2011 REVIEW OF THE FISHERY MANAGEMENT PLAN IN 2010 FOR

HORSESHOE CRAB

(*Limulus polyphemus*)

Presented to the
ASMFC Horseshoe Crab Management Board

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2011 REVIEW OF THE 2010 ASMFC FISHERY MANAGEMENT PLAN FOR HORSESHOE CRAB (*Limulus polyphemus*)

I. Status of the Fishery Management Plan

The framework for managing horseshoe crabs along the Atlantic coast was approved in October 1998 with the adoption of the Interstate Fishery Management Plan for Horseshoe Crabs (FMP). The goal of this plan is to conserve and protect the horseshoe crab resource to maintain sustainable levels of spawning stock biomass to ensure its continued role in the ecology of coastal ecosystems, while providing for continued use over time.

In 2000, the Horseshoe Crab Management Board approved Addendum I to the FMP. Addendum I established a state-by-state cap on horseshoe crab bait landings at 25 percent below the reference period landings (RPL's), and *de minimis* criteria for those states with a limited horseshoe crab fishery. Those states with more restrictive harvest levels (Maryland and New Jersey) were encouraged to maintain those restrictions to provide further protection to the Delaware Bay horseshoe crab population, recognizing its importance to migratory shorebirds. Addendum I also recommended that the National Marine Fisheries Service (NMFS) prohibit the harvest of horseshoe crabs in federal waters (3-200 miles offshore) within a 30 nautical mile radius of the mouth of Delaware Bay, as well as prohibit the transfer of horseshoe crabs in federal waters. A horseshoe crab reserve was established on March 7, 2001 by NMFS in the area recommended by ASMFC.

In 2001, the Horseshoe Crab Management Board approved Addendum II to the FMP. The purpose of Addendum II was to provide for the voluntary transfer of harvest quotas between states to alleviate concerns over potential bait shortages on a biologically responsible basis. Voluntary quota transfers require Technical Committee review and Management Board approval.

In 2004, the Board approved Addendum III to the FMP. The addendum sought to further the conservation of horseshoe crab and migratory shorebird populations in and around the Delaware Bay. It reduced harvest quotas and implemented seasonal bait harvest closures in New Jersey, Delaware, and Maryland, and revised monitoring components for all jurisdictions.

Addendum IV was approved in 2006. It further limited bait harvest in New Jersey and Delaware to 100,000 crabs (male only) and required a delayed harvest in Maryland and Virginia. Addendum V, adopted in 2008, extends the provisions of Addendum IV through October 31, 2010. In early 2010, the Board initiated Draft Addendum VI to consider management options that will follow expiration of Addendum V. The Board voted in August 2010 to extend the Addendum V provisions, via Addendum VI, through April 30, 2013. The Board also chose to include language, allowing them to replace Addendum VI with another Addendum during that time, in anticipation of implementing the ARM framework.

II. Status of the Stock

No definitions for overfishing or overfished status have been adopted by the Management Board. However, the majority of evidence in the most recent stock assessment, the 2009 Benchmark Horseshoe Crab Stock Assessment (available at http://www.asmfc.org/horseshoeCrab.htm), 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 consistent with population recovery, given that horseshoe crab females take longer to mature than males.

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 noted in the most recent stock assessment represent a downturn from the 2004 assessment. Decreased harvest quotas in Delaware Bay have potentially redirected harvest to nearby regions. Current harvest within the 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. Under a general five-year trigger, the next horseshoe crab stock assessment will likely occur in 2014.

The PRT and TC will continue to monitor any harvest increases in regions outside of Delaware Bay, which are coincident with harvest reductions within Delaware Bay. An overarching conclusion of recent coastwide assessments has been that management should be regional or embayment specific. Current harvest levels of the Delaware Bay population appear consistent with population growth. However, it is unclear whether harvest of crabs in the outlying regions is sustainable.

