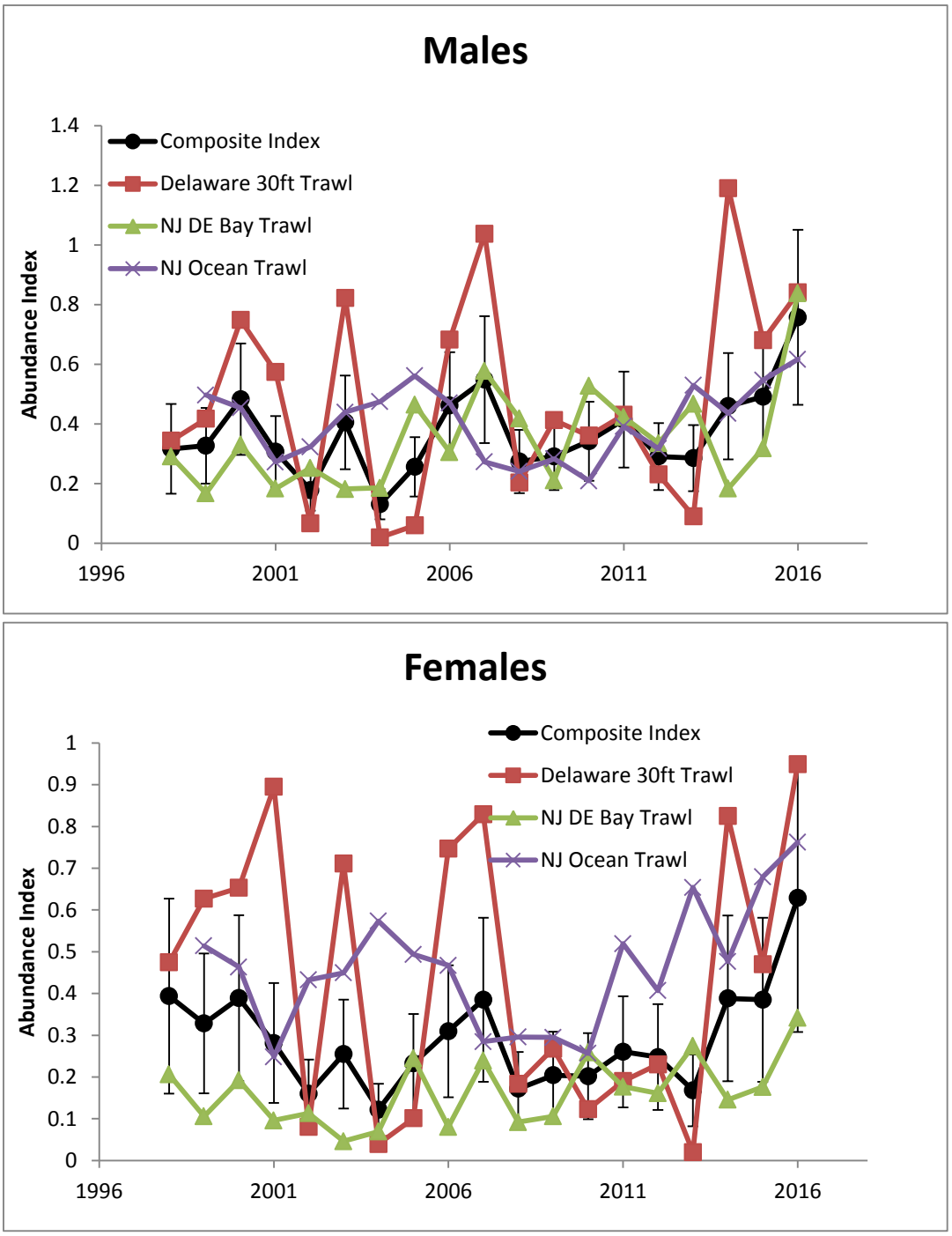


Figure 1. Comparison of the composite index of abundance from the linear mixed random effects model and the individual trawl surveys used to derive the composite index of abundance.

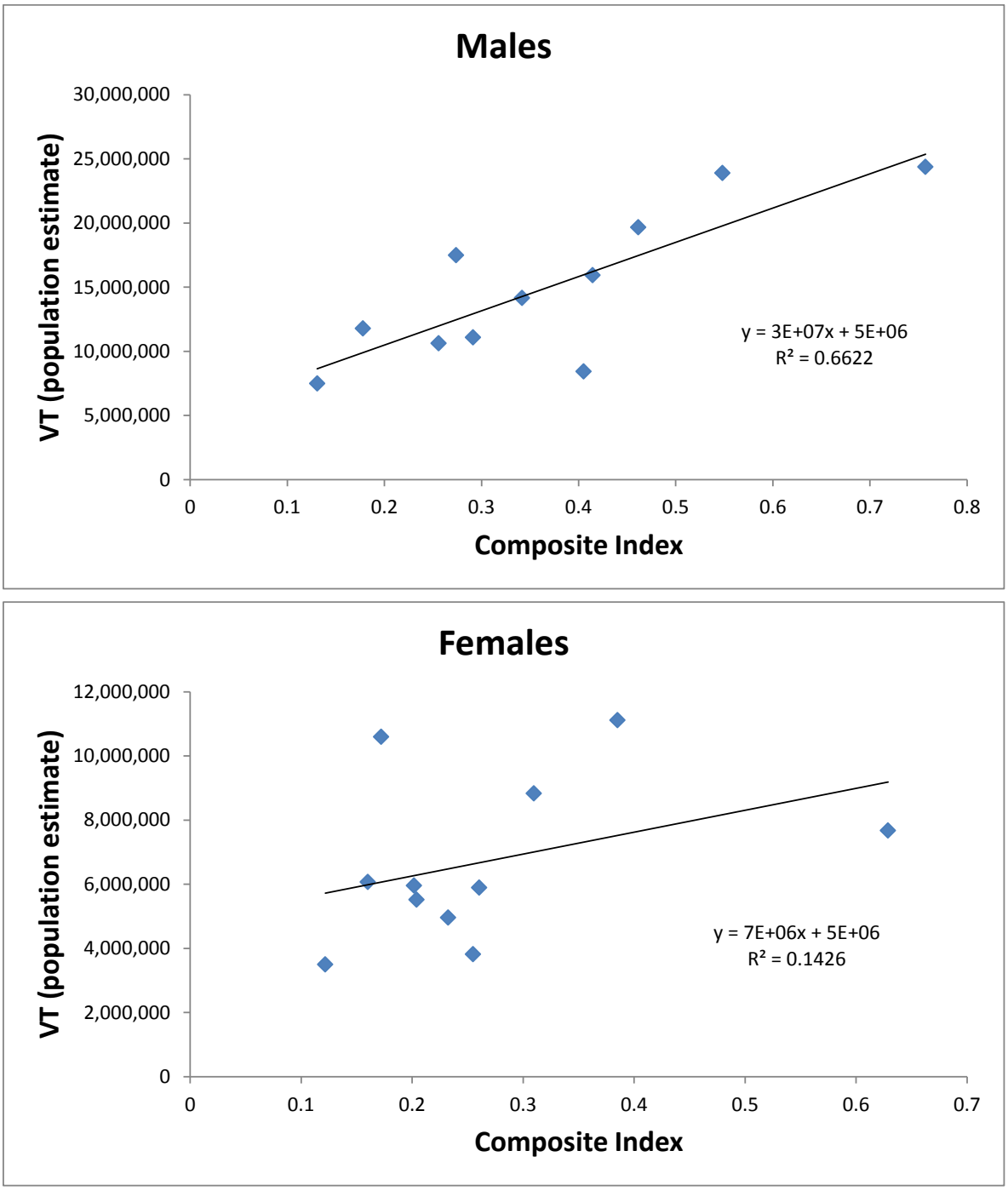


Figure 2. Linear regression models of the Virginia Tech population estimates versus the composite index of abundance of horseshoe crabs in the Delaware Bay region (2002 – 2011, 2016).

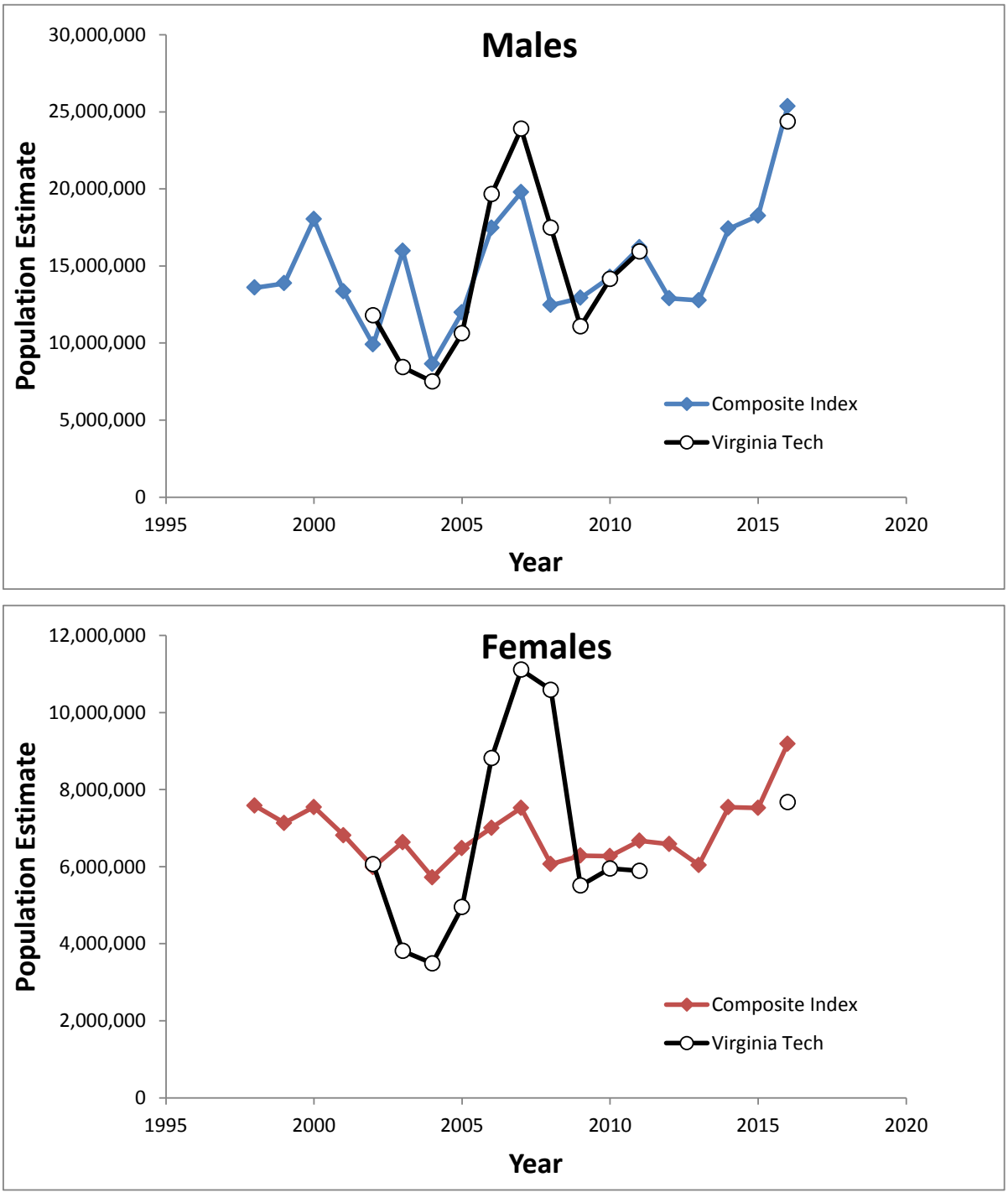


Figure 3. Time series of horseshoe crab population estimates derived from the composite index (1998 – 2016) and the Virginia Tech trawl survey (2002 – 2011, 2016).

