

**Report on the July 2024**

## **Horseshoe Crab Management Objectives Workshop**

**Prepared by**

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**Prepared for**

ASMFC Horseshoe Crab Management Board

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## **I. Acknowledgements**

Funding for the Horseshoe Crab Management Workshop was provided by the Atlantic States Marine Fisheries Commission (ASMFC). Toni Kerns, Caitlin Starks, and James Boyle led ASMFC staff efforts to design the workshop, communicate with stakeholders, and develop this report. They were assisted in these efforts by public policy mediator Kristina Weaver (Weaver Strategies LLC), who consulted on process design, facilitated the workshop, and assisted with developing the report. Shanna Madsen (Virginia Marine Resource Commission [MRC]), Joe Cimino (New Jersey Department of Environmental Protection [DEP]), John Clark (Delaware Department of Natural Resources and Environmental Control [DNREC]), and Michael Luisi (Maryland Department of Natural Resources [DNR]) provided guidance on process design. Delaware DNREC provided facility space to conduct the meeting at the Lewes Field Office.

We are grateful for the assistance of Kristina Weaver, PhD, of Weaver Strategies LLC, who served as the workshop’s impartial facilitator. Bringing more than 15 years of experience as an environmental mediator and professional facilitator, including a career with the Institute for Engagement & Negotiation at the University of Virginia, Dr. Weaver had previously facilitated a workshop with similar objectives around menhaden management convened in 2023 by the Virginia Institute for Marine Science. In addition to working closely with the ASMFC convening team, Dr. Weaver conducted stakeholder interviews to solicit input on workshop design.

We especially thank all workshop participants for contributing to candid, collegial, and productive dialogue that generated many insights and several areas of common ground. We also thank members of the public who attended and made comments in person, as well as members of the public who observed the live feed and submitted comments.

### ***Workshop Participants***

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## II. Executive Summary

Horseshoe crab is an important resource in the Delaware Bay region, where multiple stakeholder groups and members of the public have expressed perspectives regarding how the resource should be used and managed. One critical issue of contention is the extent to which the horseshoe crab population abundance and harvest levels are directly linked to the population health of red knot shorebirds (at the species level).

In response to significant stakeholder input following a 2021 revision of its Adaptive Resource Modeling (ARM) Framework for horseshoe crab modeling and regulation, the ASMFC convened professionally facilitated multi-stakeholder workshop aimed at fostering open, deep, and productive dialogue in Lewes, Delaware on July 15 and 16, 2024. The workshop convened stakeholders representing environmental NGO, fishing, biomedical, bird and horseshoe crab scientists, and management perspectives. The workshop adopted a consensus building process designed to surface core issues and concerns, gauge existing areas of common ground, and probe the extent to which new areas of agreement could be developed. Among the more important findings of the workshop were three fundamental areas where common ground was achieved:

- A consensus that there has been an increase in the horseshoe crab population in the Delaware Bay since 2010.
- Universal disapproval with the idea of using a harvest control rule regulatory framework, and an implicit affirmation of a preference for the Adaptive Resource Management Framework (ARM) as the most appropriate modeling and regulatory paradigm.
- A consensus agreement that the ASMFC should continue running the ARM but pause female harvest while several additional recommendations are considered and implemented, including: an investment in better science communication to build understanding among stakeholder groups and to educate the public about all existing channels for input; additional and focused stakeholder outreach to garner “essential concerns” (especially from members of the environmental NGO community that have registered significant disagreement with the ARM Revision); and a process to garner stakeholder input on refining the ARM reward and utility functions towards improving the model and strengthening its credibility.

Beyond these areas of consensus, additional comments, ideas, and proposals were shared and documented. In their closing remarks, participants affirmed that the workshop was highly productive and collaborative, and that important gains had been made around the stated meeting purposes (i.e., increasing understanding of stakeholder perspectives; increasing understanding of current modeling; and identifying concerns, alternatives, and areas of common ground for management). This report provides additional detail on background for the workshop and a summary of dialogue and consensus proposals. A more complete recording of input is included in Appendix 1, with workshop materials enclosed in Appendix 2.

### III. Brief Background / Context

#### a) Horseshoe Crab Ecology, Fishery, and Management

Horseshoe crab, (*Limulus polyphemus*) is an important resource, with diverse values for coastal ecosystems, Atlantic coast fisheries, and human health. Horseshoe crabs play an important ecological role in the food web for migrating shorebirds. The Delaware Bay population of horseshoe crabs is the largest along the Atlantic coast, and this region is also the largest staging area for shorebirds in the Atlantic Flyway. Millions of migrating shorebirds stopover in the Delaware Bay region during their annual migration to feed and rebuild energy reserves prior to completing their journey northward. Horseshoe crab eggs, laid on beaches, are one of the most important food sources for these birds. In addition to their role as a food source for birds, horseshoe crabs provide bait for commercial American eel and conch fisheries along the coast. With their unique blood, horseshoe crabs are also an important resource for human health. Horseshoe crabs are collected by the biomedical industry to support the production Limulus Amoebocyte Lysate (LAL), a clotting agent that is used worldwide to detect of human pathogens in patients, drugs, and intravenous devices. The challenge of fisheries managers is to ensure that horseshoe crabs are managed to meet all these diverse needs, while conserving the resource for future generations.

#### b) ARM Framework Revision

ASMFC has maintained primary management authority for horseshoe crabs in state and federal waters since it adopted the Interstate Fishery Management Plan for Horseshoe Crabs (FMP) in 1998. Since 2012, the Delaware Bay population of horseshoe crabs has been managed under the ARM Framework<sup>1</sup> in recognition of its ecological role in the Delaware Bay. The Framework considers the abundance levels of horseshoe crabs and shorebirds in determining the optimal harvest level for the Delaware Bay states of New Jersey, Delaware, Maryland, and Virginia (east of the COLREGS) to achieve multi-species objectives for horseshoe crabs and red knots. It was developed with the guidance of the Horseshoe Crab and Shorebird Technical Committees, which defined management objectives and values associated with horseshoe crab harvest. Since 2013, the Horseshoe Crab Management Board (Board) has annually reviewed recommended harvest levels from the ARM model, and specified harvest levels for the following year in the four Delaware Bay states.

In 2021, a revision to the ARM Framework was completed. The revision updated and improved the ARM model with an additional decade of data on shorebirds and horseshoe crabs in the Delaware Bay region, and advancements in modeling software and techniques, including recommendations from the original peer review. Changes to the ARM Framework are described in detail in the [2021 Revision to the Adaptive Resource Management Framework and Peer Review Report](#). The ARM Framework Revision was evaluated by an independent peer review

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<sup>1</sup> <https://asmfc.org/uploads/file/2009DelawareBayARMReport.pdf>

panel, which endorsed it as the best and most current scientific information for the management of Delaware Bay horseshoe crabs. Consequently, the Board adopted the revised ARM Framework for setting harvest specifications for the Delaware Bay region under Addendum VIII<sup>2</sup> in November 2022.

### **c) Stakeholder Survey**

During the public comment period on Addendum VIII over 30,000 comments were submitted by the public opposing the adoption of the ARM Revision in large part due to the fact that the results of the revised model run for the 2023 fishing year allowed for a limited amount of female horseshoe crab by the bait fishery for the first time. In response to the widespread concern, the Board elected to implement zero female horseshoe crab harvest for the 2023 season, despite the ARM model output. Given the apparent differences in stakeholder opinions on female harvest, in 2023 the Board conducted a survey of stakeholders including bait harvesters and dealers, biomedical fishery and industry participants, and environmental groups to better understand their diverse perspectives and values, and whether changes to horseshoe crab management for the Delaware Bay region should be considered.

The results of the survey<sup>3</sup> confirmed that the various stakeholder groups hold divergent values and perspectives. Commercial industry participants indicated they still value the harvest of female horseshoe crabs, though it has not been permitted in the Delaware Bay region since 2012. Researchers and environmental groups tended to value the protection of female horseshoe crabs and the ecological role of horseshoe crabs as a food source for shorebirds over the fishery. Considering these conflicting values, the ASMFC held a stakeholder workshop in July 2024 with participants from all stakeholder groups to generate recommendations for Board consideration regarding horseshoe crab management in the Delaware Bay region.

## **IV. Summary of Dialogue and Key Findings**

### **a) Overview of the Workshop Process**

Following the substantial public input regarding the ARM Framework Revision, and the results of the survey described above, ASMFC recognized both an urgent need and timely opportunity for multi-stakeholder dialogue to explore potential future objectives and management approaches for the Delaware Bay horseshoe crab fishery. Working with an external facilitator (Weaver Strategies LLC, see below for additional information), ASMFC convening team refined the meeting purposes:

1. Increase understanding of various stakeholder perspectives and interests.
2. Increase understanding of current horseshoe crab modeling.
3. Identify concerns, alternatives, and areas of common ground for HSC management.

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<sup>2</sup> [https://asmfc.org/uploads/file/63d2e8afHSC\\_AddendumVIII\\_November2022.pdf](https://asmfc.org/uploads/file/63d2e8afHSC_AddendumVIII_November2022.pdf)

<sup>3</sup> [https://asmfc.org/uploads/file/653932c4DB\\_HorseshoeCrab\\_ManagementSurveyReport.pdf](https://asmfc.org/uploads/file/653932c4DB_HorseshoeCrab_ManagementSurveyReport.pdf)

### ***Stakeholder Groups Represented at the Workshop***

The workshop included representation from the environmental NGO and advocacy communities, the biomedical industry, the fishing industry (including the harvest and biomedical dealer sectors), and biologists (including expertise in shorebirds and in horseshoe crabs). The workshop also included state managers from New Jersey, Delaware Maryland, and Virginia. ASMFC staff provided technical assistance. A list of stakeholders with affiliations is included in Appendix 2 of this report.

The workshop design was informed by insights from a subset of participants interviewed by the facilitator ahead of finalizing the agenda. Open-ended interviews were conducted with a member of the environmental NGO community, a member of the biomedical community, a horseshoe crab scientist, and a shorebird scientist. A member of the fishing community was also invited to participate but an interview was not successfully scheduled.

### ***Dialogue Process***

The workshop featured a presentation on the ARM Framework including a brief overview of the history of adaptive management of the species, a summary of known stakeholder perspectives, and an explanation of current modeling. Additional baseline knowledge and understanding was developed through an opportunity for each stakeholder community to share their primary concerns and perspectives. Prior to and during the workshop, participants were reminded to share not only their own perspectives but to do their best to represent their understanding of the broader stakeholder interests and concerns they represented.

The workshop facilitator introduced a consensus-building process aimed at encouraging participants to register their level of support for ideas along a three-scale gradient (where '3' indicates full support; '2' indicates support but with questions and concerns; and '1' indicates that one cannot support an idea given too many questions and concerns). Using this approach, participants with concerns were asked to share ideas that might shift their position towards support. As concrete ideas emerged through dialogue, the facilitator supported participants in developing proposals, consensus testing, openly sharing their questions and concerns, and working creatively towards refined ideas and solutions. Participants agreed (by consensus) to adopt this process as a strategy for focusing dialogue towards potential recommendations, with an understanding that this input *would not* be binding but *would be* weighed as valued input by the Board. Participants devoted the bulk of workshop time to revisiting core aspects of horseshoe crab management, testing for consensus, and developing new ideas (detailed below). The workshop agenda is included in Appendix 2.

### ***Opportunities for Public Engagement with the Workshop***

The workshop was open to members of the public, and several observed in person. At the end of each day, time was reserved for public comment (see Appendix 1 for summaries of comments). A live recording of the workshop was also broadcast for observing members of the public; despite best efforts to incorporate technology designed for better including remote

observers/listeners, there were technical difficulties with the acoustics of the space and several observers noted difficulty hearing all of the dialogue.

Overall, the Horseshoe Crab Management Workshop was highly collaborative and productive, with participants generally assessing, in their concluding remarks, that the three facets of the meeting's purpose were substantially advanced. Participants developed several recommendations around which to gauge and build consensus. Key areas are summarized below.

## **b) Consensus Proposals**

As part of the consensus-building process, participants were guided to introduce proposed ideas/recommendations to the group and to then note their level of agreement using the previously described three tier gradient system. Where all participants registered a '3' or '2,' consensus was technically achieved, with a larger portion of '3s' indicating a stronger consensus. Where any participant registered a '1,' consensus was not technically achieved and participants were prompted to engage in further dialogue, time permitting, to try and address concerns through refined proposals. Please note that participants were not required to indicate their level of support for each proposal. In many cases, there were abstentions, particularly from scientists or managers who wanted to defer to the perspectives of other stakeholders.