III. Status of Assessment Advice

The Stock Assessment was externally peer reviewed by a panel of experts. The panel included their comments and recommendations in the 2009 Horseshoe Crab Terms of Reference and Advisory Report, available at http://www.asmfc.org/horseshoeCrab.htm. Below is a selection of recommendations from their report.

Assessment Methodology

- The Panel considers the ARIMA method superior to the linear trend analysis, and recommends focusing on this approach in the future in areas where more sophisticated modeling is not possible. The Panel concluded that the ARIMA method could supersede the linear trends analysis, provided the unsmoothed (input) index estimates are reported along with the smoothed (output) estimates.
- We are concerned the surplus production model for Delaware Bay is not suitable, given the life history of horseshoe crab and the presumed mechanism of density dependence. As noted in the report, surplus production models assume an instantaneous response of the stock to changes in conditions, which seems unrealistic given the late age of maturity of horseshoe crab and the belief that density dependence operates at the egg stage. We urge that the sensitivity of the production model to this assumption be explored more

thoroughly if it is to be used further. A simple age-structured operating model (e.g., Sweka et al. 2007) could be used to generate simulated data that are then fit to the surplus production model and the biomass/exploitation rate estimates compared to true values to test for biases.

- The catch-survey methodology appears to be a promising tool for assessment in Delaware Bay, but will require further examination of the evidence for differential catchability of primiparous and mulitparous horseshoe crab. As a first step we suggest a spatial analysis of the catch data, using habitat variables as covariates that may explain differences in the distribution and thus catchability of the two life stages.

Biological Reference Points

- We recommend development of plausible biological reference points using life history information for horseshoe crab, comparisons to other species with similar life histories (e.g., long-lived, late maturing invertebrate species), and development of yield per recruit or egg per recruit models.
- We also suggest empirical reference points based on an estimated historic state are preferable to percentile-based reference points because of the vulnerability of the latter to the influence of the period for which past data are available. This is especially true when the reference point analysis is being used in an aggregated manner (i.e., across multiple surveys). Rather than basing the historical reference point on a single year, we recommend using the average across a range of years that represent, in the SASC's judgment, a period of relatively high abundance.

IV. Status of the Fishery

Bait Fishery

For most states, the bait fishery is open year round. However, because of seasonal horseshoe crab movements (to the beaches in the spring; deeper waters and offshore in the winter), the fishery operates at different times. State waters from New Jersey south to Virginia coastal waters are closed to horseshoe crab harvest and landing from January 1st through June 7th each year.

Reported coastwide bait landings in 2010 remained well below the coastwide quota (Table 2, Figure 1). Bait landings decreased 21% from the previous year, due to decreased landings in Massachusetts, Delaware, Virginia, and North Carolina. Concern for increased harvest pressure due to Delaware Bay restrictions led Massachusetts and New York to continue stricter regulations in 2010 to control harvest.

An alternative bait/gear workshop conducted under the auspices of ASMFC in 1999 introduced the concept of using bait savings devices (bait bags) in whelk (conch) pots. Free bait bags were distributed to whelk potters in the Mid Atlantic and southern New England regions through a state, federal, and NGO partnership. National Marine Fisheries Service funded the acquisition of the bait bags. The Ecological Research and Development Group (ERDG), Delaware, Maryland, New Jersey, Virginia, New York, Connecticut, Rhode Island and Massachusetts assisted in the funding and distribution of the bags. The reductions in reported bait landings in excess of the 25% reductions required under Addendum I were largely attributed to the success of this program, with the widespread use of the devices by the commercial fishery. Massachusetts

fishermen have been using bait cups in conch traps with success. The cups use about a 10th of a crab and can be fished for 2-3 days in relatively cold waters.

Reported coastwide landings since 1998 showed more male than female horseshoe crabs were annually harvested, though a large proportion of the reported landings in 1998 and 1999 were unclassified (Table 3). The American eel pot fishery prefers egg-laden female horseshoe crabs as bait, while the whelk (conch) pot fishery is less dependent on females. Unclassified landings have generally accounted for around 10% of the reported landings since 2000, although 2008 had a slightly higher proportion of unclassified landings (14%).

