ASMFC Stock Assessment Overview: Horseshoe Crab

Introduction

This document summarizes the 2019 benchmark stock assessment for horseshoe crab. The horseshoe crab assessment was evaluated by an independent panel of scientific experts through the Atlantic States Marine Fisheries Commission's External Peer Review process. The horseshoe crab assessment represents the most recent and best information on the status of the coastwide horseshoe crab stock for use in fisheries management.

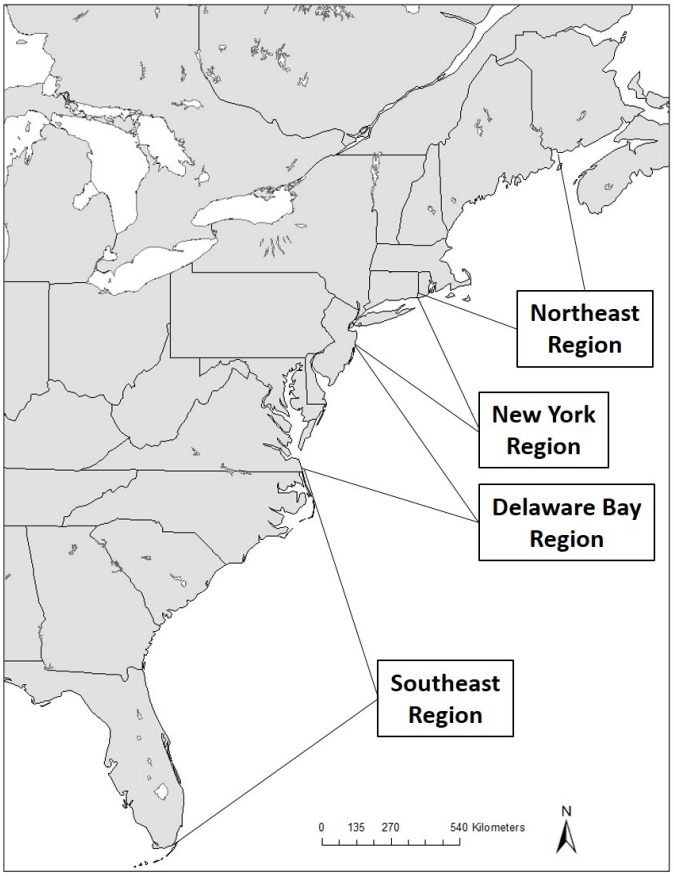
Management Overview

Horseshoe crab fisheries are managed solely by the Atlantic States Marine Fisheries Commission (ASMFC) through the 1998 Horseshoe Crab Fishery Management Plan (FMP). Addendum I (2000) to the FMP established a coastwide, state-by-state annual quota system to further reduce horseshoe crab landings. Addendum II (2001) established criteria for voluntary quota transfers between states.

Addendum III (2004) sought to further conserve horseshoe crab and migratory shorebird populations of red knot in and around the Delaware Bay by reducing horseshoe crab harvest quotas, implementing seasonal bait harvest closures in New Jersey, Delaware, and Maryland, and revising monitoring components for all jurisdictions. Addendum IV (2006) further limited bait harvest in New Jersey and Delaware to 100,000 crabs (male only) and required a delayed harvest in Maryland and Virginia. The provisions of Addendum IV were extended by Addendum V, and VI extended Addendum IV's measures through the 2013 fishing season.

Addendum VII (2012) implemented the Adaptive Resource Management (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 horseshoe crabs of Delaware Bay-origin. Since initial implementation in 2013, the ARM Framework has recommended a 500,000 male-only crab harvest in every year.

Based on tagging and genetic studies and the management of the species, the coastwide horseshoe crab stock is assessed as four populations: the Northeast, New York, Delaware Bay and Southeast regions.



What Data Were Used?