Participants were also asked by ASMFC staff to consider three "reality testing" questions when developing ideas to propose for consensus testing:

- (1) Does the idea shift us way from adaptive resource management and, if so, is that desired?
- (2) Are there resources available to implement the idea?
- (3) What information about the idea would help ASMFC make management decisions?

Consensus was achieved on five proposals/statements, as detailed below. Each statement is briefly explained and annotated with the number of participants who registered a '3' and '2' level of support. For all five of these, no participants registered a '1' (indicating cannot support, too many questions and concerns). Note that some of these statements are slightly elaborated for clarity relative to the documented versions developed with flip chart notetaking during the workshop.

- ***The horseshoe crab population has increased in the Delaware Bay since 2010.***

Participants used consensus to gauge the extent to which the group supported the above statement.

- 11-12 participants registered a '3' (full support)
- 2 participants registered a '2' (will support, but with some questions and concerns)



- ***ASMFC should conduct outreach to gather the ‘essential concerns’ of key stakeholders.***

Participants had considerable dialogue around the best way for ASMFC to gain a deeper understanding of the most significant concerns about the ARM, especially from some representatives of the environmental NGO community. Several ideas emerged and are more fully captured in Appendix 1. Participants were ultimately able to achieve consensus on the idea that there should be an outreach effort by the ASMFC to gather “essential concerns.” The precise method and timing for this outreach is to be determined.

- 8 participants registered a ‘3’ (full support)
- 2 participants registered a ‘2’ (will support, but with some questions and concerns)

- ***Using current ASMFC processes, refine the ARM reward and utility functions with stakeholder input.***

Having affirmed a preference for adaptive management over other approaches, participants agreed the reward and utility functions component of the ARM framework represent relatively “low-hanging fruit” for concerned stakeholders to provide input to improve the model and, by extension, to strengthen its credibility. While the group considered a variety of stakeholder engagement process options, consensus was ultimately reached around the suggestion to use existing ASMFC channels.

- 7 participants registered a ‘3’ (full support)
- 5 participants registered a ‘2’ (will support, but with some questions and concerns)

- ***ASMFC should improve science communication about the ARM, including optimizing existing channels for engaging with the public.***

Participants frequently spoke to the difficulty of adequately explaining and understanding the science underpinning the ARM Framework and saw an important opportunity for the ASMFC to invest in science communications efforts. Related to this, there was an acknowledgement that existing channels for the public to engage with the ASMFC may not be fully understood or utilized, and could be better explained and disseminated.

- 11 participants registered a ‘3’ (full support)
- 1 participant registered a ‘2’ (will support, but with some questions and concerns)

- ***ASMFC should continue to run the ARM by default with a recommendation to pause female harvest in the meantime (i.e., while the other recommendations listed are implemented and stakeholder input is further considered).***

Participants considered a variety of alternatives to the ARM Framework, ultimately affirming a preference to continue running the ARM but with a need to pause female harvest while the above ideas are considered and implemented.

- 11 participants registered a ‘3’ (full support)
- 2 participants registered a ‘2’ (will support, but with some questions and concerns)

### c) Proposals where Consensus was Tested but Not Reached

In working to identify and build areas of common ground, participants considered several ideas and proposals where consensus was not technically achieved. As part of the consensus-testing process, each participant registering a '1' was asked to explain their questions/concerns and offer any ideas that might shift them towards a '2' or '3', time permitting. For proposals where any participant indicated a '1' (even despite further dialogue on the idea), consensus was not achieved (see list below). In some cases, subsequent dialogue led to the consensus proposals listed above.

- ***Female harvest is appropriate under some circumstances.***

Participants used consensus to gauge the extent to which the group supported the above statement. Questions/concerns noted by the participants registering a '1' included not seeing a justification for female harvest, and that there are still too many questions about the impact of female horseshoe crab harvest given their role as a food source for red knots.

- 11 participants registered a '3' (full support)
- 2 participants registered a '2' (will support, but with some questions and concerns)
- **2 participants registered a '1' (cannot support, too many questions and concerns).** Concerns shared included:
  - *The case for expanding to female harvest has not been adequately justified.*
  - *There are remaining concerns with the model itself.*
  - *An understanding that red knots need a "superabundance" of eggs that may exceed what would be deemed as a sustainable level for horseshoe crabs.*
  - *A desire to represent the interests of Audubon members who believe female horseshoe crabs should not be harvested until red knot are delisted or there is more robust evidence about the link between eggs and red knots. This participant acknowledged the challenge and opportunity may be largely about information sharing and improving the accessibility of existing scientific knowledge.*
  - *A concern that more time is needed to fully assess data about female horseshoe crab abundance and red knot population trends, and should exercise caution having only recently "turned a corner."*

- ***The ASMFC should revert to a Harvest Control Rule (and not use Adaptive Resource Management).***

Participants universally affirmed they did not support returning to the earlier modeling approach, thus implying a strong preference for adaptive management. It should be noted that while the earlier modeling approach was not intended as a harvest control rule, it would essentially function as such under realistic horseshoe crab and red knot population conditions.

- 0 participants registered a '3' (full support)

- 0 participants registered a '2' (will support, but with some questions and concerns)
- **12 participants registered a '1' (cannot support, too many questions and concerns).**
  - *Given the level of objection to the idea of a harvest control rule, dialogue advanced from this topic expediently without itemizing all concerns. It was clear that the group prefers to find a way to stay within an Adaptive Resource Management framework.*

- ***Pause running the ARM to focus on modeling for male-only harvest based in science.***

This idea was proposed as an alternative to devoting resources to run the ARM annually while not following the output around female harvest, which some viewed as a poor use of the modelers' time and resources.

- 1 participant registered a '3' (full support)
- 3 participants registered a '2' (will support, but with some questions and concerns)
- **7 participants registered a '1' (cannot support, too many questions and concerns).**
  - *This proposal was introduced by a participant who was concerned that running the ARM annually without following its outputs would amount to a waste of resources with negative impacts on the staff who administer the model, and that the proposal would be a preferred solution to doing that. While participants did not elaborate on their specific concerns, it was clear from this consensus test that there would not be agreement on advancing this idea and dialogue quickly moved beyond it.*

- ***Work on a conflict resolution process with NGOs.***

Some participants raised the concern that those environmental NGOs with the most significant objectives to the ARM revision were not present at the workshop, and that the ASMFC should devise a way to directly work through the most serious disagreements with the environmental NGO community. Ideas discussed for this concept ranged from face-to-face meetings, to listening sessions, to independent review of the ARM by a small group of (3-4) external experts.

- 7 participants registered a '3' (full support)
- 2 participants registered a '2' (will support, but with some questions and concerns)
- **3 participants registered a '1' (cannot support, too many questions and concerns).**
  - *The primary concerns shared were that it would be unfair for ASMFC to hold private meetings with some but not all stakeholder groups or communities, and that it would discredit and undermine the rigorous external peer review process in place to evaluate the science of the ARM Framework.*

- ***Pause the ARM via an ASMFC addendum while stakeholder engagement on reward and utility functions and conflict resolution with environmental NGOs are implemented.***

This proposal was an attempt to assemble several ideas that emerged through dialogue. When consensus was not achieved, focus shifted to teasing out areas of agreement towards developing the consensus-based proposals listed above.

- 4 participants registered a '3' (full support)
- 3 participants registered a '2' (will support, but with some questions and concerns)
- **3 participants registered a '1' (cannot support, too many questions and concerns)**
  - *Participants who did not support this proposal expressed concerns about creating additional controversy and losing important information as a result of pausing the ARM, and that any pause should have a time limit.*

As time permitted, there was participant dialogue around all of the above proposals. Appendix 1 provides a more complete overview of the ideas and comments raised.

#### **d) Recommended Next Steps**

In developing consensus-based proposals, participants understood the recommendations would not be binding, neither in relation to participant adherence nor ASMFC adoption. Rather, workshop conveners emphasized that the meeting presented an opportunity to gauge where there could be areas of common ground, with an expectation that participant ideas would be seriously considered by the Horseshoe Crab Board. As was explained by ASMFC staff at multiple points, participants also understood that any further recommendations by the Board regarding the ARM would in turn be subject to public notice and opportunity to comment.

Beyond the proposal to continue running the ARM but pause female harvest for the time being, there are several recommendations the ASMFC could begin exploring and implementing using existing resources and avenues. In fact, consensus-based proposals reflect a sensitivity to resource constraints and the opportunity to optimize channels for engagement that are already available but may not be fully accessed. In light of these and other suggestions emerging from the workshop, three potential next steps for the Board to consider are described below.

##### **1. Initiate an addendum to establish a concrete interim solution (multi-year specifications)**

While the workshop participants all agreed the ARM should continue to be run while additional recommendations are addressed, they expressed a desire for more certainty around harvest specifications. Specifically, the participants agreed it would be preferable to set female harvest quota to zero for the time needed to address other recommendations. An addendum that allows the Board to set specifications for multiple years at a time would provide greater predictability about future harvest levels, but

would not abandon use of the ARM Framework. An addendum could be developed and implemented before the Board needs to set harvest specifications in the fall of 2025.

**2. Begin a dialogue with key stakeholders to identify ‘essential concerns’**

Workshop participants discussed the need for ASMFC to gain a deeper understanding of the most significant concerns about the ARM, especially from some representatives of the environmental NGO community that were not participants. ASMFC could begin such a dialogue through a series of webinar meetings with key stakeholders, with the purpose of allowing concerns or questions about the ARM Framework data and models to be raised and addressed. This could build greater collective understanding of the ARM, provide ASMFC with a list of critical concerns regarding the ARM Framework, and allow proposals of alternative methods to be considered. It could also provide preliminary direction for the next step. Depending on the format of these meetings, additional resources could be needed.

**3. Initiate a process to develop alternative reward and utility functions with stakeholder engagement**

Participants affirmed a preference for adaptive management over other approaches, but suggested the reward and utility functions component of the ARM Framework could be evaluated and modified to better address stakeholder concerns and values. The workshop discussions suggested that the process of reevaluating the reward and utility functions should engage stakeholders using existing ASMFC channels (e.g., committee meetings). It should be noted that this type of process will take time, similar to the 2021 ARM Framework Revision, and ultimately management action would be needed to implement any changes. Under the new process identified in Addendum VIII, the next ARM Framework revision would begin 2028 or 2029 but the Board can take action to start this process sooner. If this is pursued, additional resources would be needed including staff time. Depending on the timing of this process, other Commission assessments may need to be reprioritized.

Additional recommendations were developed at the workshop that could be considered as medium to longer-term goals. The first is to evaluate the Horseshoe Crab Advisory Panel (AP) to determine if it has adequate representation across stakeholder groups. This may require adding seats to the panel for non-traditional stakeholders (i.e., environmental NGOs). The states can work with ASMFC to review and modify AP membership as needed. The second is to take steps to improve science communication about the ARM, including optimizing existing channels for engaging with the public. Participants agreed that adequately explaining and understanding the science underpinning the ARM Framework is an ongoing challenge. They acknowledged the general public may not fully understand or utilize existing channels for engaging with the ASMFC, so this information needs to be better explained and disseminated. Working toward improving science communication on the ARM could be an opportunity to collaborate with key NGO stakeholders in developing outreach content and programs related to this topic and disseminating information to a wider audience. These stakeholders could provide valuable feedback on where improvements in communication could be made.