The hand, trawl, and dredge fisheries typically account for over 85% of the reported commercial horseshoe crab bait landings. Other methods that account for the remainder of the harvest include gill nets, pounds, and traps.

The dominance of the hand fishery was reflected in the seasonal distribution of landings. Most of the monthly reported coastwide harvest since 1998 came during May and June as crabs come ashore to spawn and, thus, were readily available to the fishery. There is typically a secondary mode in monthly landings during the late summer or fall. This secondary peak coincides with an increased demand for horseshoe crabs in the conch pot fishery.

Biomedical Fishery

The horseshoe crab is an important resource for research and manufacture of materials used for human health. There are four companies along the Atlantic Coast that process horseshoe crab blood for use in manufacturing Limulus Amoebocyte Lysate (LAL): Associates of Cape Cod, Massachusetts; Lonza (formerly Cambrex Bioscience), Maryland; Wako Chemicals, Virginia; and Charles River Endosafe, South Carolina. There is one company that bleeds horseshoe crabs but does not manufacture LAL: Limuli Labs, New Jersey. Addendum III requires states where horseshoe crabs are collected for biomedical use to collect and report harvest data and characterize mortality.

The Plan Review Team annually calculates total coastwide harvest and estimates mortality. It was reported that 548,751 crabs (including crabs harvested as bait) coastwide were brought to biomedical companies for bleeding in 2010 (see Table 1 below). This represents a 24% increase over the average of the previous five years. Of this total, 66,047 crabs reportedly were harvested as bait and counted against state quotas (Table 1: row C). These crabs were not included in the mortality estimates (Rows D, F, and G) below. It was reported for 2010 that 482,704 crabs were harvested for biomedical purposes only. Crabs were rejected prior to bleeding because of mortality, injuries, slow movement, and size. Based on state reports for 2010, approximately 9.2% of crabs (or 42,287 crabs) harvested and brought to bleeding facilities were rejected. Approximately 2.00% of harvested crabs suffered mortality from harvest up to the point of release.

The Technical Committee conducted a review of all available literature for estimating crab mortality during and after the bleeding process. It concluded that using an estimate of 15% mortality is reasonable and offered no better alternative. However, a recent Massachusetts study by Leschen and Correia (2010) estimated post-bleeding mortality near 30% (Leschen and

Correia 2010). Using the number of biomedical-only crabs bled (Row E) and the estimated 15% mortality rate after the bleeding process, the PRT calculated an estimated mortality of 65,763 crabs. The total coastwide mortality estimate of crabs not counted against state quotas (Row G) is 75,428 crabs for 2010.

Table 1. Characterization of Biomedical Use of Horseshoe Crabs

		2005	*2006*	*2007*	*2008*	*2009*	*2010*
A	**Number of crabs brought to biomedical facilities (bait and biomedical crabs)**	323,149	367,914	500,251	511,478	512,552	548,751
B	**Number of biomedical-only crabs harvested (not counted against state bait quotas)**	283,720	309,289	428,872	423,614	402,202	482,704
C	**Number of bait crabs bled**	32,429	38,625	71,379	87,864	110,350	66,047
D	**Reported mortality of biomedical-only from harvest to release**	4,256	4,639	3,599	2,973	6,298	9,665
E	**Number of biomedical-only crabs bled**	270,496	296,958	398,844	402,080	362,291	438,417
F	**Estimated mortality of bled biomedical-only crabs post-release**	40,574	44,543	59,833	60,312	54,344	65,763
G	**Total estimated mortality on biomedical crabs not counted against state bait quotas**	44,830	49,182	63,432	63,285	60,642	75,428

The 1998 FMP establishes a mortality threshold of 57,500 crabs, where if exceeded the Board is required to consider action. Based on an estimated total mortality of 75,428 crabs for 2010, the PRT recommends that the Board consider action. The PRT notes that estimated mortality from biomedical use is approximately 12.7% of the total horseshoe crab mortality (bait and biomedical) coastwide for 2010. The reported biomedical use of horseshoe crabs has continued to increase since the original FMP was approved.

