ASMFC Stock Assessment Overview: Horseshoe Crab

Introduction

This document summarizes the 2009 benchmark stock assessment for horseshoe crab, and the multispecies Adaptive Resource Management (ARM) framework. The horseshoe crab assessment and ARM framework were evaluated by an independent panel of scientific experts through the Commission's External Peer Review process. The horseshoe crab assessment represents the most recent and best information on the status of horseshoe crab stocks for use in fisheries management, and the ARM framework provides guidance for the multispecies management of horseshoe crab and red knot in the Delaware Bay.

Management Overview

Horseshoe crab fisheries are managed solely by the Atlantic States Marine Fisheries Commission 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 through the 2010 fishing season. The majority of regulations have focused on the Delaware Bay Region since it is considered the epicenter of the horseshoe crab population.

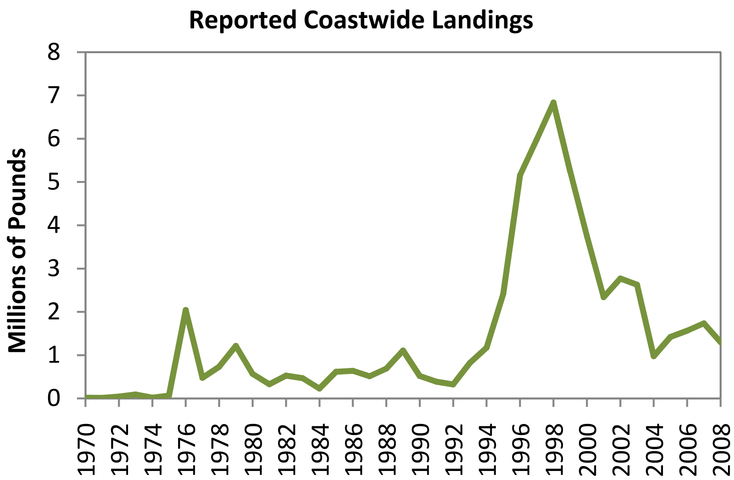
Based on tagging and genetic studies, the coastwide horseshoe crab stock is assessed as four populations, namely the New England, New York, Delaware Bay, and Southeast Regions.

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 commercial bait and biomedical fisheries, while fishery-independent data are collected through scientific research and surveys.

Life History

Horseshoe crabs are a long-lived, highly fecund species (meaning that 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 up to 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.



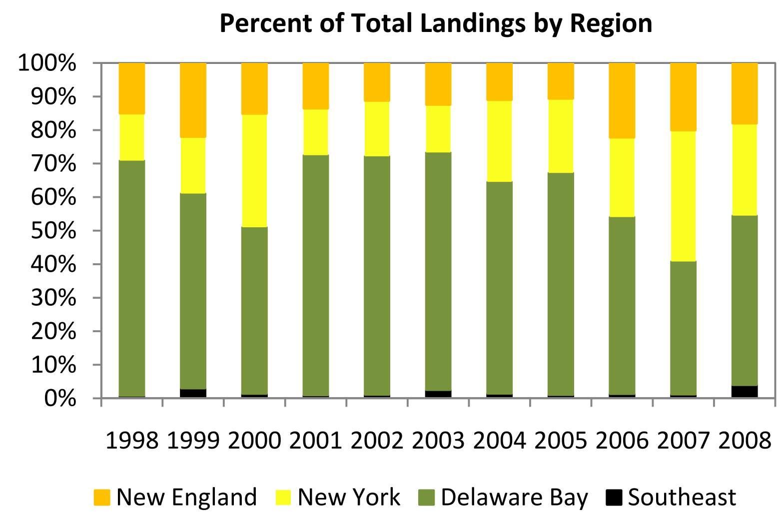
Commercial Data

In the mid-1800s to mid-1900s, about 1 to 5 million horseshoe crabs were harvested annually and sold for fertilizer or livestock feed. Harvest dropped throughout the 1950s and ceased in the 1960s. Between 1970 and 1990, reported commercial harvest ranged from less than 20,000 pounds to greater than 2 million pounds annually.

Since the mid- to late 1990s, commercial harvest has been sold primarily as bait for the American eel and whelk pot fisheries. Increased need for bait in the whelk fishery likely caused an increase in horseshoe crab harvest in the 1990s, with a peak of nearly 6 million pounds in 1997. Since state-by-state quotas took effect in 2001 and the use of bait-saving devices spread, reported landings dropped to around 1.2 million pounds in 2008. The majority of horseshoe crab harvest comes from the Delaware Bay Region, followed by the New York, New England, and Southeast Regions.

Trawls, hand harvests, and dredges make up the bulk of commercial horseshoe crab bait landings. Discard mortality occurs in various dredge fisheries and may vary seasonally with temperature, impacting both mature and immature horseshoe crabs; however the actual rate of discard mortality is unknown.

Some states allow a minimal number of crabs to be retained for personal use, but landings are not quantified. The limit for personal use is typically 25 crabs/person/day.