MEMO

To: Delaware Bay ARM Working Group
From: Jim Lyons, USGS Patuxent Wildlife Research Center, Laurel, MD
Re: Red Knot Stopover Population Estimate for 2017
Date: 15 August 2017

1 Acknowledgments

We thank the many volunteers in Delaware and New Jersey who collected mark-resight data in 2017. We are grateful to A. DeRose-Wilson (Delaware DFW), A. Dey (New Jersey ENSP), and volunteers in Delaware and New Jersey for data entry and data management, and L. Usyk (bandedbirds.org) for data management.

2 Methods

Mark-resight data and counts of marked and unmarked birds were conducted according to the methods for mark-resight investigations of Red Knots in Delaware Bay (Lyons 2016). Red knots have been individually marked with engraved leg flags in Delaware Bay and other locations for many years; each leg flag is engraved with a unique 3-character alphanumeric code (Clark et al. 2005). Surveys to locate flagged birds were conducted on each beach every three days according to the sampling plan (Table 1). During these resighting surveys, agency staff and volunteers recorded the alphanumeric combinations on leg flags for birds that were detected. While searching for birds marked with engraved leg flags, observers also periodically use a scan sampling technique to count marked and unmarked birds in randomly selected portions of Red Knot flocks (Lyons 2016).

Table 1. Dates for mark-resight sampling occasions (3-day periods) in Delaware Bay.

Sample	Dates	Sample	Dates
1	≤10 May	6	23-25 May
2	11-13 May	7	26-28 May
3	14-16 May	8	29-31 May
4	17-19 May	9	1-3 June
5	20-22 May	10	≥4 June

As in previous years, all flag resightings were validated with banding data available in the data repository bandedbirds.org. Resightings without a corresponding record in bandedbirds.org of physical capture and banding (i.e., "misread" errors) were not included in the analysis (orange engraved flags from Argentina notwithstanding). Banding data from Argentina are not available in bandedbirds.org, therefore all resightings of orange engraved flags were included in the analysis without validation using banding data. We also deleted resightings of 21 flagged individuals whose flag codes were accidentally deployed in both New Jersey and South Carolina (A. Dey, pers. comm.).

We used the mark-resight data and data from the scan samples of the marked-ratio to estimate stopover population size using the methods of Lyons et al. (2016). In this "superpopulation" approach, passage population size is estimated using the Jolly-Seber model for open populations to account for the flow-through nature of migration areas and probability of detection during surveys.

In the analyses for Delaware Bay, the days of the season were aggregated into 3-day sampling periods, the same sampling periods used in prior analyses (a total of 10 sample periods possible each season, Table 1). Data are aggregated to 3-day periods because this is the amount of time necessary to complete mark-resight surveys on all beaches in the study (data summary provided in Appendix 1).

In the mark-resight superpopulation approach we estimate the number of birds that are carrying leg flags, and then adjust this number using the estimated proportion of the population with flags to account for unmarked birds. The estimated proportion with leg flags is thus an important statistic. We used the scan sample data (i.e., the counts of marked birds and the number checked for marks) and a binomial model to estimate the proportion of the population that is marked. To account for the random nature of arrival of marked birds in the bay and the addition of new marks during the season, we implemented the binomial model as a generalized linear mixed model with a random effect for the sampling period. More detailed methods are provided in Lyons et al. (2016) and Appendix 2.

3 Summary of Mark-resight and Count Data Collected in 2017

Mark-resight encounter data.—The Red Knot mark-resight database for 2017 contained a total of 4,182 individual birds recorded by observers in Delaware Bay at least once in 2017. One of the assumptions of the mark-resight approach is that individual identity of marked birds is recorded without error (see Lyons 2016 for discussion of all model assumptions). Some of the recording errors (i.e., flags that have not been deployed in the field) are removed before analysis using the banding data available from bandedbirds.org as described above. Other recording errors remain (including a second type of "false positive", flags that have been deployed in the past but were not in fact present in Delaware Bay in 2017). In an attempt to limit the bias created by false-positive misreads, we limited the data to those collected by observers with a misread rate of 0.029 or less, the overall average misread rate for all observers. After removing data from observers with a misread rate greater than average, the Red Knot mark-resight database for 2017 included 3,598 individual birds that were seen in Delaware Bay at least once in 2017. Birds from six countries were detected in Delaware Bay in 2017 (Table 2).

Table 2. Number of flags detected by banding location (flag color).

Banding location (flag color)	No. flagged individuals detected
U.S. (lime green)	2,524 (70.2%)
U.S. (dark green)	556 (15.5%)
Argentina (orange)	289 (8.0%)
Canada (white)	153 (4.3%)
Brazil (dark blue)	50 (1.4%)
Chile (red)	26 (<1%)
Total	3,598 (100%)

Marked-ratio data.—In 2017, 688 marked-ratio scan samples were collected: 360 samples in Delaware and 328 in New Jersey (Appendix 3).

Aerial and ground count data.—One aerial survey was conducted on 26 May 2017. A ground survey was attempted on the same day, but this resulted in an incomplete count as only a subset of locations were surveyed. Rough seas prevented access to some locations in NJ normally surveyed by boat and Delaware collaborators were not aware of the aerial survey plans in time to deploy observers to all beaches (Table 3). A. Dey compiled the aerial and ground survey data (Table 3).

4 Summary of 2016 Migration

Most of the birds arrived between 14 and 19 May; numbers of arrivals in the bay peaked on or about 18 May, when approximately 28% of the stopover population arrived (Fig. 1a). Similar to 2016, and unlike 2014 and 2015, relatively few birds arrived in the later stages of the migration season in 2017. For example, in 2014 a relatively large proportion of the stopover population (about 25%) arrived during 23-25 May, i.e., late in the season given typical departure dates. Similarly, in 2015 a late wave of arrivals between 23 and 28 May accounted for approximately 26% of the population. In 2017, there was not a substantial late wave of arrivals; most birds arrived before or during the 18 May sampling occasion.

Stopover persistence is the probability that a bird present in the bay during sampling occasion i is present in the bay at sampling occasion i +1. Estimated stopover persistence declined steadily from the beginning of the 2017 season to 24 May, a small increase in persistence around 18 May notwithstanding (Fig. 1b). This pattern suggests substantial turnover in the population in 2017.

Following Lyons et al. (2016), we used the Jolly-Seber model to estimate stopover duration. In 2017, estimated stopover duration was 9.5 days (95% CI 9.1–10.0 days), shorter than estimated stopover during in 2016 when the model-based estimate of stopover duration was 12.3 days (95% CI 11.8–13.2 days). These model-based estimates of stopover duration account for probability of detection, i.e., these estimates are not negatively biased by the time present before first, and after last, detection by observers. These results suggest that birds had shorter stays in Delaware Bay in 2017 than in 2016.

In 2017, mean probability of resighting across all 3-day sampling periods was relatively constant and relatively high. Probability of resighting was generally above 0.5 for most of the season, and peaked at 0.66 around 30 May.

The estimated proportion of the 2016 stopover population with marks (leg flags) was 0.099 (95% CI 0.090–0.109, Fig. 2), very similar to the 2016 estimate. As expected, the proportion marked was fairly steady throughout the season and did not fluctuate dramatically (Fig. 2).

5 Stopover Population Estimation

The passage population size in 2017 was estimated at 49,405 (95% CI, 46,368–53,109), similar to the passage population size estimate in 2016 (47,254 [95% CI 44,873 – 50,374]). This superpopulation estimate accounts for turnover in the population and probability of detection.

The time-specific stopover population estimates in 2017 increased steadily between 10 and 18 May and then remained fairly constant during 18-24 May at approximately 24,500 birds (Fig. 1d).

Aerial surveys in 2016.—The aerial survey conducted on 26 May 2016 detected 17,969 birds, an index that falls between the two surrounding mark-resight estimates. The aerial survey total was approximately 26% less than the mark-resight estimate for the 23-25 May sample period and approximately 25% more than the mark-resight estimate for the 26-28 May sample period (Table 3, Fig. 1d).

6 References

Clark, N.A., S. Gillings, A.J. Baker, P.M. González, and R. Porter. 2005. The production and use of permanently inscribed leg flags for waders. Wader Study Group Bull. 108: 38–41.

Lyons, J.E., W.P. Kendall, J.A. Royle, S.J. Converse, B.A. Andres, and J.B. Buchanan. 2016. Population size and stopover duration estimation using mark-resight data and Bayesian analysis of a superpopulation model. Biometrics 72:262-271.

Lyons, J.E. 2016. Study design guidelines for mark-resight investigations of Red Knots in

Table 3. Number of Red Knot detected during aerial and ground surveys of Delaware Bay in 2017. Data were provided by A. Dey, New Jersey Division of Fish and Wildlife, Nongame and Endangered Species Program.

	New Jersey	Delaware	Total
26 May 2016			
Aerial survey	13,147	4,822	17,969
Partial ground survey*	7,116	1,540	8,656

* Note: ground survey in New Jersey did not include boat survey area from Bidwell Creek to Beadons Cove due to rough seas; ground survey in Delaware included only Mispillion Harbor because Delaware collaborators were not made aware of aerial survey plans in sufficient time to organize a full ground count.

Table 4. Stopover (passage) population estimate using mark-resight methods compared to peak-count index using aerial- or ground-survey methods. The mark-resight estimate of stopover (passage) population accounts for population turnover during migration; peak-count index, a single count on a single day, does not account for turnover.