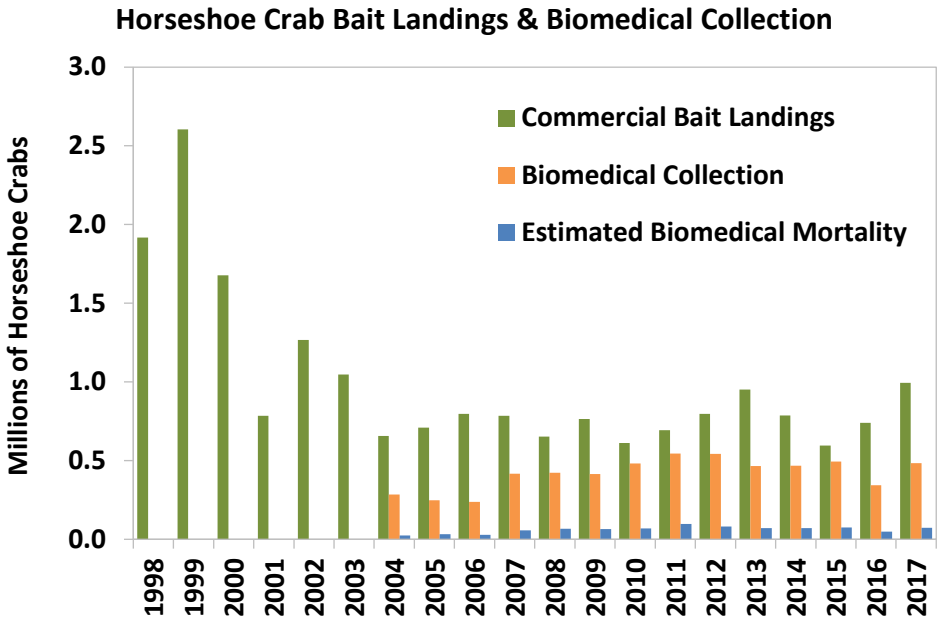
The horseshoe crab assessment used both fishery-dependent and independent data, as well as information about horseshoe crab biology and life history. Fishery-dependent data come largely from the commercial bait fishery and estimates of use by the biomedical industry, while fishery-independent data are collected through scientific research and surveys.

Life History

Horseshoe crabs are a long-lived, highly fecund species (meaning they produce a lot of eggs); however, they are subject to high egg and larval mortality due to predation and unfavorable environmental conditions. Horseshoe crabs breed in late spring on Atlantic coast beaches, laying eggs in nests buried in the sand. Larvae typically hatch from the eggs within 2 to 5 weeks, then settle within a week of hatching and begin molting. Juvenile crabs initially remain in intertidal flats, near breeding beaches. Older juveniles move out of intertidal areas to deeper bay and shelf waters and then return as adults to spawn on beaches in the spring. Adults overwinter in the bays or shelf waters. Horseshoe crabs are thought to mature around 10 years of age and may live over 20 years. Horseshoe crabs undergo stepwise growth by periodically shedding their shells (molting) until maturity, with females typically maturing later and attaining larger sizes than males.

Commercial Data

Since 1998, states have been required to report annual landings to ASMFC through the compliance reporting process and to the Atlantic Coastal Cooperative Statistics Program (ACCSP) Data Warehouse. Landings used in this assessment for 1998 through 2017 were validated by state agencies through ACCSP. Reported landings data show that commercial harvest of horseshoe crabs was high in the late 1990s, declined in the early 2000s, and has been relatively stable since 2004. The majority of bait harvest comes from the Delaware Bay Region, followed by the New York, New England, and Southeast Regions. The bulk of commercial horseshoe crab bait landings are caught by trawls, hand harvests, and dredges.