Horseshoe crabs are also harvested commercially by hand or trawl for the biomedical industry which uses their blood cells to test for the presence of gram-negative bacteria. Blood from the horseshoe crab is obtained by collecting adults, extracting a portion of their blood, and releasing them alive. Crabs are inspected to cull out the damaged or dying ones and then transported to the bleeding facility. Following bleeding, most crabs are returned near the location of capture; however, since 2004, states have the ability to enter bled crabs into the bait market and count those crabs against the bait quota. Total estimated mortality on biomedical crabs not counted against state bait quotas has increased from about 45,000 in 2004 to 63,000 in 2008.

Fishery-Independent Surveys

The horseshoe crab assessment used over 30 state and federal surveys to characterize trends in abundance of horseshoe crab. Nine surveys were located in the New England Region, 6 in the New York Region, 11 in the Delaware Bay Region, and 5 in the Southeast Region. The National Marine Fisheries Service trawl survey was associated with the Delaware Bay Region because the data used corresponded to tows taken south of Long Island and north of Albemarle Sound.

What Models Were Used?

Two trend-based methods (#1 and #2 below) were used to assess all four regional stocks and an additional two methods (#3 and #4 below) were used to assess the Delaware Bay Region. For several of these methods, 1998 was used as the benchmark year for comparison of survey trends, assuming that abundance was relatively low in the year preceding implementation of the FMP. Not all surveys were used in each assessment method. Note that traditional age-based methods could not be used because there is no technique available to measure the ages of horseshoe crabs.

Coastwide analyses

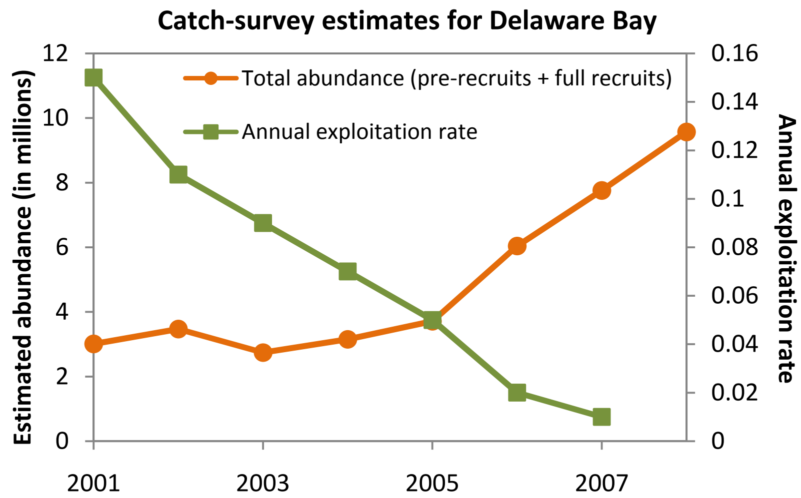
1) Trend analysis. Used in previous assessments, this method involved estimating an overall straight line trend through survey data within a region from 1998-present in order to identify population changes. In the New England and New York Regions, there was evidence of stock decline (significant declines in 3 of 9 indices in New England and 3 of 6 indices in New York). In contrast, survey indices in the Delaware Bay region were increasing or stable (significant increases in 10 out of 20 indices with no significant declines), indicating the population is recovering. The Southeast Region did appear to be increasing (significant increases in 3 out of 4 indices).

2) *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. The majority of survey indices, both coastwide and within the Delaware Bay region, increased over time but several are still below 1998 levels. New England Region indices have generally shown a decline with 2 out of 3 surveys (67%) likely falling below the 1998 reference point. The New York Region only showed a likely decline below 1998 levels in 1 out of 5 (20%) surveys. Within the Delaware Bay region, 5 out of 11 surveys (45%) were likely less than the 1998 reference point. None of the 3 surveys analyzed in the Southeast Region were likely to have dropped below 1998 levels. The peer review panel supported ARIMA as the preferred stock assessment method for tracking horseshoe crab trends coastwide.

Delaware Bay Region analyses

3) *Surplus production model.* This stock assessment model evaluates trends of all life stages combined, estimating total population size and fishing mortality in each year. The model estimated that relative abundance decreased from 1991-2000, then increased steadily to the present. Current (2009) relative biomass was estimated to be approximately equal to relative biomass in 1996-1997. Estimates of relative fishing mortality peaked in 1998-1999 then declined. Current (2008) relative fishing mortality is approximately equal to the 1991 level. Surplus production model results should be considered with caution because they do not account for the long lag time between egg stage and entry to the fishery.

4) *Catch-survey analysis.* The catch-survey analysis (CSA) estimated Delaware Bay stock dynamics from 2001 to 2007 by dividing the population into one of two life stages (pre-recruits and full recruits to the fishery) and tracking trends in the relative abundance of these two stages in the Virginia Tech Benthic Trawl Survey. Estimated stock size increased over time from approximately 3 to 9.6 million females while annual fishery exploitation rates declined from 15% to 1%. The peer review panel supported CSA as the preferred stock assessment method for horseshoe crab in Delaware Bay, but data limitations preclude its use in the other three geographic regions.



