Horseshoe Crab Adaptive Resource Management (ARM) Framework Stakeholder Workshop

Jan 29-30, 2026

Meeting Logistic Details

- Meeting location
  - Spinnaker Room, Courtyard by Marriott Ocean City Oceanfront
    Two 15th St, Ocean City, MD 21842

Objectives & Meeting Outcomes

1. Promote a shared understanding of Adaptive Resource Management (ARM) Framework and the components of the Utility, Reward, and Harvest (U/R/H) functions that represent stakeholder values
2. Elicit and discuss stakeholder values related to the U/R/H functions
3. Identify broadly-supported recommendations for revising the U/R/H functions, document different perspectives, and discuss next steps and opportunities for improving the ARM Framework

Pre-Workshop Reading

- Workshop Pre-read (this document: *required*)
- ARM Subcommittee Memo on Reviewing RUH Functions (*required*)
- Additional ARM / Model background materials – provided at end of this document (*optional*)

Draft agenda

TIME	AGENDA ITEM	SUMMARY
Thursday, Jan 29		
8:30 AM	Doors open	Gather; tea and coffee
9:00 AM	Welcome & introductions	• Welcome to the workshop, introductions, and ice breaker
9:30 AM	Process & ARM overview	• Overview of agenda, project workplan, and process scope • Review values-based model components: Utility, Reward, and Harvest (U/R/H) functions, including 7 values-based components to discuss • Review and confirm group principles for values elicitation • Q&A
10:15 AM	Utility background	• Brief review of utility components in the current ARM • Review and discuss red knot benchmark abundances
10:30 AM	Break	
10:50 AM	Utility elicitation, & discussion	• Review and elicit stakeholder values for model components: red knots and horseshoe crab harvest utility
12:00 PM	Lunch	Provided
1:00 PM	Utility elicitation & discussion (continued)	• Elicit stakeholder values (continued) • Review responses; Discuss and strive for broad agreement on updates to values-based components; document different perspectives

2:30 PM	Break	
3:00 PM	Utility elicitation & discussion (continued)	• Review responses; Discuss and strive for broad agreement on updates to values-based components; document different perspectives
4:45 PM	Wrap-up & next steps	• Wrap-up and outlook for Day 2
5:00 PM	Adjourn	
6:00 PM	Dinner	Location TBD
Friday, Jan 30		
8:30 AM	Doors open	Gather; tea and coffee
9:00 AM	Welcome & recap	• Welcome, recap of Day 1
9:30 AM	Horseshoe crab harvest & precautionary approaches	• Review existing ARM harvest policy functions • Discuss concerns related to female horseshoe crab harvest, "under what conditions would female horseshoe crab harvest be acceptable?", and possible ways to update the ARM to reflect a precautionary approach
10:30 AM	Break	
10:50 AM	Horseshoe crab harvest & precautionary approaches	• Morning session, continued
12:00 PM	Lunch	Provided
1:00 PM	Reward/Harvest discussion & elicitation	• Review and confirm group principles for values elicitation • Review and discuss additional Reward and Harvest model components; elicit values as needed
3:00 PM	Break	
3:30 PM	Additional ideas for the ARM	• Discuss and document ideas for improving the ARM's engagement process, science, or other components for the future
4:15 PM	Wrap-up & next steps	• Revisit any previous workshop items • Wrap-up and next steps • Reflections from group
5:00 PM	Adjourn	

Note: This agenda is subject to change over the course of the workshop, depending on the direction of the group.

The document below summarizes key definitions and details related to the ARM framework, as well as its three types of values-based components: Reward, Utility, and Harvest functions.

We provide key questions that will be discussed in the workshop in light orange boxes.

The document ends with a sheet of definitions for common terms (Appendix 1) and a list of supplemental background documents for optional reading (Appendix 2).