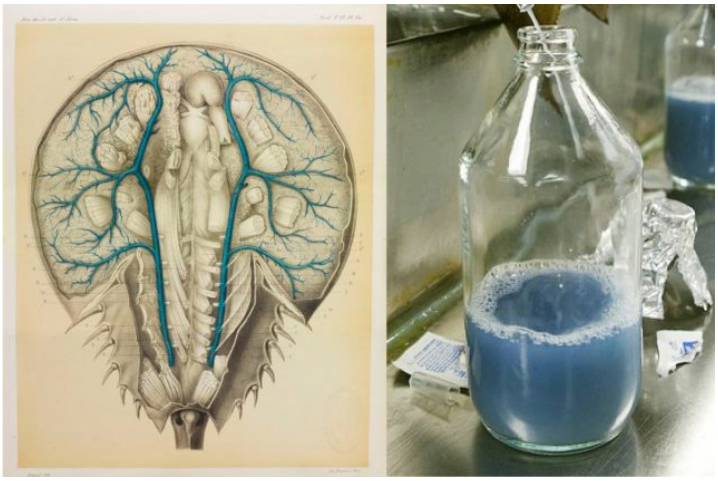


Horseshoe crabs are also collected by the biomedical industry to support the production of Limulus amebocyte lysate (LAL), a clotting agent in horseshoe crab blood cells that is used in the detection of pathogens in health patients, drugs and intravenous devices. Blood from the horseshoe crab is obtained by collecting and

Please note the following details regarding biomedical collection numbers:

* Annually reported biomedical collection numbers include all crabs brought to bleeding facilities except those harvested as bait and counted against state quotas.
* Most collected biomedical crabs are returned to the water after bleeding; a 15% mortality rate is estimated for all bled crabs.

extracting a portion of their blood. As required by the FMP, most crabs collected and bled by the biomedical industry are released alive to the water from where they were collected. However, a portion of these crabs die from the procedure. Crabs harvested for bait are sometimes bled prior to being processed and sold by the bait industry; these crabs are counted against the bait quota. Biomedical use has increased since 2004, when reporting began, but has been fairly stable in recent years. Previous assessments and management documents have applied a mortality rate of 15% to the number of horseshoe crabs bled and released alive to estimate the number of crabs that are presumed dead as a result of the capture and bleeding process. This assessment maintains the 15% mortality rate based on an updated analysis of available literature on this topic.



On the left, venous system of the horseshoe crab from Milne-Edwards's *Recherches sur l'anatomie des Limules* – American Museum of Natural History. On the right, extracted blue blood from horseshoe crabs (Mark Thiessen – National Geographic)

Horseshoe crabs are also encountered in several other commercial fisheries. Discard mortality occurs in various dredge, trawl and gillnet fisheries and may vary seasonally with temperature, impacting both mature and immature horseshoe crabs. However, the actual rate of discard mortality is unknown. Commercial discards were estimated for the Delaware Bay region as part of this assessment with data from the NOAA Fisheries Northeast Fisheries Science Center's Northeast Fisheries Observer Program. Estimates indicate a significant amount of horseshoe crabs are captured and discarded in other fisheries, possibly on the same scale as the bait fishery, although substantial uncertainty is associated with the estimates and quantifying discards will require further work in future assessments.

Data Confidentiality

The stock assessment was conducted with the inclusion of biomedical data on a regional basis, which are confidential. The report for peer review included confidential data but these data were redacted for the Technical Committee and public report. Biomedical data are not confidential at the coastwide level. Confidential data are data such as commercial landings or biomedical collections that can be identified to an individual or single entity. Federal and state laws prohibit the disclosure of confidential data, and ASMFC abides by those laws. In determining what data are confidential, most agencies use the "rule of 3" for commercial catch and effort data. The "rule of 3" requires three separate contributors to fisheries data in order for the data to be considered non-confidential. This protects the identity of any single contributor. In some cases, annual summaries by state and species may still be confidential because only one or two dealers process the catch. Alternatively, if there is only one known harvester of a species in a state, the harvester's identity is implicit and the data for that species from that state are confidential.

In this assessment, although three biomedical facilities operate in the Delaware Bay region, these data are confidential because only two facilities operate outside this region. Therefore, if Delaware Bay regional collections were released, those with knowledge of confidential collections (such as facility employees) for one of the facilities outside of the Delaware Bay region would, through subtraction from the coastwide total, also know collections for the other facility.

