Atlantic States Marine Fisheries Commission

ADDENDUM VIII TO THE INTERSTATE FISHERY MANAGEMENT PLAN FOR HORSESHOE CRABS

Implementation of the 2021 Adaptive Resource Management Framework Revision

November 2022

Sustainable and Cooperative Management of Atlantic Coastal Fisheries

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1.0 Introduction

The Atlantic States Marine Fisheries Commission's (Commission or ASMFC) Horseshoe Crab Management Board (Board) approved the Interstate Fishery Management Plan for Horseshoe Crabs (FMP) in October 1998. The goal of the FMP includes management of horseshoe crab populations for continued use by current and future generations of the fishing and non-fishing public, including the biomedical industry, scientific and educational researchers, migratory shorebirds, and other dependent fish and wildlife, including federally listed sea turtles. ASMFC maintains primary management authority for horseshoe crabs in state and federal waters. The management unit for horseshoe crabs extends from Maine through the east coast of Florida.

Additions and changes to the FMP have been adopted by the Board through seven addenda. The Board approved Addendum I in 2000, establishing a coastwide, state-by-state annual quota system to reduce horseshoe crab landings. Addendum I also included a recommendation to the federal government to create the Carl N. Shuster Jr. Horseshoe Crab Reserve. The Board approved Addendum II in 2001, establishing criteria for voluntary quota transfers between states. Addenda III (2004) and IV (2006) required additional restrictions on the bait harvest of horseshoe crabs of Delaware Bay-origin and expanded biomedical monitoring requirements. Addenda V (2008) and VI (2010) extended the restrictions within Addendum IV. The provisions of Addendum VI were set to expire after April 30, 2013. Addendum VII replaced Addendum VI requirements by establishing a management program for the Delaware Bay Region (i.e., coastal and bay waters of New Jersey and Delaware, and coastal waters only of Maryland and Virginia), using the Adaptive Resource Management (ARM) Framework to set annual specifications for this Region.

Addendum VIII implements the 2021 Revision to the ARM Framework and will be used to annually produce bait harvest recommendations for male and female horseshoe crabs of Delaware Bay-origin, based on the abundance of horseshoe crabs and red knots.

2.0 Overview

2.1 Statement of the Problem

The Board initiated Addendum VIII in January 2022 to consider use of the recent 2021 Revision of the ARM Framework (ASMFC 2021) in setting annual bait harvest specifications for horseshoe crabs of Delaware Bay-origin. Delaware Bay horseshoe crab management using the ARM Framework was originally established under Addendum VII for use during the 2013 fishing season and beyond. 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).

In the past decade, more data has been collected on shorebirds and horseshoe crabs, and modeling software and techniques have advanced. Additionally, the original ARM Framework used software that is now antiquated, not supported, no longer runs on current computer

operating systems, and is limited in its capacity to incorporate uncertainty when determining optimum harvest strategies. Thus, the ARM Subcommittee was tasked with revising the ARM Framework to address critiques from the previous peer review panel, include newly available data, and transition to new modeling software.

Following the recommendations of the independent peer review panel, which endorsed the ARM Revision as the best and most current scientific information for the management of horseshoe crabs in the Delaware Bay Region, the Board reviewed and accepted the ARM Framework Revision in January 2022. Addendum VIII incorporates the recommended changes in the ARM Framework Revision into the management program for setting bait harvest specifications of Delaware Bay-origin horseshoe crabs.

2.2 Background

The original ARM Framework and Addendum VII were developed in response to public concern regarding the horseshoe crab population and its ecological role in the Delaware Bay. While the stock assessment at that time (ASMFC 2009a) found increases in the Delaware Bay horseshoe crab abundance, the red knot (*rufa* subspecies), one of many shorebird species that feed on horseshoe crab eggs, was at low population levels. To address these concerns, an effort began to develop a multi-species approach to managing horseshoe crabs by employing the tools of structured decision making and adaptive management. In 2007, the Horseshoe Crab and Shorebird Technical Committees met and endorsed the development of a structured decision making (SDM) framework and adaptive management approach. An ARM Subcommittee was formed including representatives from state and federal partners, as well as horseshoe crab and shorebird biologists. The Subcommittee produced a framework for adaptive management of horseshoe crabs in the Delaware Bay that was constrained by red knots. It was peer-reviewed with a coastwide benchmark stock assessment for horseshoe crab in 2009 (ASMFC 2009a, 2009b).

Addendum VII, approved in February 2012, implemented the 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 optimal harvest level for the Delaware Bay states of New Jersey, Delaware, Maryland, and Virginia (east of the COLREGS). Since 2013, the Board has annually reviewed recommended harvest levels from the ARM Subcommittee, who run the ARM model, and specified harvest levels for the following year in New Jersey, Delaware, Maryland, and Virginia.