## V. Appendix 1: Additional Comments and Ideas

*The notes in Appendix 1 capture public comment and additional participant comments and ideas shared across the one and one-half days of dialogue. Notes on the dialogue were captured on flipcharts (by the facilitator) and via laptop recording (by ASMFC staff). Raw notes have been edited, re-organized, and consolidated for clarity. Some acronyms are used in these notes (e.g., “HSC” means “horseshoe crab”). Bullets represent distinct comments by a participant; sub-bullets indicate direct follow-up comments in response to points made.*

### a) Public Comment

*The notes below capture comments by members of the public who attended the workshop in person. Public comment was invited at the end of each day.*

- Framing of Science vs. Politics - We are all looking for the best science and lack of answers drives a precautionary approach
- Stakeholder engagement suggestions:
  - Make information publicly available as quickly as possible and consider timing for input
  - A previous offer to field questions about registered concerns was not taken up
  - Technical committees do not allow for meaningful engagement
- There is a great deal we do not know about red knots
  - We have to govern horseshoe crabs with management tools that can be improved
  - Disagrees with not harvesting females; request that ASMFC not give up on the ARM
  - Cannot understand opposition to collection for *Limulus* amebocyte lysate (LAL) given the interests human health and lack of adequate replacement
  - Political avenues are wrong - decisions should be made in rooms like this
- Everyone here is an expert and if we listen to each other discuss facts in our area of expertise it would be easier to get past the idea of “misinformation”
  - Would love to see egg density data included in ARM
  - Fish also consume HSC eggs
  - What’s the carrying capacity of the ecosystem?
- Education is very important. Some groups ignore the facts
  - Media coverage is upsetting; data are not placed in context
- Importance of public input in the process
  - Dialogue today advanced when it became more specific re: concerns
  - Take public comment seriously (i.e., 34,000 submitted comments)
  - Even technical comments were ignored initially by the Horseshoe Crab Board and the process was difficult for the public to engage in
  - Concerned about red knot decline and trajectory

## **b) Participant Hopes for the Workshop**

*These hopes were recorded during the initial round of introductions on Day 1. While closing comments were not recorded, participants largely affirmed that their hopes for the workshop had been substantially realized.*

- Get along
- Get an idea of how much science we can put in this
- Increase understanding of the science
- “We’ll see how this works out.”
- Clarify misconceptions / misinformation
- Build relationships and consensus
- Find common ground
- Good science and strong protections for HSC
- Discuss what adaptive management mean
- Learn and gain understanding
- Consensus
- Feel heard
- Gain understanding
- Learn
- Hearing from everyone and finding a way forward
- Share perspectives and listen
- Increase common understanding about the ARM
- Consensus
- Come out with Objectives
- Better shared understanding of facts and science
- Support restoration and protection of both species

## **c) Fundamental Interests of Stakeholder Groups**

*Prior to shifting into consensus building, participants were asked to help refine the collective understanding of the ecosystem of issues and concerns across all stakeholder groups. Participants were reminded that they should speak not only about their own perspectives, but try to capture the concerns of the broader network of stakeholders they represented. Each cluster of stakeholders broke into small group discussion then reported back to the large group.*

### **“Fundamental Interests” of Each Stakeholder Group (report back of small group discussion on key areas of concern)**

#### *Biomedical Community - Fundamental Interests*

- We are collectors not harvesters
- Ubiquity and magnitude of LAL medical applications in terms of safety and success
- Human health
- Products, processes, procedures have evolved over time
- State legislatures getting involved – concern about the topic being taken away from scientists

- Misinformation – Is biomedical really a top risk for horseshoe crab?
- LAL regulation is very complex
- Health risks of synthetics currently – we are trying to get to synthetics but LAL remains the gold standard now

#### *Red Knot Scientists - Fundamental Interests*

- Recovering the red knot is a requirement of our work
- Best available science to optimize recovery resources
- Risk aversion given uncertainty - avoid overshoot
- Consensus would advance recovery
- Improve science communication across all data sets
- Link between horseshoe crab and red knot still valid - lots going on across life cycle
- Need consensus in collection methods for surveying horseshoe crab egg data

#### *HSC Scientists - Fundamental Interests*

- Questioning of scientific integrity of HSC scientists has been really difficult
- Scientists are NOT in “back pocket” of industry
- Context is very important. Especially in the media, there is a need to look at population size and mortality data together (not in isolation)
- Media spin has been a major problem
- Clarification on timing of the VT survey - spring / fall / summer

#### *Managers - Fundamental Interests*

- Strong reaction to ARM outcome was concerning because the ARM uses best available science and includes red knot considerations
- Fear of continued misinformation given that HSC is actually one of the better communicated models. Sense that no matter what comes out, misinformation will seek to overcome it
- No matter what, people won't be happy – polarization
- Alternative hypotheses for red knot trends seem to be unwelcome
- We manage on science, not “vibes”
- Is misinformation intentional bias or about education / misunderstanding?
- Best available science doesn't mean “great” science – err on abundance of caution
- Prefer to leave politics out of it BUT options become political and HSC is very politically charged
- Can't lose sight of human health
- Haven't harvested females since 2012, so what IS harming red knot?
- Wants to get out of a position of fear

#### *Fishermen - Fundamental Interests*

- HSC quotas are important
- Demand market fluctuates mainly on conch
- Females - it's not the commercial harvesters impacting them currently, but this used to be an important market



- Presence of females in harvest can help sell males too, even if there are limited numbers of females; “something is better than nothing”
- Issue of misinformation, not relying on best available science, overreacting
- Want to uncover the real problems for red knot
- Long term, generational view – a lot is invested over generations and fishermen take a generational perspective
- Regulation has been a battle through the lifetime of a fisherman, and is not always logical
- Faced with an argument that we “protect a dinosaur” given public perceptions
- Female is commercially 10X better than a male at market in terms of size and effectiveness
- 2022 ARM is good news and an improvement
- Younger generations haven’t experienced female harvest
- Water quality supports good larvae recruitment on all levels. Plastics are a big issue we can all get behind
- Fishermen are stewards and keep good records

#### *Environmental NGOs - Fundamental Interests*

- Biological indicators are still very fragile re: red knot
- There is a very real link and we are in a crisis
- Does ARM adequately capture fluctuations?
- Why is there a need for female harvest?

#### **d) Discussion of the 2022 ARM Objective Statement**

Participants were prompted to consider the 2022 ARM Objective Statement and to discuss the extent to which it still reflected their interests and concerns.

**2022 Statement:** Manage harvest of horseshoe crabs in the Delaware Bay to maximize harvest but also to maintain ecosystem integrity, provide adequate stopover habitat for migrating shorebirds, and ensure that the abundance of HSCs is not limiting the red knot stopover population or slowing recovery.

- Note that the consensus reached in this room may be higher than what would be reached outside of this room
- Note that for biomedical the word to use is “collect” not “harvest”
- Could be strengthened with more specificity, measurability, inclusion of criteria
  - Conversely, more specific numbers could lead us back to a threshold approach and away from the ARM
- Need to clarify how limitation is defined and whether it’s an appropriate measure
- Shorebird communities dislike “maximize harvest”
  - Optimal vs. Maximum?
  - Manage?
  - Add “sustainable”?

- “Adaptive”? Element of time could signal the ability to incorporate data over time
- Replace “stopover habitat” with “food habitat”
- Edit to avoid use of “but”
- How to define “adequate”?
- Caution that wordsmithing could be perceived as “lipstick on a pig”
- Alternate verbiage:
  - “Provide sustainable harvest opportunity while also maintaining ecosystem integrity...”
  - “Accommodate sustainable harvest...”

*A participant then developed a “strawman” Objective Statement revision, in light of this input, and provided the revision to the facilitator ahead of Day 2. The workshop facilitator shared with the group that this had been provided and could be discussed. Ultimately the group did not have time to consider this revision given time constraints, but it is included here:*

“Through adaptive management based on best available science, optimize harvest of horseshoe crabs in the Delaware Bay Region to maintain ecosystem integrity, provide adequate food resources for migrating shorebirds, and ensure that the abundance of horseshoe crabs is not limiting the red knot stopover population or slowing recovery, while also accommodating sustainable harvest.”

#### **e) Additional Participant Comments**

*The facilitator and ASMFC staff worked to record participant comments, questions, concerns, and ideas across the 1.5 days of dialogue. While recording could not capture every comment at a transcript level, a robust list of issues that were surfaced is included here:*

- It was a mistake not to include some of the NGOs with the greatest concerns at the workshop
- What is ASMFC’s long-term plan?
- “Threatened with Extinction” is misinformation in the media and is frustrating; NGOs may have differences but are operating from an umbrella group that is spreading misinformation
- We need to celebrate successes also re: HSC population gains, hatchery operations
  - Hatcheries are not really successful
- HSC recovery has had a lag
  - There may be a lag for red knot too; other factors could be impacting the link
- Why was there such a strong response to the ARM?
  - Timing of ARM revisions came up against uncertainty in the field recently and raised questions about translation of datasets
  - Trust issues
- Question: Why does the NGO community call to ban any harvest?
  - Don’t group all NGOs together
  - Issue of enforcement capacity

- Don't call views that disagree with you "misinformation"
- Bias on Managers' side as reaction to other extreme
- If ARM is best available science, then (a) why ignore it? (b) what signal does ignoring it send?
  - "best available" is not necessarily great but can become better
  - Ways to make science better?
- Difference between current ARM and "adaptive management"?
- Science, even if great, will always have uncertainty
- Board should be open to additional stakeholder input around functions
- Public is extremely risk averse given decline in red knot
- Science is also political
- Re-evaluate how model reflects public sentiment
- Need more communication with stakeholders on existing channels to provide input to ASMFC
- No reason to go away from the current modeling approach
  - Issue is female harvest
  - Need ability to be flexible
- If we don't harvest females for now, why run the ARM every year?
  - Don't run ARM until a future point?
  - Find a model for male harvest?
- ARM incorporates uncertainty already and is revised over time
  - Male only harvest could be a large number if based in science
  - Reward and Utility Function is where stakeholder input is most valuable (i.e., economic value of females, probability of red knot extinction)
- Give ARM time and see how it goes
- Re: Utility and Reward Functions, new ARM doesn't have a real option for no female harvest
  - Are we more concerned when red knot are high or low? Issues with abundance
  - Incorporate switch somehow
- Watermen perspective re: "following the science" - Trust
- Proposed female harvest would be so small couldn't detect effect
- You can't just turn the ARM off - inputs will be lost in reality
- Could be outcry with either option - "which do you want to defend"
- Can current ARM be adjusted so no females is an option?
  - Unclear
  - Could re-weight Reward Function
- No one wants to back away from "best available science" including the environmental community
- Useful from a Scientist perspective: Task ARM subcommittee with identifying alternative Reward and Utility Functions for stakeholder consideration through a consensus process

## **VI. Appendix 2: Workshop Materials**

The following pages include these workshop materials:

- Workshop Agenda
- Slide Deck – Presentation on “Adaptive Resource Management (ARM) Framework Overview”
- Terminology Handout



# Atlantic States Marine Fisheries Commission

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## **Horseshoe Crab Workshop: Sharing Perspectives + Identifying Areas of Common Ground for Future Management Agenda**

July 15-16, 2024  
DNREC Lewes Field Office  
901 Pilottown Road, Lewes, Delaware 19958

### **MEETING PURPOSE**

1. Increase understanding of various stakeholder perspectives and interests.
2. Increase understanding of current horseshoe crab (HSC) modeling.
3. Identify concerns, alternatives, and areas of common ground for HSC management.

### **DAY 1 AGENDA**

9:00 a.m. – 5:00 p.m.

**9:00-9:30 Coffee/Networking**

**9:30-10:00 Opening Remarks and Introductions**

- The ASMFC Horseshoe Crab Board is very open to whatever outcomes emerge and is especially interested in understanding where stakeholders can develop common ground
- There are two groups anticipating the deliverables of this workshop:
  - Managers who need to understand the core framework and objective for HSC management
  - Scientists who need to convert management needs into adjustments to current modeling or into new modeling approaches

**10:00-10:15 Overview of Dialogue Process**

- Consensus-based process as a tool for surfacing areas of agreement and encouraging stakeholders to offer solutions and alternative ideas where there is disagreement.
- Guidelines for inclusive dialogue.

**10:15-11:00 Presentation on the Current Model**

- Overview of the issues including discussion of:
  - History of HSC management
  - Structured decision making
  - Rationale behind the current adaptive modeling framework
  - Overview of data and data issues
  - Acknowledgement of stakeholder concerns
- Clarifying questions

**11:00-11:10 QUICK BREAK**

**11:10-11:45 Questions about the Current Model (continued)**

**11:45-12:30 LUNCH (brought in)**

**12:30-1:45 Dialogue on the Issues**

- What are the issues of concern for the three main stakeholder communities represented at the workshop: Scientists, NGOs, Harvester / Biomedical?
- Ask questions of one another as we gain a more comprehensive understanding of the issues.



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**1:45-2:00**            **QUICK BREAK**

**2:00-2:45**            **Revisiting the ARM Objective**

- Consider the 2022 ARM Objective Statement:
  - **Manage harvest of horseshoe crabs in the Delaware Bay to maximize harvest but also to maintain ecosystem integrity, provide adequate stopover habitat for migrating shorebirds, and ensure that the abundance of horseshoe crabs is not limiting the red knot stopover population or slowing recovery.**
- Question: *Does this Objective reflect stakeholder values?*

**2:45-4:00**            **Dialogue on Female Harvest**

- Question: *In what scenario or under what conditions would stakeholders be comfortable with female harvest?*
  - Where there IS the possibility of support, what conditions would address stakeholder concerns?
  - Where there IS NOT the possibility of support, what are the implications for management?

**4:00-4:30**            **Public Comment**

**4:30-5:00**            **Closing Day 1**

**5:00**                    **Adjourn**

## **DAY 2 AGENDA**

8:30 a.m. – 12:30 p.m.