V. Status of Research and Monitoring

The Horseshoe Crab FMP set forth an ambitious research and monitoring strategy in 1999 and again in 2004 to facilitate future management decisions. Despite limited time and funding there are many accomplishments since 1999. These accomplishments were largely made possible by forming partnerships between state, federal and private organizations, and the support of over a hundred public volunteers.

Addendum III Monitoring Program

Addendum III requires affected states to carry out three monitoring components. States report monthly harvest numbers and annual landings by sex and harvest method for at least a portion of

the catch. States with biomedical fisheries landings are required to monitor and report harvest numbers and mortality associated with the transportation and bleeding of the crabs. Last, states must identify spawning and nursery habitat along their coasts. All states have completed this requirement and a few continue active monitoring programs.

Virginia Tech Research Projects

The VT benthic survey was conducted for its ninth year in a row for the Delaware Bay region. While the survey was unable to sample in the NY Apex in 2009, this area was again covered in 2010. Additionally, 2010 marked the first year that the survey included tows within lower Delaware Bay.

Major findings through the 2010 survey include: 1) relative abundance of newly mature and mature horseshoe crabs in the Delaware Bay area increased slightly since 2009; 2) relative abundance of immature horseshoe crabs in the Delaware Bay were significantly lower in 2010 than in 2009; 3) mean catch per tow of immature crabs inside Delaware Bay was significantly higher than in the coastal Delaware Bay area; 4) relative abundance of all demographic groups in the New York apex has remained fairly consistent since 2002; and 5) mean sizes of newly mature and mature horseshoe crabs have remained consistent since 2002.

Through donations by the biomedical and the fishing industry, slightly more than $117,000 has been pledged for the VT Trawl Survey for 2011. That still leaves the survey approximately $83,000-93,000 short of its total necessary budget. FY2011 appropriations have been stalled by multiple continuing resolutions from Congress. Further, a current ban on earmarks, which had been the previous sources of Congressional funds, is likely to prevent further appropriations for FY 2011 as well as FY 2012. The PRT stresses the importance of the survey, as it is expected to provide the most reliable estimates of horseshoe crab population abundance.

In 2008, Virginia Tech initiated a tagging study to characterize the horseshoe crab population of Tom's Cove, Virginia. Mark/recapture data is being used to estimate the local population size. Data collection will continue as tagged crabs are recaptured and data are reported.

Spawning Surveys

The redesigned spawning survey was completed for the twelfth year in 2010; however, results for 2010 are not yet available. For 2009, no trend was detected in the baywide index of female spawning activity for the time series. There was a significant increase in the index of male spawning activity over the time series. Both male and female indices of spawning activity were precise ($CV_{males} < 20\%$; $CV_{females} < 14\%$ over the entire series). Most spawning activity was observed in May in 2009. Sex ratios observed in the surveys have increasingly favored males, which is consistent with the sex-specific trends in spawning activity. The observed spawning sex ratio in 2009 was 4.7:1.

Egg Studies

The first coordinated baywide horseshoe crab egg sampling was completed in 2005. The purpose of this survey was to provide a baywide index of horseshoe crab surface egg abundance during the spring shorebird migration. Monitoring the availability of horseshoe crab eggs throughout the Delaware Bay is an important step in managing horseshoe crabs and migratory

shorebirds. Such monitoring activities may be useful in establishing harvest thresholds, guiding beach nourishment activities, setting time-of-year restrictions, etc. Prior horseshoe crab egg surveys conducted by the states of Delaware and New Jersey were not designed to provide a baywide index of egg availability to migratory shorebirds. Survey design and implementation was the result of cooperation by numerous state and federal agencies, university researchers, and input from members of the horseshoe crab stock assessment and shorebird technical committees. A long-term funding source to ensure a continuation of the survey by both states has not been identified. Details in survey reporting responsibilities and format still need to be formalized.

