Atlantic States Marine Fisheries Commission

Horseshoe Crab Management Board

October 21, 2020
10:30 – 11:15 a.m.
Webinar

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 *(J. Cimino)*	10:30 a.m.
2.	Board Consent • Approval of Agenda • Approval of Proceedings from October 2019	10:30 a.m.
3.	Public Comment	10:35 a.m.
4.	Set 2021 Harvest Specifications **Final Action** • Review Horseshoe Crab and Red Knot Abundance Estimates and 2020 Adaptive Resource Management (ARM) Model Results (*J. Sweka*) • Set 2021 Harvest Specifications (*J. Cimino*)	10:40 a.m.
5.	Progress Update on ARM Revisions (*J. Sweka*)	10:55 a.m.
6.	Consider Fishery Management Plan Review and State Compliance for the 2019 Fishing Year (*C. Starks*) **Action**	11:05 a.m.
7.	Review and Populate Advisory Panel Membership (*T. Berger*) **Action**	11:10 a.m.
8.	Other Business/Adjourn	11:15 a.m.

MEETING OVERVIEW

Horseshoe Crab Management Board Meeting
Wednesday, October 21, 2020
10:30 – 11:15 a.m.
Webinar

Chair: Joe Cimino (NJ) Assumed Chairmanship: 10/19	Horseshoe Crab Technical Committee Chair: Jeff Brunson (SC)	
Vice Chair: VACANT	Horseshoe Crab Advisory Panel Chair: Allen Burgenson (MD)	Law Enforcement Committee Representative: Doug Messeck (DE)
Delaware Bay Ecosystem Technical Committee Chair: Wendy Walsh (FWS)	Adaptive Resource Management Subcommittee Chair: Dr. John Sweka (FWS)	Previous Board Meeting: October 29, 2019
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 29, 2019 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. Set 2021 Harvest Specifications (10:40 - 10:55 a.m.) Final Action
Background • In September 2020, the DBE TC and Adaptive Resource Management (ARM) Subcommittee met to review results of 2019-2020 horseshoe crab and red knot population abundance surveys in the Delaware Bay region (**Supplemental Materials**). • The Virginia Tech Trawl Survey was conducted in 2019, so the ARM Subcommittee used population estimates from this survey to estimate horseshoe crab abundance in the Delaware Bay region. A report was also provided on the red knot stopover population estimate for 2020 (**Briefing Materials**). • The ARM model was run using estimated abundances of horseshoe crabs in fall of 2019 and red knots in spring of 2020 to provide a recommendation for harvest specifications for Delaware Bay states in 2021 (**Briefing Materials**).
Presentations • Horseshoe Crab and Red Knot Abundance Estimates and 2020 ARM Model Results by J. Sweka

Board actions for consideration at this meeting

- Consider ARM harvest recommendations and set specifications for states in the Delaware Bay region in 2021.

5. Progress Report on ARM Revisions (10:00 - 10:40 a.m.)

Background

- In October 2019, the Board directed the ARM Subcommittee to begin working on updates to the Adaptive Resource Management (ARM) Framework to revisit several aspects of the ARM model to incorporate horseshoe crab population estimates from the Catch Multiple Survey Analysis (CMSA) model used in the 2019 Benchmark Stock Assessment and the most current scientific information available for horseshoe crabs and red knots.
- In the last year, the ARM Subcommittee has been working on incorporating the CMSA model into the ARM, moving the model to a new software platform, improving model structure, and updating the red knot population model.
- The ARM model revision is tentatively scheduled to go to peer review in the summer of 2021 and be brought to the Board at the August or October 2021 meeting.

Presentations

- Progress Report on ARM Revisions by J. Sweka

6. Consider Fishery Management Plan Review and State Compliance for the 2019 Fishing Year (11:05 - 11:10 a.m.) Action

Background

- State Compliance Reports were due July 1, 2020.
- 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 C. Starks

Board actions for consideration at this meeting

- Accept FMP Review and State Compliance Reports for the 2019 Fishing Year.
- Approve *de minimis* requests.

7. Review and Populate Advisory Panel Membership (11:10 - 11:15 a.m.) Action

Background

- Christina Lecker, a biomedical representative from Virginia, has been nominated to the Horseshoe Crab Advisory Panel (**Briefing Materials**).

Presentations

- Nominations by T. Berger

Board actions for consideration at this meeting

- Approve Horseshoe Crab Advisory Panel nomination

8. Other Business/Adjourn

Horseshoe Crab

Activity level: Medium

Committee Overlap Score: Low (SAS overlaps with BERP)

Committee Task List
• ARM & DBETC – Incorporate Catch Multiple Survey Analysis horseshoe crab population estimates into the ARM model • TC – Communicate with Kepley Biosystems' to determine whether trials should be conducted for OrganoBait • TC – July 1st: Annual compliance reports due • ARM & DBETC – Fall: Annual ARM model to set Delaware Bay specifications, review red knot and VT trawl survey results

TC Members: Jeff Brunson (SC, TC Chair), Derek Perry (MA), Natalie Ameral (RI, Vice Chair), Deb Pacileo (CT), Catherine Ziegler (NY), Samantha Macquesten (NJ), Jordan Zimmerman (DE), Steve Doctor (MD), Ellen Cosby (PRFC), Adam Kenyon (VA), Jeffrey Dobbs (NC), Eddie Leonard (GA), Claire Crowley (FL), Linda Stehlik (NMFS), Chris Wright (NMFS), Joanna Burger (Rutgers), Gregory Breese (USFWS), Mike Millard (USFWS), Kristen Anstead (ASMFC), Caitlin Starks (ASMFC)

Delaware Bay Ecosystem TC Members: Wendy Walsh (USFWS, Chair), Amanda Dey (NJ), Henrietta Bellman (DE, Vice Chair), Jordan Zimmerman (DE), Steve Doctor (MD), Adam Kenyon (VA), Jim Fraser (VA Tech), Eric Hallerman (VA Tech), Mike Millard (USFWS), Greg Breese (USFWS), Kristen Anstead (ASMFC), Caitlin Starks (ASMFC)

ARM Subcommittee Members: John Sweka (USFWS, Chair), Larry Niles (NJ), Linda Barry (NJ), Henrietta Bellman (DE), Jason Boucher (DE), Steve Doctor (MD), Wendy Walsh (USFWS), Conor McGowan (USGS/Auburn), David Smith (USGS), Jim Lyons (USGS, ARM Vice Chair), Jim Nichols (USGS), Kristen Anstead (ASMFC), Caitlin Starks (ASMFC)

DRAFT PROCEEDINGS OF THE

ATLANTIC STATES MARINE FISHERIES COMMISSION

HORSESHOE CRAB MANAGEMENT BOARD

Wentworth by the Sea
New Castle, New Hampshire
October 29, 2019

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

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INDEX OF MOTIONS

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

2. **Approval of Proceedings from August 2019** by consent (Page 1).

3. **Move to postpone Draft Addendum VIII indefinitely** (Page 9). Motion by Mike Luisi; second by Chris Wright. Motion carried (Page 9).

4. **Move to select Harvest Package 3 (500,000 male-only crabs) for 2020 horseshoe crab bait harvest in Delaware Bay** (Page 11). Motion by Stewart Michels; second by Mike Millard. Motion carried (Page 11).

5. **Move to approve the 2019 FMP Review, state compliance reports, and *de minimis* status for Potomac River Fisheries Commission, South Carolina, Georgia, and Florida** (Page 13). Motion by Stewart Michels; second by Mel Bell. Motion carried (Page 13).

6. **Move to adopt a July 1st due date for state compliance reports** (Page 14). Motion by Stewart Michels; second by Mel Bell. Motion carried (Page 14).

7. **Move to adjourn** by consent (Page 14).

ATTENDANCE

Board Members

Dan McKiernan, MA, proxy for D. Pierce (AA)
Raymond Kane, MA (GA)
Rep. Sarah Peake, MA (LA)
Bob Ballou, RI (Chair)
Eric Reid, RI, proxy for Sen. Sosnowski (LA)
Justin Davis, CT (AA)
Bill Hyatt, CT (GA)
Sen. Craig Miner, CT (LA)
John McMurray, NY, proxy for Sen. Kaminsky (LA)
Maureen Davidson, NY, proxy for J. Gilmore (AA)
Emerson Hasbrouck, NY (GA)
Joe Cimino, NJ (AA)
Tom Fote, NJ (GA)
Adam Nowalsky, NJ, proxy for Sen. Andrzejczak (LA)
Stewart Michels, DE, proxy for D. Saveikis (AA)
Roy Miller, DE (GA)
Mike Luisi, MD, proxy for Bill Anderson (AA)
Russell Dize, MD (GA)
Robert Brown, MD, Governor Appointee proxy
Phil Langley, MD, proxy for Del. Stein (LA)
Bryan Plumlee, VA (GA)
Pat Geer, VA, proxy for Sen. (LA)
Steve Murphey, NC (AA)
Jerry Mannen, NC (GA)
Mel Bell, SC, proxy for R. Boyles (AA)
Malcolm Rhodes, SC (GA)
Sen. Ronnie Cromer, SC (LA)
Doug Haymans, GA (AA)
Spud Woodward, GA (GA)
Jim Estes, FL, proxy for J. McCawley (AA)
Rep. Thad Altman, FL (LA)
Marty Gary, PRFC
Chris Wright, NMFS
Mike Millard, USFWS

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

Ex-Officio Members

Douglas Messeck, Law Enforcement Representative
John Sweka, ARM Subcommittee Chair

Staff

Robert Beal
Toni Kerns
Mike Schmidtke
Kristen Anstead

Guests

Chris Batsavage, NC DMF
Nora Blair, Charles River Labs
Robert Brown, MWA
Robert Bruce, MWA
John Clark, DE DFW
Kelly Denit, NOAA
Philip Forester, Philadelphia, PA
Lewis Gillingham, VMRC
Doug Grout, NH (AA)
Brett Hoffmeister, Assoc. of Cape Cod
Arnold Leo, E. Hampton, NY
Chip Lynch, NOAA
David Pierce, MA (AA)
Alesia Reed, NOAA
Mike Ruccio, NOAA
Sam Underwood, Assoc. of Cape Cod
Renee Zobel, NH F&G

The Horseshoe Crab Management Board of the Atlantic States Marine Fisheries Commission convened in the Wentworth Ballroom of the Wentworth by the Sea Hotel, New Castle, New Hampshire; Tuesday, October 29, 2019, and was called to order at 9:45 o'clock a.m. by Chairman Malcolm Rhodes.

CALL TO ORDER

CHAIRMAN MALCOLM RHODES: I'll call the meeting of the Horseshoe Crab Management Board to order. My name is Malcolm Rhodes; I'm up here at the podium with Dr. Mike Schmidtke and Dr. John Sweka, and Doug Messeck of Law Enforcement.

APPROVAL OF AGENDA AND PROCEEDINGS

CHAIRMAN RHODES: You all had previously received the agenda and the proceedings from the August meeting, were there any changes to those? Any objections to accepting them as written? Seeing none we'll move those accepted.

PUBLIC COMMENT

CHAIRMAN RHODES: We had a sign in sheet for public comment on issues not being brought before the Board, and I had no one signed up, but does anyone in the public need to address the management board? All right seeing no one coming up, I'm going to turn the meeting over to Dr. Sweka, it's all yours.

REVIEW DELAWARE BAY ECOSYSTEM TECHNICAL COMMITTEE AND ADAPTIVE RESOURCE MANAGEMENT SUBCOMMITTEE REPORT

DR. JOHN SWEKA: Back in September, September 11 and 12, there was a joint meeting between the Delaware Bay Ecosystem Technical Committee and the Adaptive Resource Management Subcommittee, or the ARM. The purpose of this meeting was to develop recommendations to the Horseshoe Crab Management Board for the ARM following the 2019 Horseshoe Crab benchmark stock assessment.

In our two groups we developed six consensus recommendations, which I'll give you some background on each one, and present each one of them today. The first recommendation is kind of a formalization of the process that we have been doing. I just want to get it formalized as to the way we do routine business each year.

The Virginia Tech Survey is conducted in the fall, and red knot abundance is estimated in the spring. Both primiparous and multiparous crabs that survive from the fall to the spring will spawn and represent the total number of crabs that can provide eggs to the shorebirds. A better estimate of the number of crabs producing eggs during the shorebird stopover period would actually decrement the abundance of horseshoe crabs estimated in the fall by half a year's worth of mortality.

RECOMMENDED UPDATES TO THE ARM MODEL

DR. SWEKA: A simple equation there, the crabs that are available in the spring when the birds are stopping over is just your primiparous plus your multiparous crabs decremented by mortality, or half of annual mortality. Our first recommendation then is for annual input into the ARM Framework. We should combine the primiparous and multiparous abundances from the Virginia Tech Trawl Survey with half a year mortality applied to the estimates. This would apply to the ARM Framework immediately. Our second recommendation pertains to the underlying horseshoe crab model, our Population Dynamics Model within the Arm Framework. It's been ten plus years since we developed the underlying horseshoe crab model. It started out from a publication back in 2007 as an age-structured model.

It was then converted into a stage-structured model in 2008, when we were developing the

ARM, and then the ARM Model was peer reviewed in 2009. The bottom line is we know a lot more now. We have more year's-worth of data, new mortality estimates coming out of our last stock assessment, estimates of dead discards, and we have a peer reviewed and approved stock assessment model., the Catch Multiple Survey Analysis or CMSA.

What we're proposing is to use the underlying model from the CMSA as the revised population dynamics model for horseshoe crabs. It is much simpler than the stage-structured model that we currently use. Here is the equation for it. It's just a function of the number of multiparous and primiparous crabs added together decremented by mortality and catch subtracted.

Again, horseshoe crabs are assessed in the fall by the Virginia Tech Trawl Survey, and will spawn the following spring. The catch would be equal to all removals from all sources. This is bait, biomedical, and dead discards all combined. One caveat with this model is somehow we need to produce the recruits, or the R in the equation there for use in the projection model, which projects the population through time, and helps us then decide what's our best management option today.

What we're proposing to do is come up with an assumed stock-recruitment relationship based on either median recruitment or hockey stick sort of stock recruitment relationship, and this is something that can be refined as we move through time. The advantages of moving to this new underlying horseshoe crab population dynamics model is Number 1, it's empirical.

It's driven by the observed data and has less emphasis on literature values for the various life history parameters. For example, the adult mortality within the current model, and also includes the actual number of removals. We don't have any need to make any assumptions about abundance of juvenile stages of horseshoe crabs.

The observed data provide an immediate feedback and model adjustment, and another big advantage is that the assessment model that we would use to estimate the abundance of horseshoe crabs, and the projection model are contained within the same modeling framework. This has been a criticism of previous peer reviewers on previous models.

Also we already have a funded USGS position under Dr. Dave Smith at the Leetown Science Center, and his Post-doc will be able to and has the funding and the time to transition the current modeling framework from ASDP that's the advanced casted dynamic programming to MDPSolve, so it's a new software that we would be developing this revised model in.

ASDP is now antiquated software, MDPSolve is newer software, and also a big advantage of moving to MDPSolve is that ASMFC staff will also be able to run the model. Another thing that we may look at in this recommendation is the utility function on female harvest of horseshoe crabs. Currently there is no value to harvesting female horseshoe crabs, unless the female horseshoe crab population estimate has reached 80 percent of the carrying capacity within the Delaware Bay, and that's 11.2 million crabs.

Then, once that threshold is reached females have value. You can see this, it's modeled as this knife-edged function. Into the future if we move forward with this new revised model, the carrying capacity might change, given the new underlying horseshoe crab population dynamics model.

Remember, our estimate of carrying capacity within the Delaware Bay is not an empirical estimate; it's based on theoretical modeling with the age-structured model that we currently use. Another question we might ask and explore is some proportion of K a suitable threshold, or should we move to some just absolute number of horseshoe crabs?

These things remain to be further discussed. The second recommendation is to move forward with using the Catch Multiple Survey Analysis Model for estimation and projection as the underlying horseshoe crab population model within the ARM Framework, and to reassess the ARM utility of female horseshoe crab harvest as a function of female abundance.

Recommendation 3 pertains to the red knot portion of the ARM Framework. McGowan et al in 2011, their published paper quantified the relationship between horseshoe crab abundance and red knot mass gain and survival. This paper then used data that was available from 1997 through 2008. Over time we've now doubled the amount of available data for this analysis.

It makes sense that it would be a good idea to go back, reanalyze that data, see if those relationships still hold, or if the parameters have changed. Also, within the ARM Framework we have three models describing the relationship between red knots and horseshoe crabs. The first model is horseshoe crabs do not limit red knots.

The second model is horseshoe crabs limit red knot fecundity, and the third model is horseshoe crabs limit red knot fecundity and survival. Within the ARM Framework we can apply weights to each one of these models; you know which one do we believe in the most? The current weight on each is 0.2, 0.4, and 0.4.

The third recommendation from our groups is to update the red knot survival mass gain model with the most recent data, and also to evaluate the red knot model weights. Recommendation 4 pertains to incorporation of biomedical data. We've been previously tasked by the Board to come up with options on how best to incorporate biomedical mortality into the current ARM Framework.

By moving to the Catch Multiple Survey Analysis as our assessment model, the biomedical mortality is accounted for in the population estimate, because that is one of the direct inputs of removals of horseshoe crabs. Biomedical mortality can also be modeled in projections of the horseshoe crab population dynamics model, while making optimum bait harvest recommendations on into the future. We can assume an average of the past few recent years, assume that would continue to take place from the biomedical industry, and put that into our projections. The Catch Multiple Survey Analysis use does not alter the harvest packages that could be recommended, so it does not require a new addendum. Recommendation 4 is use of CMSA accounts for biomedical mortality in the ARM Framework, which is a previous Board task, so we can consider that accomplished.

Recommendation 5 pertains to data confidentiality issues, which have been discussed over and over, you know at all levels within horseshoe crab management. Again we have our Rule of 3, and within Delaware Bay there are more than three biomedical companies, but if we disclose the number of biomedically bled crabs within Delaware Bay, then the companies in the northeast and the southeast would then be able to figure out what each other had bled on an annual basis.

The annual population estimates from the Catch Multiple Survey Analysis could be used to back calculate the biomedical mortality in the Delaware Bay. That is where we run into our confidential issue. We're still stuck with a conundrum of a black box assessment with real data versus non-confidential data assessment that is less accurate.

Our recommendation to handle this, and there is quite a few words on this slide, first we would request disclosure of confidential biomedical data for use in the base run of the CMSA estimate. If the Board does not agree with making the request or the companies say no to the disclosure, then we should run the CMSA with the confidential biomedical data with 15 percent mortality applied, run it without biomedical data, and run it with non-confidential coastwide biomedical data with 15 percent mortality applied.

The harvest package will be made based on the population estimates from the CMSA that includes confidential data, as it represents the best dataset available. But we would also publish 0 percent biomedical and coastwide biomedical population estimates to represent population balance.

Recommendation 6 pertains to Delaware Bay origin crabs. What is a Delaware Bay Crab? Our working definition for the last several years has been a crab that could spawn within Delaware Bay during some portion of its life. Here is how we like to think about it. We have the map here on the left showing the area that's covered by the Virginia Tech Trawl Survey.

With the VIMS diagram there you can think of the Virginia Tech crabs that are encountered by the Trawl Survey are all crabs that can spawn within Delaware Bay. But some portion of them you have crabs that occur in Maryland waters and crabs that occur in Virginia waters. What proportion of each one of those could spawn in Delaware Bay at some point in their life?

The harvest allocations under Addendum VII were based on genetic information that was available at the time. We now have new genetic information, and we also have new tagging analysis coming out of our 2019 stock assessment that quantifies movement rates from into and out of the Delaware Bay area.

Recommendation 6 is just to more formally reevaluate the definition of Delaware Bay crabs, and the implications towards the population estimates and harvest allocations that come from the ARM. Just to recap all of our recommendations. The first one is for input into the ARM combined primiparous, multiparous crabs and decrement it by half a year's mortality. The second recommendation was to move forward using the Catch Multiple Survey Analysis model for estimation and projection, and reassess the utility function of female crabs.

The third recommendation is to update red know survival mass gain, and evaluate red knot model weights. The fourth one is to use the CMSA, because it accounts for biomedical mortality within the ARM Framework. The fifth recommendation outlines a path forward to deal with the confidential data issue.

We can request access and public disclosure of the confidential data, and if not we run the Catch Multiple Survey Model with the real confidential data, but then put bounds on the resulting population estimate based on either 0 biomedical, or the coastwide biomedical harvest. Finally, recommendation 6 was to reevaluate the definition of Delaware Bay crabs and what implications it has towards population estimates and harvest allocations.

Implementation of these recommendations, first we would need a formal charge by the Management Board to the ARM Workgroup to incorporate these recommendations. After that we would have obviously several in-person meetings or webinars, you know maybe not the entire ARM Workgroup, maybe it's just a subset of us that are actually doing the hard computer program coding.

I want to reiterate that we do have a funded USGS Post-doc position for model coding, and we could be fully moving forward by March of 2020, and have this completed by March of 2021 or by the end of 2021. After that we would, you know like any stock assessment process, we would present the results to the Delaware Bay Ecosystem Technical Committee. Because this is such a radical change to the ARM modeling framework, it would require an external peer review.

After that a presentation to the Management Board, and approval for management use. In reality from this point, we're probably looking at an approximate two-year timeframe before implementation of all these recommendations could be implemented. Until then the current ARM Framework would continue as is as we've been doing for the past number of years. With that I'll take any questions.

CHAIRMAN RHODES: I want to thank you for the presentation. You hit a lot of points that we've talked at in here over the years, and you clarified them well, and brought them down to those six working points, which was I thought very helpful. I'll turn it over to the Board, any questions, yes, Mr. Hyatt?

MR. BILL HYATT: I've been hearing from a number of people who are expressing the opinion that egg density on spawning beaches can somehow be figured into this assessment over time. Their argument is largely based upon data that they say has accumulated over time showing that the egg densities are nowhere near what they were in the 1990s on many of these beaches. I was wondering if you could just speak to that a little bit. I believe I've seen in some of the materials that that issue has come up at your meetings. I don't know if it's ever been discussed or brought up before this group at all, but I appreciate if you could just lend some insight to that.

DR. SWEKA: We've talked about egg densities and the use of that data in our stock assessment very extensively, you know ever since before the stock assessment in 2009. The problem with the egg density data is that it's highly variable. Methodologies have changed, even the comparison to the egg densities that were in the literature back in the '80s and '90s, you know methodologies have changed. The data is highly variable.

The state of Delaware a few years ago stopped doing their egg surveys because we weren't using them for any stock assessment purposes, so now it's just New Jersey that's continuing to do the egg density estimation. Also there were differences in methodology between Delaware and New Jersey, just differences in the methods of processing the egg samples.