**8:30-8:45**            **Day 2 Kick-off**

**8:45-9:45**            **Developing Management Recommendations**

- Questions:
  - Are there any aspects of the current modeling framework that you really want to see *preserved* moving forward?
  - For any aspects that are objectionable, what alternatives would respect broad stakeholder interests?
  - Are there other recommendations you want to make to the HSC Board?

**9:45-10:00**           **QUICK BREAK**

**10:00-11:30**        **Developing Management Recommendations (continued)**

**11:30-11:45**        **Next Steps**

**11:45-12:15**        **Public Comment**

**12:15-12:30**        **Closing Comments**

**12:30**                 **Adjourn**

# Adaptive Resource Management (ARM) Framework Overview



**Stakeholder Workshop**  
**July 2024**

# HSC History



- 1998 – Fisheries Management Plan approved
- 2001, 2004 – Addenda III and IV further restrict HSC harvest in DE Bay region states (NJ, DE, MD, VA)
- 2007 – Effort to develop multi-species management approach
- 2009 – Original Adaptive Resource Management (ARM) Framework completed
- 2012 – Addendum VII approved, instituting ARM for setting the DE Bay states bait harvest level
- 2013 – Coastwide stock assessment update
- 2019 – Coastwide benchmark stock assessment
- 2022 – ARM Revision completed and Addendum VIII approved to implement use of Revision
- 2024 – Coastwide stock assessment update



# ARM History



- Pre-2012 (Ad. VII): HSC managed with single-species approach
  - Bait harvest quotas based on historical harvest levels
- HSC and Shorebird Technical committees recommend multi-species models linking HSC and red knots
- ARM work group formed to develop models, guided by the TCs
- Delaware Bay Ecosystem TC formed (Shorebird + HSC)

# Stakeholder Concerns with ARM



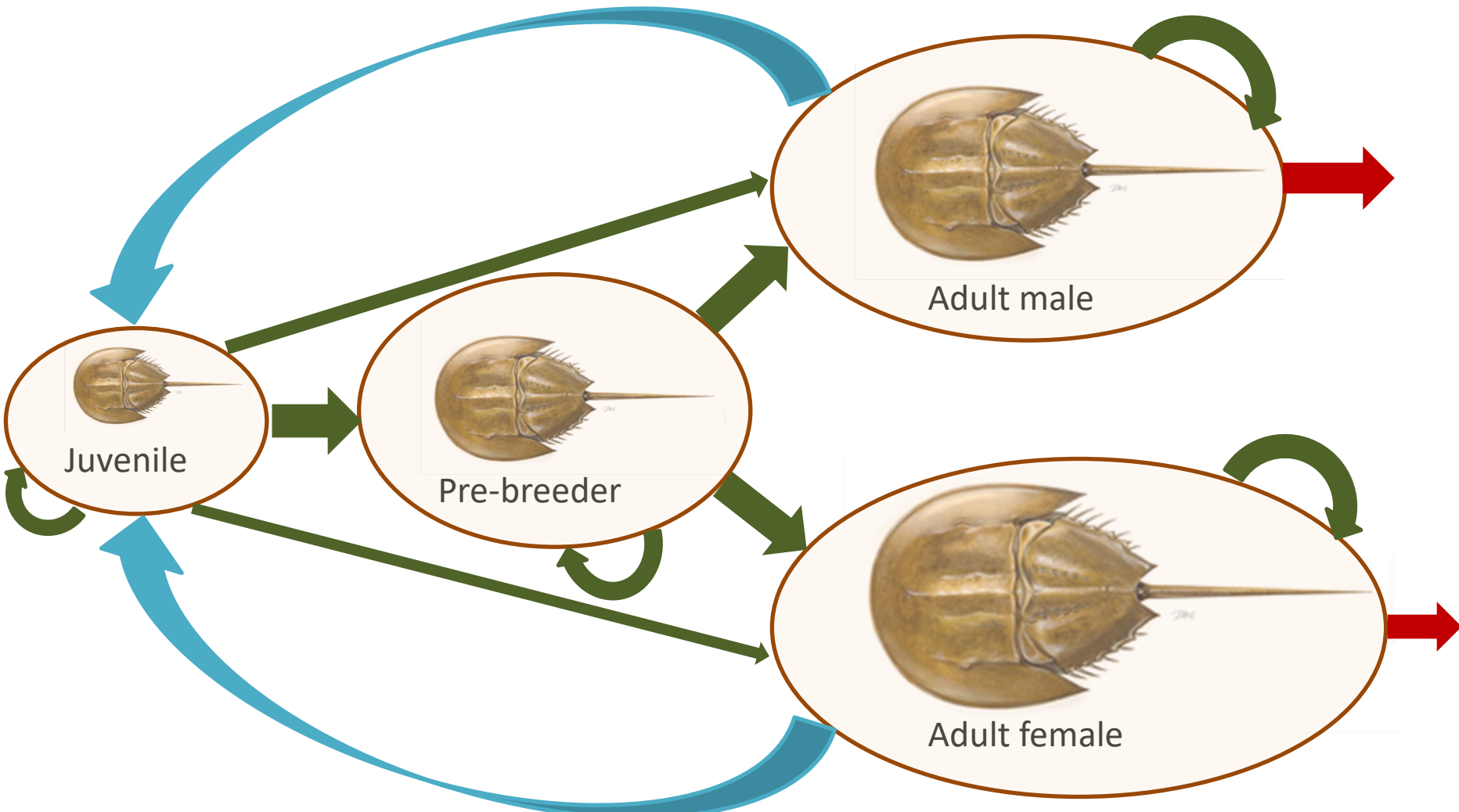
- Underestimates HSC importance to REKN
- Underestimates HSC numbers
- Disagreement with female harvest opportunity
- HSC / REKN numbers should be higher before female harvest allowed
- Underestimates negative impact of biomedical use
- Issues with model assumptions
- Issues with data inputs (e.g., HSC and REKN surveys, egg density surveys)
- Does not consider impact of changes to shoreline habitat

# Structured Decision Making

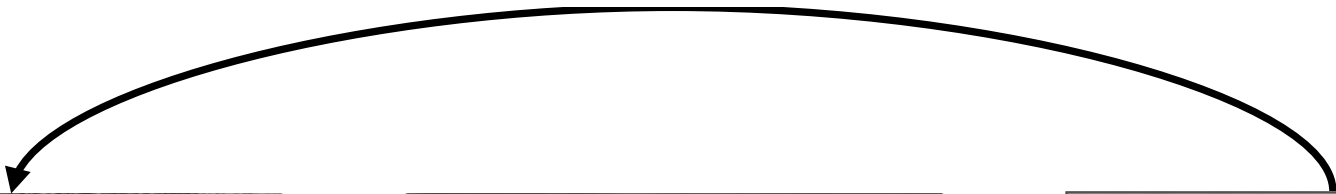


- Approach to decision making that includes views of all stakeholders
- Uses modeling to predict and assess potential consequences of various actions
- Process:
  - Define problem
  - Identify management objectives
  - Determine potential alternative actions
  - Develop models that can project the consequences of those actions
  - Adapt (to reflect changes in stakeholder values or information about the system)

# HSC Population Dynamics



# Red Knot Population Dynamics



# Terminology



- **Objective statement:** “what matters?”, problem statement with stakeholder input, contains essential values and performance measures
- **Utility function:** a graphical representation of the values and risk tolerance (e.g., defines under what conditions HSC harvest is valued)
- **Harvest policy:** how many HSC can be harvested (within specified bounds)?
- **Constraints:** bounds put in place to control maximizing or minimizing another objective (e.g., if the red knot population gets to X value, you can harvest up to Y female HSC)
- **Reward function:** what you get out of the system based on your values and the status of the system and it is what is being maximized (reward = HSC harvest)

## Problem Statement (or, “Objective Statement”)

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

Need to translate it into measurable values...

# 2009 ARM Framework



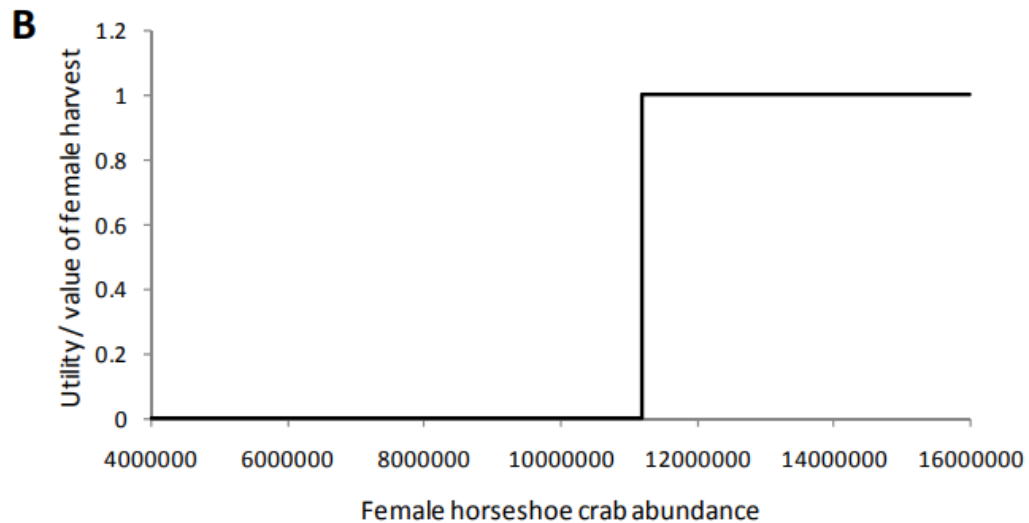
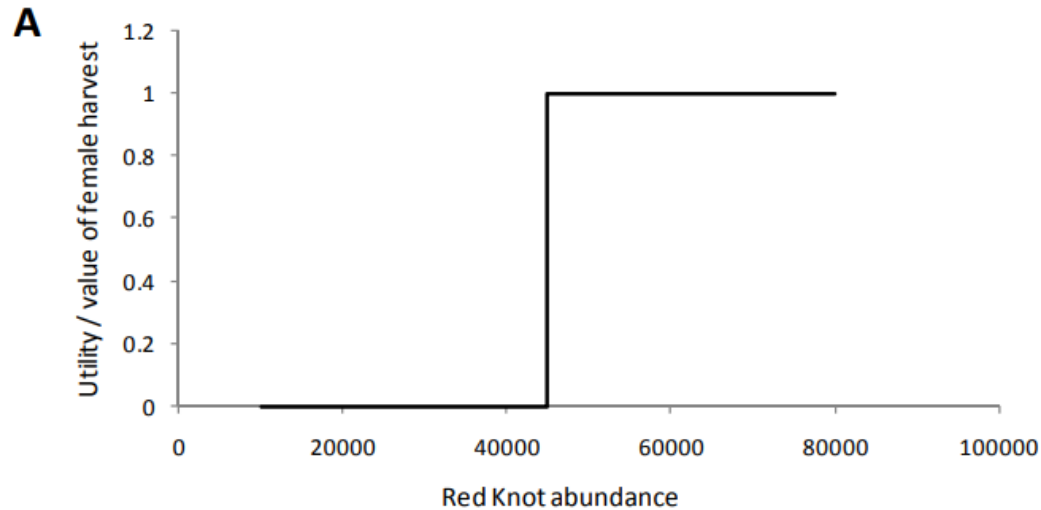
- Through stakeholder engagement identified:
  - Maximize HSC harvest with limitations (**constraints**):
    1. Female HSC harvest only when red knots or female HSC are above a specific value
      - 81,900 red knots
      - 11.2 million female HSC
    2. Male harvest only when males do not limit HSC reproduction
      - 2 males:1 females during spawning survey