Year	Stopover population[a] (mark-resight *N**)	95% CI Stopover population *N**	Peak-count index [aerial (A) or ground (G)]
2011	43,570	(40,880–46,570)	12,804 (A)[b]
2012	44,100	(41,860–46,790)	25,458 (G)[c]
2013	48,955	(39,119–63,130)	25,596 (A)[d]
2014	44,010	(41,900–46,310)	24,980 (A)[c]
2015	60,727	(55,568–68,732)	24,890 (A)[c]
2016	47,254	(44,873–50,574)	21,128 (A)[b]
2017	49,405[e]	(46,368–53,109)	17,969 (A)[f]

[a] estimate for entire season, including population turnover
[b] 23 May
[c] 24 May
[d] 28 May
[e] Data management procedures to reduce bias from recording errors in the field not the same as previous years; see text at section 3 Mark-resight data.
[f] 26 May

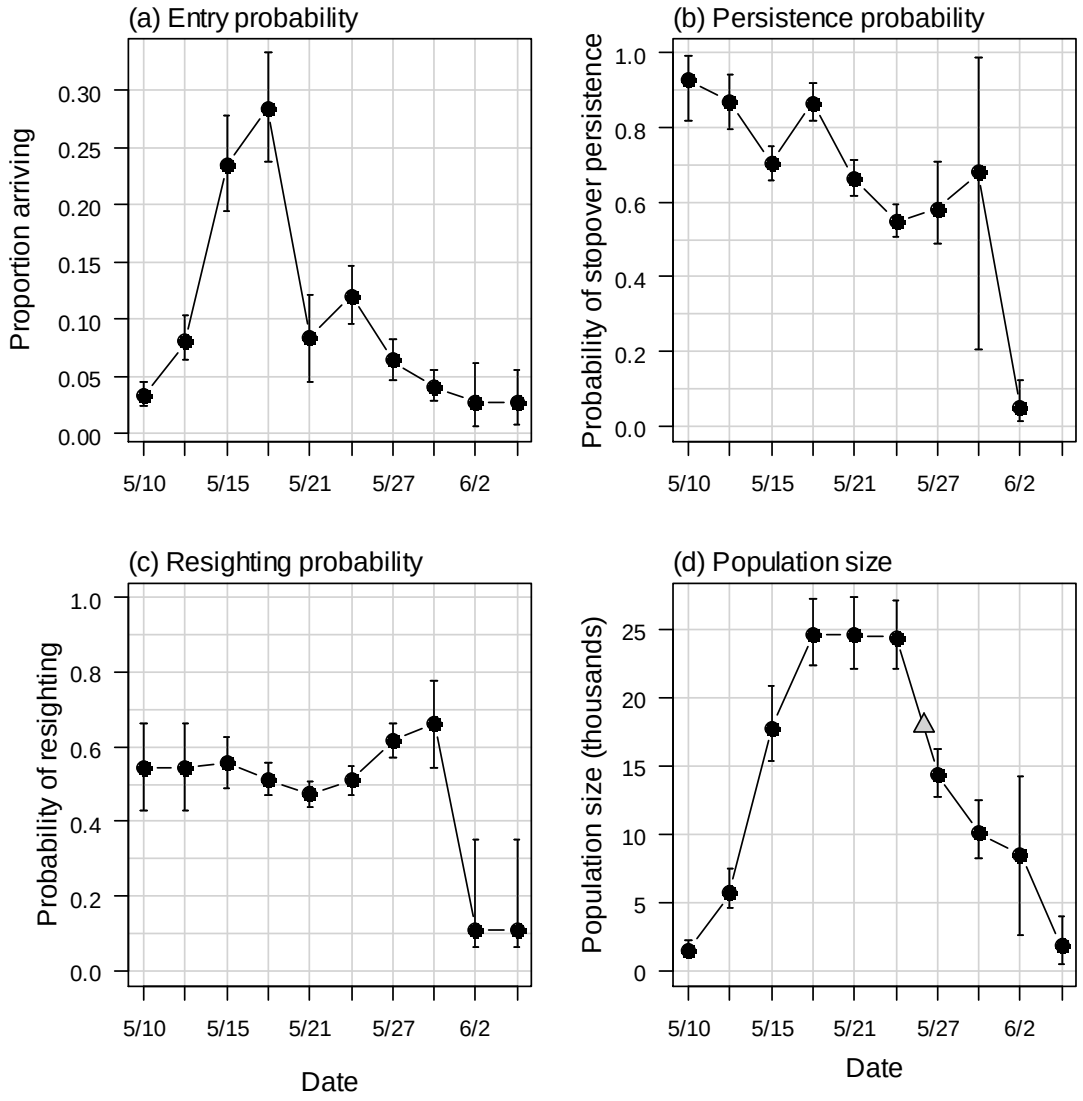


Figure 1. Estimated parameter values at sampling points throughout the 2017 season for Red Knot stopover population analysis at Delaware Bay using mark-resight data and the Jolly-Seber model for open populations: (a) proportion of stopover population arriving in Delaware Bay, (b) stopover persistence, (c) probability of resighting, and (d) time-specific stopover population size. Triangle in (d) is total count made by aerial survey on 26 May 2017.

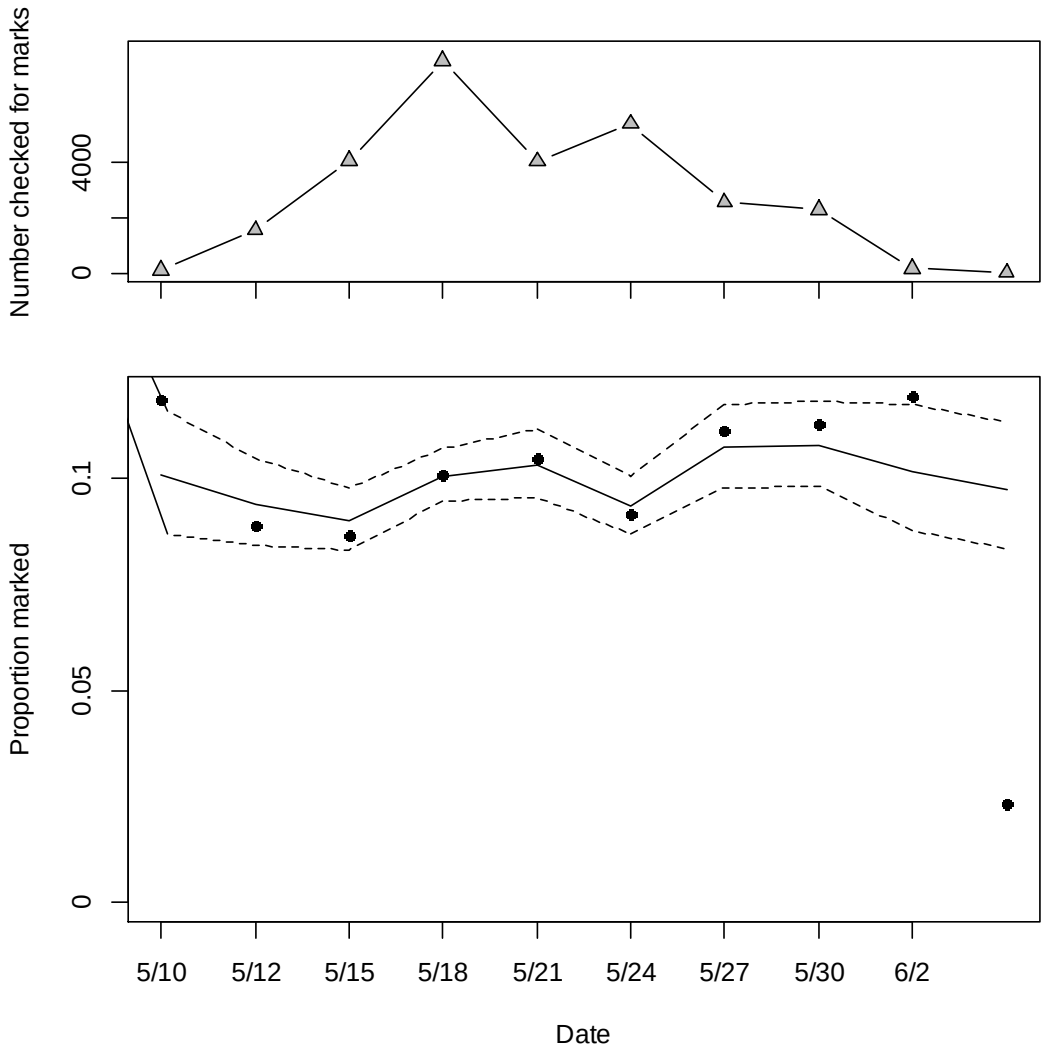


Figure 2. Estimated proportion of the Delaware Bay stopover population that has leg flags in 2017. Marked proportion was estimated from marked-ratio scan samples for each 3-day sampling period. The dates for the sampling periods are shown in Appendix 1. Sample size (number scanned, i.e., checked for marks) for each sample period is shown in the upper panel. The estimated proportion marked at each sample occasion (bottom panel) was estimated with the generalized linear mixed model described in Appendix 2. Solid and dashed lines are median proportion marked and 95% CI; filled circles show (number with marks/number scanned).

Appendix 1. Summary of 2017 mark-resight data ("m-array"). NR = never resighted.

			Next resighted at sample									
Sample	Dates	Resighted	2	3	4	5	6	7	8	9	10	NR
1	7-10 May	85	44	11	3	3	3	3	2	0	0	16
2	11-13 May	289		147	28	11	11	6	1	0	0	85
3	14-16 May	882			333	84	72	16	4	0	0	373
4	17-19 May	1268				564	166	49	16	0	0	473
5	20-22 May	1205					407	126	41	1	0	630
6	23-25 May	1158						405	78	6	1	668
7	26-28 May	955							372	10	1	572
8	29-31 May	725								57	0	668
9	1-3 June	96									1	95

Appendix 2. Statistical Methods to Estimate Stopover Population Size Using Mark-Resight Data and Counts of Marked Birds

We converted the observations of marked birds into encounter histories, one for each bird, and analyzed the encounter histories with a Jolly-Seber (JS) model (Jolly 1965, Seber 1965, Crosbie and Manly 1985, Schwarz and Arnason 1996). The JS model includes parameters for recruitment (β), survival (φ), and capture (p) probabilities; in the context of a mark-resight study at a migration stopover site, these parameters are interpreted as probability of arrival to the study area, stopover persistence, and resighting, respectively. Stopover persistence is defined as the probability that a bird present at time t remains at the study area until time $t + 1$. The Crosbie and Manley (1985) and Schwarz and Arnason (1996) formulation of the JS model also includes a parameter for superpopulation size, which in our approach to mark-resight inferences for stopover populations is an estimate of the marked (leg-flagged) population size.

We chose to use 3-day periods rather than days as the sampling interval for the JS model given logistical constraints on complete sampling of the study area; multiple observations of the same individual in a given 3-day period were combined for analysis. A summary (m-array) of the mark-resight data is presented in an appendix.

We made inference from a fully-time dependent model; arrival, persistence, and resight probabilities were allowed to vary with sampling period [β_t φ_t p_t]. In this model, we set $p_1 = p_2$ and $p_{K-1} = p_K$ (where K is the number of samples) because not all parameters are estimable in the fully-time dependent model (Jolly 1965, Seber 1965, Crosbie and Manly 1985, Schwarz and Arnason 1996).

We followed the methods of Royle and Dorazio (2008) and Kéry and Schaub (2012, Chapter 10) to fit the JS model using the restricted occupancy formulation. Royle and Dorazio (2008) use a state-space formulation of the JS model with parameter-expanded data augmentation. For parameter-expanded data augmentation, we augmented the observed encounter histories with all-zero encounter histories (n = 2000) representing potential recruits that were not detected (Royle and Dorazio 2012). We followed Lyons et al. (2016) to combine the JS model with a binomial model for the counts of marked and unmarked birds in an integrated Bayesian analysis. Briefly, the counts of marked birds (m_s) in the scan samples are modeled as a binomial random variable:

$$m_s \sim Bin(C_s, \pi), \quad (1)$$

where m_s is the number of marked birds in scan sample s, C_s is the number of birds checked for marks in scan sample s, and π is the proportion of the population that is marked. Total stopover population size $\widehat{N^*}$ is estimated by

$$\widehat{N^*} = \widehat{M^*}/\hat{\pi} \quad (2)$$

where $\widehat{M^*}$ is the estimate of marked birds from the J-S model and $\hat{\pi}$ is the proportion of the population that is marked (from Eq. 1). Estimates of marked subpopulation sizes at each resighting occasion t $\left(\widehat{M_t^*}\right)$ are available as derived parameters in the analysis. We calculated an estimate of population size at each mark-resight sampling occasion $\widehat{N_t^*}$ using $\widehat{M_t^*}$ and $\hat{\pi}$ as in equation 2.