The egg density information, I mean it is a check. It could be viewed as kind of a qualitative check on abundance, but the Stock Assessment Subcommittee, the ARM Workgroup, overall we've just considered it not reliable enough to use as an index of what is available for horseshoe crabs.

Also at the same time, Conor McGowan's work relating, you know we already showed a direct relationship between red knot mass gain and survival, and abundance of adult female horseshoe crabs. We already have that direct linkage there that we don't have to add another step in there with eggs.

CHAIRMAN RHODES: Roy Miller.

MR. ROY W. MILLER: Dr. Sweka, thank you for the presentation. A question concerning that graph you showed with the knife-edged utilization of female horseshoe crabs. Did you say there has been consideration given to some harvest of females that would not be knife edge, but be gradually phased in to flatten out that particular graph a little bit?

DR. SWEKA: I don't know if we've really discussed how the function might change. But moving forward with this new Population Dynamics Model, where that threshold is at 11.2 million, you know that could change. It is a possibility to have a different utility function. That is something that would have to be discussed amongst stakeholders and among the ARM Workgroup members.

Everything is on the table. I mean back after the 2009 stock assessment when the ARM Model was first peer reviewed that was a question even by the peer reviewers. Should it be a knife-edge function like this? Is 11.1 million too few females to have any harvest, but 11.2 million is okay.

MR. MILLER: Yes that is just kind of what I was thinking. I wondered if we ramped up harvest of females at something less than 11.2 coming up to the full utilization that's something beyond 11.2, if that might ease the pressure on New York, for instance, to supply female horseshoe crabs for the industry.

DR. SWEKA: I mean all I can say at this point is the utility function is something that we would look at, and possibly throw out a couple options for that utility function in the revised model.

CHAIRMAN RHODES: Mike Millard.

DR. MIKE MILLARD: Thank you, John for that report. I wonder if we could jump back to that slide that has the three competing models about the relationship between horseshoe crabs and red knots. It's embedded within the ARM. We've been at this I guess since 2013 with the ARM Model. Is there some way that we're able to see, or is there some clarity emerging about which one of these models is doing the best job or best describes the system?

DR. SWEKA: Yes we could, you know through Bayesian model updating, we could look at where we started and where we end up currently. We've seen that female horseshoe crab abundance has increased, and the red knot abundance has kind of stayed steady. Given the empirical data, perhaps we would start to put a little more weight on the first model, and a little less weight on the others.

That might be one option. How these weights were originally developed was through expert opinion. We went around the table among the ARM Workgroup members, and everybody threw out which model they had the most faith in based on expert opinion, so we could also elicit expert opinion once again to update some of these model weights.

CHAIRMAN RHODES: Are there any further questions? Tom Fote.

MR. THOMAS P. FOTE: I really don't have a question coming from me, but I have a question that I was asked about three years ago while I was sitting in a room, and I was at a conference and basically wound up in a room with former Governor Christine Todd Whitman of New Jersey. The first two questions she asked me in this room, now this is 20 years later after her being governor and going to EPA and everything.

She says, how are my horseshoe crabs going and red knots, and how is the glass eel situation? I had to give a 15 minute briefing. I always said, God you never think you get to the governor on issues like this, and here it is 22 years later and she's still worrying how the glass eels and the horseshoe crabs are. It's amazing how important things stick in their minds, so it reaffirmed the job I do representing the governor.

CHAIRMAN RHODES: Chris Wright.

MR. CHRIS WRIGHT: In the review process of this next thing, is it just going to be the Delaware TC that is going to be presented? I would think that we should also do this to the regular Horseshoe Crab TC.

DR. MIKE SCHMIDTKE: With the structure that was put in place related to the TCs when the Delaware Bay TC was formed. That one is kind of on equal footing, so to speak, with the Horseshoe Crab TC. If the Board wants both TCs to review this then that is something that may be able to be done, but the structure that is currently in place is the ARM Subcommittee reports to the Delaware Bay TC, Delaware Bay TC reports directly to the Board. The Delaware Bay TC does not report to the Horseshoe Crab TC, so they kind of operate in two different realms there.

MR. WRIGHT: I would prefer that the TC would look at it. I mean it's hard to make judgments on things if we don't get a broad perspective.

CHAIRMAN RHODES: Bill Hyatt.

MR. HYATT: Just going back to the comment you made a few minutes ago relative to not seeing an increase in the red knots relative to the concurrent increase in horseshoe crabs. This would speak back to the question that they asked earlier. The folks that I'm hearing from would argue that simply seeing the increase in the crabs does not mean you're seeing an increase in the eggs on the beaches, which would relate to the impact on the red knots. I think that is largely the thesis behind their desire to at some point in this process have some index of egg density on these important beaches as part of the process, so just a comment.

CHAIRMAN RHODES: Are there any further comments or questions? Stew.

MR. STEWART MICHELS: John, if the Board chooses to move forward with recommending to the group that they follow through on this. Would it also make sense to also charge this group with giving consideration to alternate suite of, perhaps harvest packages at that same time, or do you think it should be get one out of the way first before we initiate looking into a suite of harvest packages?

DR. SWEKA: I guess from a technical standpoint it really doesn't make a lot of difference in the technical modeling. If the management board would like to choose a different suite of harvest packages, I guess that is up to the management board's discretion to make that recommendation to us, and we could obviously evaluate any number of harvest packages that are put forth.

CHAIRMAN RHODES: Are there any further questions?

DR. SCHMIDTKE: Just one note related to Stew's question, if alternate harvest packages were to be actually approved for implementation that would have to happen through an addendum process. They could be explored through this process simply by Board direction, but any approval or use of alternate harvest packages would have to go through addendum process.

CHAIRMAN RHODES: Mike Millard.

DR. MILLARD: I want to follow up on that a little bit. My understanding is regarding female harvest. If we were to change the packages, and maybe include more opportunities for female harvest that as it stands now, if the threshold for the utility function, females have no value. Until that is met, the model will never pick a package with females in the harvest. Do I have that correct?

DR. SWEKA: Yes that is correct.

DR. MILLARD: Well if I could follow up. Your recommendation Number 2 is going to possibly address that about changing the threshold when females have value.

DR. SWEKA: Yes. We change that threshold; perhaps a different harvest package would be selected.

CHAIRMAN RHODES: That would be at the adoption in two years; hopefully two years from now when everything is prepared and we're looking at specs for the 2022 season would be the earliest we would be looking at that I would think. Yes, okay. But at this point what is the Board's desire? Do we want to charge or make a formal recommendation and charge to look at all six of these areas? Do we need to discuss any parts of it? I'm going to turn it over to the Board at this point. Stew.

MR. MICHELS: I would very much be interested in charging the Delaware Bay ARM Working Group and Delaware Bay Ecosystem Technical Committee, is that what it's called, with exploring these recommendations further. Do they have a motion prepared?

CHAIRMAN RHODES: We don't need a motion. All right I'm seeing a lot of heads shaking. Is there any objection to moving forward with these six areas, recognizing that the first one would actually become implemented this year? We would start with that immediately.

DR. SCHMIDTKE: Just one clarification. What has been said, the ARM Subcommittee would be the group that is actually doing the work. It would be subject to review by the Delaware Bay TC, and as the Board has expressed interest in the Horseshoe Crab TC also reviewing this work. Both of those groups could be part of the review, but the ARM Subcommittee would be the group that's actually doing the work and charged with that task.

CONSIDER RE-INITIATION OF POSTPONED DRAFT ADDENDUM VIII

CHAIRMAN RHODES: We'll move on to the next item in the agenda, and this actually ties in to quite a few things of what we talked about. Several meetings ago we started talking about a Draft Addendum VIII, we discussed it at the last meeting, and it's being brought up again. At this point I'm going to turn it over to Mike to do a quick synopsis through it, and I think it may be clear where we move forward from that point, considering what we just did.

DR. SCHMIDTKE: This is just going to give a brief timeline of what happened with Draft Addendum VIII, as far as its development, and then its eventual postponement, bringing us to this meeting today where it's being considered for either reinitiation or not. In August 2016, Draft Addendum VIII was initiated with two main goals of incorporating mortality associated with the biomedical industry into the ARM Model, and then exploring bait harvest packages that would allow female horseshoe crab harvest.

There is an appendix in the ARM Framework Review from 2016, but the basic gist of this is there were additional harvest packages that were proposed that would allow female harvest in a more limited fashion than the five that are currently used. In October 2016, there was a motion approved to postpone development of Draft Addendum VIII until after the benchmark stock assessment was completed.

That was completed earlier this year, but in the meantime October of 2017 the Board was presented with ARM sensitivity runs, or alternative runs that were conducted on two biomedical mortality inclusion options, and these two different options, both when they included showed minimal impact of biomedical mortality on the harvest package selection. The Board also received clarification in October of 2017 that of how the utility function works in the ARM Model for females in that unless horseshoe crab females or red knots exceed their respective threshold, no female harvest would be selected by the model regardless of any alternative or additional harvest packages that would be added to the Framework.

In May of 2019, the benchmark stock assessment was completed, leading to the Board needing to consider Draft Addendum VIII, and whether it would proceed further. In the benchmark stock assessment there were runs conducted with and without biomedical mortality in the Delaware Bay for females in that region.

The results showed no significant impact of this mortality on that population. Following this the Board tasked the ARM Subcommittee with incorporating the stock assessment model, which is what John just went through. That brings us to today, where the ARM Subcommittee and Delaware Bay TC have submitted recommendations that would incorporate biomedical mortality, and these recommendations would do so without the need for an addendum.

There are really two courses of action that the Board could take at this point. The Board could direct staff to resume development of Draft Addendum VIII, or if the Board does not desire to resume development of this draft addendum, then there would need to be Board action indicating such.

CHAIRMAN RHODES: Any members of the Board want to discuss this action? Yes, Mike.

MR. MICHAEL LUISI: In thinking back to the interest that I know we had in Maryland when this Addendum was initiated. It was to explore. You know the piece that I remember most vividly was the exploration of harvest packages that could include female harvest, given that we were making a shift in our bait industry from a male/female combined harvest to a male only harvest.

There were a lot of concerns by the industry that that shift to male only was going to impact their markets. Since then the issue has subsided, and I believe that our industry has found some balance with the male only harvested at this point, and they're focused very heavily on that biomedical industry as well.

Personally, I don't think we as in the state of Maryland have the same interest at this time. I think it's been generally accepted that knife-edge modeling approach to having both red knots and horseshoe crab biomass at a certain point before females can be harvested again. It's kind of a generally accepted term, I think at this point.

I look forward to the work that's going to be done over the next few years. If it were up to me I would say let's not focus any more attention to revisiting this addendum. It would be my opinion that we could probably put it to rest, and allow for staff to work on developing the work that was just presented by Dr. Sweka. That would be my opinion, thank you.

CHAIRMAN RHODES: Mike, if I'm hearing what you are saying, you would like to make a motion to postpone indefinitely the development of Draft Amendment VIII.

MR. LUISI: I can do that, sure.

CHAIRMAN RHODES: I appreciate it, do we have a second? We have a second by Chris Wright. Is there any objection to this motion? Seeing none it is accepted unanimously.

SET 2020 HARVEST SPECIFICATIONS

REVIEW OF THE HORSESHOE CRAB AND RED KNOT ABUNDANCE AND HARVEST PACKAGE

CHAIRMAN RHODES: Dr. Sweka, we move back to you for the Review of the Horseshoe Crab and Red Knot Abundance and Harvest Package.

DR. SWEKA: Okay this is our annual update on the status of both red knots and horseshoe crabs, and to make a harvest recommendation for the next harvest season. Within the adaptive resources management framework, our underlying objective is to manage the harvest of horseshoe crabs in the Delaware Bay to maximize harvest, but also maintain ecosystem integrity, and provide adequate stopover habitat for migrating shore birds.

We have both red knot and horseshoe crab population thresholds, which describe when the harvest of female horseshoe crabs has value. We have red knot and horseshoe crab abundance estimates each year coming from the Virginia Tech Trawl Survey, which surveys in the fall, and then the red knot population estimate comes from a mark-resight population estimate conducted each spring.

As you know there are five possible harvest packages, and annually we make our harvest recommendations based on the status of red knot and horseshoe crabs. Just to recap and refresh everyone's memory on the five harvest policies or harvest packages that we have. They range from a full moratorium to a maximum harvest of 420,000 males and 210,000 females, including two male-only-harvest options.

Harvest Package 1 is the most conservative, which is a full moratorium on both sexes, and they ramp up to Harvest Package 5, which allows harvest on both males and females. For the past several years since the ARM Framework has been used for management, we've been implementing Harvest Package 3; things haven't changed significantly enough to alter that recommendation.

The population thresholds, female horseshoe crabs have value to harvest, once 80 percent of the theoretical model-based carrying capacity is reached, and that is 11.2 million female crabs. The abundance threshold for red knots is 81,900 birds and that if their population reached that then female horseshoe crabs have value to harvest.

We also want to maintain a spawning beach sex ratio of at least two males to every female, and this is so that we don't harvest so many males that egg fertilization may be compromised by a female dominated sex ratio. If both populations are below the threshold there is no female harvest, and if the sex ratio falls below two to one, there is no horseshoe crab harvest.

For red knot abundance, this graph shows the time series that we have with the population estimates in blue and confidence intervals, and in green are the peak red knot counts from aerial surveys flown over the beach every spring. In 2019 estimates were similar to estimates from 2016 to 2018. In 2019 the estimated stopover duration for birds that arrive at the beach was 12.1 days, which was slightly more than in 2018, which was 9.7 days. In 2019, the estimate was 45,133 red knots stopping in the Delaware Bay, which is obviously below the threshold of 81,900 birds.

For horseshoe crab abundance, again it's based on the Virginia Tech Trawl Survey. The trawl survey wasn't funded every single year. There was a gap between 2013, well actually 2012 and 2015, where we came up with a composite index based on the Delaware 30 foot trawl, New Jersey/Delaware Bay Trawl, and the New Jersey Ocean Trawl, and we found the relationship between that and the Virginia Tech Trawl when there were overlapping years.

In 2018 there was an estimate of 7.9 million females, which that is also under the 11.2 million threshold. But as you can see from 2009, generally from 2009 through 2018 we have a general increasing trend in the abundance of female horseshoe crabs, and also the abundance of males, although the last couple of year's males have declined slightly.

In 2018 there were 7.9 million females, and 16.6 million males. We put these together, our crab abundance and our red knot abundance. You know we see the numbers I just discussed. Ultimately from the ARM Framework the recommended harvest package is once again Package Number 3, which calls for a male-only harvest of 500,000 males. Both red knots and female horseshoe crabs are below the threshold, which would give the harvest of female's value, so therefore no female harvest is recommended.

When we partition this out among the states, these are each states quotas according to the allocation scheme that was developed in the last addendum. For Delaware Bay origin crabs, and then also the total quota, which accounts for the proportion of Maryland and Virginia's crabs that are not of Delaware Bay origin, and also the two-to-one male-to-female offset that was adopted during the last addendum? I'll take any questions.

CHAIRMAN RHODES: Any questions, Mike Luisi?

MR. LUISI: I may have missed it in the past, but you mentioned John that the spawning beach sex ratio is something that could have an effect to which crabs are able to be harvested, if that sex ratio were to drop below two-to-one. What is the current ratio as we understand it right now?

DR. SWEKA: It is definitely on the beach it is over two, Stew is indicating up around five. Was it 5.2 in our last assessment, you know most recent data? Yes, it's very skewed towards male, despite having a male-only harvest for a number of years now.

CHAIRMAN RHODES: Are there any other questions? All right I'm looking for a motion to accept harvest package from the Board. Stew Michels.

MR. MICHELS: Motion to accept the recommended harvest package for management.

CHAIRMAN RHODES: Second, Mike Millard, any discussion, any objection, all right seeing none that motion passes also.

CONSIDER FISHERY MANAGEMENT PLAN REVIEW AND STATE COMPLIANCE REPORTS

CHAIRMAN RHODES: Mike we'll turn it over to you for the FMP and State Compliance Reports.

DR. SCHMIDTKE: The Horseshoe Crab Plan Review Team conducted the 2019 FMP Review. That report was provided in the supplemental materials for the meeting, and I'll give a brief summary of that right now. The FMP was approved in 1998; there are seven addenda, the most recent of which established the ARM Framework for managing in the Delaware Bay.

Looking at a figure of annual total harvest, we see the coastwide bait harvest decline shortly after the FMP was established, and has remained fairly consistent since about 2004. Coastwide biomedical only collections and the estimated biomedical mortality have also been fairly consistent, going back to about 2010. There was some period of increase in earlier years, but most recently both uses of horseshoe crab have remained fairly consistent.

In 2018 bait harvest was 658,589 crabs, the majority of which came from Massachusetts, Virginia, and New York. This was a 35 percent decrease from bait harvest in 2017, and it accounted for about 41 percent of the coastwide quota. There was one overage that was noted. Delaware had an overage of a reduced quota.

They had an overage in 2017, therefore they adjusted their quota in 2018, and they exceeded their adjusted quota by about 3,000 crabs, so they have reduced their quota again for 2019 as well. Looking at the biomedical use, there were about 464,000 biomedical only crabs collected in 2018. This was a slight decrease from 2017, leading to a mortality estimate of about 71,000 crabs.

The biomedical only mortality estimate, as a reminder it includes the reported number of crabs that were observed dead during the bleeding process, with an addition of 15 percent multiplied by the number of crabs that were bled. The biomedical mortality accounted for 10 percent of the directed removals, directed removals being defined as the biomedical use as well as the bait harvest.

The FMP allows for states to request *de minimis* status if they have a combined average for bait landings in numbers of crabs for the last two years. That is less than 1 percent of the coastwide landings for the same period. *De minimis* states are exempt from a required harvest cap. There are four jurisdictions that requested de minimis, PRFC, South Carolina, Georgia, and Florida. All of these qualify for *de minimis* status in 2019.

New Jersey did qualify, as they are in a moratorium for horseshoe crab bait harvest, but they did not request this status. The Plan Review Team developed the following recommendations. As the first one that the Board would continue seeking long term funding for the Virginia Tech Trawl Survey.

This is the basis for a lot of work that goes on for horseshoe crabs in the Delaware Bay, as well as for the stock assessment model use in that region. It has been funded through 2020, but the PRT recommends the Board continue seeking that long term funding for this survey. There have been some issues, as far as turning in compliance reports on time. The current due date for those reports are March 1, and for several years now there have been states that have had difficulty meeting this deadline. Most of the time compliance for this species hasn't been reviewed until the summer of the fall meeting anyway, so in a way to try to accommodate the needs of states and their scheduling, as far as when their data is available.

The PRT recommends that the Board would change the due date to July 1. This would allow kind of a similar timeframe for review in either the summer of the fall. The PRT also recommends that the Board encourage and continue to monitor the actions that are being taken to reverse the negative population trends in the New York region.

The Board gave direction during the last meeting for this population to be monitored, since it has a poor status from the last assessment. There are data included in the FMP review for this region. The most recent data for all of the state surveys that are conducted in that region have shown an increase from the previous year, but the PRT will continue to monitor the progress of this region going forward.

The FMP requires the Board to consider action if the biomedical use and the mortality associated with the biomedical use rather, exceeds the threshold spelled out in the original FMP. The mortality did exceed this threshold. The threshold I believe is 57,500. The use did exceed that threshold, but the PRT would note to the Board that the assessment results do not indicate significant mortality from the current levels of biomedical use.

Additionally, biomedical use has been consistent over the last ten years, and so it doesn't seem to be showing trends of increase associated with that. The PRT also would recommend that the Board continue to have a focus in directing staff and committees to look at the characterization of discard removals. That was a very significant component of mortality indicated from the last stock assessment, and the PRT just wants to kind of keep that as a focal point moving forward for directed efforts.

Discard removals are one thing that can be looked at through the recommended work from the ARM Subcommittee, so that is something that can be looked at moving forward. Finally, the PRT would recommend that the Board approve the 2019 FMP Review, State Compliance Reports, and *de minimis* status for the Potomac River Fisheries Commission, South Carolina, Georgia, and Florida.

CHAIRMAN RHODES: Great thank you, any questions from the Board? Yes, Joe.

MR. JOE CIMINIO: I'm curious on that last point. If either the TC is going to explore other possible places where they might find information on discards, or if maybe the PRT is suggesting to states to maybe try and find new ways to get out there and estimate discards.

DR. SCHMIDTKE: I think what was discussed within the PRT was one for states to focus on ways to improve the discard estimation, kind of the primary way that we rely on right now for getting that information is through Northeast Fisheries Observer Program. But if there is any way to improve the mortality estimates associated with some of the gears or for states to improve on their end, the estimation of those discards, then that would be encouraged. The other aspect of it that those would be kind of looked at on a more frequent basis. That is something that would be done, at least for the Delaware Bay through the recommended ARM work.

CHAIRMAN RHODES: Yes, Dan.

MR. DANIEL McKIERNAN: Is there a thorough description of where this bycatch is occurring seasonally, temporally, and what the target species is for those trips that are creating bycatch and discards?

DR. KRISTEN ANSTEAD: I can answer that. That was a big comment from our peer review. We just took a stab at the bycatch, and we did it on an annual basis for all of Delaware Bay. That resolution might not be there for seasonal, plus by state, plus by gear, plus by target, but it's certainly something that with this approved, passed forward for the ARM that we would consider looking at. We'll have that resolution in the data, but we're certainly going to give it another try.

CHAIRMAN RHODES: Any other questions? All right I'm looking for a motion, all right Steward Michels.

MR. MICHELS: Okay, motion to accept the PRT Report and Requests for *de minimis* status. There you go, how about this.

CHAIRMAN RHODES: Would you like to read that report?

MR. MICHELS: Move to approve that 2019 Fishery Management Plan Review, State Compliance Reports and *de minimis* status for Potomac River Fisheries Commission, South Carolina, Georgia, and Florida.

CHAIRMAN RHODES: Thank you, second by Mr. Bell. Is there any discussion, any objection? Seeing none, that passes unanimously also.

OTHER BUSINESS

CHAIRMAN RHODES: Is there any other business? Yes, Mr. Miller?

MR. MILLER: It's a very minor thing, Mr. Chairman, but I noticed in one of our handouts the Horseshoe Crab Harvest Recommendation based on Adaptive Resource Management ARM Framework, and most recent monitoring data. I spotted a small typo at the bottom of the page. It probably should be corrected. The last under monitoring data it shows red knot abundance time 1,000. I think there is a decimal point mistake in that so it should come to 45,000 as opposed to 4,500. Thank you.

CHAIRMAN RHODES: Thank you for pointing that out and that will be altered. Any other business, yes Mr. Michels.

MR. MICHELS: Just one more thing. There was a recommendation in that Plan Review Team Report for July 1 report due date. Does this motion adequately address that?

CHAIRMAN RHODES: If you would make that motion that would give specific direction that would be great.