Overview of the Adaptive Resource Management (ARM) framework

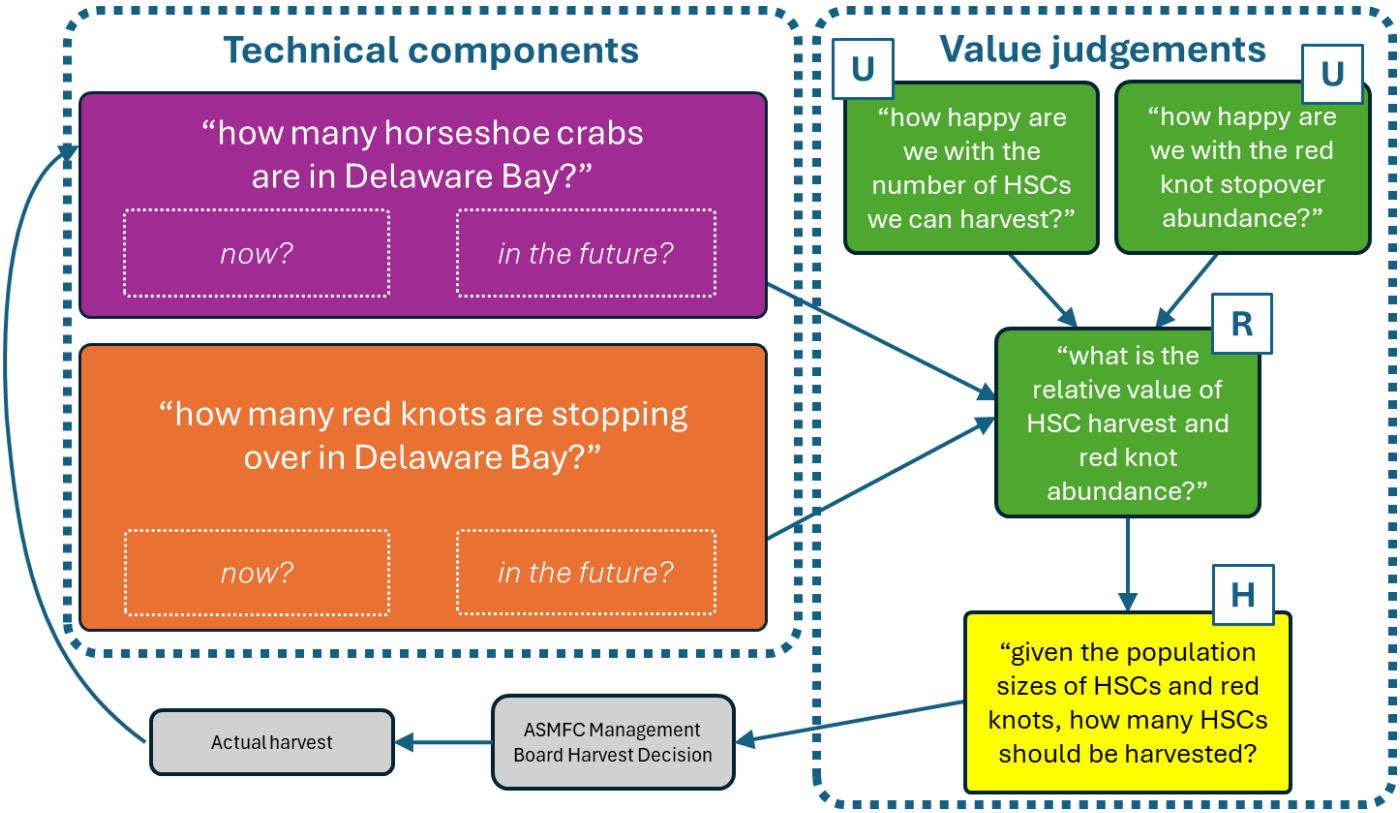
The Adaptive Resource Management (ARM) framework is used by the Atlantic States Marine Fisheries Council (ASMFC) to set annual harvest limits of horseshoe crabs in Delaware Bay. The ARM framework has been developed and updated since pre-2008 using numerous technical committees, peer review, and best available science.