2.3 Original ARM Framework

A goal of the ARM Framework is to transparently incorporate the views of stakeholders along with predictive modeling to assess the potential consequences of multiple, alternative management actions in the Delaware Bay Region. The ARM process involved several steps: 1) identify management objectives and potential actions, 2) build alternative predictive models with confidence values that suggest how a system will respond to these management actions,

3) implement management actions based on those predictive models, 4) monitor to evaluate the population response to management actions, validate the model predictions, and provide timely feedback to update model confidence values and improve future decision making, 5) as necessary, incorporate new data into the models to generate updated, improved predictions, and 6) revise management actions as necessary to reflect the latest state of knowledge about the ecosystem. The ARM Framework is an iterative process that adapts to new information and success of management actions.

Underlying the original ARM model are population models for both red knots and horseshoe crabs. The optimization routine in the ARM model determines the best choice among five potential harvest packages (numbers of male and females that can be harvested) given the current abundance of each species in order to maximize the long-term value of horseshoe crab harvest. The ARM model values female horseshoe crab harvest only when the abundance of red knots reaches 81,900 birds (a value related to the historic abundance of red knots in the Delaware Bay) or when the abundance of female horseshoe crabs reaches 80% of their predicted carrying capacity (11.2 million assuming a carrying capacity of 14 million; ASMFC 2009b). On an annual basis, the ARM model is used to select the optimal harvest package to implement for the next year given the current year's estimate of horseshoe crab abundance from the swept area estimate from the VA Tech trawl survey and a mark-resight estimate of red knot abundance.

Within this ARM Framework, a set of alternative multispecies models were developed for the Delaware Bay Region to predict the optimal strategy for horseshoe crab bait harvest. These models accounted for the need for red knot stopover feeding during migrations through the region. The models also incorporated uncertainty in model predictions and are meant to be updated with new information as monitoring and management progress.

On an annual basis, the ARM model is used to select the optimal harvest package to implement for the next year given the current year's estimate of horseshoe crab abundance from the swept area estimate from the Virginia Tech trawl survey and a mark-resight estimate of red knot abundance. Under the original ARM Framework, the harvest packages for horseshoe crab bait harvest that can be selected by the ARM model are:

Package 1) Full harvest moratorium on both sexes
Package 2) Harvest up to 250,000 males and 0 females
Package 3) Harvest up to 500,000 males and 0 females
Package 4) Harvest up to 280,000 males and 140,000 females
Package 5) Harvest up to 420,000 males and 210,000 females

The numbers of horseshoe crabs in the packages listed above are totals for the Delaware Bay Region, and not per state. Since its implementation in 2013, neither the 81,900 red knot threshold nor the 11.2 million female horseshoe crab thresholds have been met and harvest package 3 has been selected every year (2013-2022) by the Framework and specified by the Board for the Delaware Bay bait harvest limit.

2.4 Allocation of the ARM Harvest Output under Addendum VII

The ARM Framework incorporates horseshoe crabs from the Delaware Bay Region as one unit. The modeling and optimization portions of the Framework do not address distribution and allocation of the harvest among the four Delaware Bay states. Allocation of the overall Delaware Bay harvest allowance was established in Addendum VII. Based on tagging and genetic analysis (ASMFC 2019, 2021), there is very little exchange between Chesapeake Bay and Delaware Bay horseshoe crab populations. However, there is movement of horseshoe crabs between coastal embayments (from New Jersey through Virginia) and Delaware Bay.

An allocation model for the four Delaware Bay states was developed to allocate the optimized harvest output by the ARM Framework, which is described in Section 2.4 of Addendum VII, and summarized below.

Each state's allocation of the total Delaware Bay-origin harvest recommended by the ARM Framework was determined by multiplying the state's quota under Addendum VI by the proportion of the state's total harvest that is of Delaware Bay-origin (lambda, λ), then dividing this value by the sum of the values for each of four states (Table 1). The state lambda values established in Addendum VII were based on the genetic data available at the time. Virginia's quota level and landings refer to those quota and landings that occur east of the COLREGS line, as these crabs have been shown to be part of a mixed stock.

Table 1. Calculation of State Allocations of Delaware Bay Harvest Established in Addendum VII

State	Lambda	Addendum VI Quota	Delaware Bay-Origin Quota	Addendum VII Allocation of Delaware Bay-Origin Quota
NJ	1.00	100,000	100,000	32.4%
DE	1.00	100,000	100,000	32.4%
MD	0.51	170,653	87,033	28.2%
VA (east of COLREGS)	0.35	60,998	21,349	7.0%

Along with the state allocation percentages, Addendum VII also established two additional provisions impacting the state quotas for Maryland and Virginia. First, it established a harvest cap for Maryland and Virginia, which set a maximum limit on the total level of allowed harvest by Maryland and Virginia to provide protection to non-Delaware Bay-origin crabs. The cap is based on Addendum VI quota levels for Maryland and Virginia; the Maryland cap is 170,653 crabs, and the Virginia cap is 60,998 crabs. These caps apply except when the ARM Framework recommends a package that prohibits harvest of female horseshoe crabs. When female harvest is prohibited, a second provision allows for a 2:1 offset of males:females for Maryland and Virginia, which allows the total male harvest of Maryland and Virginia to rise above the cap level. Note again that Virginia's quota only refers to the number of crabs that can be harvested east of the COLREGS line.