To better account for the random nature of the arrival of marked birds and addition of new marks during the season, we used a time-specific model for proportion with marks in place of equation 1 above:

$$m_{s,t} \sim Binomial\left(C_{s,t}, \pi_t\right) \quad (3)$$

$$for\ s\ in\ 1, \ldots, n_{samples}\ and\ t\ in\ 1, \ldots, n_{occasions}$$
$$logit(\pi_t) = \alpha + \delta_t$$
$$\delta_t \sim Normal(0, \sigma^2_{occasions})$$

where m_s is the number of marked birds in scan sample s, C_s is the number of birds checked for marks in scan sample s, δ_t is a random effect time of sample s, and π_t is the time-specific proportion of the population that is marked. Total stopover population size $\widehat{N^*}$ was estimated by summing time-specific arrivals of marked birds to the stopover (B_t) and expanding to include unmarked birds using estimates of proportion marked:

$$\widehat{N^*} = \sum \widehat{B_t}/\pi_t$$

Time-specific arrivals of marked birds are estimated from the Jolly-Seber model using $\widehat{B_t} = \widehat{\beta_t}\widehat{M^*}$ where $\widehat{M^*}$ is the estimate of the number of marked birds and $\widehat{\beta_t}$ is the fraction of the population arriving at time t.

Appendix 3. Number of marked-ratio scan samples.

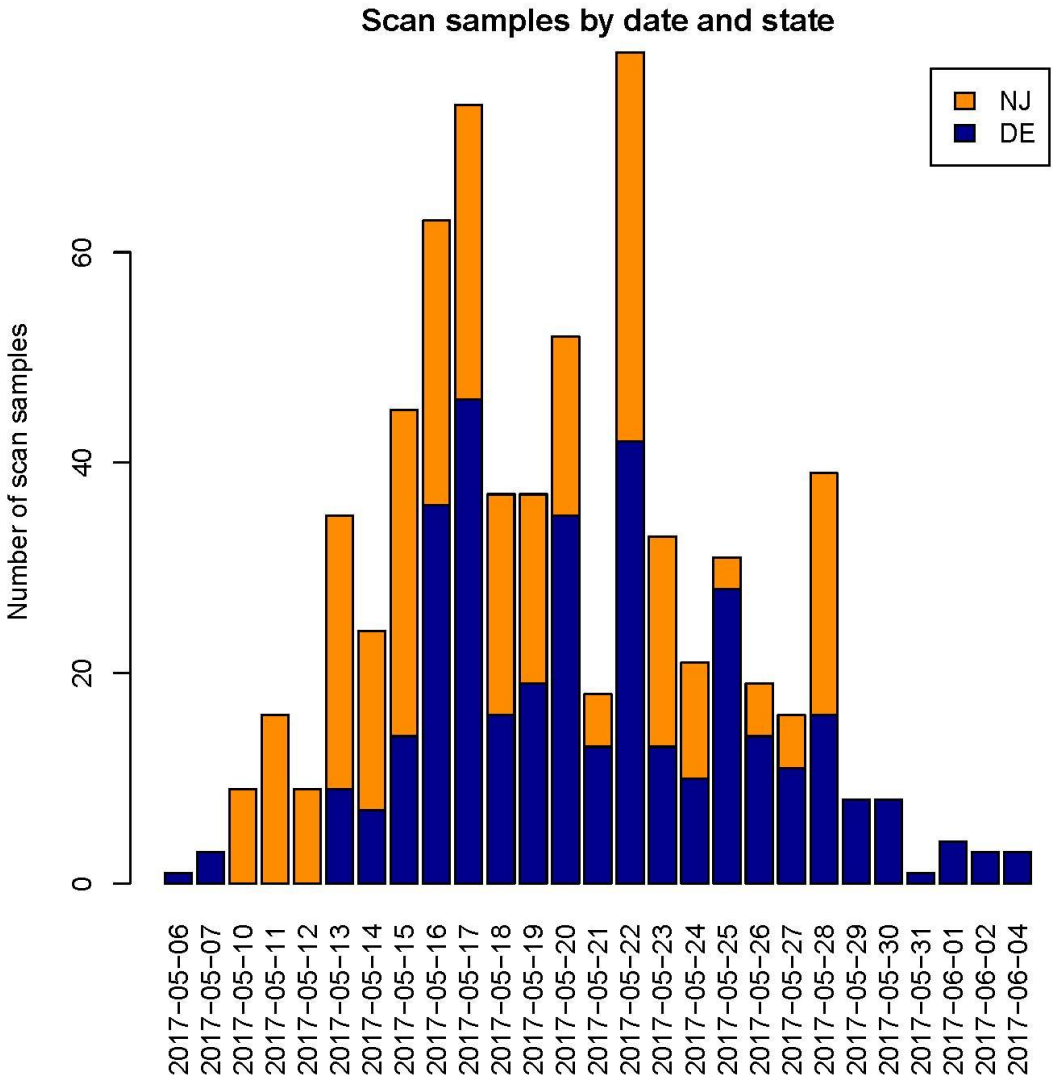


Figure A2. Number of marked-ratio scan samples collected in Delaware Bay in 2017 by field crews in Delaware (blue) and New Jersey (orange).

Appendix 4 Minimum length-of-stay

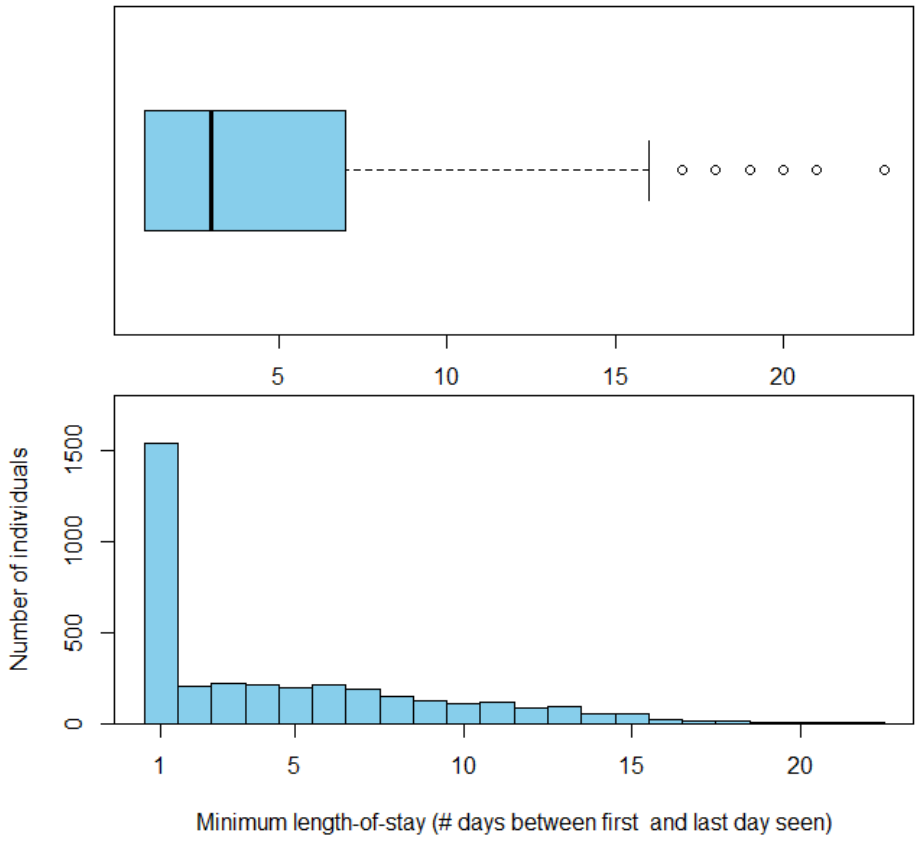


Figure A5. Minimum length-of-stay (MINLOS) in 2017 (n = 3,598 birds). This is a plot of raw data and is not a model-based estimate. MINLOS does not account for time present before first, or after last, detection and therefore is negatively biased. The mean and median MINLOS in 2017 were 4.6 and 3 days, respectively. Model-based estimates of stopover duration suggest that stopover in 2017 was approximately 9.5 days.

Atlantic States Marine Fisheries Commission

Horseshoe Crab Advisory Panel Conference Call

Thursday September 21st, 2017

Call Summary

1) **Welcome/Introductions**

Advisory Panel Members: Dr. Jim Cooper (Chair), Allen Burgenson, Benjie Swan, Brett Hoffmeister, Jay Harrington, Rick Robins

ASMFC Staff: Mike Schmidtke (FMP Coordinator), Toni Kerns

2) **Update from October 2016 Board Meeting**

Mike Schmidtke updated the AP on results of the last Horseshoe Crab Board (Board) meeting (October, 2016). At this Board meeting, harvest specifications were set for the 2017 fishing year, with specifications for the Delaware Bay coming from the ARM model, development of Draft Addendum VIII was postponed until after the 2018 stock assessment, the ARM Subcommittee was tasked with conducting alternative runs of the ARM model that incorporated biomedical mortality, and the TC was tasked with conducted a survey of horseshoe crab bait use in the eel and whelk fisheries.

3) **Review 2017 ARM Model Run** (*M. Schmidtke*)

Mike Schmidtke presented information about the 2017 run of the ARM model for the Delaware Bay region. The model has two types of thresholds that impact potential harvest package selection. If female horseshoe crabs are less than 80% carrying capacity (approximately 11.2 million female crabs) and red knots are less than 81,900 birds in the superpopulation estimate, no female harvest options will be selected by the model. If the spawning beach sex ration falls below 2 males to 1 female, no male harvest options will be selected by the model.

Brett Hoffmeister commented that the potential scenario of a large female population that would lower the sex ratio below the 2 male to 1 female threshold. Rick Robins commented that the sex ratio used is that on the beach during spawning and is an operational ratio, attributable to spawning behavior and generally significantly higher (more males) than that of the population as a whole. Current spawning beach populations of horseshoe crab are heavily male-skewed and have exceeded the 2 male to 1 female threshold in every year the ARM model has been run. The sex ratio threshold was originally intended to ensure an adequate number of males are available to allow horseshoe crab population persistence under conditions of male-only harvest. However, if the case occurred that the female crab population threshold is exceeded and the sex ratio threshold is not, harvest package options for this population may need to be reconsidered.

Benjie Swan asked about the potential of re-evaluating these threshold levels, stating that due to current and historical levels and trends in horseshoe crab and red knot populations, attaining either of these threshold levels may be unrealistic. The AP generally agreed that an 80% carrying capacity female crab threshold is much higher than comparable threshold levels used for other species, while recognizing that a higher threshold is needed due to the multispecies management approach being used by the ARM. Mike Schmidtke commented that threshold levels used in this model go beyond the capacity of ASMFC alone and would require cooperation from other agencies that are more informed of red knot management and population needs. Rick Robins commented that the Commission should be commended for the conservative nature of the ARM model and the recent stability, particularly in the bait fishery, that has resulted from this approach.

Red knot abundance in 2017 (49,405 birds) increased from 2016, but with shorter stopover duration by approximately 3 days. Horseshoe crab abundance in 2016 was estimated by the Virginia Tech Horseshoe Crab Trawl Survey as 25.4 million males and 7.7 million females. Neither female horseshoe crabs nor red knots exceeded their population thresholds, thus female harvest package options were not available in the 2017 run of the ARM model. The ARM model selected harvest package 3 (500,000 males; 0 females) as the recommended 2018 harvest quota for the Delaware Bay region.