MR. MICHELS: Okay, therefore I move to adopt a July 1 due date for annual compliance reports for the horseshoe crab fishery management plan.

CHAIRMAN RHODES: Thank you, and a second by Mr. Bell. Is there any discussion, any objection? Seeing none, okay the motion is move to adopt a July 1 due date for the State Compliance Reports for Horseshoe Crab, motion by Mr. Michels, second by Mr. Bell. Again, are there any objections? Seeing none, it passes unanimously. Mr. Luisi.

MR. LUISI: No objection, I just wanted to bring up another one of the recommendations that I thought I heard regarding the stock condition in New York. Mike, was there anything? I listened to you, but if you could just go back to what the Plan Review Team was suggesting, or do we need to take any action to start any work down that path?

DR. SCHMIDTKE: From the previous Horseshoe Crab Board meeting, New York has already started taking some actions on the state level, and I believe Connecticut may be moving down that path as well, so the Board kind of accepted that the states would take responsibility for actions in their state, and that the Plan Review Team would just monitor the progress to this point. If anything were to happen further, then the Board could consider that at a later time.

ADJOURNMENT

CHAIRMAN RHODES: Thank you for the clarification. If there is no other business then this meeting is adjourned.

(Whereupon the meeting adjourned at 10:50 o'clock a.m. on October 29, 2019)

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 2020

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
Sources of data for horseshoe crab abundance were a set of trawl surveys conducted by Virginia Tech university.[2] Red Knot abundance estimates are taken from a mark-resight estimate for red knot abundance[3]. These data and methods can be evaluated in the respective reports from those studies.

Horseshoe crab abundance (millions)			Red knot abundance	
Year	Male	Female	Year	Male and female
2019 (Fall)	8.9	4.7	2020 (Spring)	40,222

Harvest recommendations

Decision matrix was optimized incorporating recommendations on red knot stopover population estimates and associated calibration of red knot threshold[4]. I followed the accepted procedure used in all past years where the empirical abundance estimates did not exactly fit the discretized population size "bins." For each empirical estimate I use the closest discretized abundance "bin" that was not larger than the estimate, in other words I rounded down to the nearest bin.

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] Virginia Tech Trawl Survey report, January 15, 2019

[3] Jim Lyons' 2019 estimate in the 10 September, 2019 Memo

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

Results of the 2019 Horseshoe Crab Trawl Survey:

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

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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 relative abundance of demographic groups with results from previous years. Mean catch-per-tow of immature and newly mature horseshoe crabs in the coastal Delaware Bay area have been variable since 2002 with no trend. Mean catch-per-tow of mature females and males are correlated, and both appear to display an increasing trend over time. Mean catches of immature and mature crabs in lower Delaware Bay are generally larger than catches in the coastal area, although usually not statistically significantly so. Mean catch-per-tow and population estimates of newly mature males are correlated with values for newly mature females of the same year-class the following year. Our findings will be used to parameterize the Adaptive Resource Management model used to set annual harvest levels for horseshoe crabs.

Introduction

To properly manage the mid-Atlantic horseshoe crab (*Limulus polyphemus*) fishery, accurate information on relative abundance levels and trends is needed. The Adaptive Resource Management model (McGowan et al. 2011) adopted by the ASMFC requires annual, fishery-independent indices of newly-mature recruit and adult abundances. 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 relative abundance and demographics. Here, we report our cumulative results through the fall 2019 trawl survey.

We have provided the Adaptive Resource Management (ARM) Subcommittee relative abundance estimates of horseshoe crabs in the DBA and LDB surveys to inform the ARM model runs. Herein, we present the population estimates through the 2019 survey. Gear catchability has not been evaluated for these estimates, so they should be considered conservative.

Methods

The 2019 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, and again from 2016 to 2018. 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 and in 2016-2018. Due to frequent and prolonged weather delays, the surveys were conducted over a protracted period from 30 August to 19 October 2019.

The DBA survey area was stratified by distance from shore (0-3 nm, 3-12 nm) and bottom topography (trough, non-trough) 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 an 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. Start and end positions of each tow were recorded when the winches were stopped and when retrieval began, respectively. Bottom water temperature was recorded for each tow. We sampled 45 stations in the DBA survey and 8 stations in the LDB. Three planned LDB sites were not completed due to excessive vegetation.

Horseshoe crabs were culled from the catch, and either all individuals or a subsample were examined for prosomal width (PW, 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. Means calculated using the normal-distribution model are additive, within rounding errors.

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.

The average 15-minute tow in the DBA was 1.17 kilometers at 4.7 KPH. The average 15-minute tow in the LDB was 1.20 km at 4.8 KPH. Valid net-spread measurements were obtained from 46 tows and averaged 10.1 meters. We used the net-spread (*S*, in meters)/tow speed (*C*, in KPH) relationship developed from previous trawl surveys to estimate net-spread for collections in which net-spread was invalid or not measured ($S = 13.84 - 0.858 \times C$).

For each tow, catch density (catch/km^2) was calculated from the product of tow distance (in km) and estimated net-spread (converted from meters to km) assuming that all fishing was done only by the net, and that there was no herding effect from the ground gear (sweeps):

$$\text{catch/km}^2 = \text{catch/[tow distance (km)} \times \text{net-spread (km)]}.$$

Within each stratum, the mean catch per square-kilometer and associated variance were calculated assuming a normal-distribution model and a lognormal delta-distribution model. Stratum mean densities and variance estimates were combined to produce a stratified mean density ($\bar{X}_{st}$) using formulas for a stratified random sampling design as with the catch-per-tow estimates described above. Population totals were estimated by multiplying stratified mean density ($\bar{X}_{st}$) by survey area (DBA = 5127.1 km^2; LDB = 528.4 km^2):

$$\text{Population total} = \bar{X}_{st} \times (5127.1 \text{ or } 528.4 \text{ km}^2).$$

Results

Delaware Bay area

Stratified mean catches-per-tow for all demographic categories were relatively consistent from 2016 to 2019 (Tables 1 and 2; Figure 2). Stratified mean catches of mature females and males have been variable over the time-series, but are significantly correlated ($r = 0.854$; $T = 5.70$; $p < 0.001$; $n = 14$). Both mature females and males were relatively less abundant in 2019 than in the previous five years. Yearly trends from the delta- and normal-distribution models followed similar patterns for all demographic groups.

Mean catches of newly mature males generally are correlated with mean catches of newly mature females the following year in 2002-2018 ($r = 0.746$; $T = 3.36$; $p = 0.008$, $n = 11$). However, by adding results in 2019, the correlations are not statistically significant any more ($r = 0.393$; $T = 1.35$; $p = 0.206$, $n = 12$), potentially due to low mean catches of newly mature females in 2019.

Lower Delaware Bay

This was the seventh year of sampling within the Delaware Bay. Stratified mean catches of immature female and male crabs and newly mature female crabs in 2019 were the least for the time-series (Tables 3 and 4; Figure 3). Mean catches of mature females were lower than in 2019, although not significantly different based on overlapping confidence limits. Mean catches of mature males are significantly correlated with mean catches of mature females ($r = 0.894$; $T = 4.47$; $p = 0.007$; $n = 7$).

Size distributions

Size-frequency distributions of immature horseshoe crabs in the DBA survey display considerable variability (Figure 4). 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 show that modal group in 2010 either (Figure 5).

We had previously reported that mean prosomal widths of mature and newly mature male and female crabs in the DBA survey displayed slight but detectable decreases over time (Hata and Hallerman 2017, 2019). Those trends appear to continue through the 2019 survey (Table 5; Figure 6). In addition, decreasing trends in mean PW were observed for mature females and males in the lower Delaware Bay survey, but an increasing trend was detected for newly mature males.

Sex ratios

Mature males were typically more than twice as numerous as mature females throughout the survey time-series. Sex ratios (M:F) from mean catch-per-tow in the DBA surveys ranged from 1.72 in 2019 to 3.64 in 2016, averaging 2.38 over all years. The ratio of newly mature males to females was highly variable, ranging from 0.11 in 2003 to 5.60 in 2019, and averaged 1.44. This may reflect sampling effects, 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 lower Delaware Bay than on the coast. Sex ratios (M:F) ranged from 2.60 in 2018 to 6.15 in 2016, averaging 3.98. As on the coast, sex ratios of newly mature crabs within the Bay were variable, and ranged from 0.45 in 2010 to 6.10 in 2012, averaging 3.09, with an exception of 2019 in which mean catches of newly mature females were zero. The higher sex ratios within Delaware Bay may reflect a tendency for male horseshoe crabs to remain near the spawning beaches.

Population estimates

Annual population estimates of immature crabs in the DBA survey mirror trends observed in the catch-per-tow estimates, and have been variable over time with a large peak in 2009 (Tables 6 and 7). Similarly, population estimates of newly mature crabs increased from 2002 to 2008, but have remained consistently low since 2009. Estimated numbers of mature males and females have been greater since 2006. Population estimates of mature females are significantly correlated with estimates of mature males (*r*

= 0. 854; $T = 5.68$; $p < 0.001$; $n = 14$), as observed for mean catches per tow above. Population estimates of newly mature females are significantly correlated with estimates of newly mature males ($r = 0.571$; $T = 2.41$; $p = 0.033$; $n = 14$). Population estimates of newly mature females are significantly correlated with estimates of newly mature males the previous year in 2002-2018 ($r = 0.745$; $T = 3.35$; $p = 0.009$; $n = 11$), as observed for mean catches per tow above. Assuming males entering the newly mature category are of the same year-class as females entering that category the following year, annual trends for males may forecast similar trends for females. However, population estimates of newly mature females are not significantly correlated with estimates of newly mature males the previous year when incorporating estimates in 2019 ($r = 0.403$; $T = 1.39$; $p = 0.195$; $n = 12$), as observed for mean catches per tow above.

Population estimates of immature crabs in lower Delaware Bay have been consistent with coastal estimates since the LDB survey began in 2010 (Tables 8 and 9). On average, 29% of the total number of immature females and 33% of immature males occurred within Delaware Bay, although the LDB sampling area composed only 9.3% of the total combined area. In 2019, 13% of immature females and 17% of immature males occurred within the Bay. Considerably fewer newly mature and mature crabs were in the Bay compared to the coast. Over the whole time-series, about 9% of the combined population of newly mature females occurred within the Bay, while 16% of newly mature males were in the Bay. In 2019, 0 and 22% of newly mature females and males, respectively, occurred within Delaware Bay. About 23% of mature females and 31% of mature males occurred within the Bay on average, with 18 and 39%, respectively, occurring within the Bay in 2019. Within the combined survey population, the sex ratio of mature males:females ranged from 2.24 to 4.07, and averaged 3.09, with a ratio of 2.34 in 2019.

Effects of sampling period

The 2019 DBA survey was conducted from late August to late September. The average bottom water temperature in 2019 was the highest in the time series (Table 10; Figure 7). The 2019 lower Delaware Bay survey was conducted in mid-October, nearly a month earlier than in 2018, and later than the DBA survey. As a result, the average LDB water temperature was 5.6 C° cooler than the average DBA temperature. Horseshoe crabs that were within the Bay during most of the DBA survey because of the warm temperature, and not enumerated, may have moved out of the Bay by the time the LDB survey was conducted, and again not enumerated. This may have resulted in underestimates of horseshoe crabs in both survey areas and contributed to the apparent decrease in mature M:F ratios in both survey areas since 2016.

When comparing survey time-frames and water temperatures, it appears that the DBA mean catches of immature crabs are correlated with mean sampling dates but not with water temperature; in contrast, mean catches of mature crabs were correlated with mean water temperatures (Table 11). Within the lower Delaware Bay, mean catches were not correlated with mean water temperatures or sampling dates.

Key findings

1. Mean catch-per-tow of immature male and female horseshoe crabs in the coastal Delaware Bay area have been variable since 2002 with no trend, and remain 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 2006 (males) or 2008 (females) and show no long-term trend.
3. Mean catch-per-tow of mature males and females in the coastal Delaware Bay area have been variable throughout the time-series, but show increasing trends since 2002.
4. Mean catch-per-tow of immature horseshoe crabs in the coastal Delaware Bay area may be related to sampling date. Mean catch-per-tow of mature horseshoe crabs may be related to water temperature.
5. Annual mean prosomal widths of newly mature and mature horseshoe crabs in the coastal Delaware Bay area show decreasing trends.

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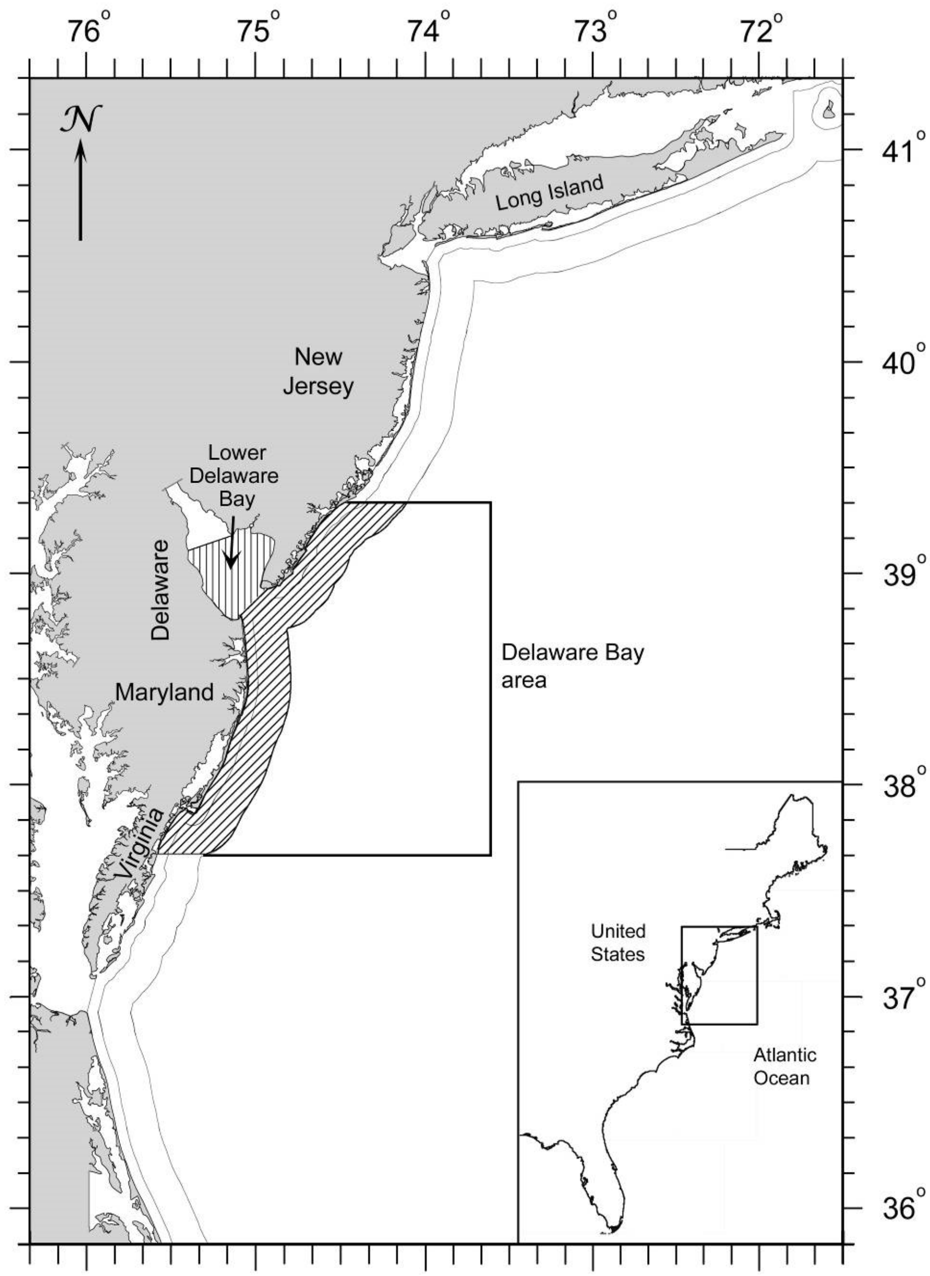


Figure 1. Fall 2019 horseshoe crab trawl survey sampling area. The coastal Delaware Bay area (DBA) and Lower Delaware Bay (LDB) survey areas are indicated. Mean catches among years were compared using stations within the shaded portions of the survey areas.

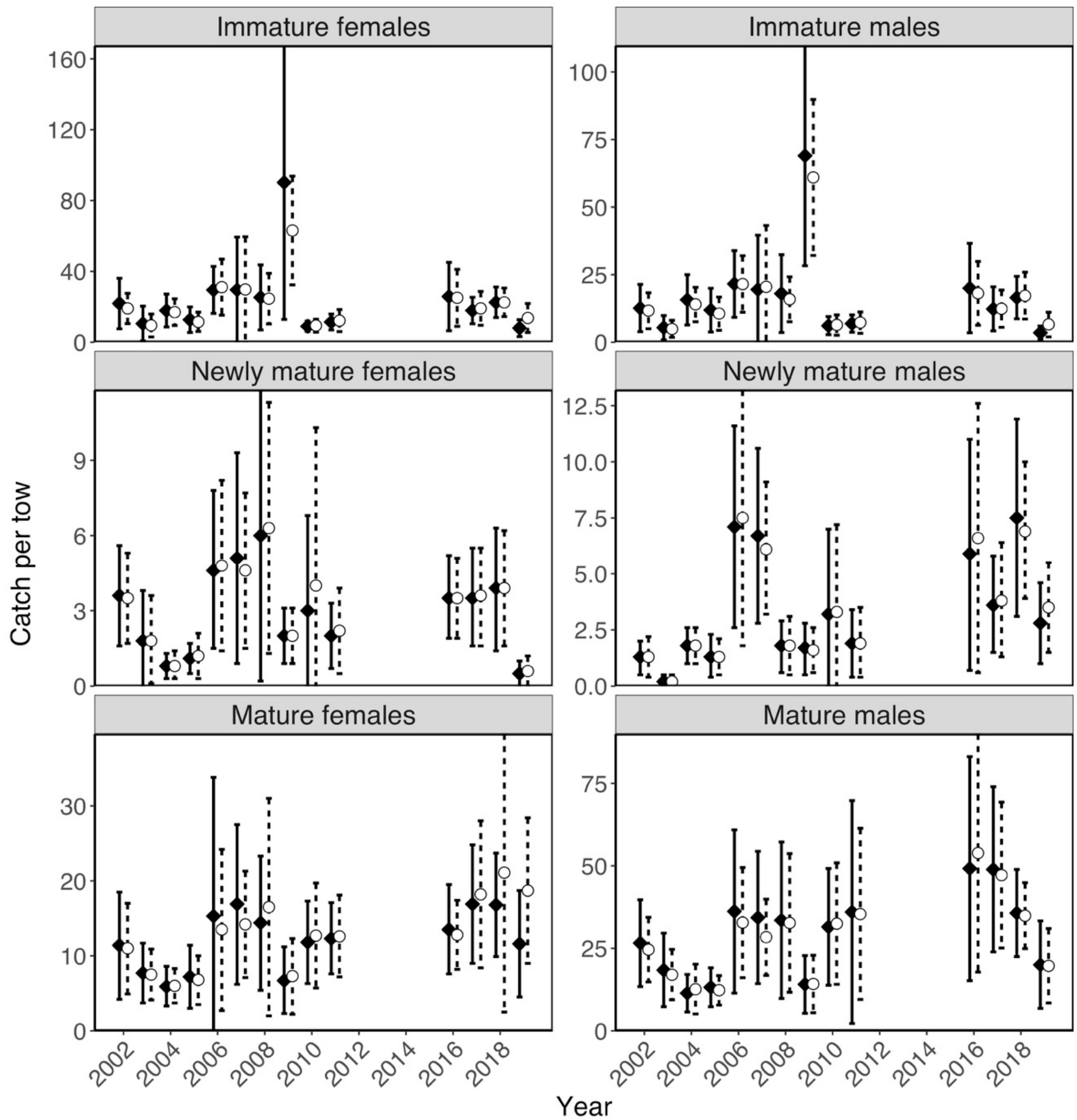


Figure 2. Plots of stratified mean catches per 15-minute tow of horseshoe crabs in the coastal **Delaware Bay area** survey by demographic group. Vertical lines indicate 95% confidence limits. Solid symbols and lines indicate the **delta distribution** model. Open symbols and dashed lines indicate the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

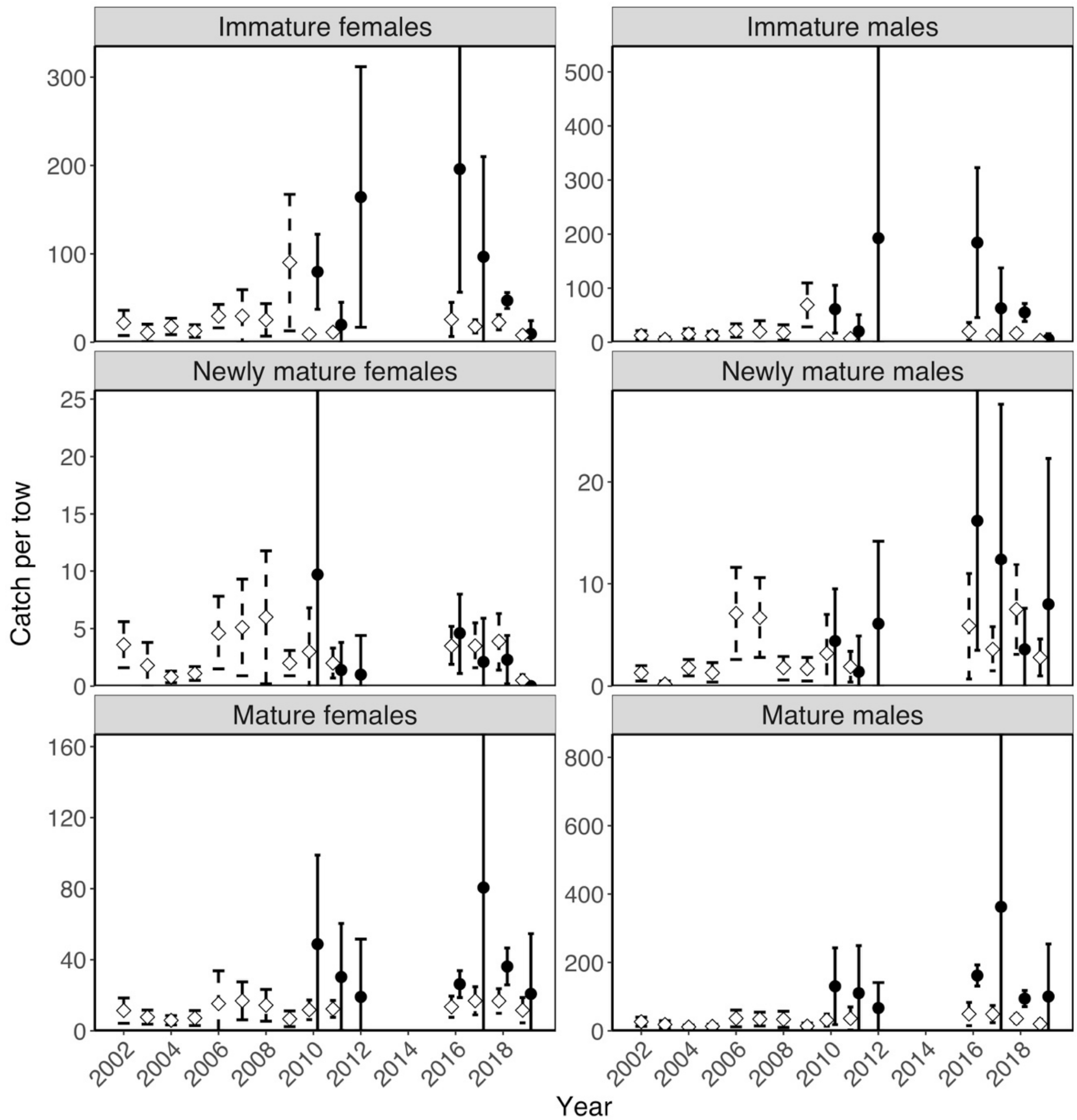


Figure 3. Plots of stratified mean catches per 15-minute tow of horseshoe crabs in the **lower Delaware Bay** survey by demographic group, with coastal **Delaware Bay area** survey means for comparison. Vertical lines indicate 95% confidence limits. Only the **delta distribution** model means are presented for clarity. Solid symbols and lines indicate the **lower Delaware Bay** survey. Open symbols and dashed lines indicate the coastal **Delaware Bay area** survey. Note differences in *y*-axis scales.