Fishery-Independent Surveys

The horseshoe crab assessment used 17 fishery-independent surveys to characterize trends in abundance of horseshoe crab. Two surveys were located in the Northeast region, 4 in the New York region, 7 in the Delaware Bay region, and 5 in the Southeast region.

What Models Were Used?

Tagging data from the U.S. Fish and Wildlife Service horseshoe crab database were explored by region to estimate survival. The highest survival rates were in the Delaware Bay and coastal Delaware-Virginia regions. The lowest survival rates were in coastal New York-New Jersey and the Southeast.

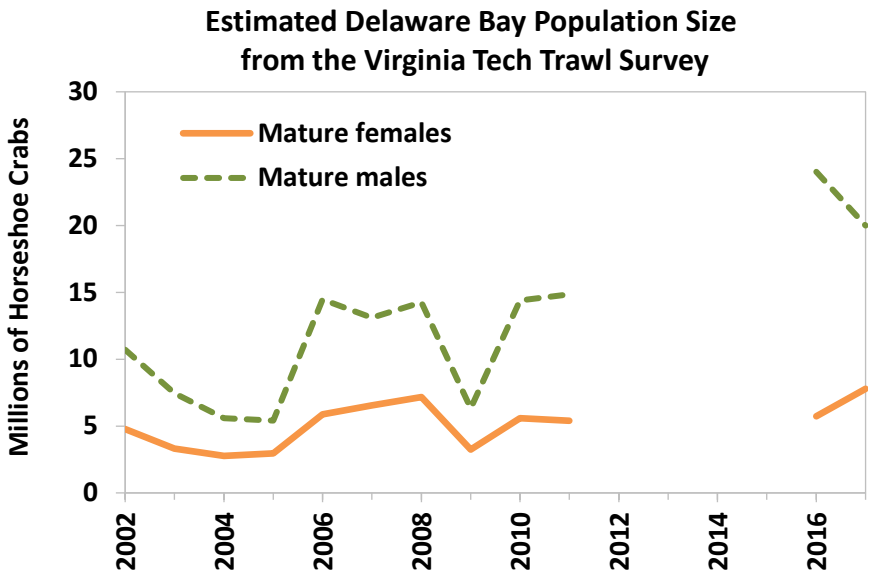
A trend analysis was used to assess regional and coastwide stocks and an additional stage-based model using pre-recruits and full recruits were used to assess the Delaware Bay region. For the trend analysis, 1998 was used as the benchmark year for comparison of survey trends since it was the first year of FMP implementation. Not all surveys were used in each assessment method. Traditional age-based methods could not be used because there is no technique available to measure the ages of horseshoe crabs.

Coastwide and Regional Trend Analysis

Autoregressive Integrated Moving Average (ARIMA). A smooth trend was generated for each survey, then the probability that the most recent year's survey value had dropped below the 1998 level was estimated (see table on next page). In the Northeast Region, 1 out of 2 surveys were likely less than the 1998 reference point. In the New York Region, 4 out of 4 surveys were likely less than the 1998 reference point. In the Delaware Bay Region, 2 out of 5 surveys were likely less than the 1998 reference point. Finally, in the Southeast Region, no survey was below the 1998 reference point. Coastwide, 7 out of 13 surveys were likely less than the 1998 reference point.

Delaware Bay Region Analysis

Catch multiple survey analysis. The catch multiple survey analysis (CMSA) estimated Delaware Bay stock dynamics from 2003-2018 by dividing the population into 1 of 2 life stages (pre-recruits and full recruits to the fishery). It then tracked trends in the relative abundance of these two stages in the Virginia Tech Benthic Trawl Survey and one-stage abundance indices from the New Jersey Ocean Trawl and Delaware Adult Trawl Surveys. The model included commercial bait harvest, regional confidential biomedical data and commercial discard estimates. The CMSA indicated adult abundance in the Delaware Bay was stable from 2003-2012 and then began increasing considerably in the past few years. This finding is consistent with stock rebuilding due to a period of significantly reduced commercial landings and tight management controls on the fishery beginning in the early 2000s in this region. The results of the model are considered confidential since they included regional biomedical data, but sensitivity runs indicated the mortality attributed to biomedical collection does not have a significant effect on population estimates or fishing mortality.