Though the survey has been conducted on a baywide basis since 2005, the results have not been reported regularly. Survey researchers from both sides of the Delaware Bay met to discuss reporting details and responsibilities. Researchers agreed to follow a report format similar to the annual Delaware Bay horseshoe crab spawning survey report. Concerns were raised over the large discrepancies in mean egg abundance found on Delaware beaches versus New Jersey beaches. Although the large differences in mean egg abundance between the two sides may be real, researchers were expected to conduct side-by-side sampling in 2008 to ensure these differences were not the result of sampling and/or counting procedures. The draft report of this study, summarizing data from 2005-09, concluded that the side-by-side differences, while not statistically significant, did raise concerns about the consistently higher counts by Delaware samplers (35%) than by New Jersey samplers. Overall conclusions included that egg densities are highly variable, in terms of season, year, and spatial distribution.

Delaware includes a report on their egg sampling efforts in their annual compliance report. Results from Delaware indicated an average surface egg density of 136,051 eggs/m^2 for 2010, over a 3-fold increase from 2009 and a substantial increase from all previous years of sampling. The past years have shown a continuing increase in egg density. Peak density coincided with peak shorebird migration, indicating that the two events were synchronous in 2010. Again, as in the past, the highest mean egg density (greater than 1 million eggs/m^2) occurred in Mispillion Harbor, although significant increases were seen on Pickering Beach and Kitts Hummock. The high levels of egg densities throughout the Delaware Bay area are believed to have allowed shorebirds to use many areas for feeding, rather than concentrating on a few beaches. This occurrence may be considered a sign of success for foraging conditions in Delaware.

Tagging Studies

The USFWS continues to maintain a toll-free telephone number as well as a website for reporting horseshoe crab tag returns and assists interested parties in obtaining tags. Tagging work continues to be conducted by biomedical companies and other parties involved in outreach and spawning surveys. In some cases, the tagging efforts would benefit by establishing clearly defined objectives and insuring better coordination among researchers. To increase quality of tagging data being collected and supplied to the USFWS in Annapolis, the Tagging Subcommittee developed an application to potential horseshoe crab taggers. The application gives reviewers discretion when issuing tags and better understanding of taggers' objectives. The subcommittee also developed guidelines for a coastwide tagging program. The intent of drafting such guidelines was to encourage existing tagging programs to follow a similar direction and to provide new programs with direction. Ultimately, it is hoped that all horseshoe crab

programs along the coast will be coordinated to achieve common objectives that will benefit management of the species.

Since 1999, over 165,000 crabs have been tagged and released along the Atlantic coast. Over 10% of tagged crabs have been recaptured and reported. Crabs have been tagged and released from every state on the Atlantic Coast from Georgia to Massachusetts. In the early years of the program, tagging was centered around Delaware Bay; however, in recent years, more tagging has occurred in the Long Island Sound and the Massachusetts Coast as well as new tagging programs in South Carolina and Georgia. The Technical Committee noted that recapture rates inside and outside Delaware Bay are likely not directly comparable due to increased re-sighting effort and spawning concentration in Delaware Bay compared to other areas along the coast. There may be data in the USFWS tagging database to determine differences in effort and recapture rates.

Adaptive Resource Management Modeling
The ARM Work Group is a subset of the ASMFC Horseshoe Crab (HSC) and the former USFWS Shorebird (SHBD) Technical Committees. The ARM Work Group is chaired by Dave Smith (USGS-Leetown), with lead modeler Conor McGowan.

The Work Group developed models to estimate horseshoe crab harvest levels that will support the energetic needs of the red knot population passing through Delaware Bay. A peer review of the ARM framework/model concluded it is a useful tool for management and recommended improvements as it continues refinement. The Management Board sees value in this tool and had included it in the Draft Addendum VI as an option for the horseshoe crab management program. However, implementation of the ARM Framework has been delayed due to uncertain funding for the Virginia Tech Trawl Survey, the main source of data for the model, as well as the need to determine the allocation method for the ARM harvest output.