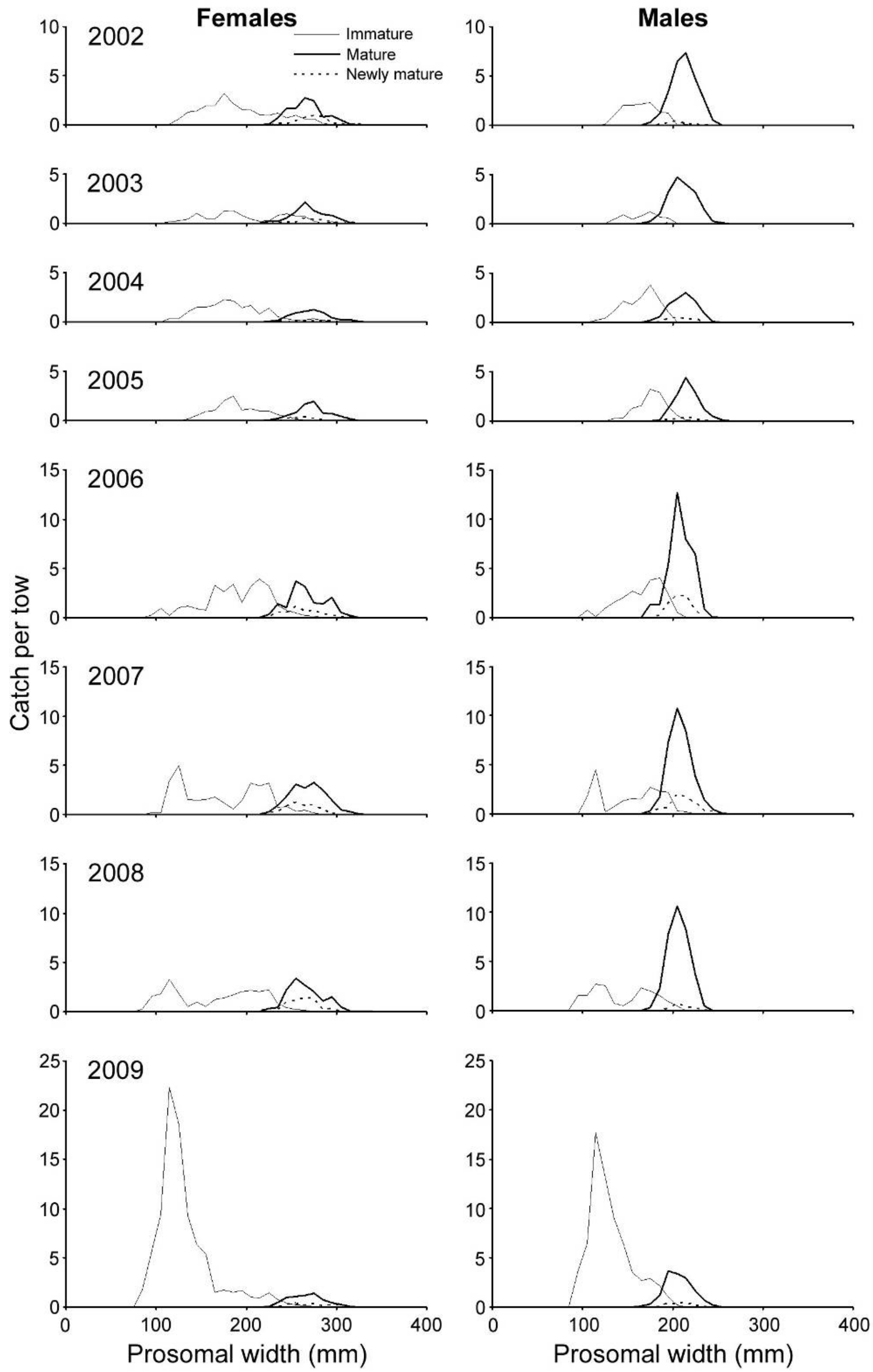


Figure 4. Relative size-frequency distributions of horseshoe crabs, by demographic group and year, in the coastal **Delaware Bay area** trawl survey. Relative frequencies are scaled to represent stratified mean catches in Table 1.

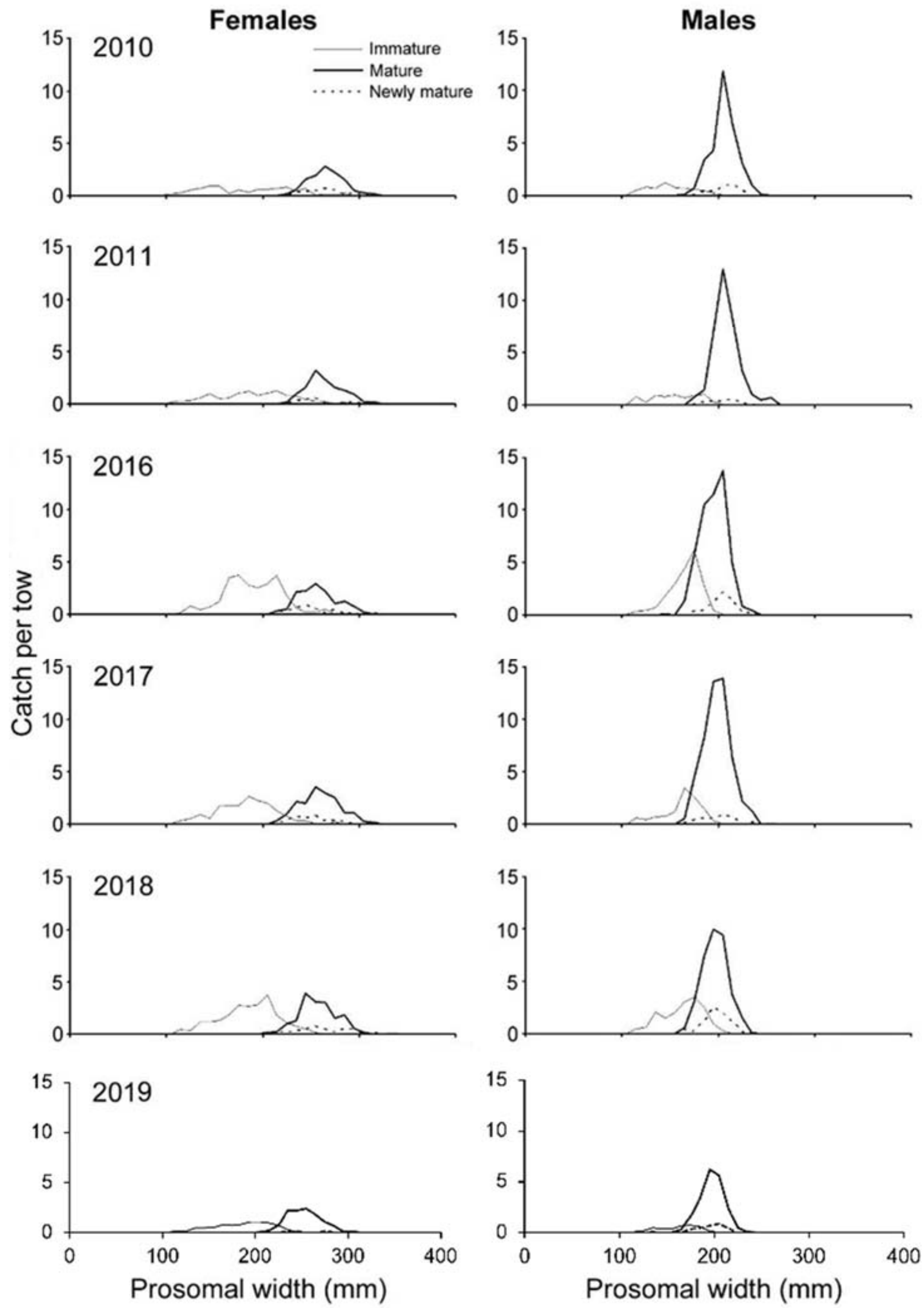


Figure 4. (continued).

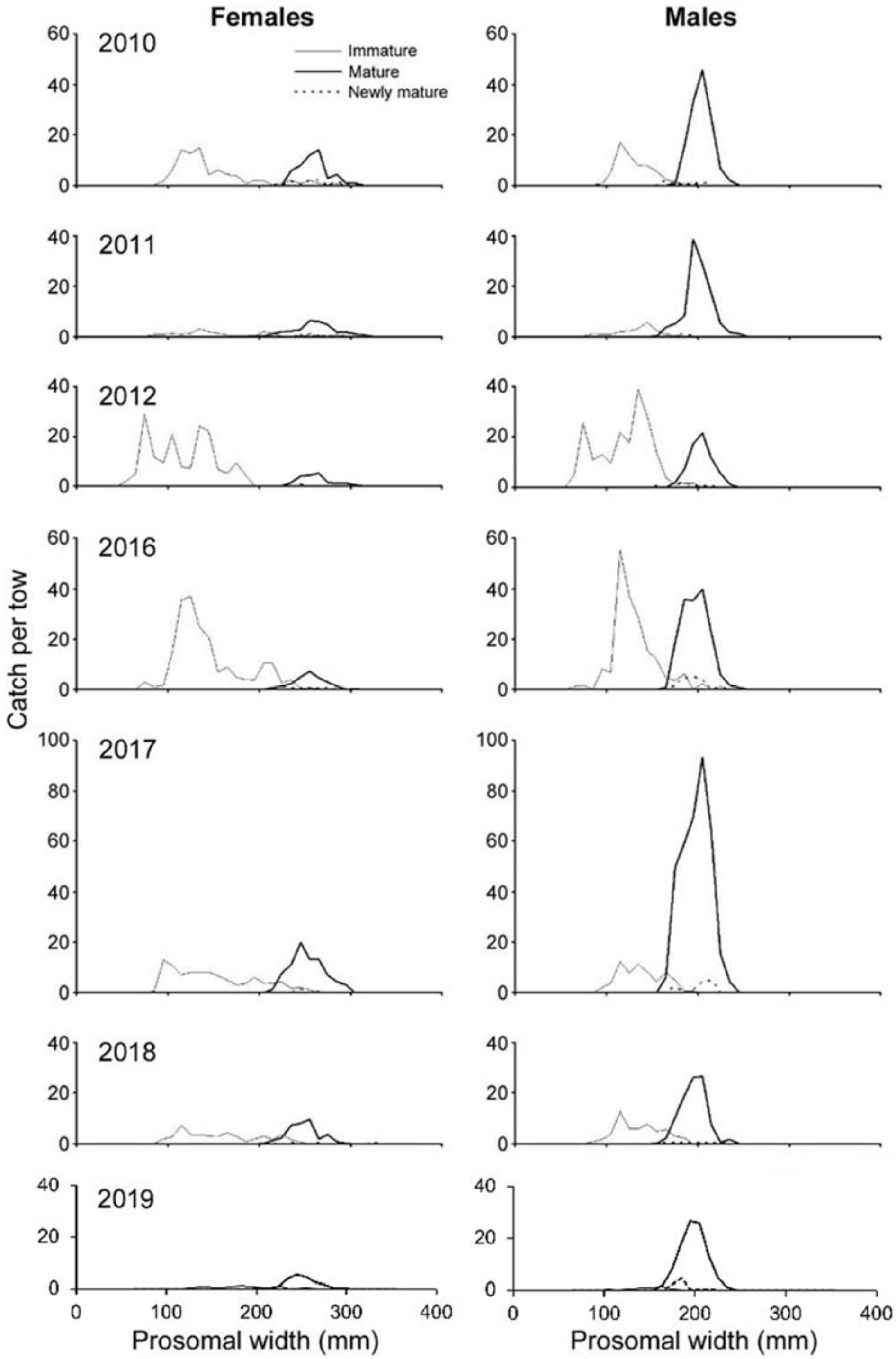


Figure 5. Relative size-frequency distributions of horseshoe crabs, by demographic group and year, in the **lower Delaware Bay** trawl survey. Relative frequencies are scaled to represent stratified mean catches in Table 3.

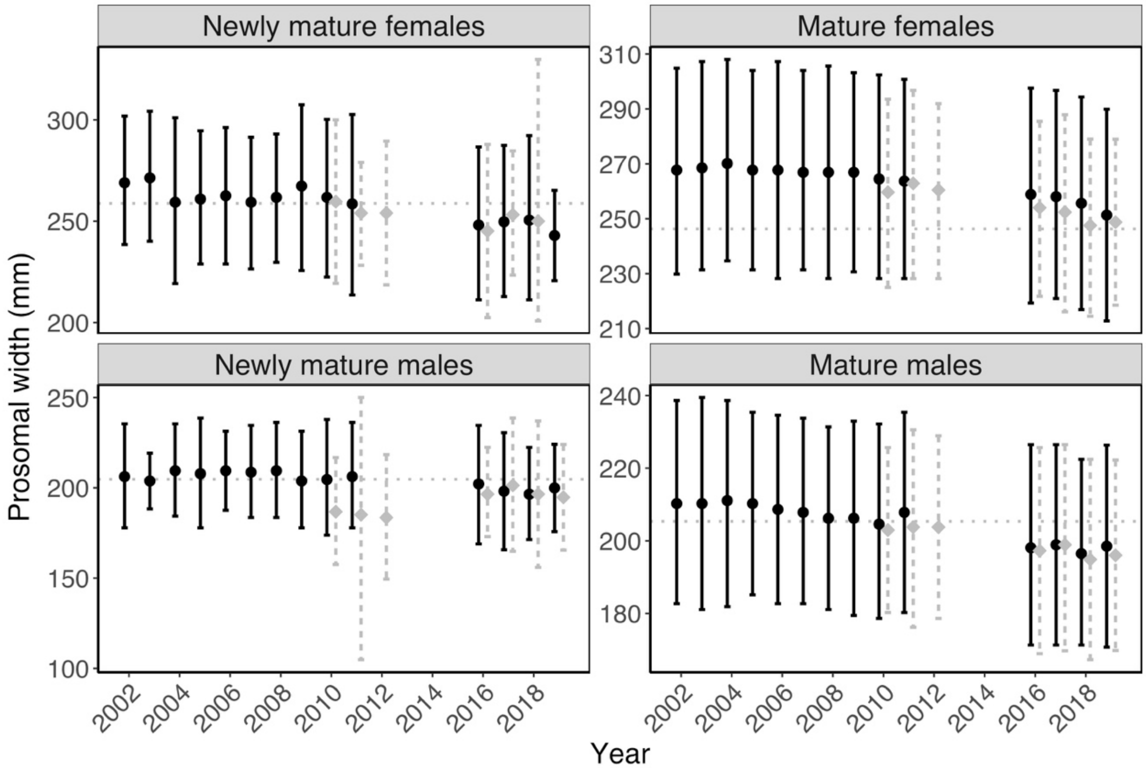


Figure 6. Mean prosomal widths (mm) (± 2 standard deviations) of mature and newly mature female and male horseshoe crabs in the Delaware Bay area (solid symbols and lines) and lower Delaware Bay (grey symbols and lines) surveys. Horizontal lines indicate overall means for all horseshoe crabs in the Delaware Bay area survey.

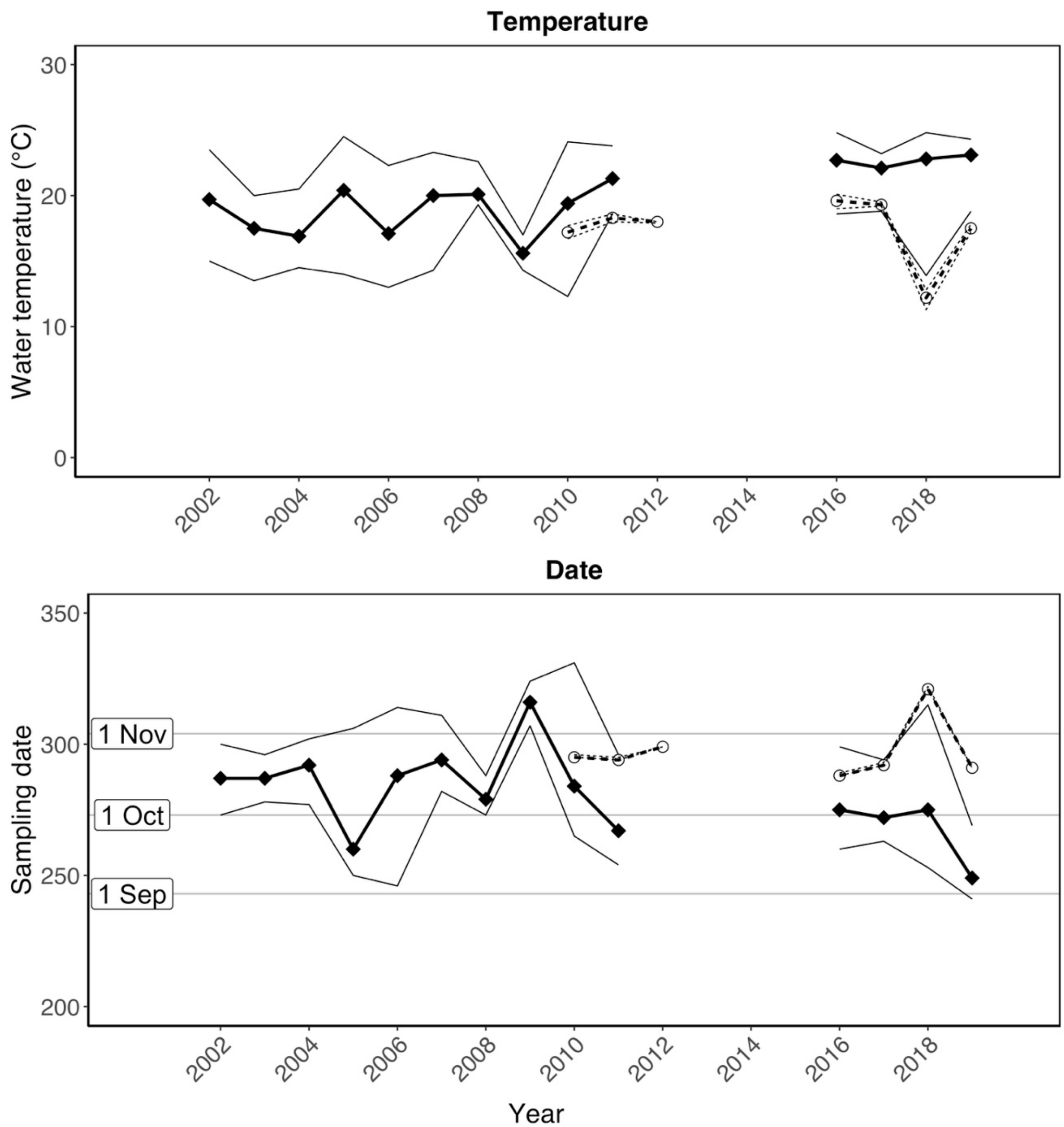


Figure 7. Plots of bottom water temperatures and ordinal sampling dates (days since 1 January) in the coastal Delaware Bay area and lower Delaware Bay trawl surveys. Solid symbols and lines indicate coastal Delaware Bay area. Open symbols and dashed lines indicate lower Delaware Bay. Points indicate mean values. Thinner lines indicate maximum and minimum values. Approximate calendar dates are indicated by gray horizontal lines for reference (ordinal dates are shifted by one day for leap years).