# 2009 ARM Utility Functions



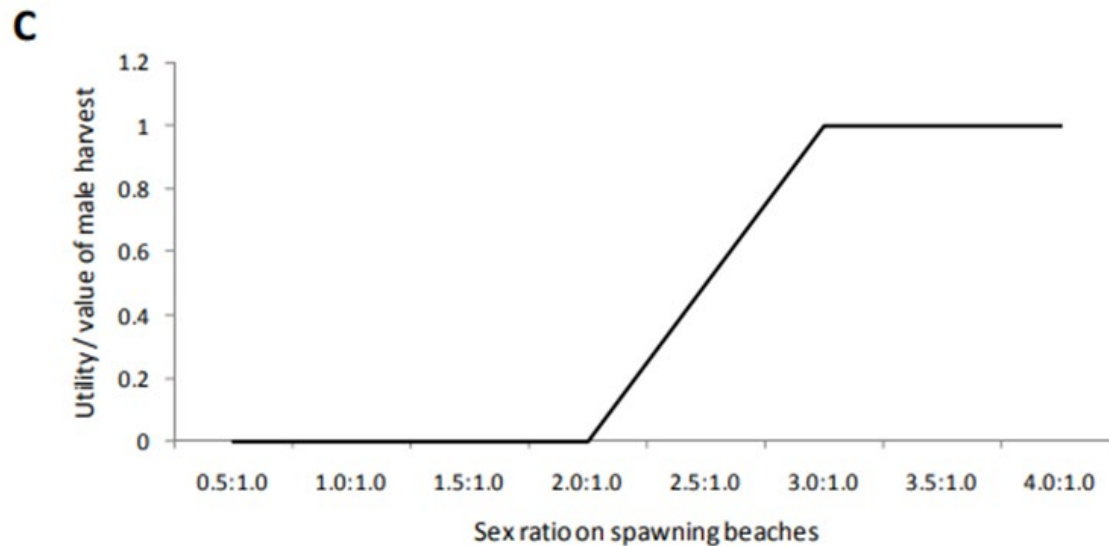
- Translate into equations



# 2009 ARM Utility Functions



- Translate into equations



# 2009 ARM Harvest Policy



Selection of 5 possible harvest packages depending on abundance of horseshoe crabs and red knots

Package	Males	Females
1	0	0
2	250,000	0
<b>3</b>	<b>500,000</b>	<b>0</b>
4	280,000	140,000
5	420,000	210,000

# 2009 ARM Reward Function



- Translates the utility functions into reward
- **Reward function** =  $R = \sum 2 \cdot H_f \cdot u_f + H_m \cdot u_m$ ,  
or  
2 x (Number of female HSC harvested) x  $u_f$   
+ (Number of male HSC harvested) x  $u_m$
- If  $u=0$ , then the reward for that harvest is 0
- Optimization (computer program) finds a value that maximizes the reward (harvest) over time

# ARM Framework (2009)



- Population models for both red knots and horseshoe crabs
- Optimization routine determines one of five harvest packages
- Set optimal harvest next year based on:
  - HSC estimate from VA Tech Trawl
  - Red knot estimate from mark-resight

# Why was the ARM revised in 2022?



- It was time!
  - Address critiques from the original peer review
  - Decade more of data for both species
  - Previously used software is obsolete
  - Evolution of modeling techniques and experience
  - Management Board request biomedical data
- Previous knife edge utility functions act as an “all or nothing” harvest control rule

# Why was the ARM revised in 2022?



Table 2: McGowan et al. 2015. Implementation of a framework for multi-species, multi-objective adaptive management in Delaware Bay. Biological Conservation 191:759-769.

C.

12.8 million male horseshoe crab.

Female horseshoe crab abundance	Female Red Knot abundance										
	<7000	7000	14,000	21,000	28,000	35,000	42,000	49,000	56,000	63,000	70,000
<1,400,000	3	3	3	3	3	3	3	3	3	3	3
1,400,000	3	3	3	3	3	3	3	5	5	5	5
2,800,000	3	3	3	3	3	3	5	5	5	5	5
4,200,000	3	3	3	3	3	3	5	5	5	5	5
5,600,000	3	3	3	3	3	3	5	5	5	5	5
7,000,000	3	3	3	3	3	3	5	5	5	5	5
8,400,000	3	3	3	3	3	3	5	5	5	5	5
9,800,000	3	3	3	3	3	3	5	5	5	5	5
11,200,000	5	5	5	5	5	5	5	5	5	5	5
12,600,000	5	5	5	5	5	5	5	5	5	5	5
14,000,000	5	5	5	5	5	5	5	5	5	5	5

\*Red Knot abundance utility threshold was originally 45,000 based on aerial counts. It was scaled up to 81,900 following the move to the mark-resight population estimate.

\*\*Always an immediate jump from 0 female harvest (Package 3) to maximum female harvest (Package 5)

# Overview of Changes



- Revised objective statement
- Revised HSC population dynamics model
- Revised red knot population dynamics model
- Revised reward function
- Change in software
- Harvest recommendations on a continuous scale



# 2022 ARM Objective Statement



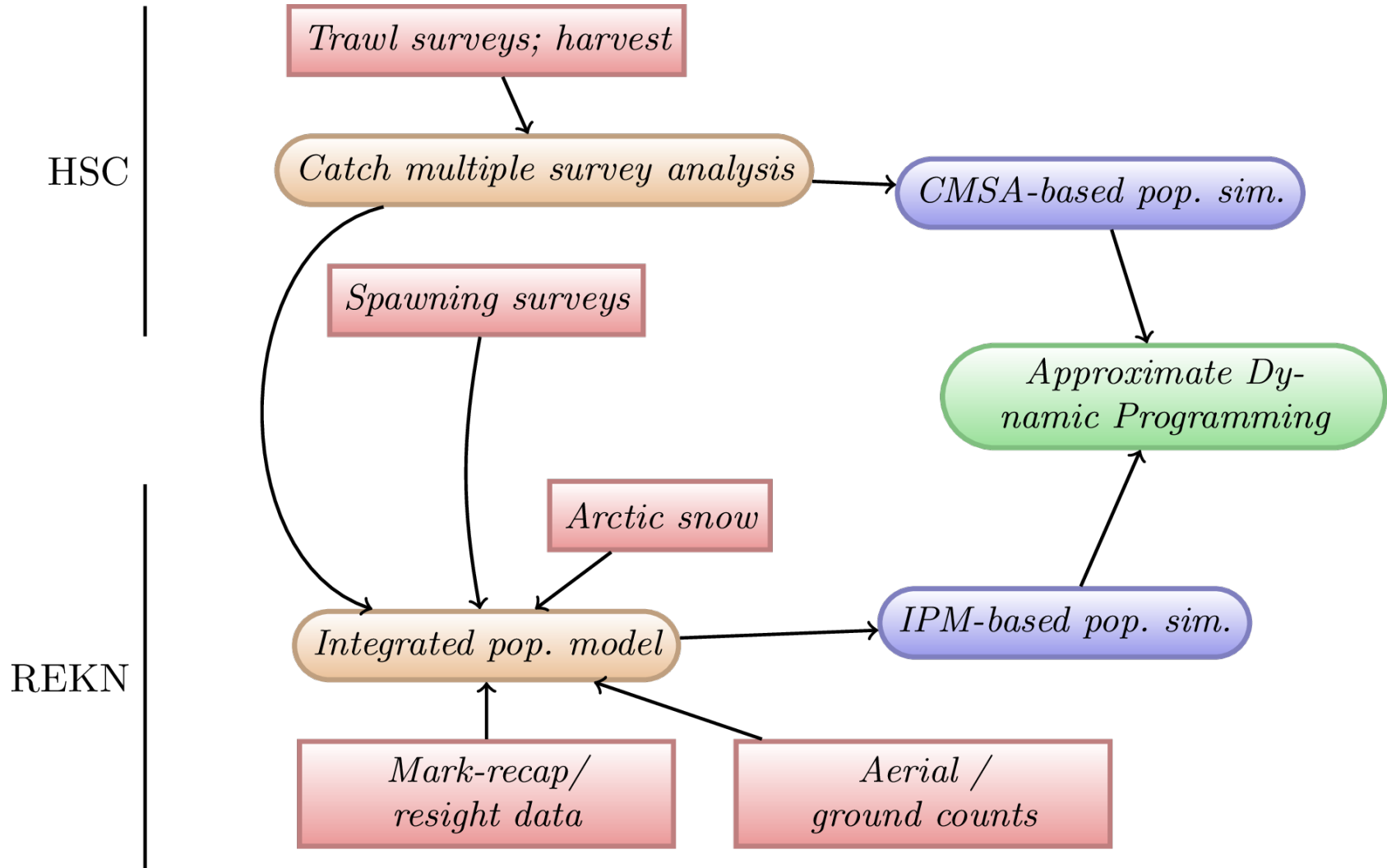
*Manage harvest of horseshoe crabs in the Delaware Bay to maximize harvest but also to maintain ecosystem integrity, provide adequate stopover habitat for migrating shorebirds, **and ensure that the abundance of horseshoe crabs is not limiting the red knot stopover population or slowing recovery.***

# 2022 ARM Inputs



- HSC Model Data
  - Virginia Tech Trawl Survey
  - DE Adult Trawl Survey
  - NJ Ocean Trawl Survey
  - Bait harvest
  - Biomedical mortality
  - Dead discards from other fisheries
  - Natural mortality from tagging data
- Red Knot Model Data
  - Mark-recapture/resight data
  - Aerial/ground counts
  - Arctic snow
  - Proportion of HSC spawning in May

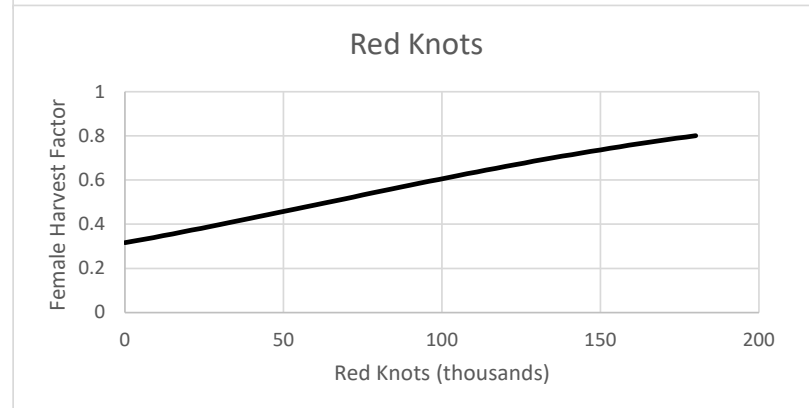
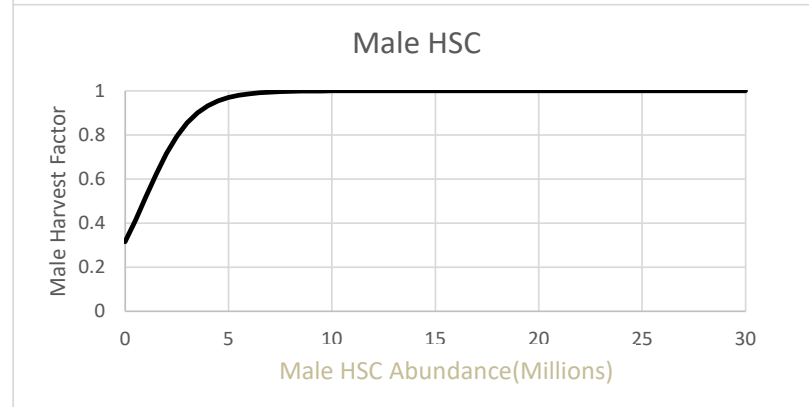
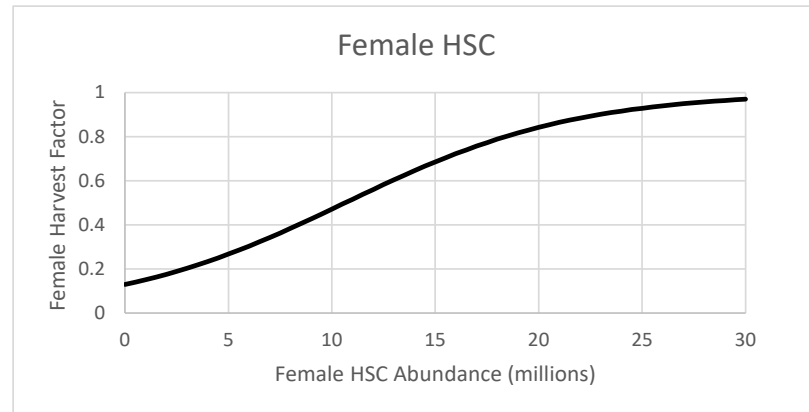
# Revised ARM Conceptual Model



# 2022 ARM Harvest Policy



- The shape of these graphs change as the ARM model explores different options.
- Each individual run will give us an HSC harvest recommendation which the model will explore.
- Over many runs, the model will find the best harvest based on current population estimates.