VI. Status of Management Measures and Issues

ASMFC
State-by-state harvest quotas are established through Addendum I. Addendum III outlines the monitoring requirements and recommendations for the states. Addendum VI sets harvest closures and quotas, and other restrictions for New Jersey, Delaware, Maryland, and Virginia. Addendum VI provisions supersede the Addendum III provisions for these four states.

The current provisions of Addendum VI expire April 30, 2013, which was approved by the Board in August 2010. Addendum VI included language that would allow the Board to replace it with another addendum prior to its expiration. Work continues to make possible management under the ARM Framework.

Shorebird
The US Fish and Wildlife Service formed the Shorebird Technical Committee in 2001 with the purpose of providing technical advice to the Board on how horseshoe crab management action might affect shorebird populations. This Committee was comprised of shorebird experts and a representative of the Horseshoe Crab Technical Committee and Stock Assessment Subcommittee. The group produced a peer-reviewed report that synthesized current literature and data on the status of shorebirds in the Delaware Bay and to determine their energetic dependency on horseshoe crab eggs. The report's findings led to the initiation of Addendum III. In 2010 the Board decided to form the Shorebird Advisory Panel, as well as the Delaware Bay Ecosystem Technical Committee, to split the roles of value-based and technical input.

The USFWS received petitions in 2004 and 2005 to emergency list the red knot under the Endangered Species Act. In fall 2005, it determined that emergency listing was not warranted at the time. The USFWS has listed the red knot *rufa* subspecies as a candidate for ESA protection. This means protection is warranted but, at this time, it is precluded by higher priority species that are at more imminent risk of extinction.

The state of New Jersey issued a notice of a proposed rule to upgrade the current state listing of the red knot from threatened to endangered on January 18, 2011. Comments on the proposed rule were due March 18, 2011.

VII. Implementation of FMP Compliance Requirements

Currently, the PRT recommends no jurisdiction is out of compliance with regard to their horseshoe crab programs. ME, NH, PRFC, SC, GA and FL have requested and qualify for *de minimis* status. Please see the PRT report on State Compliance for more information on each state's program.

The PRT recommends that Virginia adopt at least a minimum reduction of 21,562 crabs for the 2011 quota to make up for the overage that occurred in 2009 and the reported overage in 2010. Should the 2010 landings be updated and increase, the PRT recommends that the quota should be reduced further to accommodate these additional landings overages. In addition, the PRT recommends that Virginia consider an area-specific quota reduction, as most of the two-year cumulative overage occurred east of the COLREGS line. A portion of these crabs have been shown, via tagging and genetic data, to originate from Delaware Bay. Area-specific quotas to compensate for the 2009 and the reported 2010 overage would include a reduction of 52,778 crabs for east of the COLREGS (8,220 quota) and no reduction in harvest for west of the COLREGS (91,497 quota). The PRT has recognized that Virginia has had additional overages that are reported after the state compliance reports were submitted and after quotas for the fishing year have been set. The PRT recommends that Virginia address this issue, so as to provide itself and the Commission with more timely and accurate reporting of all landings that occur in and are counted against Virginia's quota.

All state reports for 2011 should continue to comply with the requirements of the FMP, Addendum I, Addendum III, and Addendum VI.

Washington, D.C. was added to the HSC Management Board to close a landings loophole that existed in the late 1990s. Since then DC has adopted regulations that prohibit landings of horseshoe crabs, thereby closing the loophole. In order to free DC of the requirement to submit compliance reports, the PRT recommends DC request removal from the HSC Board. Pennsylvania was in this same situation and was removed from the Board in 2006.

Law Enforcement
The ASMFC Law Enforcement Committee obtained and compiled this information for inclusion into the PRT Report on State Compliance. There were no significant enforcement cases regarding horseshoe crabs in 2010.