Table 1. Stratified mean catch-per-tow of horseshoe crabs in the coastal **Delaware Bay area** survey, 2002-2019, 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	21.9	36.1	7.6	0.31	6.8	2002	12.6	21.4	3.9	0.33	4.2
2003	10.5	20.4	0.7	0.43	4.6	2003	5.4	9.9	0.9	0.39	2.1
2004	17.9	27.2	8.6	0.25	4.5	2004	15.7	25.0	6.4	0.29	4.5
2005	12.7	19.9	5.5	0.28	3.5	2005	11.9	20.0	3.8	0.33	3.9
2006	29.5	42.8	16.3	0.21	6.3	2006	21.6	33.9	9.2	0.25	5.4
2007	29.6	59.4	-0.2	0.41	12.2	2007	19.5	39.6	-0.6	0.42	8.2
2008	25.3	43.7	6.9	0.33	8.3	2008	18.0	32.4	3.6	0.35	6.3
2009	90.2	167.4	12.9	0.39	35.5	2009	69.0	109.7	28.3	0.29	19.8
2010	9.0	11.9	6.1	0.16	1.4	2010	6.1	9.5	2.8	0.27	1.6
2011	11.4	15.9	6.9	0.19	2.2	2011	6.9	10.1	3.7	0.23	1.6
2016	25.8	45.1	6.5	0.36	9.2	2016	20.0	36.6	3.5	0.39	7.9
2017	17.9	25.4	10.4	0.19	3.4	2017	12.3	20.5	4.2	0.27	3.3
2018	22.5	31.2	13.9	0.18	4.1	2018	16.5	24.4	8.7	0.22	3.7
2019	8.0	12.7	3.2	0.30	2.4	2019	3.5	6.0	1.0	0.35	1.2
Mature females						Mature males					
2002	11.4	18.5	4.2	0.30	3.4	2002	26.6	39.7	13.4	0.24	6.3
2003	7.7	11.7	3.7	0.25	1.9	2003	18.4	29.6	7.3	0.28	5.2
2004	5.9	8.6	3.3	0.21	1.3	2004	11.4	17.1	5.7	0.24	2.8
2005	7.2	11.4	3.0	0.27	2.0	2005	13.2	19.1	7.3	0.21	2.8
2006	15.3	33.8	-3.2	0.44	6.7	2006	36.2	60.9	11.4	0.28	10.1
2007	16.9	27.5	6.2	0.30	5.1	2007	34.3	54.4	14.3	0.28	9.7
2008	14.4	23.3	5.4	0.29	4.2	2008	33.5	57.2	9.8	0.33	11.2
2009	6.7	11.2	2.3	0.32	2.1	2009	14.1	22.8	5.3	0.30	4.2
2010	11.8	17.3	6.3	0.22	2.6	2010	31.5	49.2	13.8	0.27	8.6
2011	12.3	17.1	7.6	0.18	2.2	2011	36.0	69.8	2.2	0.41	14.7
2016	13.5	19.5	7.6	0.21	2.9	2016	49.2	83.1	15.2	0.29	14.3
2017	16.9	24.8	9.0	0.23	3.9	2017	48.9	74.0	23.9	0.25	12.2
2018	16.8	23.7	9.9	0.20	3.3	2018	35.7	48.9	22.5	0.17	6.2
2019	11.6	18.7	4.5	0.30	3.5	2019	20.0	33.3	6.8	0.33	6.6
Newly mature females						Newly mature males					
2002	3.6	5.6	1.6	0.26	0.9	2002	1.3	2.0	0.5	0.28	0.4
2003	1.8	3.8	-0.1	0.49	0.9	2003	0.2	0.5	-0.1	0.84	0.2
2004	0.8	1.3	0.3	0.30	0.2	2004	1.8	2.6	1.0	0.21	0.4
2005	1.1	1.7	0.5	0.28	0.3	2005	1.3	2.3	0.4	0.33	0.4
2006	4.6	7.8	1.5	0.30	1.4	2006	7.1	11.6	2.6	0.36	2.7
2007	5.1	9.3	0.9	0.39	2.0	2007	6.7	10.6	2.8	0.28	1.9
2008	6.0	11.8	0.2	0.44	2.7	2008	1.8	2.9	0.6	0.32	0.6
2009	2.0	3.1	0.9	0.26	0.5	2009	1.7	2.8	0.5	0.34	0.6
2010	3.0	6.8	-0.7	0.59	1.8	2010	3.2	7.0	-0.5	0.55	1.8
2011	2.0	3.3	0.7	0.31	0.6	2011	1.9	3.4	0.4	0.37	0.7
2016	3.5	5.2	1.9	0.23	0.8	2016	5.9	11.0	0.7	0.42	2.5
2017	3.5	5.5	1.6	0.27	0.9	2017	3.6	5.8	1.5	0.29	1.0
2018	3.9	6.3	1.4	0.30	1.2	2018	7.5	11.9	3.1	0.27	2.1
2019	0.5	1.0	0.0	0.46	0.2	2019	2.8	4.6	1.0	0.32	0.9

Table 2. Stratified mean catch-per-tow of horseshoe crabs in the coastal **Delaware Bay area** survey, 2002-2019, 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	19.1	27.6	10.5	0.22	4.1	2002	11.7	18.3	5.0	0.27	3.2
2003	9.5	15.9	3.0	0.32	3.1	2003	4.9	8.1	1.8	0.30	1.5
2004	17.0	24.5	9.5	0.21	3.6	2004	14.0	20.3	7.6	0.22	3.1
2005	11.5	17.0	6.1	0.23	2.6	2005	10.6	16.7	4.4	0.28	2.9
2006	31.1	46.9	15.3	0.24	7.5	2006	21.5	32.0	11.1	0.23	5.0
2007	29.8	59.6	0.0	0.41	12.2	2007	20.5	43.2	-2.3	0.45	9.3
2008	24.6	38.9	10.3	0.27	6.6	2008	15.9	24.2	7.6	0.24	3.8
2009	63.1	93.8	32.4	0.24	14.9	2009	61.0	89.8	32.1	0.23	14.0
2010	9.4	13.0	5.7	0.19	1.8	2010	6.4	10.1	2.6	0.29	1.8
2011	12.2	18.5	6.0	0.25	3.0	2011	7.3	11.2	3.3	0.26	1.9
2016	25.1	41.1	9.0	0.31	7.7	2016	18.1	29.9	6.3	0.31	5.7
2017	19.1	28.7	9.6	0.24	4.6	2017	12.4	19.3	5.5	0.26	3.3
2018	22.5	30.6	14.5	0.17	3.8	2018	17.2	25.9	8.6	0.24	4.1
2019	13.7	21.9	5.5	0.30	4.1	2019	6.6	11.1	2.0	0.34	2.2
Mature females						Mature males					
2002	11.0	17.0	4.9	0.26	2.8	2002	24.6	34.4	14.8	0.19	4.7
2003	7.5	10.9	4.1	0.22	1.6	2003	17.0	24.7	9.4	0.21	3.6
2004	6.0	8.3	3.7	0.19	1.1	2004	12.6	20.2	5.1	0.29	3.6
2005	6.8	10.0	3.5	0.22	1.5	2005	12.3	16.7	7.8	0.17	2.1
2006	13.5	24.2	2.7	0.31	4.2	2006	32.8	49.5	16.1	0.22	7.4
2007	14.2	21.3	7.1	0.24	3.4	2007	28.4	39.9	16.8	0.20	5.6
2008	16.5	31.0	2.0	0.41	6.8	2008	32.7	53.7	11.7	0.31	10.0
2009	7.3	12.3	2.2	0.33	2.4	2009	14.2	22.9	5.5	0.29	4.1
2010	12.7	19.7	5.7	0.26	3.3	2010	32.5	50.9	14.1	0.27	8.8
2011	12.6	18.1	7.2	0.20	2.6	2011	35.4	61.4	9.5	0.32	11.5
2016	12.8	17.4	8.2	0.17	2.2	2016	53.9	90.0	17.8	0.30	16.2
2017	18.2	28.0	8.4	0.26	4.8	2017	47.2	69.3	25.1	0.23	10.8
2018	21.1	39.6	2.5	0.41	8.7	2018	34.9	44.9	24.9	0.14	4.8
2019	18.7	28.4	9.0	0.26	4.8	2019	19.7	31.0	8.4	0.28	5.6
Newly mature females						Newly mature males					
2002	3.5	5.3	1.7	0.24	0.9	2002	1.3	2.2	0.4	0.31	0.4
2003	1.8	3.6	0.1	0.45	0.8	2003	0.2	0.5	-0.2	0.84	0.2
2004	0.8	1.4	0.3	0.33	0.3	2004	1.8	2.6	1.0	0.21	0.4
2005	1.2	2.1	0.3	0.35	0.4	2005	1.3	2.1	0.5	0.29	0.4
2006	4.8	8.2	1.4	0.33	1.6	2006	7.5	13.2	1.8	0.36	2.7
2007	4.6	7.7	1.5	0.32	1.5	2007	6.1	9.1	3.2	0.23	1.4
2008	6.3	11.3	1.3	0.37	2.3	2008	1.8	3.1	0.5	0.34	0.6
2009	2.0	3.1	0.9	0.26	0.5	2009	1.6	2.6	0.6	0.30	0.5
2010	4.0	10.3	-2.3	0.74	3.0	2010	3.3	7.2	-0.6	0.56	1.9
2011	2.2	3.9	0.5	0.38	0.8	2011	1.9	3.5	0.4	0.38	0.7
2016	3.5	5.1	1.9	0.22	0.8	2016	6.6	12.6	0.6	0.43	2.9
2017	3.6	5.5	1.6	0.27	1.0	2017	3.8	6.4	1.3	0.32	1.2
2018	3.9	6.2	1.6	0.28	1.1	2018	6.9	10.0	3.9	0.21	1.5
2019	0.6	1.2	0.0	0.48	0.3	2019	3.5	5.5	1.5	0.29	1.0

Table 3. Stratified mean catch–per-tow of horseshoe crabs in the **lower Delaware Bay** survey area in 2010-2019, 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	79.7	122.2	37.3	0.21	16.5	2010	61.2	105.5	16.9	0.30	18.1
2011	19.7	45.2	-5.9	0.47	9.2	2011	20.2	50.7	-10.4	0.55	11.0
2012	164.3	311.8	16.9	0.32	53.1	2012	192.6	548.4	-163.3	0.43	82.7
2016	196.0	335.5	56.6	0.29	57.0	2016	184.2	322.9	45.5	0.32	58.7
2017	96.7	210.0	-16.7	0.46	44.1	2017	62.9	137.6	-11.7	0.46	29.0
2018	47.2	56.2	38.1	0.08	3.8	2018	55.1	71.8	38.4	0.12	6.8
2019	9.5	24.3	-5.3	0.60	5.7	2019	5.7	15.8	-4.5	0.70	4.0
Mature females						Mature males					
2010	48.8	98.9	-1.2	0.40	19.5	2010	130.3	242.6	18.1	0.34	43.7
2011	30.3	60.4	0.2	0.36	10.8	2011	110.2	249.0	-28.6	0.45	50.0
2012	19.1	51.6	-13.4	0.40	7.6	2012	66.8	141.1	-7.4	0.35	23.3
2016	26.3	33.9	18.7	0.12	3.2	2016	161.7	192.5	131.0	0.08	13.3
2017	80.6	167.1	-5.8	0.39	31.1	2017	362.7	868.5	-143.2	0.50	182.2
2018	36.2	46.6	25.8	0.12	4.3	2018	94.3	117.9	70.7	0.11	10.0
2019	20.8	54.7	-13.0	0.63	13.2	2019	100.4	254.0	-53.2	0.59	59.7
Newly mature females						Newly mature males					
2010	9.7	25.8	-6.3	0.64	6.2	2010	4.4	9.5	-0.8	0.46	2.0
2011	1.4	3.8	-0.9	0.58	0.8	2011	1.4	4.9	-2.2	0.94	1.3
2012	1.0	4.4	-2.3	0.76	0.8	2012	6.1	14.2	-2.0	0.48	2.9
2016	4.6	8.0	1.1	0.31	1.4	2016	16.2	29.0	3.5	0.30	5.0
2017	2.1	5.9	-1.7	0.65	1.4	2017	12.4	27.6	-2.7	0.44	5.4
2018	2.3	4.4	0.2	0.35	0.8	2018	3.6	7.6	-0.5	0.44	1.6
2019	0.0	0.0	0.0	NA	0.0	2019	8.0	22.3	-6.4	0.70	5.6

Table 4. Stratified mean catch-per-tow of horseshoe crabs in the **lower Delaware Bay** survey area in 2010-2019, 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	79.5	116.5	42.6	0.19	15.1	2010	60.4	95.7	25.1	0.25	15.3
2011	21.3	54.2	-11.5	0.55	11.8	2011	21.5	57.2	-14.3	0.60	12.9
2012	165.5	287.6	43.4	0.30	49.9	2012	183.9	360.1	7.8	0.34	63.4
2016	186.5	284.7	88.3	0.22	40.1	2016	167.9	249.7	86.0	0.21	34.6
2017	90.8	176.0	5.6	0.37	33.2	2017	58.2	109.0	7.5	0.36	20.7
2018	47.1	55.6	38.6	0.08	3.6	2018	54.9	69.6	40.2	0.11	6.2
2019	16.0	30.4	1.5	0.35	5.6	2019	10.7	21.7	-0.4	0.40	4.3
Mature females						Mature males					
2010	49.1	99.8	-1.7	0.40	19.7	2010	128.0	227.9	28.2	0.30	38.9
2011	28.6	49.9	7.4	0.27	7.7	2011	100.3	187.7	13.0	0.31	31.5
2012	18.7	46.2	-8.9	0.34	6.4	2012	65.3	111.7	18.8	0.28	18.1
2016	26.2	33.4	19.0	0.11	3.0	2016	161.8	192.4	131.1	0.08	13.3
2017	80.5	165.0	-4.0	0.38	30.4	2017	303.4	531.7	75.2	0.27	82.2
2018	36.2	47.2	25.1	0.12	4.3	2018	94.7	120.3	69.0	0.11	10.8
2019	29.3	54.8	3.8	0.34	9.9	2019	49.9	90.0	9.9	0.31	15.6
Newly mature females						Newly mature males					
2010	9.6	24.9	-5.7	0.62	5.9	2010	4.3	9.1	-0.5	0.43	1.9
2011	1.4	3.8	-0.9	0.58	0.8	2011	1.4	4.9	-2.2	0.94	1.3
2012	1.0	4.4	-2.3	0.76	0.8	2012	6.1	14.1	-1.9	0.47	2.9
2016	4.5	8.0	1.1	0.30	1.3	2016	16.0	27.2	4.9	0.27	4.3
2017	2.1	5.9	-1.7	0.65	1.4	2017	12.4	25.7	-1.0	0.42	5.2
2018	2.3	4.3	0.3	0.34	0.8	2018	3.6	7.6	-0.5	0.44	1.6
2019	0.0	0.0	0.0	NA	0.0	2019	8.5	22.9	-5.9	0.66	5.6

Table 5. Results of correlation analyses of mean prosomal width (mm) and survey year for newly mature and mature males and females from the Delaware Bay area and lower Delaware Bay surveys. 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*
Delaware Bay area				
2002-2019				
Mature females	14	-10.39	<0.001	-0.949
Newly mature females	14	-6.72	<0.001	-0.889
Mature males	14	-12.10	<0.001	-0.961
Newly mature males	14	-4.62	<0.001	-0.800
Lower Delaware Bay				
2010-2019				
Mature females	7	-6.89	0.001	-0.951
Newly mature females	7	-2.05	0.110	-0.716
Mature males	7	-6.10	0.002	-0.939
Newly mature males	7	3.58	0.016	0.848

Table 6. Estimated population (in thousands) of horseshoe crabs in the coastal **Delaware Bay area** survey, 2002-2019, 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	9,470	15,665	3,275	0.31	581	2002	5,483	9,284	1,683	0.33	357
2003	4,585	8,848	321	0.43	388	2003	2,303	4,217	390	0.39	174
2004	7,774	11,770	3,778	0.25	379	2004	6,810	10,895	2,725	0.29	387
2005	5,630	8,856	2,404	0.28	306	2005	5,260	8,839	1,681	0.33	337
2006	12,928	18,691	7,164	0.21	533	2006	9,327	14,554	4,100	0.24	442
2007	13,684	27,486	-118	0.41	1,100	2007	8,966	18,246	-314	0.42	740
2008	10,933	18,650	3,216	0.32	684	2008	7,841	13,917	1,766	0.35	532
2009	39,032	72,868	5,197	0.39	2,998	2009	29,864	47,269	12,460	0.28	1,654
2010	3,954	5,220	2,688	0.16	120	2010	2,686	4,144	1,229	0.26	139
2011	4,965	6,945	2,985	0.20	189	2011	3,092	4,547	1,637	0.23	139
2016	11,699	20,462	2,935	0.36	817	2016	9,102	16,649	1,555	0.39	701
2017	7,505	10,708	4,302	0.19	276	2017	5,091	8,465	1,717	0.27	269
2018	10,173	14,285	6,061	0.19	378	2018	7,507	11,173	3,842	0.23	333
2019	3,397	5,516	1,279	0.31	1,048	2019	1,487	2,614	360	0.38	558
Mature females						Mature males					
2002	4,959	8,084	1,834	0.30	289	2002	11,584	17,335	5,834	0.24	539
2003	3,379	5,160	1,599	0.25	167	2003	8,069	13,029	3,110	0.29	454
2004	2,735	4,043	1,426	0.23	122	2004	5,150	7,788	2,511	0.25	251
2005	3,138	4,942	1,333	0.27	164	2005	5,844	8,461	3,228	0.22	245
2006	6,611	14,330	-1,108	0.42	542	2006	15,825	26,060	5,589	0.27	844
2007	7,746	12,704	2,789	0.31	462	2007	15,795	25,104	6,487	0.28	873
2008	6,311	10,202	2,419	0.29	360	2008	14,647	24,995	4,299	0.33	952
2009	2,975	4,971	979	0.32	186	2009	6,240	10,197	2,283	0.30	369
2010	5,178	7,616	2,740	0.23	228	2010	13,963	21,910	6,015	0.28	749
2011	5,290	7,282	3,297	0.18	182	2011	15,060	29,000	1,120	0.40	1,179
2016	6,024	8,635	3,413	0.21	245	2016	21,941	37,216	6,665	0.29	1,260
2017	7,185	10,525	3,844	0.23	319	2017	20,664	31,208	10,119	0.25	1,001
2018	7,326	10,520	4,131	0.21	298	2018	15,749	21,880	9,619	0.18	564
2019	5,110	8,454	1,767	0.32	1,655	2019	8,924	15,202	2,646	0.35	3,108
Newly mature females						Newly mature males					
2002	1,537	2,400	675	0.26	79	2002	548	869	227	0.28	30
2003	794	1,633	-45	0.49	76	2003	78	221	-65	0.84	13
2004	358	575	141	0.29	20	2004	789	1,127	451	0.21	32
2005	479	753	206	0.27	25	2005	597	1,002	191	0.33	39
2006	2,051	3,509	594	0.31	123	2006	3,113	5,113	1,113	0.31	188
2007	2,373	4,339	408	0.40	183	2007	3,129	4,972	1,287	0.28	171
2008	2,571	4,984	158	0.43	218	2008	757	1,254	261	0.31	46
2009	885	1,361	410	0.26	45	2009	725	1,240	210	0.34	48
2010	1,338	2,990	-314	0.59	153	2010	1,422	3,070	-226	0.55	153
2011	845	1,360	331	0.30	49	2011	749	1,335	164	0.36	53
2016	1,608	2,357	860	0.23	71	2016	2,608	4,884	331	0.42	212
2017	1,480	2,274	687	0.26	76	2017	1,523	2,392	654	0.28	83
2018	1,773	2,923	622	0.31	108	2018	3,341	5,367	1,316	0.29	186
2019	242	472	12	0.47	114	2019	1,271	2,154	389	0.34	437

Table 7. Estimated population (in thousands) of horseshoe crabs in the coastal **Delaware Bay area** survey, 2002-2019, 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	8,222	11,875	4,568	0.21	344	2002	5,076	7,998	2,155	0.28	273
2003	4,089	6,860	1,317	0.32	255	2003	2,114	3,462	766	0.30	123
2004	7,376	10,616	4,135	0.21	305	2004	6,033	8,786	3,281	0.22	260
2005	5,104	7,521	2,687	0.23	227	2005	4,673	7,414	1,932	0.28	255
2006	13,714	20,988	6,439	0.25	672	2006	9,378	13,971	4,786	0.23	428
2007	13,692	27,335	48	0.41	1,088	2007	9,350	19,735	-1,035	0.45	828
2008	10,595	16,578	4,612	0.26	544	2008	6,897	10,443	3,350	0.23	314
2009	27,375	40,519	14,232	0.23	1,242	2009	26,435	38,730	14,140	0.23	1,162
2010	4,102	5,706	2,497	0.19	152	2010	2,781	4,423	1,139	0.29	156
2011	5,426	8,433	2,420	0.27	284	2011	3,301	5,219	1,382	0.28	182
2016	11,292	18,441	4,144	0.30	668	2016	8,185	13,512	2,858	0.31	498
2017	7,948	11,818	4,077	0.23	364	2017	5,082	7,829	2,335	0.26	257
2018	10,115	13,839	6,391	0.18	346	2018	7,768	11,653	3,882	0.24	358
2019	14,855	15,027	14,682	0.01	85	2019	66	236	-104	1.27	84
Mature females						Mature males					
2002	4,779	7,431	2,128	0.26	243	2002	10,711	14,972	6,450	0.19	400
2003	3,308	4,851	1,764	0.22	144	2003	7,454	10,827	4,082	0.21	312
2004	2,767	3,919	1,615	0.20	109	2004	5,586	8,875	2,297	0.28	308
2005	2,957	4,323	1,592	0.22	124	2005	5,408	7,322	3,494	0.17	181
2006	5,867	10,517	1,218	0.31	353	2006	14,461	21,734	7,188	0.23	637
2007	6,553	9,864	3,243	0.25	313	2007	13,100	18,506	7,694	0.20	514
2008	7,172	13,336	1,008	0.40	561	2008	14,244	23,240	5,247	0.30	838
2009	3,230	5,523	936	0.33	211	2009	6,319	10,255	2,383	0.29	360
2010	5,588	8,698	2,478	0.26	289	2010	14,396	22,600	6,192	0.27	765
2011	5,388	7,629	3,147	0.20	205	2011	14,858	25,890	3,825	0.33	951
2016	5,735	7,770	3,700	0.17	193	2016	24,017	40,197	7,837	0.30	1,416
2017	7,785	12,033	3,537	0.27	403	2017	19,985	29,245	10,724	0.23	884
2018	9,463	18,463	464	0.44	818	2018	15,264	19,849	10,680	0.15	433
2019	6,420	6,506	6,334	0.01	43	2019	11,660	11,824	11,497	0.01	81
Newly mature females						Newly mature males					
2002	1,509	2,278	741	0.24	72	2002	561	925	196	0.31	33
2003	787	1,547	26	0.45	69	2003	78	222	-66	0.84	13
2004	367	613	120	0.32	23	2004	786	1,120	452	0.20	31
2005	531	908	154	0.34	36	2005	580	927	233	0.29	33
2006	2,122	3,705	540	0.33	139	2006	3,377	6,076	678	0.38	251
2007	2,129	3,584	674	0.33	135	2007	2,841	4,214	1,468	0.23	129
2008	2,697	4,780	613	0.36	192	2008	776	1,315	237	0.33	50
2009	883	1,366	399	0.26	45	2009	708	1,157	259	0.31	43
2010	1,770	4,532	-992	0.74	255	2010	1,464	3,180	-252	0.56	159
2011	882	1,495	269	0.34	58	2011	766	1,343	190	0.36	54
2016	1,583	2,304	863	0.22	68	2016	2,939	5,588	290	0.43	248
2017	1,502	2,323	680	0.27	79	2017	1,590	2,623	557	0.32	98
2018	1,780	2,866	695	0.29	101	2018	3,064	4,466	1,663	0.22	131
2019	77	225	-70	0.94	73	2019	112	267	-43	0.68	77