4) **Alternative ARM Model Runs Incorporating Biomedical Mortality**

At the last Board meeting, the ARM Subcommittee was tasked with performing alternative runs of the ARM model that incorporated biomedical mortality data. Runs were completed using 3-year averages of biomedical mortality in the Delaware Bay. Biomedical mortality is currently calculated as the number of horseshoe crabs reported as observed dead during the collection, transport, and handling processes plus 15% multiplied by the number of crabs bled.

The AP expressed concern with the 15% estimated mortality rate, generally indicating that they believe this rate to be lower. Brett Hoffmeister commented that adding observed mortality to the estimated 15% exacerbates the issue by increasing the effective mortality above 15%. Several members of the AP agreed, stating that they had the initial impression that the 15% rate encompassed all steps of the biomedical process. In an email following the call, Mike Schmidtke explained that the 15% rate is not all-encompassing because it is applied only to bled crabs rather than all crabs collected. Mortality at steps prior to bleeding is reported annually and then added to 15% assumed to occur as a result of the bleeding and release stages of the biomedical process.

Jay Harrington commented that the biomedical industry typically bleeds adult crabs and that natural mortality is not explicitly accounted for by the 15% estimated mortality rate. While natural mortality is not explicitly accounted for in this estimate, this estimate is not intended to evaluate sustainable collection levels of crabs for biomedical purposes, because biomedical collections are not limited by a quota. This rate is intended to only to annually estimate the amount of mortality occurring due to biomedical collections. Sustainability of these collections

and all methods of removals, will be evaluated via natural mortality and other population descriptors through the upcoming stock assessment process.

Two methods were chosen by the ARM Subcommittee for incorporating biomedical mortality into the ARM model. The "Preferred" Option of the ARM Subcommittee subtracts biomedical mortality estimates in the Delaware Bay region from the current harvest packages. Rick Robins commented that this approach should be adjusted such that the biomedical catch is incorporated as additive to the bait quota since both fisheries have operated in parallel prior to implementation of the ARM and it is not biologically or ecologically necessary to put these fisheries in conflict with respect to quotas from the harvest packages. The "Minority" Option adds biomedical mortality as a removal source (similar to bait harvest) in the population dynamics model, with no change to the harvest packages. Neither option for incorporating biomedical mortality resulted in drastic changes to harvest package selection or frequency in the resulting decision matrix. ****The AP recommends that since incorporation of biomedical data made little difference to the results of these runs, that biomedical data should not be incorporated into annual ARM model runs to recommend harvest specifications****. Several AP members agreed that use of the "Preferred" Option could compromise the confidentiality of facilities outside of the Delaware Bay region. Therefore, ****the AP recommends that if the Board pursues incorporation of biomedical data into annual ARM model runs, it should be done through the "Minority" Option of adding biomedical mortality as a removal source in the internal population dynamics model****.

5) **2018 Stock Assessment Procedures**

Mike Schmidtke presented the draft Terms of Reference and assessment timeline. Dr. Jim Cooper asked if there would be a time for AP participation in the assessment. Mike Schmidtke explained that the assessment is conducted by the Stock Assessment Subcommittee (SAS), with assistance from the Technical Committee (TC) as needed. The AP may view the final assessment, but does not have a role in its development. The AP would have a role in reviewing any management decisions that are made as a result of the assessment.

Mike Schmidtke explained the assessment workshops and how confidential data would potentially be handled at each step of the assessment. Prior to the Data Workshop, a press release will be published requesting horseshoe crab data. Of interest to several members of the AP is the biomedical component of data requested. Studies describing mortality at various steps of the biomedical process, particularly during bleeding and post-bleeding, would be useful in evaluating biomedical mortality levels. Dr. Jim Cooper commented that a preference for peer-reviewed literature, specifically non- or reduced consideration of studies conducted by biomedical companies and state agencies that are not in the peer-reviewed literature, could eliminate the most useful information available on post-bleeding mortality. Dr. Cooper further commented that some studies found within the peer-reviewed literature drastically depart from biomedical practices to the point that these studies would misinform biomedical mortality estimates. The Data Workshop is tentatively scheduled for January, 2018, so all data submissions should be received by then.

The AP expressed concern with literature that supports biomedical mortality rates greater than 15%. The AP feels that methods used in these studies were not consistent with those of biomedical facilities. Furthermore, several of these studies were conducted prior to the establishment of the biomedical best management practices (BMP). As biomedical practices have evolved and improved over recent years according to standards set by the BMPs, the practices of those studies are less consistent with current methods employed by biomedical facilities. Benjie Swan commented that she would submit a review evaluating these studies for future consideration by the Board and other Committees.

Mike Schmidtke explained that the Data Workshop is where submitted data will be considered for use in the assessment. All SAS members are required to gain confidential data access from all states submitting confidential data prior to viewing confidential data at the Data Workshop. Confidential access will be requested by SAS members for each state involved in the horseshoe crab fishery (Florida-Massachusetts) using the Atlantic Coastal Cooperative Statistics Program's Confidential Access Request application (as well as additional state-specific applications, where required). Within the application process and under direction of the Commission's Fishery Data Use Policy, SAS members will not be allowed to publicly distribute or discuss confidential assessment information. Additionally, SAS members will not be permitted to use confidential assessment information for purposes outside of the assessment. When confidential data is discussed at the Data Workshop, doors will be closed (both figuratively and literally) to those TC members who are not authorized to view confidential data. If questions arise about confidential data, they will be conducted in a closed-door session with the SAS and the TC representative of the providing state.

At the Assessment Workshop, the SAS applies models to the data from the Data Workshop. This meeting will only include SAS members. Confidential data may not be shown in the published Assessment Report. The SAS and ASMFC Staff are still considering potential options for handling confidentiality at this step of the assessment. One potential strategy under consideration is to have two Assessment Reports, one including confidential data for Peer Review and the other without confidential data that can be made public.

At the Review Workshop, a Peer Review Panel evaluates the Assessment Report. All Peer Review Panel members will be required to gain confidential access from all states submitting confidential data prior to viewing an Assessment Report that includes confidential data. Confidential data may not be shown in the published Review Report. ASMFC Staff are still considering potential options for handling confidentiality at this step of the assessment. One potential strategy under consideration is to have two Review Reports, one including confidential data to provide feedback for the SAS and the other without confidential data that can be made public.

This assessment is the first time that biomedical data is being included in the assessment process. As such, several members of the AP feel that evaluation of studies used to estimate biomedical mortality should be conducted by someone who has familiarity with methods used in the biomedical industry. Dr. Jim Cooper commented that at least one reviewer should be a

scientist from the biomedical community that can critically review the methodology of scientific studies used to estimate mortality associated with biomedical bleeding of horseshoe crabs. Toni Kerns explained that Peer Review Panels may be selected through the Center of Independent Experts or from federal or university scientists that have an expertise on multiple aspects of the assessment. Therefore, someone who has knowledge of the biomedical bleeding process may be considered if he or she has expertise in other areas of the assessment such as population dynamics or assessment models, but would be less likely to be considered as strictly a biomedical specialist.

6) **Other Business/Adjourn**

Jay Harrington commented on indirect interactions of horseshoe crabs and red knots that are not currently accounted for by the ARM model. Horseshoe crabs are known to feed on shellfish. Red knots have been documented to feed on similar types of shellfish in addition to horseshoe crab eggs. Jay proposed that in a way, the ARM model may be conflicted as horseshoe crabs or red knots increase and compete for similar food sources. Additionally, Jay commented that literature indicates that horseshoe crab abundance levels are not correlated with red knot survivorship or reproduction. Jay will be submitting a memo outlining literature on the relationship between horseshoe crabs and red knots.

2017 REVIEW OF THE ATLANTIC STATES MARINE FISHERIES COMMISSION FISHERY MANAGEMENT PLAN FOR

HORSESHOE CRAB

(*Limulus polyphemus)*

2016 Fishing Year

Horseshoe Crab Plan Review Team:

Sheila Eyler, U.S. Fish and Wildlife Service

Stewart Michels, Delaware Department of Natural Resources and Environmental Control

Derek Orner, National Marine Fisheries Service

Mike Schmidtke, Chair, Atlantic States Marine Fisheries Commission

October 2017

Table of Contents

I. Status of the Fishery Management Plan

Date of FMP Approval:	December 1998
Amendments	None
Addenda	Addendum I (April 2000) Addendum II (May 2001) Addendum III (May 2004) Addendum IV (June 2006) Addendum V (September 2008) Addendum VI (August 2010) Addendum VII (February 2012)
Management Unit:	Entire coastwide distribution of the resource from the estuaries eastward to the inshore boundary of the EEZ
States With Declared Interest:	Massachusetts - Florida
Active Boards/Committees:	Horseshoe Crab Management Board, Advisory Panel, Technical Committee, and Plan Review Team; Delaware Bay Ecosystem Technical Committee

a) Goals and Objectives

The Interstate Fishery Management Plan for Horseshoe Crabs (FMP) established the following goals and objectives.

2.0. Goals and Objectives

The goal of this Plan is to conserve and protect the horseshoe crab resource to maintain sustainable levels of spawning stock biomass to ensure its continued role in the ecology of the coastal ecosystem, while providing for continued use over time. Specifically, the goal includes management of horseshoe crab populations for continued use by:

1) *current and future generations of the fishing and non-fishing public (including the biomedical industry, scientific and educational research);*
2) *migrating shorebirds; and,*
3) *other dependent fish and wildlife, including federally listed (threatened) sea turtles.*

To achieve this goal, the following objectives must be met:

(a) prevent overfishing and establish a sustainable population;

(b) achieve compatible and equitable management measures among jurisdictions throughout the fishery management unit;

(c) establish the appropriate target mortality rates that prevent overfishing and maintain adequate spawning stocks to supply the needs of migratory shorebirds;

(d) coordinate and promote cooperative interstate research, monitoring, and law enforcement;

(e) identify and protect, to the extent practicable, critical habitats and environmental factors that limit long-term productivity of horseshoe crabs;

(f) adopt and promote standards of environmental quality necessary for the long-term maintenance and productivity of horseshoe crabs throughout their range; and,

(g) establish standards and procedures for implementing the Plan and criteria for determining compliance with Plan provisions.

b) Fishery Management Plan Summary

The framework for managing horseshoe crabs along the Atlantic coast was approved in October 1998 with the adoption of the Interstate Fishery Management Plan for Horseshoe Crabs (FMP). The goal of this plan is to conserve and protect the horseshoe crab resource to maintain sustainable levels of spawning stock biomass to ensure its continued role in the ecology of coastal ecosystems, while providing for continued use over time.

In 2000, the Horseshoe Crab Management Board approved Addendum I to the FMP. Addendum I established a state-by-state cap on horseshoe crab bait landings at 25 percent below the reference period landings (RPL's), and *de minimis* criteria for those states with a limited horseshoe crab fishery. Those states with more restrictive harvest levels (Maryland and New Jersey) were encouraged to maintain those restrictions to provide further protection to the Delaware Bay horseshoe crab population, recognizing its importance to migratory shorebirds. Addendum I also recommended that the National Marine Fisheries Service (NMFS) prohibit the harvest of horseshoe crabs in federal waters (3-200 miles offshore) within a 30 nautical mile radius of the mouth of Delaware Bay, as well as prohibit the transfer of horseshoe crabs in federal waters. A horseshoe crab reserve was established on March 7, 2001 by NMFS in the area recommended by ASMFC. This area is now known as the Carl N. Shuster Jr. Horseshoe Crab Reserve.