VIII. Research Needs/PRT Recommendations

Funding for Research and Monitoring Activities
The PRT strongly recommends the continuation of the VT benthic trawl survey in order to provide the critical information for stock assessments and the ARM model. A long-term benthic sampling program for horseshoe crabs has been repeatedly identified as a critical stock assessment need and now an ARM necessity for implementation. This effort provides a statistically reliable estimate of horseshoe crab relative abundance at a relatively low cost. Although Congressional funding seems unlikely for FY 2011 and FY 2012, the PRT recommends seeking funding from multiple avenues, including state and federal governments, as well as industry stakeholders and non-governmental organizations.

Tagging
All entities that currently have tagging programs are encouraged to continue. The PRT recommends using USFWS tags and reporting all data to the repository in the USFWS office in Annapolis.

Biomedical Industry
According to the FMP, the Board must consider potential restrictions on biomedical harvest because estimated mortality exceeded 57,500 horseshoe crabs in 2010.

The PRT reminds states that they are required to obtain the information outlined in Addendum III. This became a requirement in 2004. Please refer to Monitoring Requirement Component A_2. States must report that information in their annual compliance reports.

The PRT recommends that the Technical Committee continues to explore opportunities to engage the biomedical companies through improved reporting and possible tagging programs. However, before tagging programs using bled crabs are recommended, issues about mortality of bled and tagged crabs should be resolved. There are some research efforts underway in South Carolina that may help to address these issues. Those studies are scheduled to be completed by 2012.

Adaptive Resource Management Modeling
The application and continued refinement of the ARM modeling can provide a valuable tool to guide horseshoe crab management in the Delaware Bay area and support red knot recovery. The PRT recommends the Board implement the ARM Framework.

IX. Literature Cited

Leschen, A.S., and S.J. Correia. 2010. Mortality in female horseshoe crabs (*Liumulus polyphemus*) from biomedical bleeding and handling: implications for fisheries management. Marine and Freshwater Behaviour and Physiology, 43(2): 135-147.

Sweka, J. A., D. R. Smith, and M. J. Millard. 2007. An age-structured population model for horseshoe crabs in the Delaware Bay area to assess harvest and egg availability for shorebirds. Estuaries and Coasts 30(2): 277-286.

Thompson, M. 1998. Assessments of the population biology and critical habitat for the horseshoe crab, *Limulus polyphemus*, in the South Atlantic Bight. M.S. Thesis, Medical University of South Carolina, University of Charleston, Charleston, South Carolina. 50 pp. + appendices.

Table 2. Reported commercial horseshoe crab bait landings by jurisdiction.

Jurisdiction	RPL	Addendum IV Quota	State Quota [c]	2001	2002	2003	2004	2005	2006	2007	2008	2009	Prel. 2010
ME	13,500	13,500	-	100	150	98	0	0	0	0	0	0	0
NH	350	350	-	0	120	0	0	0	0	5	0	41	0
MA	440,503	330,377	165,000	134,143	138,613	125,364	69,436	73,740	171,906	150,829	103,963	98,332	54,782
RI	26,053	26,053	13,586	3,490	3,886	5,824	6,030	8,260	15,274	15,564	15,549	18,729	12,502
CT [b]	64,919	48,689	-	12,175	32,080	15,186	23,723	15,311	26,889	25,098	32,565	27,065	29,387
NY	488,362	366,272	150,000	129,074	177,271	134,264	142,279	155,108	172,381	298,222	148,719	123,653	124,553
NJ	604,049	100,000	0	261,239	281,134	113,940	46,569	87,250	3,444	0	0	0	0
PA [d]	-	0	-	0	0	0	0	0	-	-	-	-	-
DE	482,401	100,000	-	244,813	298,318	356,380	127,208	154,269	147,813	76,663	102,113	102,659	61,751
MD	613,225	170,653	-	170,653	278,211	168,865	161,928	169,821	136,733	172,117	163,495	165,434	161,545
PRFC	-	0	-	0	0	0	0	0	0	0	0	0	0
DC	-	0	-	0	0	0	0	0	0	0	0	0	0
VA	203,326	152,495	-	48,880	42,954	106,577	94,713	97,957	155,704	79,570	68,149	187,546	139,022
NC	24,036	24,036	-	9,130	12,988	24,367	9,437	7,713	10,331	9,300	26,191	33,025	9,899
SC	-	0	-	0	0	0	0	0	0	0	0	0	0
GA	29,312	29,312	-	0	0	0	0	0	0	0	0	0	0
FL	9,455	9,455	-	0	200	1,628	0	0	469	186	50	0	993
TOTAL	2,999,491	1,371,192		1,013,697	1,265,925	1,052,493	681,323	769,429	840,944	827,554	660,794	756,484	594,434
Pct. Reduction Relative to RPL				66.2%	57.8%	64.9%	77.3%	74.3%	72.0%	72.4%	78.0%	74.8%	80.2%
Pct. Reduction Relative to Addendum IV Quota										39.6%	51.8%	44.8%	56.6%