Table 8. Estimated population (in thousands) of horseshoe crabs in the **lower Delaware Bay** survey area in 2010-2019, 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	3,510	5,199	1,822	0.20	1,306	2010	2,632	4,476	788	0.29	1,426
2011	870	1,931	-191	0.44	723	2011	881	2,160	-397	0.52	871
2012	8,021	15,084	958	0.32	4,814	2012	9,381	21,965	-3,204	0.42	7,484
2016	9,046	15,558	2,534	0.29	5,037	2016	8,429	14,813	2,044	0.32	5,110
2017	4,536	10,029	-956	0.47	4,044	2017	2,920	6,458	-618	0.47	2,605
2018	2,211	2,803	1,619	0.10	436	2018	2,597	3,516	1,678	0.15	735
2019	525	1,278	-229	0.56	293	2019	308	816	-201	0.64	198
Mature females						Mature males					
2010	2,117	4,260	-25	0.39	1,578	2010	5,657	10,247	1,067	0.32	3,379
2011	1,348	2,599	96	0.33	853	2011	4,829	10,570	-912	0.43	3,913
2012	938	2,522	-646	0.39	697	2012	3,263	6,864	-338	0.35	2,142
2016	1,274	1,710	837	0.15	358	2016	7,735	9,709	5,761	0.10	1,527
2017	3,674	7,501	-153	0.38	2,609	2017	16,794	40,517	-6,929	0.51	16,170
2018	1,771	2,588	953	0.18	602	2018	4,616	6,600	2,631	0.18	1,535
2019	1,148	3,011	-715	0.63	725	2019	5,746	14,583	-3,092	0.60	3,438
Newly mature females						Newly mature males					
2010	414	1,087	-260	0.63	496	2010	187	409	-35	0.46	163
2011	65	170	-40	0.58	72	2011	58	208	-93	0.94	103
2012	50	214	-114	0.76	72	2012	301	710	-109	0.49	279
2016	206	357	55	0.30	117	2016	727	1,268	186	0.29	398
2017	88	249	-73	0.66	110	2017	542	1,100	-16	0.40	411
2018	115	220	9	0.36	78	2018	148	290	7	0.40	113
2019	0	0	0	NA	0	2019	361	1,022	-299	0.71	257

Table 9. Estimated population (in thousands) of horseshoe crabs in the **lower Delaware Bay** survey area in 2010-2019, 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	3,503	5,155	1,851	0.18	1,216	2010	2,588	4,056	1,120	0.24	1,175
2011	938	2,311	-435	0.53	936	2011	935	2,437	-567	0.58	1,024
2012	8,125	14,222	2,027	0.31	4,716	2012	9,023	17,690	356	0.35	5,907
2016	8,618	13,190	4,046	0.22	3,536	2016	7,725	11,638	3,812	0.21	3,027
2017	4,325	8,829	-178	0.41	3,316	2017	2,731	5,408	53	0.38	1,971
2018	2,209	2,780	1,638	0.10	420	2018	2,595	3,529	1,661	0.15	722
2019	852	868	836	0.01	6	2019	566	566	566	0.00	0.02
Mature females						Mature males					
2010	2,124	4,340	-91	0.41	1,631	2010	5,600	9,916	1,285	0.30	3,177
2011	1,290	2,239	340	0.27	647	2011	4,479	8,332	625	0.31	2,627
2012	915	2,242	-412	0.34	584	2012	3,188	5,456	921	0.28	1,669
2016	1,264	1,647	880	0.13	315	2016	7,727	9,570	5,883	0.10	1,475
2017	3,654	7,307	2	0.36	2,490	2017	13,805	23,702	3,908	0.26	6,746
2018	1,782	2,666	898	0.19	651	2018	4,647	6,901	2,393	0.19	1,659
2019	1,932	1,948	1,916	0.00	6	2019	8,356	8,356	8,356	0.00	0.02
Newly mature females						Newly mature males					
2010	418	1,097	-260	0.63	500	2010	185	391	-22	0.43	152
2011	65	170	-40	0.58	72	2011	58	208	-93	0.94	103
2012	50	214	-114	0.76	72	2012	302	719	-114	0.50	284
2016	205	355	55	0.28	110	2016	716	1,176	256	0.25	339
2017	88	249	-73	0.66	110	2017	541	1,090	-9	0.40	405
2018	114	226	3	0.35	76	2018	149	296	1	0.41	114
2019	0	0	0	NA	0	2019	401	408	394	0.00	3

Table 10. 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	max	min	mean	max	min
Delaware Bay area						
2002	19.7	23.5	15.0	287	300	273
2003	17.5	20.0	13.5	287	296	278
2004	16.9	20.5	14.5	292	302	277
2005	20.4	24.5	14.0	260	306	250
2006	17.1	22.3	13.0	288	314	246
2007	20.0	23.3	14.3	294	311	282
2008	20.1	22.6	19.3	279	288	273
2009	15.6	17.0	14.3	316	324	307
2010	19.4	24.1	12.3	284	331	265
2011	21.3	23.8	18.6	267	296	254
2016	22.7	24.8	18.6	275	299	260
2017	22.1	23.2	18.8	272	294	263
2018	22.8	24.8	13.9	275	315	253
2019	23.1	24.3	18.8	249	269	241
Lower Delaware Bay						
2010	17.2	17.7	16.7	295	296	295
2011	18.3	18.6	18.0	294	295	294
2012	18.0	18.0	17.9	299	299	299
2016	19.6	20.1	19.0	288	289	288
2017	19.3	19.5	19.2	292	293	292
2018	12.2	12.8	11.3	321	322	321
2019	17.5	17.8	17.2	291	291	291

Table 11. 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 14 years, and the lower Delaware Bay surveys included 7 years. Statistics presented include correlation coefficient, *r*; *T*-score; and probability, *p*. Data are from Tables 1, 3, and 10.

	Water temperature			Ordinal date		
	r	*T*	*p*	*r*	*T*	*p*
Delaware Bay area						
Immature females	-0.511	-2.06	0.062	0.734	3.75	0.003
Immature males	-0.521	-2.12	0.056	0.720	3.59	0.004
Mature females	0.567	2.39	0.034	-0.209	-0.74	0.473
Mature males	0.559	2.34	0.038	-0.188	-0.66	0.520
Newly mature females	0.092	0.32	0.755	0.257	0.92	0.375
Newly mature males	0.318	1.16	0.268	0.009	0.03	0.974
Lower Delaware Bay						
Immature females	0.423	1.04	0.345	-0.244	-0.56	0.598
Immature males	0.301	0.71	0.511	-0.113	-0.26	0.809
Mature females	0.133	0.30	0.776	-0.058	-0.13	0.901
Mature males	0.428	1.06	0.338	-0.334	-0.79	0.464
Newly mature females	0.024	0.05	0.959	-0.098	-0.22	0.834
Newly mature males	0.556	1.49	0.195	-0.512	-1.33	0.240

MEMO

To: Delaware Bay ARM Working Group
From: Jim Lyons, USGS Patuxent Wildlife Research Center, Laurel, MD
Re: Red Knot Stopover Population Estimate for 2020
Date: 23 September 2020

1 Acknowledgments

We thank the many volunteers in Delaware and New Jersey who collected mark-resight data in 2020. We are grateful to Henrietta Bellman (Delaware DFW) and Amanda Dey (New Jersey ENSP), and numerous volunteers in Delaware and New Jersey for data entry and data management, and Lena Usyk (bandedbirds.org) for data management.

2 Methods

Red knots have been individually marked at Delaware Bay and other locations with engraved leg flags for many years; each leg flag is engraved with a unique 3-character alphanumeric code (Clark et al. 2005). Mark-resight data (sight records of individually-marked birds and counts of marked and unmarked birds) were collected on the Delaware and New Jersey shores of Delaware Bay according to the methods for mark-resight investigations of Red Knots in Delaware Bay (Lyons 2016).

Surveys to locate leg-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 surveyed the entire beach and recorded as many alphanumeric combinations as possible.

As in previous years, all flag resightings were validated with physical capture and banding data available in the data repository at http://www.bandedbirds.org/. Resightings without a corresponding record of physical capture and banding (i.e., "misread" errors) were not included in the analysis. However, 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 omitted resightings of 21 flagged individuals whose flag codes were accidentally deployed in both New Jersey and South Carolina (A. Dey, pers. comm.) because it is not possible to confirm individual identity in this case.

While searching for birds marked with engraved leg flags, observers also periodically used 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 survey periods (3-day sampling occasion) in Delaware Bay.

Survey period	Dates	Survey period	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	4-6 June

To estimate stopover population size, we used the methods of Lyons et al. (2016) to analyze 1) the mark-resight data (flag codes), and 2) data from the scan samples of the marked-ratio. In this "superpopulation" approach, passage population size is estimated using the Jolly-Seber model for open populations, which accounts for the flow-through nature of migration areas and probability of detection during surveys.

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

With the mark-resight superpopulation approach, we estimated the number of birds that were carrying leg flags, and then adjusted this number to account for unmarked birds using the estimated proportion of the population with flags. 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 2020

Survey effort was limited in early May 2020 due to health and safety concerns during the novel coronavirus pandemic.

Mark-resight encounter data.—With birds from six countries reported, the 2020 Red Knot mark-resight database included a total of 1,587 individual birds recorded at least once by observers in Delaware Bay (Table 2).

Because little or no survey effort was conducted during period 10 at the end of the season (4-6 June) in 2020, our analyses were restricted to periods 1-9, during which a total of 1,551 individual bird were recorded at least once in Delaware Bay. The number of marked birds detected and available for analysis in 2020 was approximately 50% lower than the number in the 2019 analysis (n = 3,072) and 60% lower than the number detected and used for analysis in 2018 (n = 3,820 birds).

One assumption 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). As noted above, some field-recording errors are evident when sight records are compared to physical capture records available from bandedbirds.org; any engraved flag reported by observers that does not have a corresponding record of physical capture is omitted. Field observers submitted 3,364 resightings in 2020; 100 were not valid (i.e., no corresponding banding data), for an overall misread read of 2.9%. These invalid resightings were removed before analysis, but a second type of "false positive" is still possible, i.e., false positive detection of flags that were deployed prior to 2020 but were not in fact present in Delaware Bay in 2020. It is not possible to identify this second type of false positive by cross-referencing to physical captures (banding data) or other QA/QC methods.

Marked-ratio data.—In 2020, 734 marked-ratio scan samples were collected: 376 scan samples in Delaware and 358 in New Jersey (Appendix 3).

Aerial and ground count data.—Ground surveys were conducted on 24 and 26 May 2020 (Table 3; data provided by A. Dey, New Jersey Division of Fish and Wildlife, Endangered and Nongame Species Program).

4 Summary of 2020 Migration

The pattern of arrivals at Delaware Bay in 2020 suggests early arrival by approximately 55% of the passage population. During the first resighting survey period of the year (between 8 and 10 May), observers detected 257 marked individuals. Resighting data suggest that many of these early arrivals did not remain at Delaware Bay long (see below). Another wave, approximately 30% of the stopover population, arrived at Delaware Bay during sampling periods 4 and 5, i.e., between 17 and 22 May (Fig. 1a).

Stopover persistence is the probability that a bird present in the bay during sampling period i is present in the bay at sampling period i +1. Estimated stopover persistence was low in the first sampling period; many of the birds present at the beginning of the season were not seen again and likely departed the stopover shortly after arriving (Fig. 1b and Appendix 1). From 13 to 18 May (periods 2-4), stopover persistence was relatively high. Around 21 and 24 May, stopover persistence declined and many birds departed the stopover. After 24 May, stopover persistence was very low; most birds had departed the study area by the end of May. Following Lyons et al. (2016), we used the Jolly-Seber model to estimate stopover duration. In 2020, estimated average stopover duration was 10.7 days (95% credible interval 9.9 – 11.7 days), a shorter stopover duration than in 2019 (12.1 days).

Probability of resighting in 2020 was lower than in recent years. Resighting probability was approximately 10-30% for much of the season, before increasing to about 60% around 27 May and remaining high for the remainder of the season (Fig. 1c).

The estimated proportion of the 2020 stopover population with marks (leg flags) was 0.096 (95% CI 0.088–0.103, Fig. 2)

5 Stopover Population Estimation

The passage population size in 2020 was estimated at 40,444 (95% credible interval: 33,627–49,966). This superpopulation estimate accounts for turnover in the population and probability of detection. The 2020 estimate is slightly lower than estimated population size in 2018 and 2019 (Table 4) and the confidence interval is wider. The uncertainty in the population estimate is due in part to the low probability of resighting in 2020 compared to other years, likely due to limited sampling effort that was possible during the coronavirus pandemic. Probability of detection was especially low at the beginning of the season (Fig. 1c) due in part to restrictions on activity in public spaces in early May due to the pandemic.

The time-specific stopover population estimates in 2020 started off high in sampling period 1 (23,640) based on evidence of early arrivals, then declined to less than 10,000 in period 2 (Fig. 1d). Following period 2, there was a steady increase in the population until period 5 (21 May) as birds arrived and remained in the study area. Population size peaked again at approximately 17,700 near 21 May. The stopover population then declined steadily until nearly all birds had departed the study area in early June (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 Delaware Bay. Unpublished report. 13 pp.

Table 2. Number of flags detected in 2020 by banding location (flag color).

	No. flagged individuals detected	
Banding location (flag color)	***2019***	***2020***
U.S. (lime green)	2,368	1255
U.S. (dark green)	351	161
Argentina (orange)	216	89
Canada (white)	156	52
Brazil (dark blue)	35	21
Chile (red)	10	9
Total	3,136	1,587

Table 3. Number of Red Knots detected during aerial and ground surveys of Delaware Bay in 2020. Data provided by A. Dey, New Jersey Division of Fish and Wildlife, Nongame and Endangered Species Program.

	Delaware	New Jersey	Total
Aerial Surveys			
None in 2020			
Ground Surveys			
24 May 2020	1,293	18,104	19,397
26 May 2020	632	5441	6,073

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]
2018	45,221	(42,568 – 49,508)	32,930 (A)[b]
2019	45,133	(42,269 – 48,393)	30,880 (A)[g]
2020	40,444	(33,627 – 49,966)	19,397 (G)[c]

[a] passage population 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; data from observers with greater than average misread rate were not included in the analysis
[f] 26 May
[g] 22 May

This information is preliminary or provisional and is subject to revision. It is being provided to meet the need for timely best science. The information has not received final approval by the U.S. Geological Survey (USGS) and is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

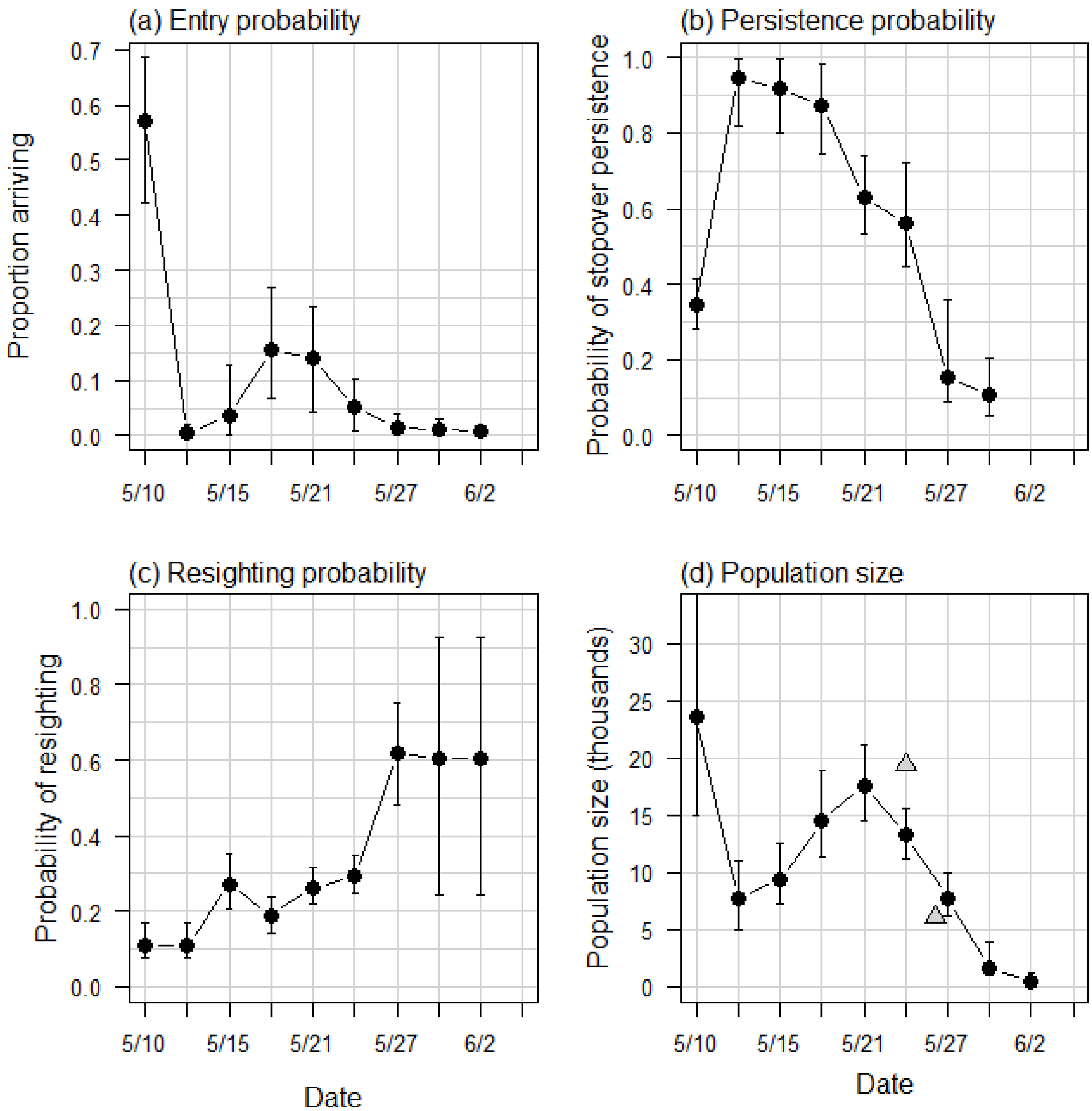


Figure 1. Estimated Jolly-Seber (JS) model parameters from a mark-resight study of Red Knots in Delaware Bay in 2020: (a) proportion of stopover population arriving at Delaware Bay, (b) stopover persistence, (c) probability of resighting, and (d) time-specific stopover population size. Dates on the x-axis represent sampling occasions (3-day survey periods). Triangles in (d) are total ground counts conducted on 24 and 26 May 2020 (no aerial survey in 2020).

This information is preliminary or provisional and is subject to revision. It is being provided to meet the need for timely best science. The information has not received final approval by the U.S. Geological Survey (USGS) and is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

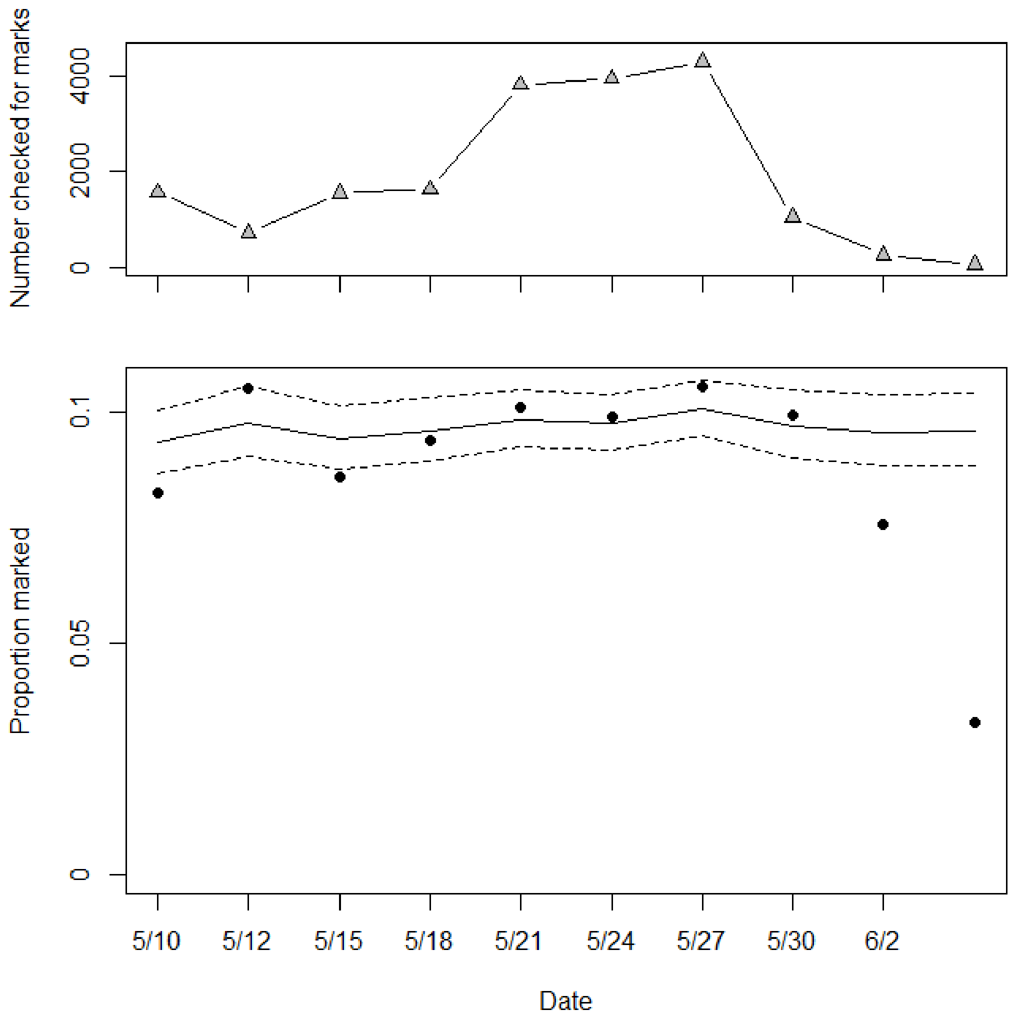


Figure 2. Estimated proportion of the Delaware Bay stopover population carrying leg flags in 2020. The marked proportion was estimated from marked-ratio scan samples for each 3-day sampling period. The dates for the sampling periods are shown in Table 1. Sample size (number scanned, i.e., checked for 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 estimated median proportion marked and 95% credible interval; filled circles show (number with marks/number scanned).

Appendix 1. Summary of 2020 mark-resight data (“m-array”). NR = never resighted.

			Next resighted at sample								
Sample	Dates	Resighted	2	3	4	5	6	7	8	9	NR
1	8-10 May	257	10	26	8	19	10	7	0	0	177
2	11-13 May	56		16	4	0	3	4	1	0	28
3	14-16 May	235			47	31	20	18	2	0	117
4	17-19 May	259				67	22	26	1	0	143
5	20-22 May	455					87	67	4	0	297
6	23-25 May	377						133	6	0	238
7	26-28 May	483							45	1	437
8	29-31 May	96								7	89
9	1-3 June										

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* $(\widehat{M_t^*})$ 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:

$$m_{s,t} \sim Binomial(C_{s,t}, \pi_t) \quad (3)$$
$$for\ s\ in\ 1, \ldots, n_{samples}\ and\ t\ in\ 1, \ldots, n_{occasions}$$
$$logit(\pi_t) = \alpha + \delta_t$$
$$\delta_t \sim Normal(0, \sigma^2_{occasions})$$

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.