What is the Status of the Stock?

To date, a formal set of reference points has not been adopted by the Horseshoe Crab Management Board. However, the majority of evidence in the stock assessment indicates abundance has increased in the Southeast and Delaware Bay Regions. In the Delaware Bay Region, increasing trends were most evident in juvenile indices, followed by indices of adult males. A significant increase in adult females was observed in the Virginia Tech Benthic Trawl Survey. These patterns are indicative of population recovery, given that horseshoe crab females take longer to mature than males.

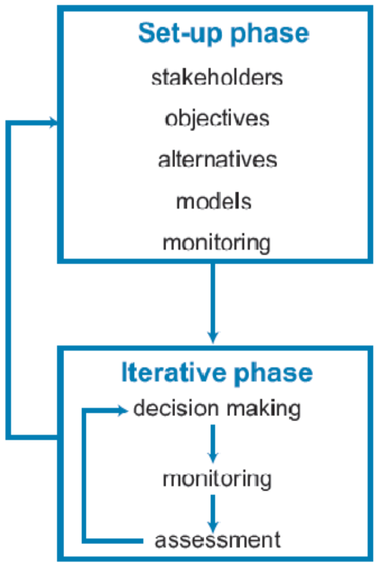
Regional Trends in Horseshoe Crab Abundance

Region	Time series duration of longest dataset	Conclusion about population change
New England	1978 - 2008	Declined
New York	1987 - 2008	Declined
Delaware Bay	1988 - 2008	Increased
Southeast	1993 - 2009	Increased

In contrast, declining abundance was evident in the New York and New England regions. Declines in the New England Region had been evident in the 2004 assessment; however, declines in the New York Region represent a downturn from the 2004 assessment. Decreased harvest quotas in Delaware Bay have likely redirected harvest to nearby regions. Current harvest within New England and New York Regions may not be sustainable. Continued precautionary management is therefore recommended coastwide to anticipate effects of redirecting harvest from Delaware Bay to outlying populations.

Adaptive Resource Management in Delaware Bay

Horseshoe crab eggs are considered essential food for several shorebird species in the Delaware Bay, the second largest migratory staging area for shorebirds in North America. The 2004 horseshoe crab assessment suggested a framework be developed that linked management of horseshoe crab harvest to multispecies objectives, particularly red knot shorebird recovery. In 2007, the Commission Horseshoe Crab and US Fish and Wildlife Service Shorebird Technical Committees met jointly and formed a working group that was tasked with development of a multispecies Adaptive Resource Management (ARM) framework for Delaware Bay. The goal of the ARM framework was to transparently incorporate views of stakeholders and utilize predictive modeling to assess the potential consequences of multiple, alternative management actions in Delaware Bay.



After setting objectives and identifying alternative management actions, ARM involves several steps: 1) building models that make predictions about how a system will respond to management actions, 2) implementing management actions based on those predictions, 3) monitoring the ecosystem to evaluate the accuracy of model predictions, 4) inserting new data into the models to generating updated predictions, and 5) revising management actions as necessary to reflect the latest state of knowledge about the ecosystem. ARM is an iterative process that evolves continuously as new information is gathered and the effects of management actions are evaluated.

Within this ARM framework, a set of alternative multispecies models have been developed for the Delaware Bay Region to predict the optimal horseshoe crab harvest strategy that would still allow enough eggs to be available for red knot population needs. These models incorporate uncertainty in model predictions and will be updated with new information as monitoring progresses.

Above figure illustrates the double loop learning process of adaptive management (Williams et al. 2007).

Data and Research Needs

Horseshoe crab assessments would be greatly improved by better characterization of the commercial catch 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 CSA in regions outside the Delaware Bay and implementation of the ARM framework in Delaware Bay are high priorities that will require additional data collection efforts.

Whom Do I Contact For More Information?

Atlantic States Marine Fisheries Commission
1444 Eye St NW 6th Floor
Washington, DC 20005
Phone: (202) 289-6400
Fax: (202) 289-6051
E-mail: info@asmfc.org

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

Exploitation rate: the annual rate at which horseshoe crab are removed from the population by fishing.

Surplus production model: a stock assessment model that aggregates all ages (or stages) of animals together, then estimates total biomass (or abundance) and fishing mortality in each year assuming a specific pattern of population growth.

References

ASMFC. 2004. Horseshoe crab stock assessment report. 87 pages.

ASMFC. 2009. Guide to Fisheries Science and Stock Assessments. Washington, DC. http://www.asmfc.org/publications/GuideToFisheriesScienceAndStockAssessments.pdf

ASMFC. 2009. Horseshoe crab stock assessment report. 120 pages.

Delaware Bay Adaptive Resource Management Working Group. 2009. A Framework for Adaptive Management of Horseshoe Crab Harvest in the Delaware Bay Constrained by Red Knot Conservation. 81 pages.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2007. Adaptive management: the US Department of the Interior technical guide. Adaptive Management Working Group, U.S. Department of the Interior, Wash DC.