In 2001, the Horseshoe Crab Management Board approved Addendum II to the FMP. The purpose of Addendum II was to provide for the voluntary transfer of harvest quotas between states to alleviate concerns over potential bait shortages on a biologically responsible basis. Voluntary quota transfers require Technical Committee review and Management Board approval.

In 2004, the Board approved Addendum III to the FMP. The addendum sought to further the conservation of horseshoe crab and migratory shorebird populations in and around the Delaware Bay. It reduced harvest quotas and implemented seasonal bait harvest closures in New Jersey, Delaware, and Maryland, and revised monitoring components for all jurisdictions.

Addendum IV was approved in 2006. It further limited bait harvest in New Jersey and Delaware to 100,000 crabs (male only) and required a delayed harvest in Maryland and Virginia. Addendum V, adopted in 2008, extends the provisions of Addendum IV through October 31, 2010. In early 2010, the Board initiated Draft Addendum VI to consider management options

that would follow expiration of Addendum V. The Board voted in August 2010 to extend the Addendum V provisions, via Addendum VI, through April 30, 2013. The Board also chose to include language, allowing them to replace Addendum VI with another Addendum during that time, in anticipation of implementing an adaptive resource management (ARM) framework.

The Board approved Addendum VII in February 2012. This addendum implemented an ARM framework for use during the 2013 fishing season. The framework considers the abundance levels of horseshoe crabs and shorebirds in determining the optimized harvest level for the Delaware Bay states of New Jersey, Delaware, Maryland, and Virginia (east of the COLREGS).

II. Status of the Stock and Assessment Advice

No definitions for overfishing or overfished status have been adopted by the Management Board. However, the majority of evidence in the most recent stock assessment, the 2013 Stock Assessment Update (available at http://www.asmfc.org/species/horseshoe-crab#stock), indicates abundance has increased in the Southeast region. In the Delaware Bay Region, increasing trends were most evident in juvenile indices, followed by indices of adult males. Over the time series of the survey, no trend in the abundance of female crabs is evident.

In contrast, continued declines in abundance were evident in the New York and New England regions. Decreased harvest quotas in Delaware Bay have potentially redirected harvest to nearby regions. Current harvest within the New England and New York Regions may not be sustainable. Continued precautionary management is therefore recommended coastwide to anticipate effects of redirecting harvest from Delaware Bay to outlying populations.

III. Status of the Fishery

Bait Fishery

For most states, the bait fishery is open year round. However, because of seasonal horseshoe crab movements (to the beaches in the spring; deeper waters and offshore in the winter), the fishery operates at different times. New Jersey has prohibited commercial harvest of horseshoe crabs in state waters since 2006. State waters of Delaware are closed to horseshoe crab harvest and landing from January 1st through June 7th each year, and other state horseshoe crab fisheries are regulated with various seasonal/area closures.

Reported coastwide bait landings in 2016 remained well below the coastwide quota (Table 1, Figure 1). Bait landings increased 34% from the previous year, due primarily to unusually low landings in Rhode Island, Maryland and Virginia during 2015. North Carolina harvested 1,161 crabs over their 24,036 crab quota, and received a 1,250 crab quota transfer from Georgia.

Table 1. Reported commercial horseshoe crab bait landings by jurisdiction.

Jurisdiction	ASMFC Quota 2016	State Quota 2016	2012	2013	2014	2015	2016
MA	330,377	165,000	106,821	128,774	106,645	108,054	101,642
RI	26,053	12,545	19,306	18,030	13,319	6,255	20,917
CT	48,689	48,689	18,958	21,503	20,634	19,632	12,135
NY	366,272	150,000	184,721	169,739	134,370	145,324	176,632
NJ*	162,136	0	0	0	0	0	0
DE*	162,136	162,136	100,255	163,582	168,044	151,262	159,545
MD*	255,980	255,980	169,087	240,688	148,269	27,494	157,013
PRFC	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0
VA**	172,828	172,828	151,887	156,761	145,266	102,235	133,453
NC***	24,036	25,286	22,902	26,559	21,196	24,948	25,197
SC	0	0	0	0	0	0	0
GA	29,312	28,062	0	5,745	0	0	0
FL****	9,455	9,455	0	0	2,046	264	689
TOTAL	1,587,274	1,028,280	773,937	931,381	759,789	585,468	787,223

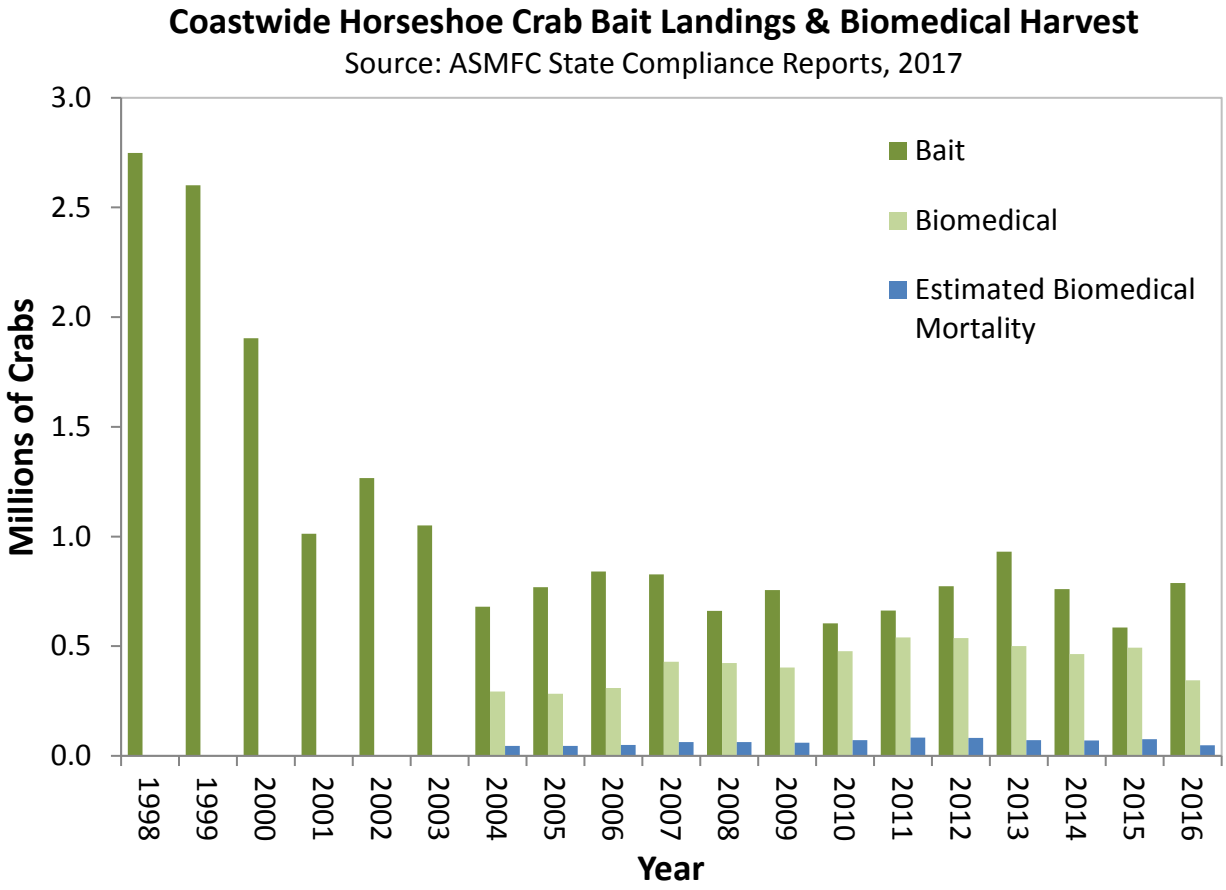
***Male-only harvest**

****Virginia harvest east of the COLREGS line is limited to 81,331 male-only crabs under the ARM harvest package #3. Virginia harvests east of the COLREGS in 2015 and 2016 were 24,460 and 39,012, respectively. The total above represents harvest on both sides of the COLREGS line.**

*****Note there was quota transfer of 1,250 crabs from Georgia to North Carolina to cover their quota overage of 1,161 horseshoe crabs in 2016.**

******Bait landings do not include 1,528 marine life landings in 2016**

Figure 1: Number of horseshoe crabs harvested for bait and biomedical purposes, 1998 -2016.



*** Biomedical collection numbers, which are annually reported to the Commission, include all horseshoe crabs brought to bleeding facilities except those that were harvested as bait and counted against state quotas.**

*** Most of the biomedical crabs collected are returned to the water after bleeding; a 15% mortality rate is estimated for all bled crabs that are released. This number plus observed mortality reported annually by bleeding facilities via state compliance reports is noted in the above graph as 'Estimated Biomedical Mortality.'**

Reported coastwide landings since 1998 show more male than female horseshoe crabs were harvested annually. Several states presently have sex-specific restrictions in place to limit the harvest of females. The American eel pot fishery prefers egg-laden female horseshoe crabs as bait, while the whelk (conch) pot fishery is less dependent on females. Unclassified landings have generally accounted for around 10% of the reported landings since 2000.

The hand, trawl, and dredge fisheries typically account for over 85% of the reported commercial horseshoe crab bait landings. In 2016, these gears accounted for 91.8% of commercial landings. Other methods that account for the remainder of the harvest include gill nets, pound nets, and traps.

Biomedical Fishery

The horseshoe crab is an important resource for research and manufacture of materials used for human health. There are five companies along the Atlantic Coast that process horseshoe crab blood for use in manufacturing Limulus Amebocyte Lysate (LAL): Associates of Cape Cod, Massachusetts; Lonza (formerly Cambrex Bioscience), Limuli Laboratories, New Jersey; Wako Chemicals, Virginia; and Charles River Endosafe, South Carolina. Addendum III requires states where horseshoe crabs are collected for biomedical bleeding to collect and report total collection numbers, crabs rejected, crabs bled (by sex) and to characterize mortality.

The Plan Review Team annually calculates total coastwide harvest and estimates mortality. It was reported that 426,195 crabs (including crabs harvested as bait) coastwide were brought to biomedical companies for bleeding in 2016 (Table 2). This represents a decrease from the average of the previous five years (580,773 crabs). Of this total, 77,946 crabs were reported as harvested for bait and counted against state quotas, representing a 9% increase above the average of the previous five years (Table 2: row B). These crabs were not included in the mortality estimates (Rows D, F, and G) below. It was reported for 2016 that 344,467 crabs were harvested for biomedical purposes only. Males accounted for 52% of total biomedical harvest, females comprised 35%, and 13% of the harvest was unknown. Crabs were rejected prior to bleeding due to mortality, injuries, slow movement, and size (known mortality prior to bleeding is included in Row D below). Approximately 0.3% of crabs, collected solely for biomedical purposes, were observed and reported as dead from the time of collection up to the point of release. Total estimated mortality of biomedical crabs for 2016 was 47,765 crabs (at 15% post-release estimated mortality), with a range of 16,937 to 96,545 crabs (5-30% post-release estimated mortality).

Table 2. Numbers of horseshoe crabs collected, bled, and estimated mortality for the biomedical industry.