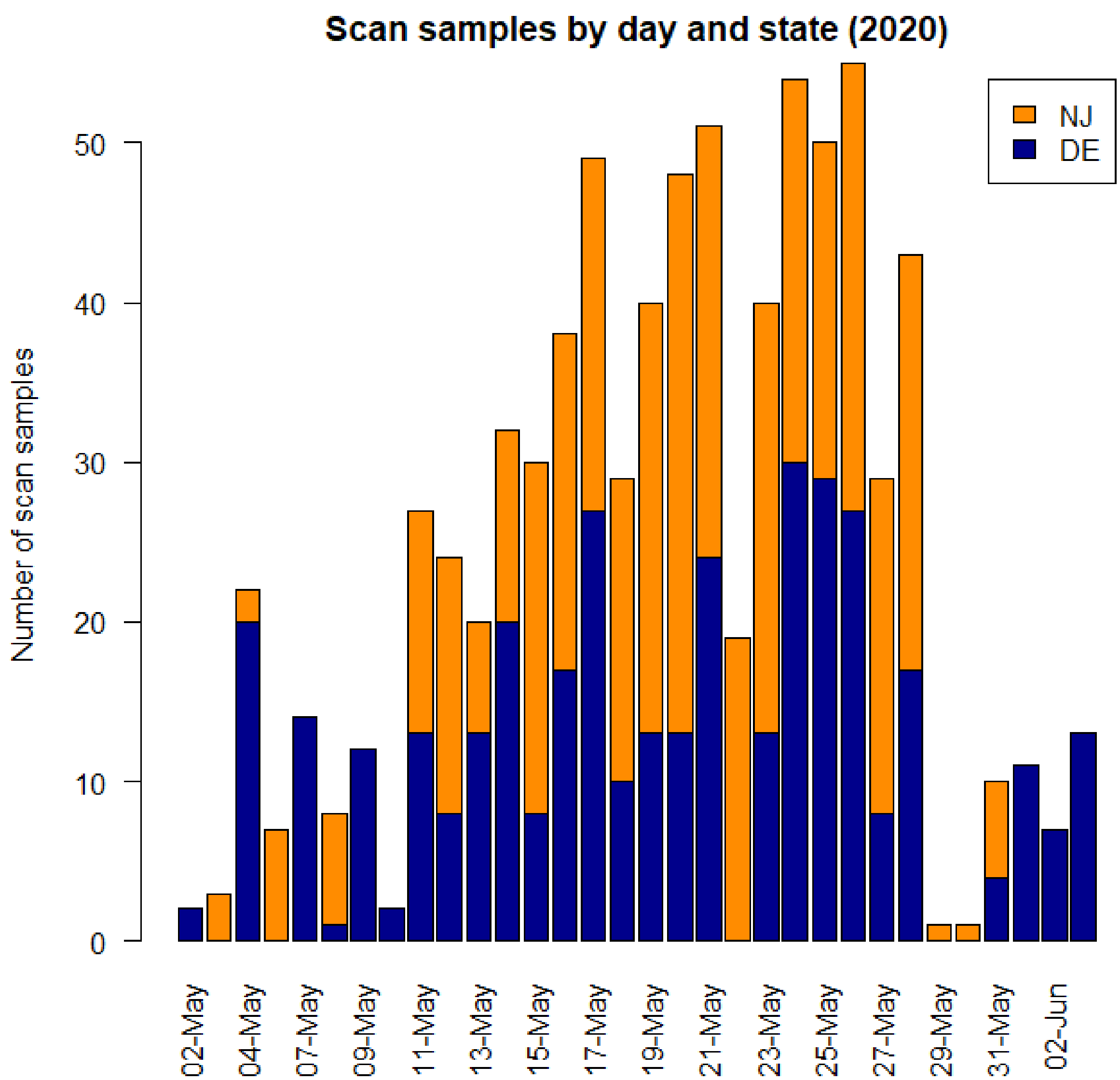


Figure A3.1. Number of marked-ratio scan samples (n = 734) collected in Delaware Bay in 2020 by field crews in Delaware (blue) and New Jersey (orange) and date. In 2020, observers in Delaware and New Jersey collected 376 and 358 scan samples, respectively.

DRAFT FOR BOARD REVIEW

ATLANTIC STATES MARINE FISHERIES COMMISSION

REVIEW OF THE INTERSTATE FISHERY MANAGEMENT PLAN

HORSESHOE CRAB
(*Limulus polyphemus*)

2019 Fishing Year

Prepared by the Plan Review Team

October 2020

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

DRAFT FOR BOARD REVIEW

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, Potomac River Fisheries Commission
Active Boards/Committees:	Horseshoe Crab Management Board, Advisory Panel, Technical Committee, and Plan Review Team; Delaware Bay Ecosystem Technical Committee

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.

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 (FMP) for Horseshoe Crabs. 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, extended 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 and beyond. The framework considers the abundance levels of horseshoe crabs and shorebirds in determining the optimized bait 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

A benchmark stock assessment was completed and approved for management use in 2019. The assessment report is available at:
http://www.asmfc.org/uploads/file/5cd5d6f1HSCAssessment_PeerReviewReport_May2019.pdf

This assessment was the first to successfully apply a stock assessment model to a component of the horseshoe crab stock. A Catch Multiple Survey Analysis (CMSA) model, a stage-based model that tracks progression of crab abundances from pre-recruits to full recruits to the fishery, was applied to female crabs in the Delaware (DE) Bay region (New Jersey-Virginia). This model estimated regional female crab abundance using relative abundance information from the Virginia Tech Benthic Trawl Survey, New Jersey Ocean Trawl Survey, and Delaware Adult Trawl Survey, and estimates of mortality including natural mortality, commercial bait harvest, commercial discard mortality, and mortality associated with biomedical use. While reference points were not approved to determine stock status, the CMSA population estimates were recommended as the best estimates for female horseshoe crab abundance in the DE Bay region.

The base CMSA model population estimates show an increase in the number of female crabs in the DE Bay region since 2012, when the ARM Framework was established via Addendum VII. This increasing trend is supported by positive trends in regional fishery-independent surveys during this time period. Population estimates from the base model are not publicly available due to the inclusion of confidential biomedical data. However, a sensitivity run assuming no biomedical mortality is publicly viewable, and these estimates are not significantly different from the base model results. Estimates of discard mortality from the Northeast Fisheries Observer Program (NEFOP) were also included in the base CMSA model and indicate that discard mortality could be significant, of similar or greater magnitude than mortality due to bait harvest. Population estimates from the CMSA are currently being considered for incorporation into the ARM Framework, which is applied annually to specify bait harvest quotas for the DE Bay region.

Autoregressive Integrated Moving Average (ARIMA) models, similar to those used in previous assessments, were applied to all regions. ARIMA models were fit to fishery-independent survey indices trends of abundance in each of the regional horseshoe crab populations: Northeast (Massachusetts-Rhode Island), New York (Connecticut-New York), DE Bay, and Southeast (North Carolina-Florida). No definitions for overfishing or overfished status have been adopted by the Management Board. However, the assessment characterized the status of each regional and the coastwide population based on the percentage of surveys within a region (or coastwide) having a >50% probability of the terminal year being below the ARIMA reference point. The ARIMA reference point was the 1998 index for each survey. “Poor” status was defined as >66% of surveys meeting this criterion, “Good” status was defined as <33% of surveys, and “Neutral” status was defined as 34–65% of surveys. Based on these criteria, stock status was neutral for the Northeast region, poor for the New York region, neutral for the Delaware Bay region, and good for the Southeast region. Coastwide, abundance has fluctuated through time with many surveys decreasing after 1998 but increasing in recent years. The coastwide status includes surveys from all regions and indicates a neutral trend, likely due to a combination of positive and negative trends.

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 along the coast. 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 season/area closures.

Reported coastwide bait landings in 2019 remained well below the coastwide quota (Table 1, Figure 1). Bait landings in 2019 totaled 660,091, excluding unreported landings from Massachusetts and confidential landings from Rhode Island. This total represents a slight decrease from 2018, however, it is likely that actual 2019 landings are greater than 2018 due to the missing data from Massachusetts. Landings increased in all states except Connecticut, with the most significant increases occurring in Maryland (119% increase from 2018) and Delaware (30% increase from 2018). Delaware harvested 5,014 crabs above their adjusted quota in 2019, and reduced their quota for 2020 from their allocated 162,136 male crabs to 157,122 male crabs.

Reported coastwide landings since 1998 show more male than female horseshoe crabs were harvested annually. Several states presently have sex-specific restrictions in place which limit or ban 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. States with greater than 5% of coastal landings are required to report sex for at least a portion of their bait harvest, and within these states, 5.3% of reported landings were unclassified in 2019.

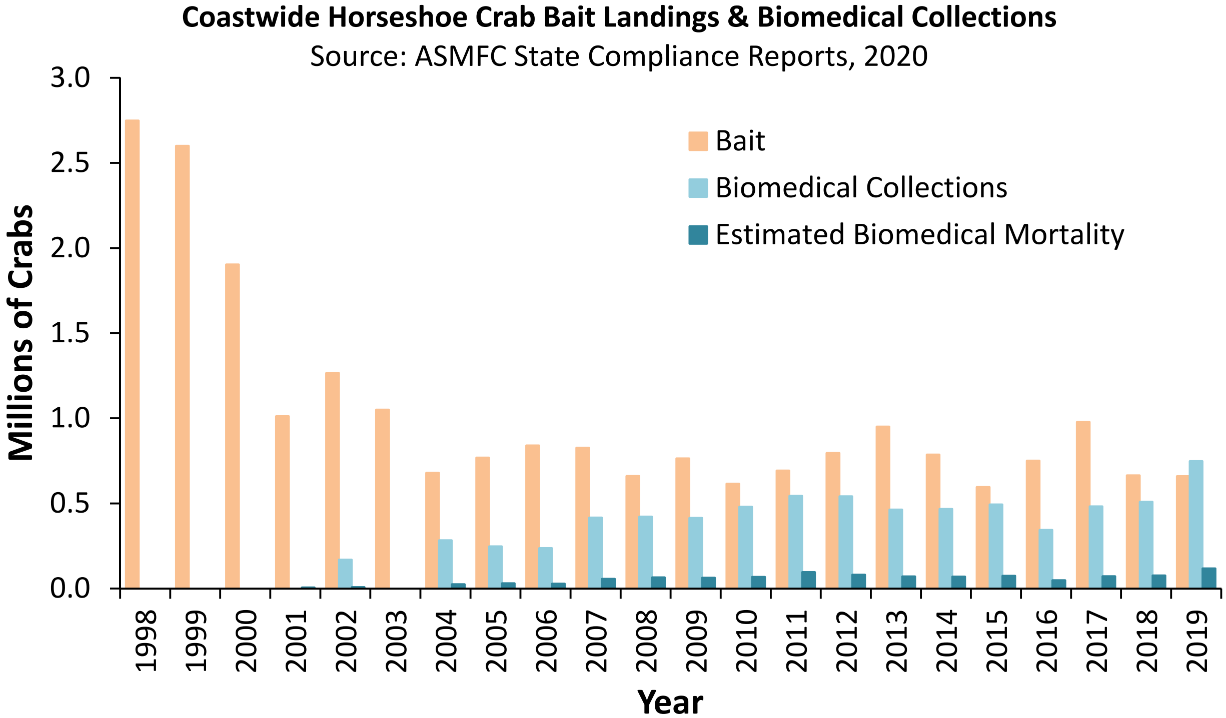
The hand, trawl, and dredge fisheries typically account for the majority of reported commercial horseshoe crab bait landings. Other gears that account for the remainder of the harvest include rakes, hoes, and tongs, fixed nets, and gill nets.

Table 1. Reported commercial horseshoe crab bait landings by jurisdiction. Note: Landings from 2017 and earlier were updated to numbers validated by all jurisdictions for use in the 2019 benchmark stock assessment.

Jurisdiction	ASMFC Quota 2019	State Quota 2019	2019	2018	2017	2016	2015
MA	330,377	165,000	***	159,002	134,707	110,399	117,611
RI	26,053	8,398	C	1,889	3,415	20,676	7,867
CT	48,689	48,689	17,588	21,870	19,944	21,945	19,632
NY	366,272	150,000	167,181	138,223	195,717	176,632	145,324
NJ*	162,136	0	0	0	0	0	0
DE*	162,136	159,211	164,225	126,065	201,132	109,836	151,262
MD*	255,980	255,980	145,907	66,647	237,146	157,013	27,494
PRFC	0	-	0	0	0	0	0
VA**	172,828	172,828	151,727	140,584	160,331	128,848	102,235
NC	24,036	24,036	13,463	10,998	25,161	25,197	24,839
SC	0	0	0	0	0	0	0
GA	29,312	29,312	0	0	0	0	0
FL	9,455	9,455	0	C	1,394	689	264
TOTAL	1,587,274	1,022,909	660,091	665,278	978,947	751,235	596,528

*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 data shown are preliminary. Virginia harvest east of the COLREGS in 2019 was 65,113 crabs. The total above represents harvest on both sides of the COLREGS line.
***2019 bait landings from Massachusetts are unavailable.

Figure 1. Number of horseshoe crabs harvested for bait and collected for biomedical purposes, 1998-2019.



* 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 assumed 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.'

Biomedical Use

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 (PRT) annually calculates total coastwide collections and estimates mortality associated with biomedical use. In 2019, 748,376 crabs coastwide were collected for biomedical for bleeding (Table 2). This does not include bait crabs that were counted against state quotas and bled. This represents a 46% increase from 2018. Males accounted for 39% of total biomedical collections and females comprised 61%. Some crabs were rejected prior to bleeding due to mortality, injuries, slow movement, and size (mortality observed while crabs were going through the biomedical process is included under 'Observed Mortality' in Table 2). Approximately 2% of crabs collected solely for biomedical purposes were observed and reported as dead from the time of collection up to the point of bleeding.

During the 2019 benchmark stock assessment, literature estimates were analyzed to estimate post-bleeding mortality. Although many of these studies did not implement biomedical best practices, these values are the only available estimates of mortality experienced after bleeding. Post-bleeding mortality was estimated at 15%. Tagging data was used in the assessment to compare survivorship between crabs that were and were not bled. These results indicated some decrease in short-term survivorship, but greater long-term survivorship for bled crabs. These results are likely attributable to the culling process used by biomedical facilities to select healthy crabs for bleeding.

Post-bleeding mortality, calculated as 15% of the number of bled biomedical-only crabs (not sold for bait), for 2019 was estimated as 102,758 crabs. Total mortality (observed mortality plus post-bleeding mortality) of biomedical crabs for 2019 was estimated as 118,411 crabs. This represents approximately 15% of the 2019 total directed use mortality (778,502 crabs), which includes both total biomedical mortality and removals for bait.

The 1998 FMP establishes a biomedical mortality threshold of 57,500 crabs that, if exceeded, requires the Board to consider management action. Based on an estimated total mortality of 118,411 crabs, this threshold was exceeded in 2019, as it has been for 12 of the last 13 years. Estimated mortality from biomedical use in 2019 represents the highest value in the time series both in numbers of crabs (a 53% increase from 2018) and as a percentage of total directed use mortality. Results of the 2019 Benchmark Stock Assessment indicate that levels of biomedical mortality prior to 2017 (the terminal year of data used in the assessment), which were relatively consistent between 2013-2018 (with the exception of 2016), did not have a significant effect on horseshoe crab population estimates or fishing mortality in the Delaware Bay region.

Table 2. Numbers of horseshoe crabs collected, bled, and estimated mortality for the biomedical industry. Numbers shown are for crabs collected solely for biomedical use. Mortality of bled crabs that later enter the bait industry is included in bait harvest.

Year	Crabs Collected	Crabs Bled	Post-Bleeding Mortality	Observed Mortality	Total Mortality
2010	480,914	412,781	61,917	6,829	68,746
2011	545,164	486,850	73,028	24,139	97,166
2012	541,956	497,956	74,693	7,370	82,063
2013	464,657	440,402	66,060	5,447	71,507
2014	467,897	432,340	64,851	5,658	70,509
2015	494,123	464,506	69,676	5,362	75,038
*2016**	344,495	318,523	47,778	1,004	48,782
2017	483,245	444,115	66,617	6,056	72,674
2018	510,407	479,142	71,871	5,588	77,459
2019	748,376	685,052	102,758	15,653	118,411

***Some biomedical collections were reduced in 2016 due to temporary changes in production.**

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 inform 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 sex 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 sex, the PRT recommends all states require sex-specific reporting for horseshoe crab harvest.

States with biomedical collections are required to monitor and report collection 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 2016-2019, and is in progress for 2020. The 2019 survey results indicate decreases from 2018 across all demographic groups (immature, newly mature, and mature females and males) in the coastal Delaware Bay area (DBA). It is noted that the 2019 Delaware Bay spawning survey was conducted from late August to late September. The average bottom water temperature in 2019 was the highest in the time series. The 2019 lower Delaware Bay (LDB) survey was conducted in mid-October, nearly a month earlier than in 2018, and later than the DBA survey. As a result, the average LDB water temperature was 5.6 C° cooler than the average DBA temperature. Horseshoe crabs that were within the Bay during most of the DBA survey because of the warm temperature, and not enumerated, may have moved out of the Bay by the time the LDB survey was conducted, and again not enumerated. This may have resulted in underestimates of horseshoe crabs in both survey areas and contributed to the apparent decrease in mature M:F ratios in both survey areas since 2016. Mean catch-per-tow of mature males and females in the coastal Delaware Bay area have shown increasing trends since 2002.

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. The VT Survey for 2020 is currently in progress and is funded for 2021. Funding sources beyond 2021 continue to be explored.

Spawning Surveys
The redesigned Delaware Bay spawning survey was completed for the 21st year in 2019. Baywide female spawning activity over the past 21 years showed no significant trend; though, the slope was slightly negative. Baywide male spawning activity showed a significant increasing trend. At the state level, trends in male spawning exhibited a significant positive slope in both states. The trend from the index of female spawning activity exhibited a slightly negative slope in Delaware, and a slightly positive slope in New Jersey. Neither was statistically significant. Female spawning activity in 2019 peaked during the third lunar period sampled (June 1 – June 5). The annual baywide sex ratio was 5.5:1 (Male: Female) the second highest ratio in the time series. The range of annual observed sex ratios on the Delaware Bay spawning beaches over the time series has ranged from 3.1:1 to 5.6:1.

Tagging Studies
The USFWS continues to maintain a toll-free telephone number and 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 coastwide horseshoe crab population. All existing and new tagging efforts are required to submit an annual application to be considered for the USFWS tagging program and all participants must submit an annual report along with their tagging and resighting 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 states coordinate with the USFWS tagging program, in order to ensure a consistent coastwide program to support management.

Since 1999, over 360,000 crabs have been tagged and released through the USFWS tagging program along the Atlantic coast. 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 Long Island Sound and the Southeast. Tagging information from this database has been used in the 2019 Benchmark Stock Assessment to define stock structure, estimate total mortality, and characterize impacts of biomedical use on crab mortality.

New York Region Monitoring
Following the 2019 Benchmark Stock Assessment, which characterized the status of the horseshoe crab population in the New York region as “Poor”, the Board directed the PRT to monitor fishery-independent surveys in this area to track progress of state management actions toward improving this regional population. During the assessment, five surveys were included in the ARIMA model to characterize this population. One of these, the Northeast Area Monitoring and Assessment Program (NEAMAP), includes sample areas outside of the New York region, making it too data-intensive to specify the regional index on an annual basis. The most recent information from the state-conducted surveys used in the assessment is summarized

below, but can be viewed in greater detail in the Connecticut and New York state compliance reports. The Western Long Island (WLI) Little Neck Bay and Manhasset Bay seine surveys were combined in the assessment to form a single index, but are shown below separately. Figures 2-5 show the annual index for each survey over the time series.

Connecticut

- Long Island Sound Trawl (Fall) – 2019 index = 0.82 kg/tow, decrease from 2018

New York

- Peconic Trawl – 2019 index = 0.2 (delta distribution average catch per unit effort [CPUE]), slight increase from 2018, below 2010-19 average (0.23)
- WLI Jamaica Bay Seine (all horseshoe crabs) – 2019 index = 0.23 (geometric mean), decrease from 2018, below 2010-19 average (0.32)
- WLI Little Neck Bay Seine (all) – 2019 index = 0.88 (geometric mean), decrease from 2018, below 2010-19 average (1.16)
- WLI Manhasset Bay Seine (all) – 2019 index = 0.68 (geometric mean), decrease from 2018, below 2010-19 average (0.65)

Figure 2. LISTS Horseshoe Crab Indices, 1992-2019.

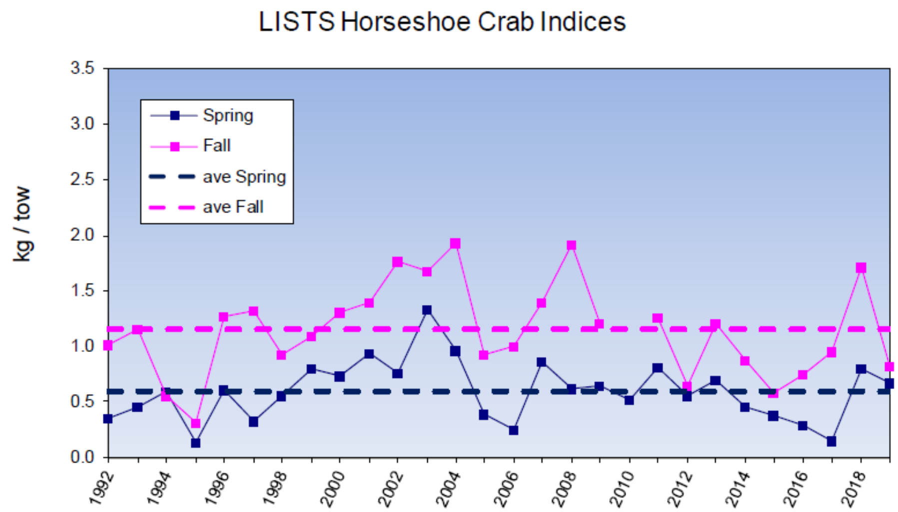


Figure 3. Peconic Bay Trawl Survey: May through July, 1987-2019.