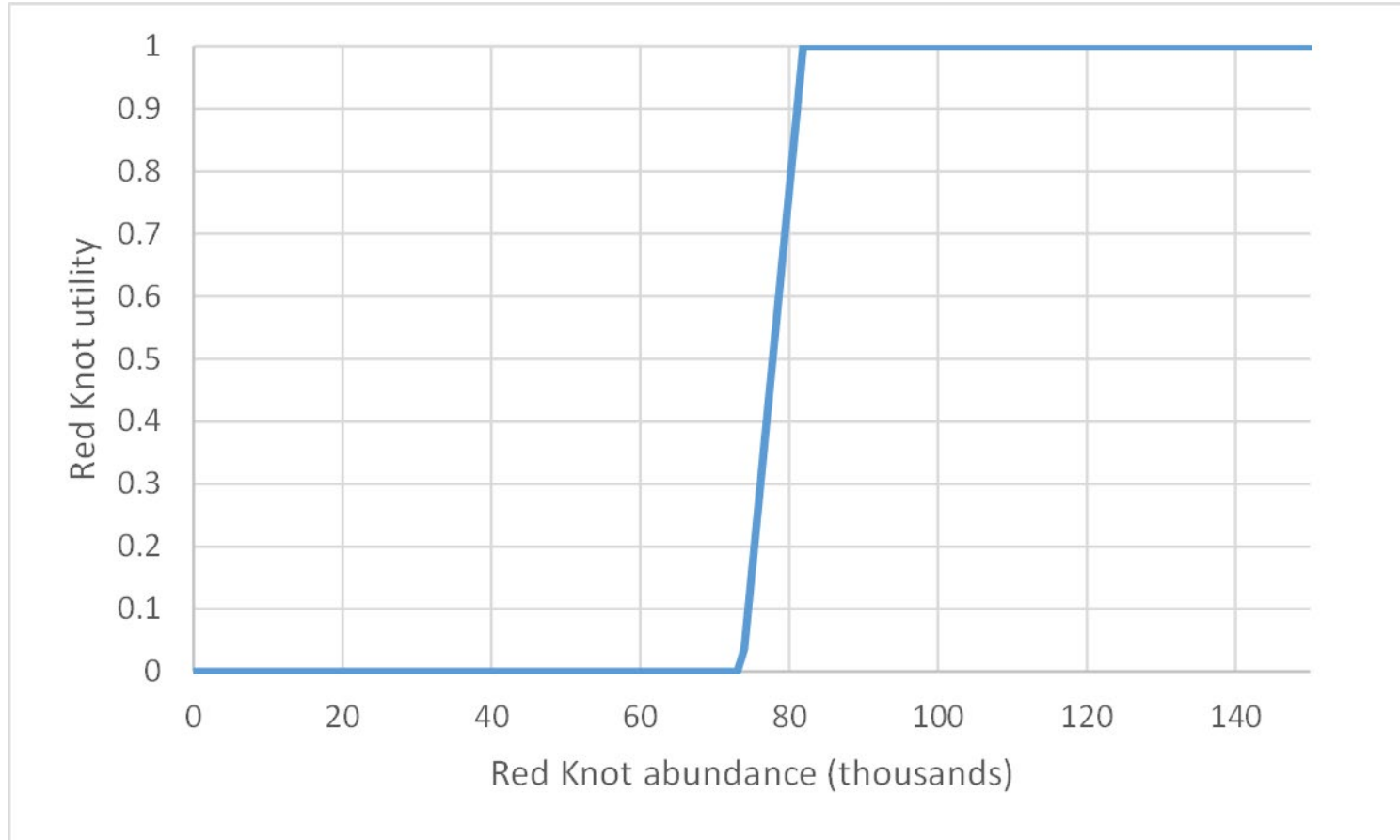
# 2022 ARM HSC Utility Function



- Whatever harvest was selected in the previous step will be put into the HSC utility function
- The HSC utility is the proportion of recommended harvest to the total possible harvest allowed (0-1)

$$u_y^h = \frac{2H_y^f + H_y^m}{2(210,000) + 500,000}$$

# 2022 ARM Utility Functions



# 2022 ARM Reward Function



$$\text{Annual reward: } r_y = u_y^h + u_y^k + u_y^h u_y^k$$

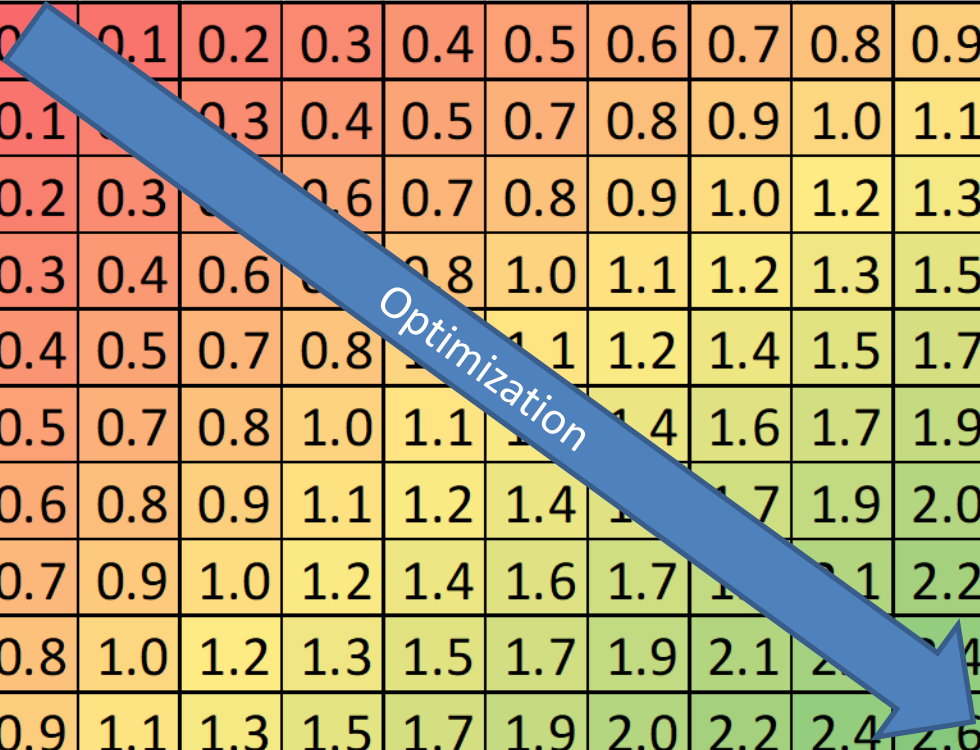
- Ideal situation is when we harvest the maximum allowed and red knots abundance  $\geq 81,900$
- Values of  $u$  can range from 0 to 1; therefore  $r_y$  can range from 0 to 3
- $r_y = 1 + 1 + 1 \times 1 = 3$  (Maximum reward)
- This formulation of the reward function prevents getting all the reward from only horseshoe crab harvest (e.g.,  $r_y = 1 + 0 + 1 \times 0 = 1$ )

# 2022 ARM Reward Function



$$r_y = u_y^h + u_y^k + u_y^h u_y^k$$

		Red Knot Utility										
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Horseshoe Crab Harvest Utility	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	0.1	0.1	0.2	0.3	0.4	0.5	0.7	0.8	0.9	1.0	1.1	1.2
	0.2	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0	1.2	1.3	1.4
	0.3	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.5	1.6
	0.4	0.4	0.5	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.7	1.8
	0.5	0.5	0.7	0.8	1.0	1.1	1.2	1.4	1.6	1.7	1.9	2.0
	0.6	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.9	2.0	2.2
	0.7	0.7	0.9	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.2	2.4
	0.8	0.8	1.0	1.2	1.3	1.5	1.7	1.9	2.1	2.4	2.4	2.6
	0.9	0.9	1.1	1.3	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.8
	1.0	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0