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.*

Key context details:

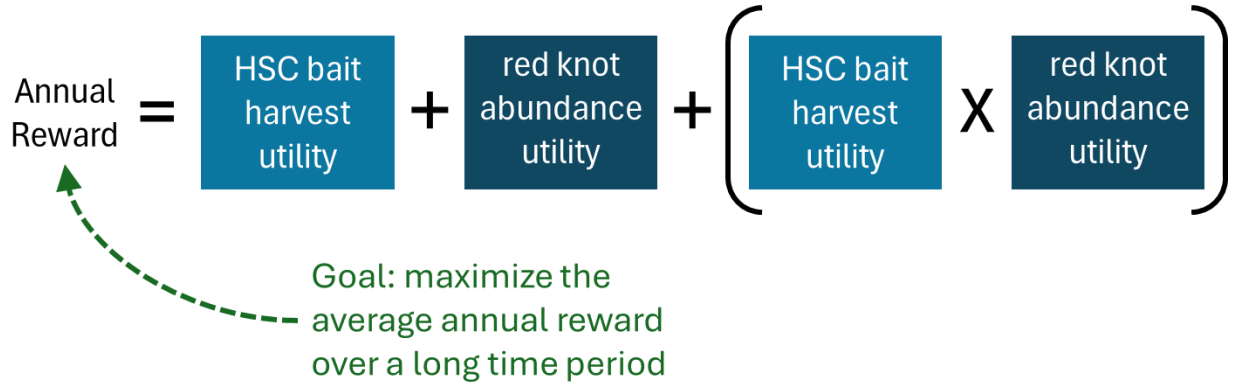
- Multi-species approach to managing the horseshoe crab bait fishery
- Incorporates population models for horseshoe crabs and shorebirds
- The ASMFC Management Board is the decision maker for this problem and has authority over how many horseshoe crabs (HSCs) are harvested for bait
- Habitat conservation decisions fall outside the purview of ASMFC
- Red Knot recovery is under the purview of the USFWS

The figure below illustrates the ARM framework and how the technical components and values-based components are related. **As a reminder, the focus of this workshop is gathering stakeholder input to update the values-based components.**



Reward

Simple definition: Reward is the sum total desirability of a given set of outcomes across objectives. It is what the ARM framework tries to maximize, and it is based on (1) horseshoe crab harvest and (2) red knot abundance over the long-term (~100 years).



HSC Bait Harvest Utility	Red Knot Abundance Utility										
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0.1	0.1		0.3	0.4	0.5	0.7	0.8	0.9	1	1.1	1.2
0.2	0.2			0.6	0.7	0.8	0.9	1	1.2	1.3	1.4
0.3	0.3	0.4			0.8	1	1.1	1.2	1.3	1.5	1.6
0.4	0.4	0.5	0.7		1	1	1.2	1.4	1.5	1.7	1.8
0.5	0.5	0.7	0.8	1	1	1	1.4	1.6	1.7	1.9	2
0.6	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.9	2	2.2
0.7	0.7	0.9	1	1.2	1.4	1.6	1.7	1.9	2	2.2	2.4
0.8	0.8	1	1.2	1.3	1.5	1.7	1.9	2	2.2	2.4	2.6
0.9	0.9	1.1	1.3	1.5	1.7	1.9	2	2.2	2.4	2.6	2.8
1	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3

Goal is to move in this direction

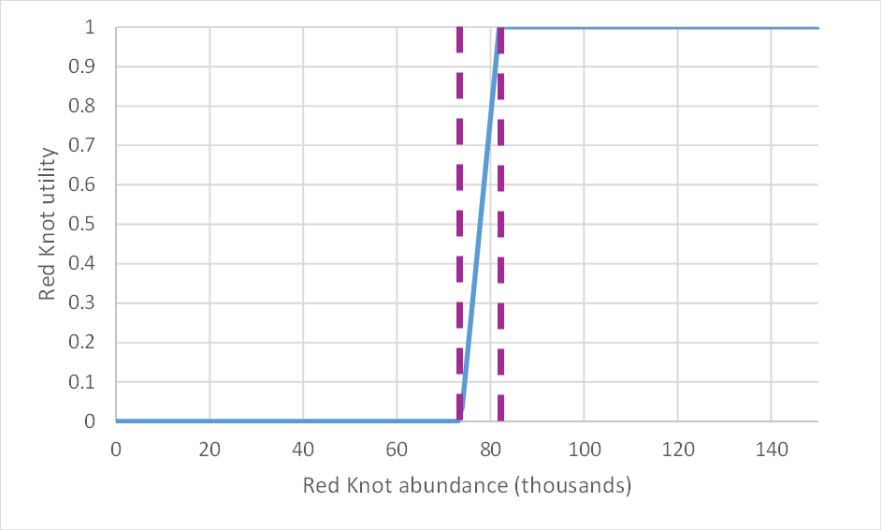
Key workshop question:

The current ARM assigns equal weight to horseshoe crab harvest and red knot abundance objectives. We recommend keeping these weights as 1:1. Are there other perspectives on adjusting these weights, and what would be the rationale?

Utility

Simple definition: Utility is the value or desirability of a given outcome for a single objective. It relates science-based states of the system (e.g., red knot abundance) to our values (e.g., level of satisfaction).

The **red knot utility function** in the current ARM (right) relates red knot stopover abundance with utility (satisfaction). It gives "0" utility for low abundances, rises quickly at 90% of a threshold abundance, and reaches "1" at the threshold abundance of 81,900 birds.



The **horseshoe crab harvest utility** function in the current ARM (below) assumes one female harvested is worth twice as much as one male harvested (see the "2" multiplier in the utility equation below.

$$\text{HSC bait harvest utility} = \frac{2 \times \text{\# females harvested} + 1 \times \text{\# males harvested}}{2 \times \text{max. female harvest \#} + 1 \times \text{max. male harvest \#}}$$

Key workshop questions:

Red knot utility function: What is your level of satisfaction at different levels of red knot stopover abundance? How should the utility curve be updated to reflect stakeholder satisfaction?

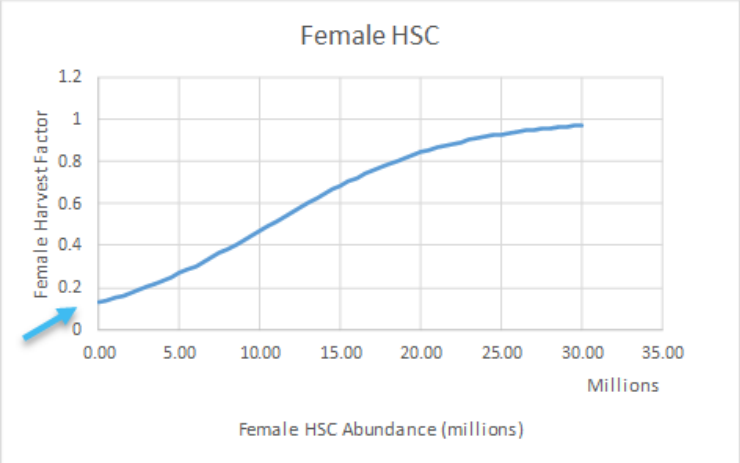
Horseshoe crab utility function: Is the relative value of females to males different than 2 to 1? Considering the horseshoe crab bait market over the next 10 years, catching one female is worth catching how many males?