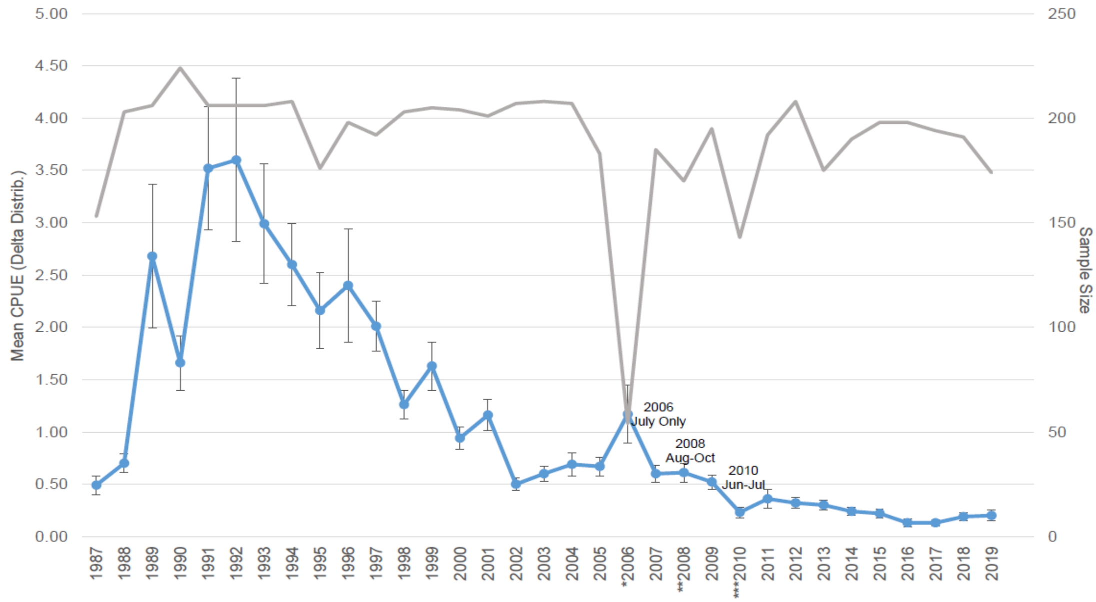


Figure 4. NYSDEC WLI Beach Seine Survey All Horseshoe Crab GM Index, 1987-2019.

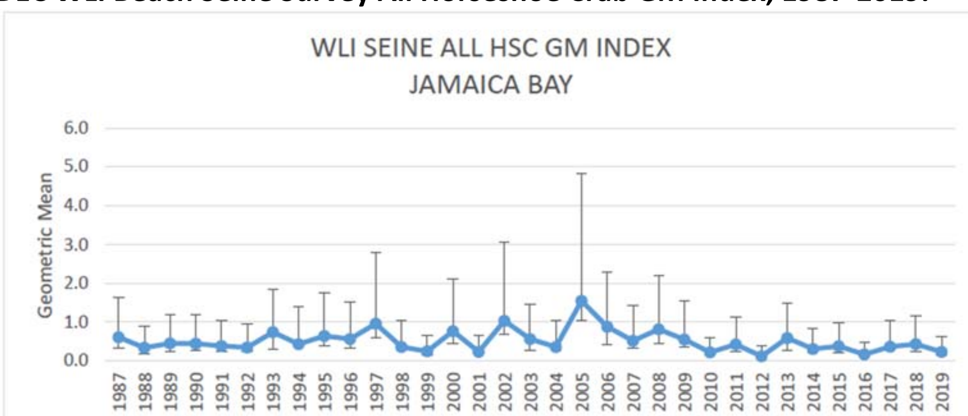


Figure 5. Little Neck Bay Seine Survey All Horseshoe Crab GM Index, 1987-2019.

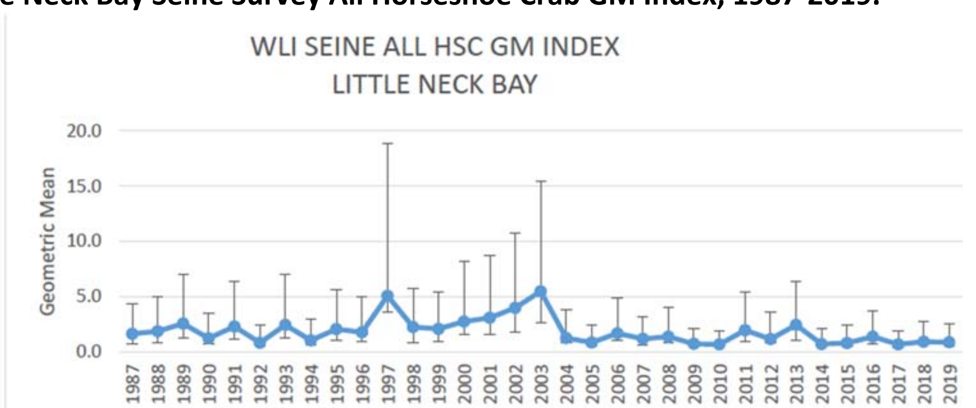
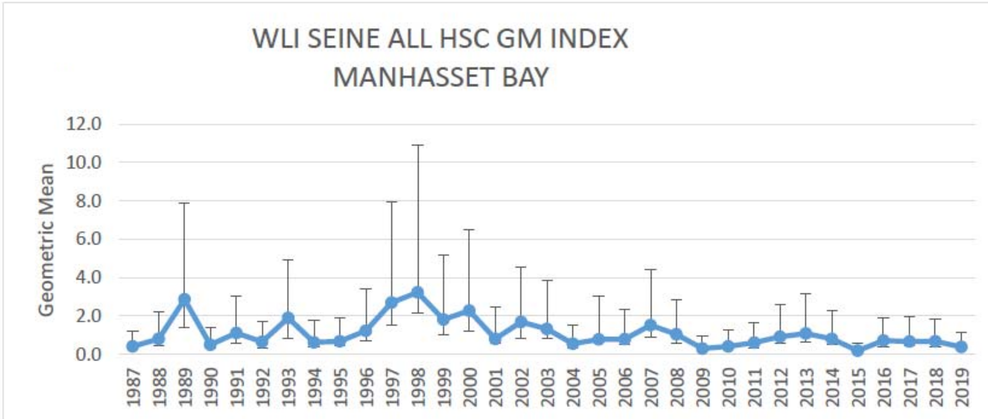


Figure 6. Manhasset Bay Seine Survey All Horseshoe Crab GM Index, 1987-2019.



V. Status of Management Measures and Issues

ASMFC

Initial 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.

State-specific charts outlining compliance and monitoring measures are included in Section VII. The PRT finds that all jurisdictions appear to be in compliance with the FMP and subsequent Addenda in 2019.

Alternative Baits

Trials testing effectiveness of alternative baits to horseshoe crab for the American eel and whelk fisheries have previously been conducted. Additionally, a survey of current bait usage in the eel and whelk fisheries was conducted in 2017. This survey is available at: http://www.asmfc.org/uploads/file/5a04b785HSC_BaitSurveyTCReport_Oct2017.pdf. The Horseshoe Crab TC is currently determining whether any additional alternative bait products will be tested in the near future.

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 designated the red knot 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. PRT Recommendations and Research Needs

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 2019 fishing season based on the 2018-19 season landings and meet the FMP requirements for being granted this status (Table 1). The PRT recommends granting these jurisdictions *de minimis* status.

Biomedical Threshold

In 2019, total biomedical mortality was more than double the FMP's mortality threshold of 57,500 crabs, which requires the Board to consider management action. This threshold has been exceeded in 12 of the last 13 years. The PRT has noted previously that the results of the 2019 Benchmark Stock Assessment indicated recent levels of biomedical use did not result in mortalities that would significantly alter population status. However, biomedical mortality in 2019 was 61% higher than the average biomedical mortality between 2009 and 2018.

Funding for Research and Monitoring Activities

The PRT strongly recommends the funding and continuation of the VT benthic trawl survey. This effort provides a statistically reliable estimate of horseshoe crab relative abundance that is essential to continued ARM implementation and use of the CMSA stock assessment model.

Discard Mortality Estimation

Results of the 2019 Benchmark Stock Assessment indicate that discard mortality may be significant, of similar or greater magnitude than bait harvest. The Review Panel's report indicated that these estimates could be further refined to reduce their uncertainty and more precisely characterize this mortality source. The PRT recommends the Board take steps to increase access to and use of data from the NEFOP, allowing for improved monitoring and estimation of discard mortality.

Improvement of the New York Regional Population

Results of the 2019 Benchmark Stock Assessment indicate a "Poor" status for the New York regional population, due to negative trends in regional abundance indices. New York and Connecticut have indicated that they will take actions within their states to improve this population. The PRT recommends that the Board encourage such actions to continue so that this population's status may improve. The PRT notes that bait harvest from New York increased by 25% from 2018 to 2019.

The PRT has begun and will continue to annually report regional indices of abundance so that progress of management actions may be tracked through the annual FMP Reviews. The PRT notes that indices of abundance from the Fall CT Long Island Sound Trawl Survey, Jamaica Bay Seine Survey, Little Neck Bay Seine Survey, and the Manhasset Bay Seine Survey all decreased from 2018; there was a slight increase from 2018 in the Peconic Bay Small Mesh Trawl Survey index.

VII. State Compliance and Monitoring Measures

MASSACHUSETTS		
	2019 Compliance	**2020 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	Not Provided	--
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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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

RHODE ISLAND		
	2019 Compliance	**2020 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 (8,398)	26,053 (8,398)
- Other Restrictions	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	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	Confidential	--
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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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	State Wildlife Grant for 2020-2021 tagging program in collaboration with URI. Status unknown beyond 2021.

CONNECTICUT		
	2019 Compliance	**2020 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	17,588	--
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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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		
	2019 Compliance	**2020 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	167,181	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	Yes	Yes
Monitoring Component A_2		
- Biomedical 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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	Yes

NEW JERSEY		
	2019 Compliance	**2020 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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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	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

DELAWARE		
	2019 Compliance	**2020 Management Proposal**
***De minimis* status**	Did not qualify for *de miminis*	Does not qualify for *de miminis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota (Adjusted Quota from Overage)	162,136 [male only] 159,211 [male only]	162,136 [male only] 157,122 [male only]
- Other Restrictions	Closed season (January 1 – June 7); season closed early on June 16	Closed season (January 1 – June 7)
- Landings	164,225 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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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		
	2019 Compliance	**2020 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
- Landings	145,907 males	--
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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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 use	Yes – through biomedical use

POTOMAC RIVER FISHERIES COMMISSION		
	2019 Compliance	**2020 Management Proposal**
***De minimis* status**	*De minimis* status granted in 2019.	*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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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		
	2019 Compliance	**2020 Management Proposal**
***De minimis* status**	Did not qualify for *de miminis*	Does not qualify for *de miminis*
Bait Harvest Restrictions and Landings		
- ASMFC Quota	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	151,727 (100,609 males)	--
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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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		
	2019 Compliance	**2020 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
- 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	13,463	--
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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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

SOUTH CAROLINA		
	2019 Compliance	**2020 Management Proposal**
***De minimis* status**	*De minimis* status granted in 2019.	*De minimis* requested for 2020 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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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	Yes

GEORGIA		
	2019 Compliance	**2020 Management Proposal**
***De minimis* status**	*De minimis* status granted in 2019.	*De minimis* requested for 2020 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)	29,312	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 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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

FLORIDA		
	2019 Compliance	**2020 Management Proposal**
***De minimis* status**	*De minimis* status granted in 2018.	*De minimis* requested for 2019 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	0	--
Monitoring Component A_1		
- Mandatory monthly reporting	Yes	Yes
- Characterize commercial bait fishery	No	Yes
Monitoring Component A_2		
- Biomedical 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 2019	Yes, VT Trawl Survey will be conducted in 2020 & 2021; 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	Yes	Yes
Monitoring Component B_4 Tagging program	No	No

Atlantic States Marine Fisheries Commission

1050 N. Highland Street • Suite 200A-N • Arlington, VA 22201
703.842.0740 • 703.842.0741 (fax) • www.asmfc.org

MEMORANDUM

October 5, 2020

To: **Horseshoe Crab Management Board**

From: **Tina Berger, Director of Communications**

RE: **Advisory Panel Nomination**

Please find attached a new nomination to the Horseshoe Crab Advisory Panel – Christina Lecker, a biomedical representative from Virginia. Please review this nomination for action at the next Board meeting.

If you have any questions, please feel free to contact me at (703) 842-0749 or tberger@asmfc.org.

Enc.

cc: Caitlin Starks

M20-110

Horseshoe Crab Advisory Panel

Bolded names await Board approval

Massachusetts

Jay A. Harrington (comm/handpicker/raker)
#6 Sherman Road
P.O. Box 321
South Orleans, MA 02662
Phone: 508.255.0582
indeepH2O@gmail.com
Appt. Confirmed 4/7/98
Appt. Reconfirmed 10/02; 10/06; 5/10; 8/18

Brett Hoffmeister (biomedical)
Associates of Cape Cod
331 Barlows Landing Row
Pocasset, MA 02559
Phone (day): 508.444.1426
BHoffmeister@acciusa.com
Appt Confirmed 2/3/16
Appt. Reconfirmed 8/18

Rhode Island

Vacancy (comm/otter trawl)

New York

John L. Turner (conservation)
10 Clark Bouelvard
Massapequa, NY 11762
Phone (day): 631.451.6455
Phone (eve): 516.797.9786
redknot@optonline.net
Appt. Confirmed 2/10/05
Appt Reconfirmed 5/10

Peter Wenczel (pot/conch)
675 West Shore Drive
Southold, NY 11971
Phone: 631.765.5669
pwenczel@optonline.net
Appt. Confirmed 4/7/98
Appt. Reconfirmed 10/02
Appt. Reconfirmed 10/06
Appt Reconfirmed 5/10
Participation: Inactive; attended last meeting in 2010

New Jersey

Benjie Swan (biomedical)
Limuli Laboratories
Dias Creek, 5 Bay Avenue
Cape May Courthouse, NJ 08210-2556
Phone: 609.465.6552
Swan24@verizon.net
Appt. Confirmed 8/5/10

Delaware

Lawrence Voss (comm./pot)
3215 Big Oak Road
Smyrna, DE 19977
Phone: (302)359-0951
shrlyvss@aol.com
Appt. Confirmed 10/24/18

2 vacancies - dealer/processor & conservation/environmental

Maryland

George Topping (comm/trawl)
32182 Bowhill Road
Salisbury, MD 21804
Phone: 443.497.2141
george@zztopping.com
Appt. Confirmed 5/16

Jeffrey Eutsler (comm/trawl)
11933 Gray's Corner Road
Berlin, MD 21811
Phone: 443.497.3078
jeffeutsler@me.com
Appt. Confirmed 2/4/98
Appt. Reconfirmed 10/02
Appt. Reconfirmed 10/06
Appt Reconfirmed 5/10

William R. Legg (comm/pot/eel)
110 Rebel Road
Grasonville, MD 21638
Phone: 410.820.5841
Appt. Confirmed 4/7/98
Appt. Reconfirmed 10/02
Appt. Reconfirmed 10/06
Appt Reconfirmed 5/10
Participation: Inactive; attended last meeting in 1998

Chair – Allen L. Burgenson (biomedical)

Horseshoe Crab Advisory Panel

Bolded names await Board approval

8875 Hawbottom Road
Middletown, MD 21769
Phone: 301.378.1263
allen.burgenson@lonza.com
Appt. Confirmed 8/21/08

Virginia

Richard B. Robins, Jr. (processor/dealer)
3969 Shady Oaks Drive
Virginia Beach, VA 23455
Phone (day): 757.244.8400
Phone (eve): 757.363.9506
richardbrobins@gmail.com
Appt. Confirmed: 2/9/00
Appt. Reconfirmed 1/2/06
Appt Reconfirmed 5/10

Christina M. Lecker
FUJIFILM Wako Chemicals U.S.A. Corporation, LAL Division
Plant Manager - Cape Charles Facility
301 Patrick Henry Avenue
Cape Charles, VA 23310
Phone: 757-331-4240, 757-331-2026
FAX: 757-331-2046
christina.lecker@fujifilm.com

1 vacancy - comm/pot/conch

South Carolina

Nora Blair (biomedical)
Charles River Laboratories Microbial Solutions
1852 Cheshire Drive
Charleston, SC 29412
843.276.7819
Nora.Blair@crl.com
Appt. Confirmed 5/1/19

Cindy Sires (comm/pot/trawl)
7609 White Point Road
Yonges Island, SC 29449
Phone: 843.607.3287
troubleyi@aol.com
Appt. Confirmed 8/5/10
Participation: Inactive; never attended meeting since appt in 2010

Nontraditional Stakeholders

Jeff Shenot
7741 market Street, Unit D
Wilmington, NC 28411-9444
Phone (day): 910.686.7527
Phone (eve): 910.619.6244
wgolder@audubon.org
Appt. Confirmed 8/2018

COMMONWEALTH of VIRGINIA

Marine Resources Commission
Building 96
380 Fenwick Road
Fort Monroe, VA 23651

Matthew J. Strickler
Secretary of Natural Resources

Steven G. Bowman
Commissioner

October 5, 2020

Tina Berger
Director of Communications
Atlantic States Marine Fisheries Commission
1050 N. Highland Street, Suite 200 A-N
Arlington, VA 22201

Tina,

I would like to nominate Christine Lecker of FujiFilm Wako Chemicals USA Corp to the Horseshoe Crab Advisory Panel. She is the plant manager of their Cape Charles, Virgina facility and has been bleeding crabs for LAL production since 2002 (previously under Wako Chemicals USA Inc.). From my discussions with her she will provide excellent representation to the panel with a Virginia/Maryland perspective on the biomedical industry. Please contact me if you have any questions or if there is anything else I need to do for this nomination. Thank-you.

Her contact information is:

Christina M. Lecker
FUJIFILM Wako Chemicals U.S.A. Corporation, LAL Division
Plant Manager - Cape Charles Facility
301 Patrick Henry Avenue
Cape Charles, VA 23310
P: 757-331-4240, 757-331-2026
F: 757-331-2046
Email: christina.lecker@fujifilm.com

Sincerely,

Patrick J. Geer
Chief of Fisheries Management

cc: Commissioner Steven Bowman

An Agency of the Natural Resources Secretariat
www.mrc.virginia.gov
Telephone (757) 247-2200 (757) 247-2292 V/TDD Information and Emergency Hotline 1-800-541-4646 V/TDD

ATLANTIC STATES MARINE FISHERIES COMMISSION

Advisory Panel Nomination Form

This form is designed to help nominate Advisors to the Commission's Species Advisory Panels. The information on the returned form will be provided to the Commission's relevant species management board or section. Please answer the questions in the categories (All Nominees, Commercial Fisherman, Charter/Headboat Captain, Recreational Fisherman, Dealer/Processor, or Other Interested Parties) that pertain to the nominee's experience. If the nominee fits into more than one category, answer the questions for all categories that fit the situation. **Also, please fill in the sections which pertain to All Nominees (pages 1 and 2). In addition, nominee signatures are required to verify the provided information (page 4), and Commissioner signatures are requested to verify Commissioner consensus (page 4). Please print and use a black pen.**

Form submitted by: Patrick Geer State: VA
(your name)

Name of Nominee: Christina M. Lecker

Address: 301 Patrick Henry Avenue

City, State, Zip: Cape Charles, VA 23310

Please provide the appropriate numbers where the nominee can be reached:

Phone (day): 757-331-4240, 757-331-2026 Phone (evening): ____________

FAX: ____________ Email: christina.lecker@fujifilm.com

FOR ALL NOMINEES:

1. Please list, in order of preference, the Advisory Panel for which you are nominating the above person.

   1. Horseshoe Crab
   2. ____________
   3. ____________
   4. ____________

2. Has the nominee been found in violation of criminal or civil federal fishery law or regulation or convicted of any felony or crime over the last three years?

   yes________ no X

3. Is the nominee a member of any fishermen's organizations or clubs?

   yes ________ no X

   If "yes," please list them below by name.

______________________________ ______________________________

______________________________ ______________________________

______________________________ ______________________________

4. What kinds (species) of fish and/or shellfish has the nominee fished for during the past year?

______________________________ ______________________________

______________________________ ______________________________

______________________________ ______________________________

5. What kinds (species) of fish and/or shellfish has the nominee fished for in the past?

______________________________ ______________________________

______________________________ ______________________________

______________________________ ______________________________

FOR COMMERCIAL FISHERMEN:

1. How many years has the nominee been the commercial fishing business? __________ years
2. Is the nominee employed only in commercial fishing? yes________ no__________
3. What is the predominant gear type used by the nominee?______________________________
4. What is the predominant geographic area fished by the nominee (i.e., inshore, offshore)?______________________________

FOR CHARTER/HEADBOAT CAPTAINS:

1. How long has the nominee been employed in the charter/headboat business? ________ years
2. Is the nominee employed only in the charter/headboat industry? yes ________ no________

   If "no," please list other type(s)of business(es) and/occupation(s):______________________________

   ____
3. How many years has the nominee lived in the home port community? ________ years

   If less than five years, please indicate the nominee's previous home port community.

   ____

FOR RECREATIONAL FISHERMEN:

1. How long has the nominee engaged in recreational fishing? _________ years

2. Is the nominee working, or has the nominee ever worked in any area related to the fishing industry? yes _______ no ________

   If "yes," please explain.

____

____

____

FOR SEAFOOD PROCESSORS & DEALERS:

1. How long has the nominee been employed in the business of seafood processing/dealing? ________________years

2. Is the nominee employed only in the business of seafood processing/dealing?

   yes ______ no ______ If "no," please list other type(s) of business(es) and/or occupation(s):

   ____

   ____

   ____

3. How many years has the nominee lived in the home port community? ________ years

   If less than five years, please indicate the nominee's previous home port community.

   ____

FOR OTHER INTERESTED PARTIES:

1. How long has the nominee been interested in fishing and/or fisheries management? 18 years

2. Is the nominee employed in the fishing business or the field of fisheries management? yes _____ no x

   If "no," please list other type(s) of business(es) and/or occupation(s):

   ____

   ____

   ____

FOR ALL NOMINEES:

In the space provided below, please provide the Commission with any additional information which you feel would assist us in making choosing new Advisors. You may use as many pages as needed.

Christina Lecker of FujiFilm Wako Chemicals USA Corp has been the plant manager of their Cape Charles, Virgina facility and has been bleeding crabs for LAL production since 2002 (previously under Wako Chemicals USA Inc.). From my discussions with her she will provide excellent representation to the panel with a Virginia/Maryland perspective on the biomedical industry.

Nominee Signature: ______________________ Date: 10/6/2020

Name: Christina Lecker
(please print)

COMMISSIONERS SIGN-OFF (not required for non-traditional stakeholders)

Patrick J Geer 10/5/2020
for Steven G. Bowman

State Director

State Legislator

Governor's Appointee