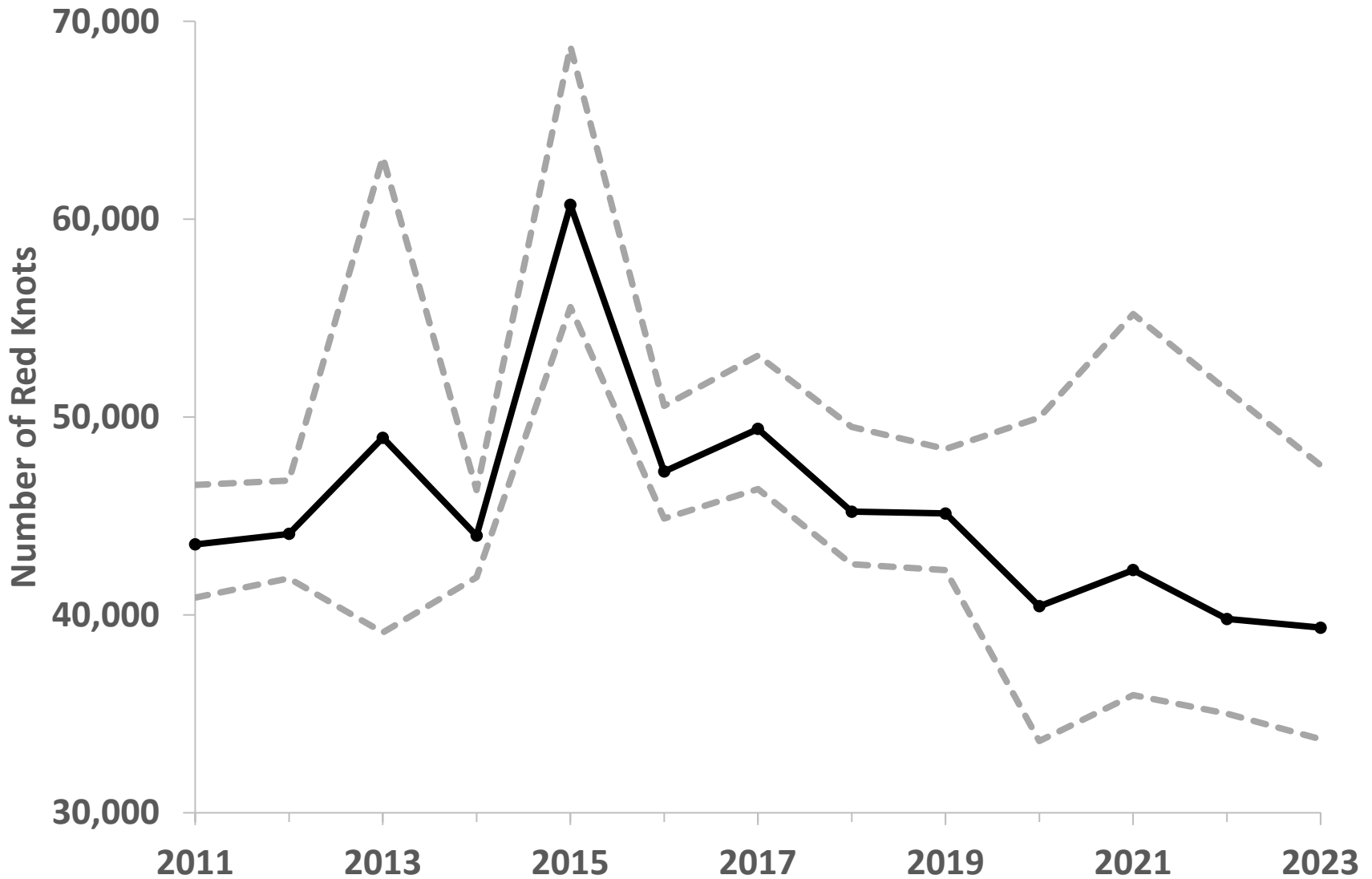


# 2022 ARM Framework Process

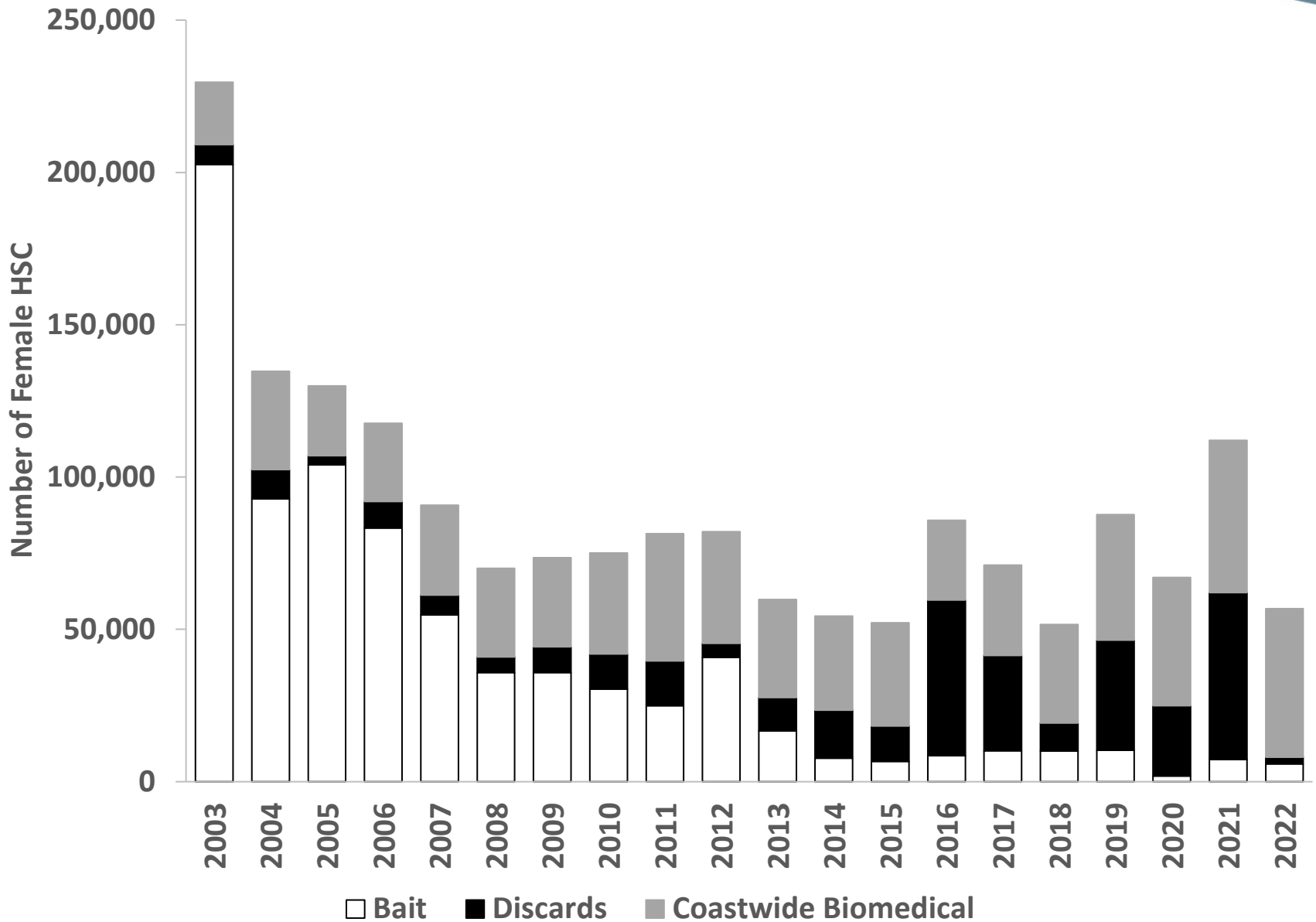


- Randomly select values that change the shape of the harvest policy curves
- Apply the recommended harvest for a given level of HSC and red knot abundance
- Project the population forward (based on population models) with the selected harvest
- Repeat, over and over and over
- Final answer: which shape of the harvest policy curves maximized the reward (over 10,000 simulations)
  - Recommended harvest