	2009	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016***
A. Number of crabs brought to biomedical facilities (bait and biomedical crabs)	512,853	552,083	623,680	624,440	554,419	536,798	564,526	426,195
B. Number of bait crabs bled	106,740	66,047	78,128	82,684	61,613	68,643	67,687	77,946
C. Number of biomedical-only crabs collected (not counted against state bait quotas)	402,503	476,962	540,323	537,514	500,565	464,709	493,144	344,467
D. Reported observed mortality of biomedical-only crabs from collection to release	6,523	6,447	8,485	7,396	5,485	5,658	5,250	1,015
E. Number of biomedical-only crabs bled	355,011	435,458	500,781	499,214	436,902	432,306	467,455	318,432
F. Estimated post-bleeding mortality of bled biomedical-only crabs (15% est. mortality)	53,252	65,319	75,117	74,882	65,535	64,846	70,118	47,765
G. Total estimated mortality on biomedical crabs not counted against state bait quotas (15% est. mortality)	59,775	71,766	83,602	82,278	71,020	70,504	75,369	48,780

*** Misinterpretation of some biomedical numbers from previously submitted reports was noted during review of these data. Previously misinterpreted numbers are corrected in the table above, but the numbers included in this table for years prior to 2016 may deviate from those of previous FMP Reviews. The Horseshoe Crab Technical Committee has constructed and recommended use of a standardized electronic reporting form that clarifies requirements of Addendum III to reduce misinterpretations of reported data in the future.**
****Some biomedical collections were reduced in 2016 due to temporary changes in production.**

The 1998 FMP establishes a mortality threshold of 57,500 crabs that, if exceeded, requires the Board to consider management action. Based on an estimated total mortality of 48,780 crabs, this threshold was not exceeded in 2016. The PRT notes that estimated mortality from biomedical use is approximately 6% of the total horseshoe crab mortality (bait and biomedical) coastwide for 2016, down from approximately 11% in 2015. Although the 57,500 crab threshold was not exceeded in 2016, because it has been exceeded in 7 of the last 8 years, the PRT continues to recommend including biomedical mortality in the next benchmark stock assessment.

IV. Status of Research and Monitoring

The Horseshoe Crab FMP set forth an ambitious research and monitoring strategy in 1999 and again in 2004 to facilitate future management decisions. Despite limited time and funding there are many accomplishments since 1999. These accomplishments were largely made possible by forming partnerships between state, federal and private organizations, and the support of hundreds of public volunteers.

Addendum III Monitoring Program

Addendum III requires affected states to carry out three monitoring components:

All states who do not qualify for *de minimis* status report monthly harvest numbers and subsample a portion of the catch for gender and harvest method. In addition, those states with annual landings above 5% of the coastwide harvest report all landings by sex and harvest method. Although states with annual landings less than 5% of annual coastwide harvest are not required to report landings by gender, the PRT recommends all states require gender reporting for horseshoe crab harvest.

States with biomedical fisheries landings are required to monitor and report harvest numbers and mortality associated with the transportation and bleeding of the crabs.

States must identify spawning and nursery habitat along their coasts. All states have completed this requirement, and a few continue active monitoring programs.

Virginia Tech Research Projects

The Virginia Tech Horseshoe Crab Trawl Survey (VT Survey) was not conducted in 2013 - 2015, due to a lack of funding, but was conducted in 2016. The 2016 survey results indicate no long-term trend in abundance of immature, newly mature, or mature female crabs, but mature male crabs have increased for the time series (2002-2016). The Adaptive Resource Management (ARM) Working Group will use the indices from this survey to estimate horseshoe crab abundance for the ARM model, which specifies harvest limits for the upcoming year. This year's VT Survey indices will also be used to tune a composite abundance index from current Delaware Bay region state trawl surveys (Delaware 30 foot trawl survey, New Jersey Delaware Bay trawl survey, and New Jersey Ocean trawl survey) that has been used to estimate horseshoe crab abundance for the ARM model when the VT Survey was not conducted. The VT

Survey has been funded for 2017. Funding sources beyond 2017 as well as alternative data sources continue to be explored.

Spawning Surveys

The redesigned Delaware Bay spawning survey was completed for the 18th year in 2016. No trend was detected in the baywide indices of spawning activity (both male and female) for the time series. No trends were detected in male or female spawning activity for Delaware or New Jersey. Most spawning activity in 2016 was observed in early June. This was only the fifth year of the 18-year survey when peak spawning did not occur in May, a critical time period for migratory shorebird foraging in Delaware Bay. The annual baywide sex ratio was 4.6:1 (Male: Female). The range of annual observed sex ratios on the Delaware Bay spawning beaches over the time series has varied from 3.1:1 to 5.2:1.

Tagging Studies

The USFWS continues to maintain a toll-free telephone number as well as a website for reporting horseshoe crab tag returns and assists interested parties in obtaining tags. Tagging work continues to be conducted by biomedical companies, research organizations, and other parties involved in outreach and spawning surveys. Beginning with the 2013 tagging season, additional efforts were implemented to ensure that current tagging programs are providing data that benefits the management of the coast-wide horseshoe crab population. All existing and new tagging programs are required to submit an annual application to be considered for the tagging program and all participants must submit an annual report along with their tagging and resight data to indicate how their tagging program addresses at least one of the following objectives: determine horseshoe crab sub-population structure, estimate horseshoe crab movement and migration rates, and/or estimate survival and mortality of horseshoe crabs. The PRT recommends all tagging programs, approved by the state, coordinate with the USFWS tagging program, in order to ensure a consistent coastwide program for providing management input.

Since 1999, over 300,000 crabs have been tagged and released through the USFWS tagging program along the Atlantic coast. Approximately 12% of tagged crabs have been recaptured and reported. Crabs have been tagged and released from every state on the Atlantic Coast from Florida to New Hampshire. In the early years of the program, tagging was centered around Delaware Bay; however, in recent years, tagging has expanded and increased in the Long Island Sound and Southeast. The Technical Committee noted that recapture rates inside and outside Delaware Bay are likely not directly comparable due to increased re-sighting effort and spawning concentration in Delaware Bay compared to other areas along the coast. There may be data in the USFWS tagging database to determine differences in effort and recapture rates.

V. Status of Management Measures and Issues

ASMFC

Initial state-by-state harvest quotas were established through Addendum I. Addendum III outlined the monitoring requirements and recommendations for the states. Addendum IV set

harvest closures and quotas, and other restrictions for New Jersey, Delaware, Maryland, and Virginia, which were continued in Addendums V and VI.

The Board approved Addendum VII, implementation of the ARM Framework, in February 2012 for implementation in 2013. Addendum VII includes an allocation mechanism to divide the Delaware Bay optimized harvest output from the ARM Framework among the four Delaware Bay states (New Jersey, Delaware, Maryland, and Virginia east of the COLREGS). Season closures and restrictions, present within Addendum VI, remain in effect as part of Addendum VII.

Included in this report are state-by-state charts outlining compliance and monitoring measures. The PRT recommends all jurisdictions were in compliance with the FMP and subsequent Addenda in 2016.

MASSACHUSETTS		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	Did not qualify for *de miminis*	Does not qualify for *de miminis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (Voluntary State Quota)	330,377 (165,000)	330,377 (165,000)
- Other Restrictions	Bait: 300 crab daily limit year round; limited entry; Biomedical: 1,000 crab daily limit; Conch pot and eel fishermen: no possession limit All: May and June 5-day lunar closures; No mobile gear harvest Fri-Sat during summer flounder season; 7" PW minimum size; Pleasant Bay Closed Area	Bait: 300 crab daily limit year round; Biomedical: 1,000 crab daily limit; Conch pot and eel fishermen: no possession limit All: May and June 5-day lunar closures; No mobile gear harvest Fri-Sat during summer flounder season; 7" PW minimum size; Pleasant Bay Closed Area
- Landings	101,642	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes, plus weekly dealer reporting through SAFIS	Yes, plus weekly dealer reporting through SAFIS
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical harvest reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes	Yes
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Yes
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes	Yes
Monitoring Component B_4 Tagging program	Yes – w/NPS and USFWS; Pleasant Bay, Monomy NWR, Waquoit Bay	Yes – w/NPS and USFWS; Pleasant Bay, Monomy NWR, Waquoit Bay

Note: The daily crab possession limit in the mobile gear fishery was changed to 300 crabs in 2014. This limit has remained in place since then.

RHODE ISLAND		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	Did not qualify for *de minimis*	Does not qualify for *de minimis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (Voluntary State Quota)	26,053 (14,655)	26,053 (12,545)
- Other Restrictions	State Restrictions: - Bait Fishery Closure: 48 hours prior to and 48 hours following new and full moons during May, June, and July - Biomedical Fishery Closure: 48 hours prior to and 48 hours following new and full moons during May, June, and July	State Restrictions: - Daily possession limit: 60 crabs per permit - Bait Fishery Closure: May 1-May 31 - Biomedical Fishery Closure: 48 hours prior to and 48 hours following new and full moons during May
- Landings	20,917	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes, weekly call in and monthly on paper	Yes, weekly call in and monthly on paper
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical harvest reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes, details within Massachusetts' reports	Captured in Massachusetts' reports
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Yes
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes, since 2000 (methods unspecified)	Yes
Monitoring Component B_4 Tagging program	RI DEM 2001-2004 only, No current state program	No

CONNECTICUT		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	Did not qualify for *de miminis*	Does not qualify for *de miminis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota	48,689	48,689
- Other Restrictions	Limited entry program, possession limits, and seasonal and area closures	Limited entry program, possession limits, and seasonal and area closures
- Landings	12,135	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	No – exempt under Addendum III because landings are < 5% of coastwide total	No – exempt under Addendum III because landings are < 5% of coastwide total
Monitoring Component A_2		
- Biomedical harvest reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Yes
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes, since 1999 (methods differ from DE Bay survey)	Yes
Monitoring Component B_4 Tagging program	Yes, in collaboration with local universities (Sacred Heart University since 2015)	Yes

NEW YORK		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	Did not qualify for *de miminis*	Does not qualify for *de miminis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (Voluntary State Quota)	366,272 (150,000)	366,272 (150,000)
- Other Restrictions	Ability to close areas to harvest; seasonal quotas and daily harvest limits	Ability to close areas to harvest; seasonal quotas and daily harvest limits
- Landings	176,632	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes (weekly May – July)	Yes
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical harvest reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Yes
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes – adapted from DE Bay survey	Yes
Monitoring Component B_4 Tagging program	Yes, since 2007	Yes

NEW JERSEY		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	Qualified for *de miminis*	Qualifies but not requesting *de miminis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (Voluntary state quota)	162,136 [male only] (0)	162,136 [male only] (0)
- Other Restrictions	Bait harvest moratorium	Bait harvest moratorium
- Landings	0	--
Monitoring Component A_1		
- Mandatory monthly reporting	N/A	N/A
- Characterize commercial bait fishery	N/A	N/A
Monitoring Component A_2		
- Biomedical harvest reporting	Pending	Yes
- Required information for biomedical use of crabs	Pending	Yes
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Yes
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes –NJ Ocean Trawl Survey, DE Bay Trawl Survey, and Surf Clam Survey (see note below).	Yes, though funding for Surf Clam Survey uncertain past 2017
Monitoring Component B_3 Implement spawning survey	Yes – since 1999	Yes
Monitoring Component B_4 Tagging program	Outside, independent groups currently	No
Monitoring Component B_5 Egg abundance survey	Yes, but removed as a mandatory component	Yes
Monitoring Component B_6 Shorebird monitoring program	Yes	Yes

Note: the Surf Clam Dredge survey continued in 2015 and 2016, after hiatus in 2013 and 2014. The survey was continued with a new vessel and new survey gear. NJ Staff is still working through conversion factors between the previous gear type and one used in 2015-16; no new information available yet.