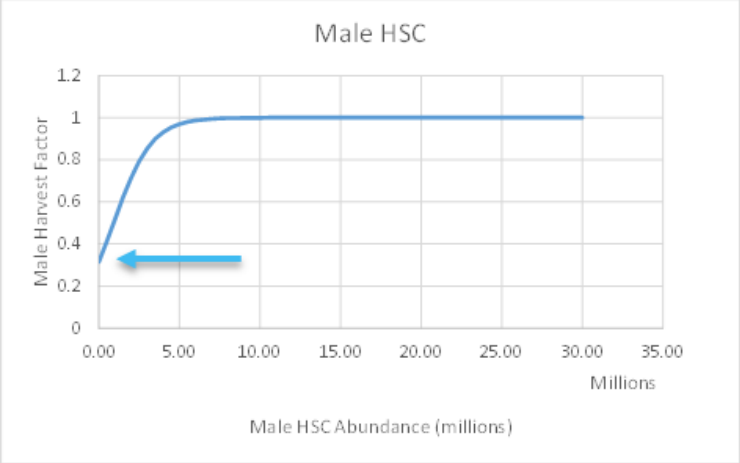
Harvest Policy

Simple definition: The harvest policy represents the key output of the ARM – a recommended annual number of male and female horseshoe crabs to harvest – where the model finds the optimal levels of harvest that maximize the long-term reward (i.e., the horseshoe crab harvest numbers and red knot population size).

The current ARM specifies that the maximum number of horseshoe crabs that could be recommended to harvest annually is 210,000 females and 500,000 males.

The current **harvest policy functions** (right) relate system conditions (e.g., female and male horseshoe crab abundance) to the proportion of those maximum sex-specific numbers that could be harvested. A harvest factor of "1" is equal to the maximum number of horseshoe crabs allowed. The ARM tests many different shapes of these policy functions and determines the shapes that maximize the long-term reward. The current policy functions identified as "optimal" do not go through 0 (see arrows to the right), meaning they technically do not allow for 0 horseshoe crab harvest even under very low crab abundances. However, this was because the ARM's science-based simulations never resulted in a situation where horseshoe crab abundance was predicted to decrease to a level that would significantly impact red knot survival.



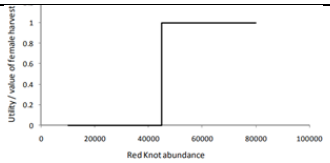
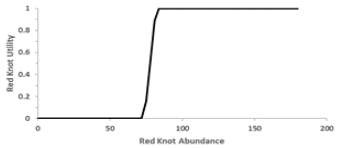


Key workshop questions:

(1) Is there interest in defining conditions that would trigger 0 harvest of female (and perhaps male) horseshoe crabs that would "sit on top" of the model? If so, what conditions would trigger 0 harvest at some times and allow harvest at other times?

(2) Is there an interest in updating the sex-specific maximum horseshoe harvest levels? If so, what would be the new maximum harvest levels, and what would they be based on?

Appendix 1. Key Definitions

Terminology	Definition	2009 ARM	2022 ARM
Objective Statement	"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.
Utility Function	"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
Constraints	"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
Harvest Policy	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).
Reward Function	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)

Appendix 2. Key supplemental background documents

Resource (title and link)	Description of relevance to this process
2009 Adaptive Management Framework	• This document explains the original ARM Framework that was developed in 2009 and later implemented in 2012 • Relevant Sections: Executive Summary, Introduction, Management Objectives, Conclusions
2021 ARM Revision and Peer Review Report	• Full report including the Peer Review Report, Supplemental Report, and ARM Framework Revision report completed in 2021. • Relevant sections: o Peer Review comments on minority opinions (pages 14-16) o Executive Summary o 8.4 Harvest Policy Functions (pages 69-70) o 8.5 Reward Function (pages 72-73) o 9 Stock Status and Conclusions (pages 77-79) o 11 Minority Opinions (pages 81-119)
ARM Revision Overview (ASMFC 2022)	Provides an abbreviated overview of the 2021 Revision of the Adaptive Resource Management (ARM) Framework.
ARM Subcommittee Memo on Reviewing RUH Functions	Recommendations to the Board from the ARM Subcommittee regarding possible ways to adjust the reward and utility functions of the ARM Framework and how to gather input from stakeholder groups to provide direction on changes.
July 2024 Horseshoe Crab Management Objectives Workshop Report	Describes the stakeholder workshop carried out in 2024 to better understand stakeholder objectives for horseshoe crab management and recommended next steps.
FAQ from USFWS (2022)	• Frequently asked questions about rufa red knots and horseshoe crabs in Delaware Bay. • Questions relate to population trends of both species, management of the horseshoe crab harvest, and conservation efforts for these species.