The Peer Review Panel supported the CMSA as a stock assessment method for horseshoe crab in the Delaware Bay, but did not approve the reference point developed by the Stock Assessment Subcommittee for determining overfished and overfishing status to compare with the model output. Regardless, the Panel indicated population estimates from the CMSA do represent the best current estimates and the ARM Committee should consider using the estimates in the Framework.

What is the Status of the Stock?

To date, no overfishing or overfished definitions have been adopted for management use. For this assessment, biological reference points were developed for the Delaware Bay region horseshoe crab population although not endorsed by the Peer Review Panel for use in management. Stock status was determined on the coastwide and regional stock levels based on the results of the ARIMA and in comparison to similar analysis in past assessments.

Stock status was based on the percentage of surveys within a region (or coastwide) having a >50% probability of the final year being below the ARIMA reference point. **"Poor"** status was >66% of surveys meeting this criterion, **"Good"** status was <33% of surveys, and **"Neutral"** status was 34 – 65% of surveys. Based on this criteria, stock status for the Northeast region was neutral; the New York region was poor; the Delaware Bay region was neutral; and the Southeast region was good. Coastwide, abundance has fluctuated through time with many surveys decreasing after 1998 but increasing in recent years. The coastwide status includes surveys from all regions and indicates a neutral trend, likely due to positive and negative trends being combined.

Applying these stock status criteria to summary ARIMA results from the 2009 benchmark assessment and 2013 assessment update gives a general idea of how status has changed through time. The stock status of the Delaware Bay and Southeast Regions have remained consistently neutral and good, respectively, through time. The status of the Northeast region has changed from poor to neutral. The status of the New York region has trended downward from good, to neutral, and now to poor. These trends should be viewed with caution because the number of surveys in each region has changed in the current assessment and the index values have changed due to a change in methods for developing indices.

Number of Surveys Below the Index-based 1998 Reference Point in the Terminal (Final) Year of ARIMA Model

Region	2009 Benchmark	2013 Update	2019 Benchmark	2019 Stock Status
Northeast	2 out of 3	5 out of 6	1 out of 2	Neutral
New York	1 out of 5	3 out of 5	4 out of 4	Poor
Delaware Bay	5 out of 11	4 out of 11	2 out of 5	Neutral
Southeast	0 out of 5	0 out of 2	0 out of 2	Good
Coastwide	7 out of 24	12 out of 24	7 out of 13	Neutral

Data and Research Needs

Horseshoe crab assessments would be greatly improved by better characterization of commercial discards and resulting mortalities, as well as fishery-independent surveys and landings by fishery, sex, and life stage. Expanding data collection and analysis of current fishery-independent surveys and implementing new surveys that target horseshoe crabs throughout their full range would reduce uncertainty about horseshoe crab stock status. Further development of the CMSA and reference points coastwide as well as considering revisions to the ARM Framework in Delaware Bay are high priorities that will require additional data collection and modeling efforts.

Whom Do I Contact For More Information?

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Glossary

Adaptive Resource Management (ARM): a structured, iterative process for decision making in the face of uncertainty whereby predictive population or ecosystem models are regularly updated with new information from scientific monitoring programs and associated management plans are adjusted accordingly.

Autoregressive Integrated Moving Average (ARIMA): a data analysis method that generates smooth trends in abundance indices and estimates the probability that an index has dropped below a specified level.

Catch multiple survey analysis (CMSA): a stock assessment method that divides the population into two or more life stages, then uses relative catch of animals in those stages within multiple surveys over time to estimate population abundance and fishing mortality.

References

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