DELAWARE		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	Did not qualify for *de miminis*	Does not qualify for *de miminis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota	162,136 [male only]	162,136 [male only]
- Other Restrictions	Closed season (January 1 – June 7)	Closed season (January 1 – June 7)
- Landings	159,545 males	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes (daily call-in reports & monthly logbooks)	Yes
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical harvest reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Yes –updates once every 5 years or as needed	Yes – updates once every 5 years or as needed
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes	Yes
Monitoring Component B_4 Tagging program	No state program but has assisted in the past with various Delaware Bay horseshoe crab tagging initiatives	No
Monitoring Component B_5 Egg abundance survey	Removed as component	Removed as component
Monitoring Component B_6 Shorebird monitoring program	Yes	Yes

Note: The egg abundance survey has been discontinued as a mandatory monitoring element. Delaware will include information on the survey if it continues, but is no longer required to perform the survey.

MARYLAND		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	Did not qualify for *de miminis*	Does not qualify for *de miminis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota	255,980 (male only)	255,980 (male only)
- Other Restrictions	Delayed harvest and closed season/area combinations	Delayed harvest and closed season/area combinations; shore harvest prohibited
- Landings	157,013	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes (weekly reports for permit holders; monthly for non-permit holders)	Yes (weekly reports for permit holders; monthly for non-permit holders)
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical harvest reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes	Yes
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Yes
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	Yes	Yes
Monitoring Component B_4 Tagging program	Yes – through biomedical harvest	Yes – through biomedical harvest

POTOMAC RIVER FISHERIES COMMISSION		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	*De minimis* status granted.	*De minimis* requested and meets criteria.
- Ability to close fishery if *de minimis* threshold is reached	No horseshoe crab fishery	No horseshoe crab fishery
- Daily possession limit <25 for *de minimis* state		
- HSC landing permit		
Bait Harvest Restrictions and Landings		
- ASMFC Quota	0	0
- Other Restrictions	None	None
- Landings	0	0
Monitoring Component A_1		
- Mandatory monthly reporting	Yes - weekly	Yes - weekly
- Characterize commercial bait fishery	Not Applicable	Not Applicable
Monitoring Component A_2		
- Biomedical harvest reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Not Applicable	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Not Applicable	Not Applicable
Monitoring Component B_3 Implement spawning survey	Not Applicable	Not Applicable
Monitoring Component B_4 Tagging program	Not Applicable	Not Applicable

VIRGINIA		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	Did not qualify for *de miminis*	Does not qualify for *de miminis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (State-reduced quota for overage)	172,828 (81,331 male-only east of COLREGS line)	172,828 (81,331 male-only east of COLREGS line)
- Other Restrictions	Closed season (January 1 – June 7) for federal waters. Effective January 1, 2013 harvest of horseshoe crabs, from east of the COLREGS line, is limited to trawl gear and dredge gear only.	Closed season (January 1 – June 7) for federal waters. Effective January 1, 2013 harvest of horseshoe crabs, from east of the COLREGS line, is limited to trawl gear and dredge gear only.
- Landings	133,453 (39,012)	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes – new permit system; limited entry to fishery and individual quotas established	Yes
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical harvest reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes	Yes
Monitoring Component A_3 Identify spawning and nursery habitat	Yes – completed	No
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	No	No
Monitoring Component B_3 Implement spawning survey	No	No
Monitoring Component B_4 Tagging program	No	No

NORTH CAROLINA		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	Did not qualify for *de miminis*	Does not qualify for *de minimis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota	24,036	24,036
- Adjusted Quota	25,286*	--
- Other Restrictions	Trip limit of 50 crabs; Proclamation authority to adjust trip limits, seasons, etc.	Trip limit of 50 crabs; Proclamation authority to adjust trip limits, seasons, etc.
- Landings	25,197	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes – trip level reporting each month	Yes – trip level reporting each month
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical harvest reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Little information available Survey discontinued after 2002 and 2003 due to low levels of crabs recorded	Not specified
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	No	No
Monitoring Component B_4 Tagging program	No	No

*Note: there was quota transfer of 1,250 crabs from Georgia to North Carolina to cover their quota overage of 1,161 horseshoe crabs in 2016.

SOUTH CAROLINA		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	*De minimis* status granted.	*De minimis* requested and meets criteria.
- Ability to close fishery if *de minimis* threshold is reached	No horseshoe crab bait fishery	No horseshoe crab bait fishery
- Daily possession limit <25 for *de minimis* state		
- HSC landing permit		
Bait Harvest Restrictions and Landings		
- ASMFC Quota	0	0
- Other Restrictions	None	None
- Landings	0	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes (Biomedical)	Yes (Biomedical)
- Characterize commercial bait fishery	Not Applicable	Not Applicable
Monitoring Component A_2		
- Biomedical harvest reporting	Yes	Yes
- Required information for biomedical use of crabs	Yes	Yes
Monitoring Component A_3 Identify spawning and nursery habitat	Completed	No
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	No	No
Monitoring Component B_4 Tagging program	Yes	Yes

GEORGIA		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	*De minimis* status granted.	*De minimis* requested and meets criteria.
- Ability to close fishery if *de minimis* threshold is reached	Yes	Yes
- Daily possession limit <25 for *de minimis* state	25/person; 75/vessel with 3 licensees	25/person; 75/vessel with 3 licensees
- HSC landing permit	Must have commercial shrimp, crab, or whelk license; LOA permit required	Must have commercial shrimp, crab, or whelk license; LOA permit required
Bait Harvest Restrictions and Landings		
- ASMFC Quota	29,312	29,312
(State Quota)	28,062*	29,312
- Other Restrictions	None	None
- Landings	0	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	No bait landings	Yes
Monitoring Component A_2		
- Biomedical harvest reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Completed	Not Applicable
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	Yes	Yes
Monitoring Component B_3 Implement spawning survey	No	No
Monitoring Component B_4 Tagging program	No	No

*Note there was quota transfer of 1,250 crabs from Georgia to North Carolina to cover their quota overage of 1,161 horseshoe crabs in 2016.

FLORIDA		
	2016 Compliance Report	**2017 Management Proposal**
***De minimis* status**	*De minimis* status granted.	*De minimis* requested and meets criteria.
- Ability to close fishery if *de minimis* threshold is reached	Yes	Yes
- Daily possession limit <25 for *de minimis* state	25/person w/ valid saltwater products license; 100/person with marine life endorsement	25/person w/ valid saltwater products license; 100/person with marine life endorsement
- HSC landing permit	See above	See above
Bait Harvest Restrictions and Landings		
- ASMFC Quota	9,455	9,455
- Other Restrictions	None	None
- Landings	689	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	No	Yes
Monitoring Component A_2		
- Biomedical harvest reporting	Not Applicable	Not Applicable
- Required information for biomedical use of crabs	Not Applicable	Not Applicable
Monitoring Component A_3 Identify spawning and nursery habitat	Yes	Yes
Monitoring Component B_1 Coastwide benthic trawl survey	Yes, VT Trawl Survey was conducted in 2016	Yes, VT Trawl Survey will be conducted in 2017; future years and spatial scope unknown at this time
Monitoring Component B_2 Continue existing benthic sampling programs	No	No
Monitoring Component B_3 Implement spawning survey	No	Yes
Monitoring Component B_4 Tagging program	No	Yes

Note: Florida reported an additional 1,528 crabs harvested along the east coast for 'marine life' use in 2016.

Alternative Baits

Delaware, Connecticut, Rhode Island and Massachusetts attempted to participate in field trials with Ecobait, available from LaMonica Fine Foods in New Jersey. Massachusetts and Delaware were unable to conduct the trials due to difficulties in securing the Ecobait samples from LaMonica; Connecticut and Rhode Island were able to conduct trials in fall 2014. The results of the study were presented to the Horseshoe Crab Technical Committee and Delaware Bay Ecosystem Technical in October 2015. The results demonstrated that the Ecobait produced by LaMonica Fine Foods performed comparable to conventional bait used by conch fishermen in Rhode Island and Connecticut. The results were presented to Board at the 2016 ASMFC Winter Meeting. Subsequently, the Board requested that a survey of current bait usage in the eel and whelk fisheries be conducted. The TC has conducted this survey and will present the results to the Board at the 2017 Annual Meeting.

Shorebird

The USFWS received petitions in 2004 and 2005 to emergency list the red knot under the Endangered Species Act. In fall 2005, it determined that emergency listing was not warranted at the time. As part of a court settlement, the USFWS agreed to initiate proposed listings of over 200 species, including the red knot. In fall 2013, the USFWS released a proposal for listing the red knot as threatened. In January 2015 the USFWS determined that red knot be designated as threatened under the Endangered Species Act.

The red knot remains listed as an endangered species in the state of New Jersey (since 2012).

VI. Research Needs/PRT Recommendations

De Minimis

States may apply for *de minimis* status if, for the last two years, their combined average horseshoe crab bait landings (by numbers) constitute less than one percent of coastwide horseshoe crab bait landings for the same two-year period. States may petition the Board at any time for *de minimis* status, if their fishery falls below the threshold level. Once *de minimis* status is granted, designated States must submit annual reports to the Board justifying the continuance of *de minimis* status.

States that qualify for *de minimis* status are not required to implement any horseshoe crab harvest restriction measures, but are required to implement components A, B, E and F of the monitoring program (Section 3.5 of the FMP; further modified by Addendum III). Since *de minimis* states are exempt from a harvest cap, there is potential for horseshoe crab landings to shift to *de minimis* states and become substantial, before adequate action can be taken. To control shifts in horseshoe crab landings, *de minimis* states are encouraged to implement one of the following management measures:

1. Close their respective horseshoe crab bait fishery when landings exceed the *de minimis* threshold;

2. Establish a state horseshoe crab landing permit, making it only available to individuals with a history of landing horseshoe crabs in that state; or

3. Establish a maximum daily harvest limit of up to 25 horseshoe crabs per person per day. States which implement this measure can be relieved of mandatory monthly reporting, but must report all horseshoe crabs harvests on an annual basis.

The following states have been removed from the Management Board in recent years: Pennsylvania (2007), Maine (2011), and New Hampshire (2014). The Potomac River Fisheries Commission, South Carolina, Georgia, and Florida are requesting *de minimis* status for the 2017 fishing season based on the 2015-16 season landings and meet the FMP requirements for being granted this status (Table 1). The PRT recommends granting these jurisdictions *de minimis* status with the provision that marine life landings from Florida be considered in determining future *de minimis* status. Regarding the transfer requests from Georgia to North Carolina, the PRT finds that the quota transfer does not pose concerns for the regional horseshoe crab population or migratory shorebirds at this time, due to the size of the transfer.

Funding for Research and Monitoring Activities

The PRT strongly recommends the continuation of the VT benthic trawl survey in order to provide the critical information for stock assessments and the ARM model. The survey is a necessity to continue ARM implementation. This effort provides a statistically reliable estimate of horseshoe crab relative abundance