3.0 Management Program

This section replaces Addendum VII to the Horseshoe Crab FMP under the adaptive management procedures established in Section 4.5 of the Fishery Management Plan.

Addendum VIII implements the ARM Revision for setting bait harvest specifications for Delaware Bay-origin horseshoe crabs. Specifically, it adopts the updates to the ARM Framework recommended in the 2021 Revision and incorporates them into the process for setting specifications for bait harvest of Delaware Bay-origin horseshoe crabs. Changes to the ARM Framework are described in detail in the 2021 Revision to the Adaptive Resource Management Framework and Peer Review Report, and include:

- Catch multiple survey analysis (CMSA) to estimate male and female horseshoe crab population estimates using all quantifiable sources of mortality (i.e., natural mortality, bait harvest, coastwide biomedical mortality, and commercial dead discards) and several abundance indices from the Delaware Bay Region
- Integrated population model (IPM) to quantify the effects of horseshoe crab abundance on red knot survival and recruitment based on data collected in the Delaware Bay
- Transition to new modeling approach which can be implemented through readily available R software and incorporates uncertainty on all life history parameters for both horseshoe crabs and red knots
- Harvest recommendations based on a continuous scale rather than discrete harvest packages as in the previous Framework
- Female harvest decoupled from the harvest of males

Harvest Recommendations

Harvest recommendations under the ARM Revision are based on a continuous scale rather than the discrete harvest packages in the previous Framework. Therefore, any harvest number up to the maximum allowable harvest could be recommended, not just the fixed harvest packages. Harvest of females is decoupled from the harvest of males so that each are determined separately. The maximum possible harvest for both females and males are maintained as in Addendum VII at 210,000 and 500,000, respectively.

Although harvest is treated as continuous in the new ARM Framework, if the continuous harvest recommendations were made public, it would be possible to back-calculate the biomedical mortality input, which is confidential. Therefore, it is necessary to round the continuous sex-specific harvest outputs to obscure the confidential biomedical data, unless the maximum sex-specific harvest is recommended.

The continuous optimal harvest recommendation from the ARM is rounded down to the nearest 25,000 horseshoe crabs. For example, if the continuous optimal harvest recommendation is 135,000 males and 96,000 females, these values would be rounded down to 125,000 males and 75,000 females.

Adaptive Management Cycle

The adaptive management cycle includes three tiers of short- and longer-term management, update, and revision processes for the ARM Framework, as follows:

1. **Annual management process:** The annual specification of harvest occurs at the ASMFC annual meeting in calendar year *t* for the harvest to be implemented the following season (year *t*+1). The CMSA requires multiple indices of abundance and removals from multiple sources. Because the necessary data take time to be finalized, and final data for a given year are available by the time of the annual meeting, the results of a run of the CMSA in year *t* will be based on data obtained from the previous two years. Inputs to the CMSA include the Virginia Tech trawl survey that is conducted in the fall of year *t*-2; Delaware and New Jersey trawl surveys from year *t*-1; and removals from year *t*-1. To match the abundance estimates of horseshoe crabs with red knot mark-resight population estimates, horseshoe crab abundance estimates from year *t*-1 and red knot population estimates from year *t*-1 are used as input to the ARM Revision harvest policy functions in year *t*. Optimal harvest recommendations are implemented in year *t*+1. The two-year time lag between data availability and implementation of optimal harvest is incorporated in the ARM Revision modeling when determining the optimal harvest based on horseshoe crab and red knot abundance.

   Each annual step is identified in the timeline below:
   - April - July (year *t*) – The ARM Work Group compiles monitoring data to run the CMSA (Virginia Tech trawl survey data from year *t*-2, New Jersey and Delaware survey data from year *t*-1, removal data from year *t*-1). The ARM workgroup estimates red knot stopover population size from the mark-resight analysis in year *t*-1.
   - August (year *t*) – The ARM Work Group inputs horseshoe crab and red knot population estimates to the ARM Revision harvest policy functions and calculates the optimal harvest.
   - September (year *t*) – The Delaware Bay Ecosystem Technical Committee reviews the ARM Revision results and optimal harvest recommendations.
   - ASMFC Annual Meeting (year *t*) – The Management Board reviews the optimal harvest recommendations from the ARM Work Group and decides on the harvest to be implemented in year *t*+1.