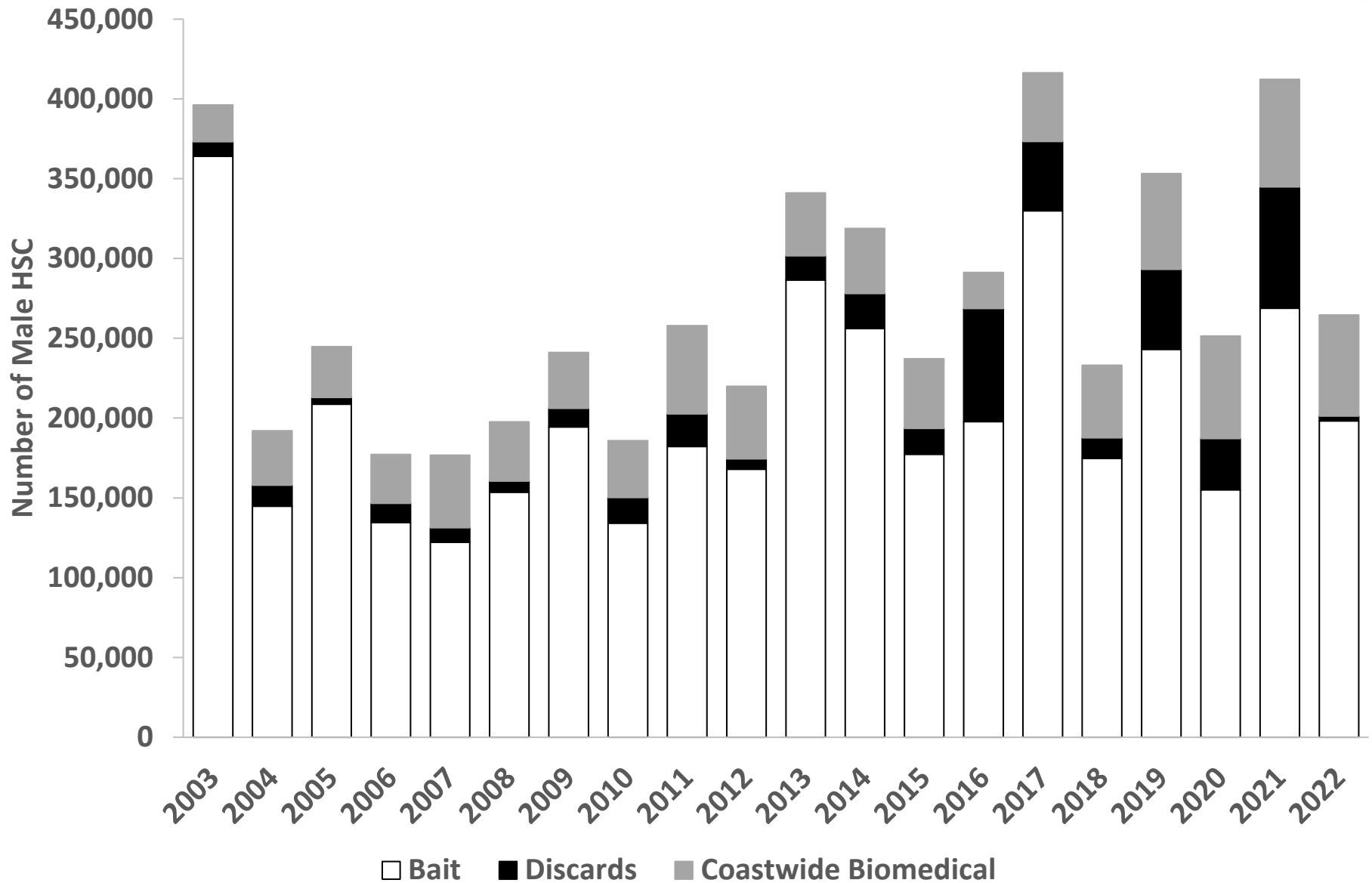
# Red Knot Population Estimates



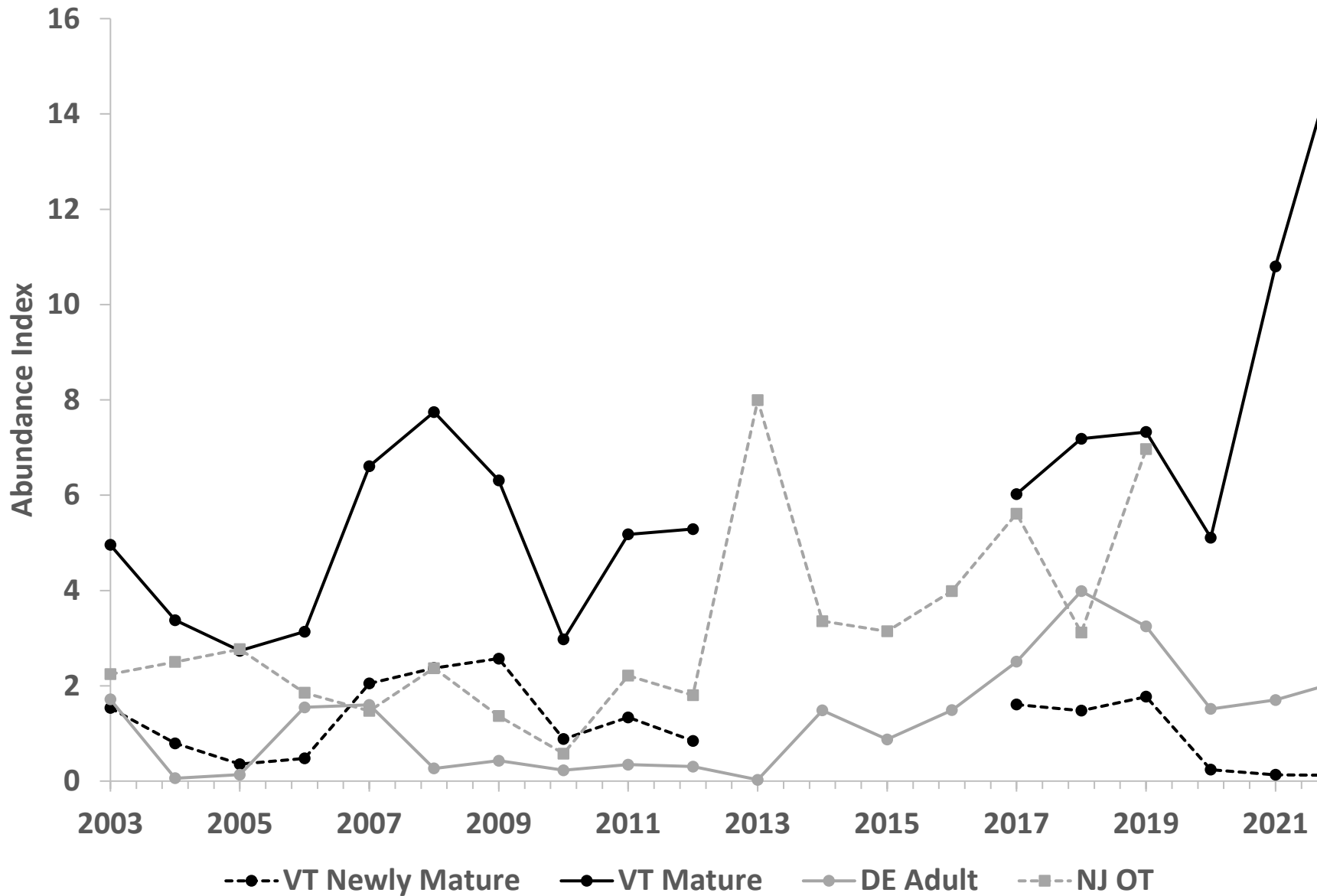
# Female Harvest



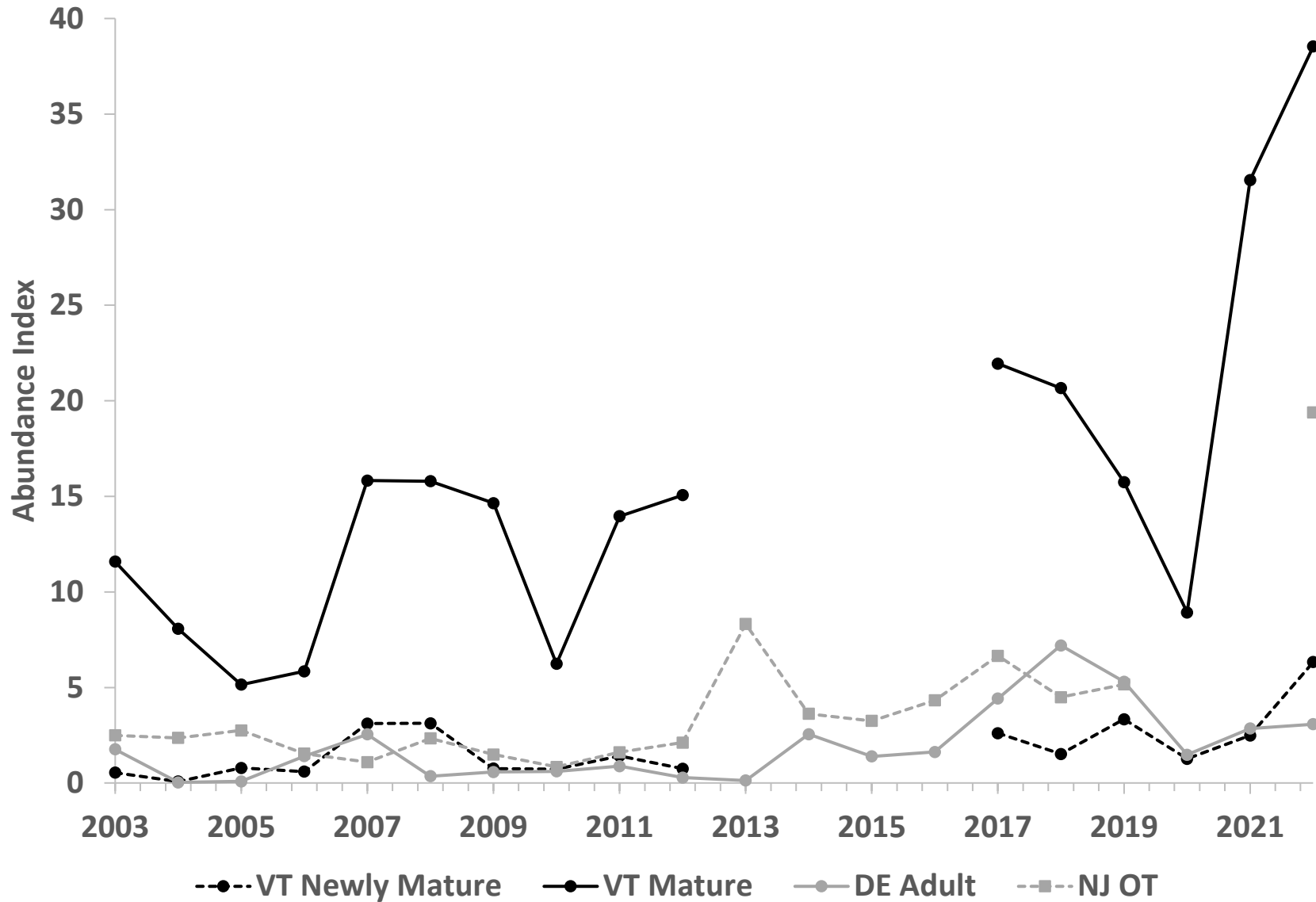
# Male Harvest



# Female Indices



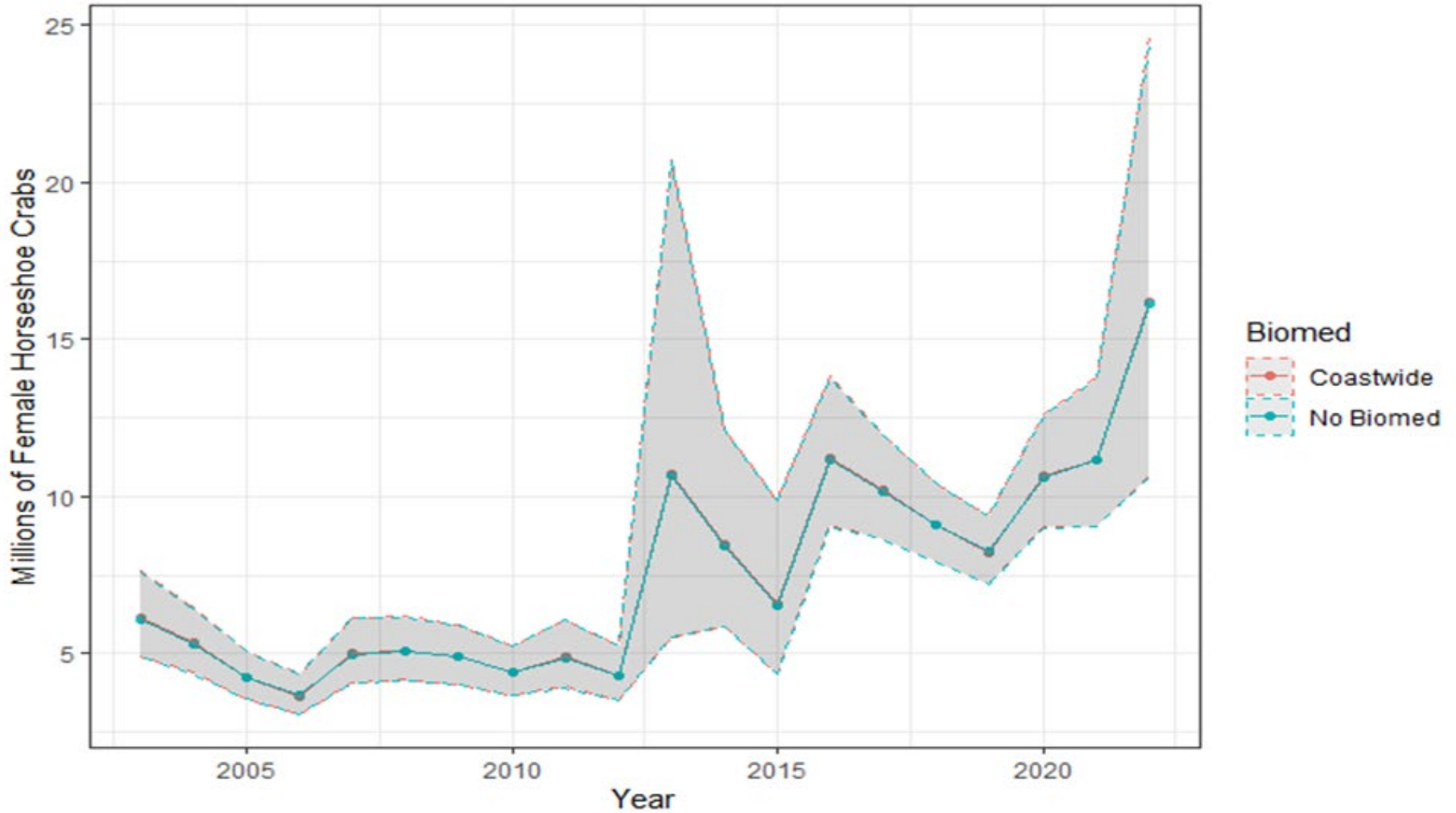
# Male Indices



# Mature Females



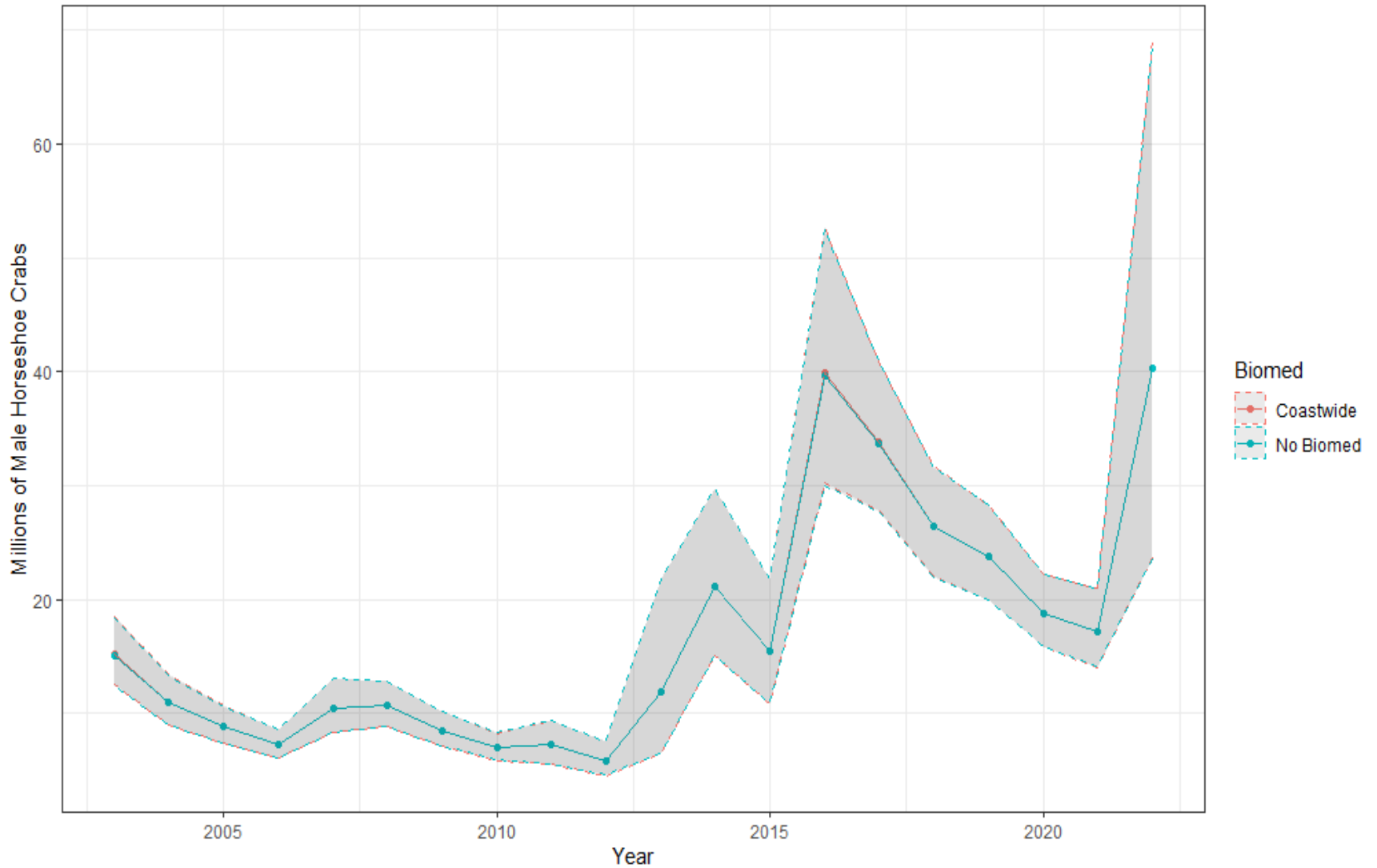
## Mature Female Horseshoe Crab Population Estimates



# Mature Males



Mature Male Horseshoe Crab Population Estimates





# 2024 Harvest Recommendation



- Harvest recommendation is based on current state of the system and optimal harvest policy function from the 2022 ARM Revision
- As per Addendum VIII, recommended harvest is rounded down to nearest 25,000 crabs
- For 2024, ARM recommended harvest:
  - 500,000 male
  - 175,000 female

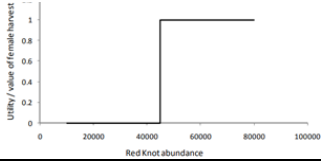
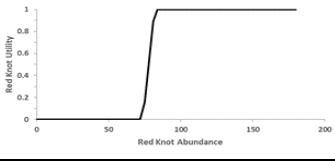
# Stakeholder Concerns with ARM



- Underestimates HSC importance to REKN
- Underestimates HSC numbers
- Disagreement with female harvest opportunity
- HSC / REKN numbers should be higher before female harvest allowed
- Underestimates negative impact of biomedical use
- Issues with model assumptions
- Issues with data inputs (e.g., HSC and REKN surveys, egg density surveys)
- Does not consider impact of changes to shoreline habitat

# Questions ?



Terminology	Definition	2009 ARM	2022 ARM
<b>Objective Statement</b>	"What matters?" A problem statement with values and performance measures.	Manage harvest of horseshoe crabs in the Delaware Bay to maximize harvest but also maintain ecosystem integrity and provide adequate stopover habitat for migrating shorebirds.	Manage harvest of horseshoe crabs in the Delaware Bay to maximize harvest but also to maintain ecosystem integrity, provide adequate stopover habitat for migrating shorebirds, and ensure that the abundance of horseshoe crabs is not limiting the red knot stopover population or slowing recovery.
<b>Utility Function</b>	"What is the value of HSC harvest under various conditions?" A graphical representation of the values and risk tolerance.	Example: 0 HSC "credit" until threshold met, then 1 	Example: 0 HSC "credit" until 90% threshold met, then increase to 1 at threshold 
<b>Constraints</b>	"If the red knot population gets to X value, you can harvest Y female HSC." Bounds to control maximizing or minimizing another objective.	<u>Male harvest allowed when:</u> -Males do not limit HSC reproduction (2:1 spawning sex ratio) <u>Female HSC harvest allowed when:</u> -Female HSC population > 11.2 million -Red knot population > 81,900	Removed due to criticisms from peer review panel (2009) and adaptive resource management specialists for being too prescriptive. Resulted in "all or nothing" harvest of HSC
<b>Harvest Policy</b>	The range of HSC harvest that is possible.	5 harvest packages (with maximum levels of 500,000 males and 210,000 females).	Gradual increase from 0 to maximum HSC harvest depending on population levels (maximum possible harvest 500,000 males, 210,000 females).
<b>Reward Function</b>	What you get out of the system based on your values and the populations' status. In the model, this is maximized in order to determine the HSC harvest levels given the current population estimates.	Reward equation includes HSC utility (from utility function) and harvest.	Reward equation includes HSC utility and harvest and red knot utility (from utility functions).

## **Adaptive Management**

*An approach to structured decision making that includes views of all stakeholders and uses modeling to predict and assess potential consequences of various actions.*

Process:

- Define problem
- Identify management objectives
- Determine potential alternative actions
- Develop models that can project the consequences of those actions
- Adapt (to reflect changes in stakeholder values or information about the system, update models based on new information)