2. **Interim update process:** Every three years, an update process occurs in which the model parameters (e.g., red knot survival and recruitment, horseshoe crab stock-recruitment relationship) are updated based on the annual routine data collected in the region.

3. **Revision process:** Every 9 or 10 years (or sooner if desired by the Board), the ARM Framework shall undergo a revision process similar to what occurred for the 2021 ARM Revision. This amount of time is appropriate given it allows for two updates to occur,

and encompasses one generation for horseshoe crabs. This process shall incorporate the following components:

- Solicit formal stakeholder input on ARM Framework to be provided to the relevant technical committees
- Technical committees review stakeholder input and technical components of ARM models and provide recommendations to the Board
- At the ASMFC Spring Meeting, Board selects final components of the ARM Framework, and tasks technical committees to work with ARM Work Group to run models/optimization
- Merge with the annual management process
    - In August, ARM Subcommittee runs models/optimization
    - At the ASMFC Annual Meeting, the Board revisits harvest decision

Allocation of the Delaware Bay-origin Harvest Recommendation

The allocation methodology established in Addendum VII is modified to update state lambda values as recommended in the 2021 Revision based on more recent genetic data analysis. Lambda indicates how much of a state's harvest is of Delaware Bay-origin (i.e., has spawned at least once in Delaware Bay). Lambda shall be assumed to be 1.00 for New Jersey and Delaware and based upon the recent genetics data and analysis (ASMFC 2021), 0.45 for Maryland, and 0.20 for Virginia.

State	Lambda, λ
NJ	1.00
DE	1.00
MD	0.45
VA	0.20

Allocation values are calculated using the same formula used under Addendum VII. Lambda is multiplied by the state's Addendum VI quota. The resulting value is divided by the sum of values for all four states to provide the percent of the Delaware Bay harvest recommendation that is allocated to each state. Virginia's quota level and landings refer to quota and landings that occur east of the COLREGS line, as these crabs have been shown to be part of a mixed stock (Shuster 1985).

State	Allocation of Delaware Bay Harvest (%)
NJ	34.6%
DE	34.6%
MD	26.6%
VA	4.2%

Harvest Cap for Maryland and Virginia

The harvest cap for Maryland and Virginia established under Addendum VII is maintained. The harvest cap places a maximum limit on the total level of allowed harvest by Maryland and Virginia, providing protection to non-Delaware Bay-origin crabs. The cap is based on Addendum VI quota levels for Maryland and Virginia. Note again that Virginia's quota only refers to the amount able to be harvested east of the COLREGS line.

MD Cap	**VA Cap**
170,653	60,998

These caps apply except when the ARM Framework outputs an optimized harvest that prohibits harvest of female horseshoe crabs. In this situation, female horseshoe crab harvest in Maryland and Virginia are prohibited but a 2:1 offset of males:females applies and allows the total male harvest of Maryland and Virginia to rise above the cap level.

2:1 Male:female Offset for Female Crabs Below the Addendum VI Levels

When a female harvest moratorium output by the ARM Framework restricts female crab harvest in Maryland and Virginia below the Addendum VI quota levels, male harvest is increased at a 2:1 ratio. These increases are the only allowable increases above the designated harvest cap above. The offsets assume an allowed harvest under Addendum VI in Virginia of 20,333 female crabs and in Maryland of 85,327 female crabs.

Fallback Option if ARM Framework Cannot be Used

As part of the 2021 ARM Framework Revision, the models are dependent on annual data sets for the yearly harvest setting, and include the following:

- Horseshoe crab abundance estimates from the Virginia Tech Horseshoe Crab Trawl Survey
- Horseshoe crab relative abundance indices from Delaware and New Jersey fishery-independent surveys
- Total horseshoe crab removals (bait harvest, biomedical mortality, and estimated commercial discards)
- Horseshoe crab spawning beach sex ratio from the Delaware Bay Horseshoe Crab Spawning Survey
- Red knot abundance estimates, including stopover counts and re-sightings

The absence of these annually-collected data sets could inhibit the use of the ARM Framework depending on which data sets are missing. If model results are not available for the fall harvest decision, the Board, via Board action and after consultation of the relevant Technical Committees and Advisory Panels, may set the next season's harvest by one of the following methods:

- Based upon Addendum VI quotas and management measures for New Jersey, Delaware, and Maryland, and Virginia coastal waters; or,
- Based upon the previous year's ARM Framework harvest level and allocation for New Jersey, Delaware, and Maryland, and Virginia coastal waters. Harvest can be more conservative than the previous year's ARM Framework harvest level and allocation for New Jersey, Delaware, and Maryland, and Virginia coastal waters.

4.0 Compliance

This Addendum is effective as of November 10, 2022.

5.0 Literature Cited

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