*RPL = Reference Period Landings

Table 3. Commercial horseshoe crab bait landings by sex by jurisdiction.

	2003			2004			2005			2006			2007		
	Males	Females	Unknown	Males	Females	Unknown	Males	Females	Unknown	Males	Females	Unknown	Males	Females	Unknown
ME	0	0	98	0	0	0	0	0	0	0	0	0	0	0	0
NH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
MA	60,877	64,487	0	28,469	36,153	3,814	36,549	37,191	0	82,525	80,734	8,647	72,433	68,972	9,424
RI	0	0	5,824	0	0	6,030	0	0	8,260	0	0	15,274	0	0	15,564
CT	0	0	13,386	0	0	23,788	0	0	15,240	0	0	25,280	0	0	24,761
NY	66,417	67,847	0	69,275	73,004	0	83,830	71,278	0	89,992	82,389	0	154,905	129,215	0
PA	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-
NJ	84,518	29,422	0	33,725	12,844	0	58,426	18,665	10,159	2,028	1,416	0	0	0	0
DE	233,878	122,502	0	83,380	43,074	754	104,940	49,329	0	120,952	26,861	0	76,663	0	0
MD	95,792	73,073	0	96,955	64,973	0	108,707	61,114	0	46,833	89,900	0	70,568	101,549	0
PRFC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VA	28,862	56,940	20,775	19,344	41,987	33,382	28,825	44,296	24,836	61,597	70,768	23,339	39,017	39,203	1,350
NC	0	0	24,367	0	0	9,437	0	0	7,462	0	0	10,331	0	0	7,091
SC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FL	0	0	1,628	0	0	0	0	0	0	0	0	469	0	0	186
Total	570,344	414,271	66,078	331,148	272,035	77,205	421,277	281,873	65,957	403,927	352,068	83,340	413,586	338,939	58,381
Grand Total	1,050,693			680,388			769,107			839,335			810,906		

	2008			2009			2010 Preliminary		
	Males	Females	Unknown	Males	Females	Unknown	Males	Females	Unknown
ME	0	0	0	0	0	0	0	0	0
NH	0	0	0	0	0	41	0	0	0
MA	48,046	53,764	2,153	42,343	48,040	7,949	13,086	21,390	20,306
RI	0	0	15,549	9,835	7,064	1,830	6213	4851	1,438
CT	0	0	32,535	0	0	27,065	0	0	29,387
NY	78,581	67,353	2,785	59,652	59,687	2022	59,140	65,393	20
NJ	0	0	0	0	0	0	0	-	0
DE	102,113	0	0	102,659	0	0	61,751	0	0
MD	97,237	66,258	0	114,134	50,698	602	119,207	42,338	0
PRFC	0	0	0	0	0	0	0	0	0
DC	-	-	-	-	-	`	-	-	-
VA	29,756	23,529	14,864	112,654	64,892	0	85,984	53,022	0
NC	0	0	26,191	0	0	33,025	0	0	9,899
SC	0	0	0	0	0	0	0	0	0
GA	0	0	0	0	0	0	0	0	0
FL	0	0	50	0	0	0	0	0	993
Total	355,733	210,904	94,127	441,277	230,381	72,534	345,381	186,994	62,043
Grand Total	660,764			744,192			594,418		

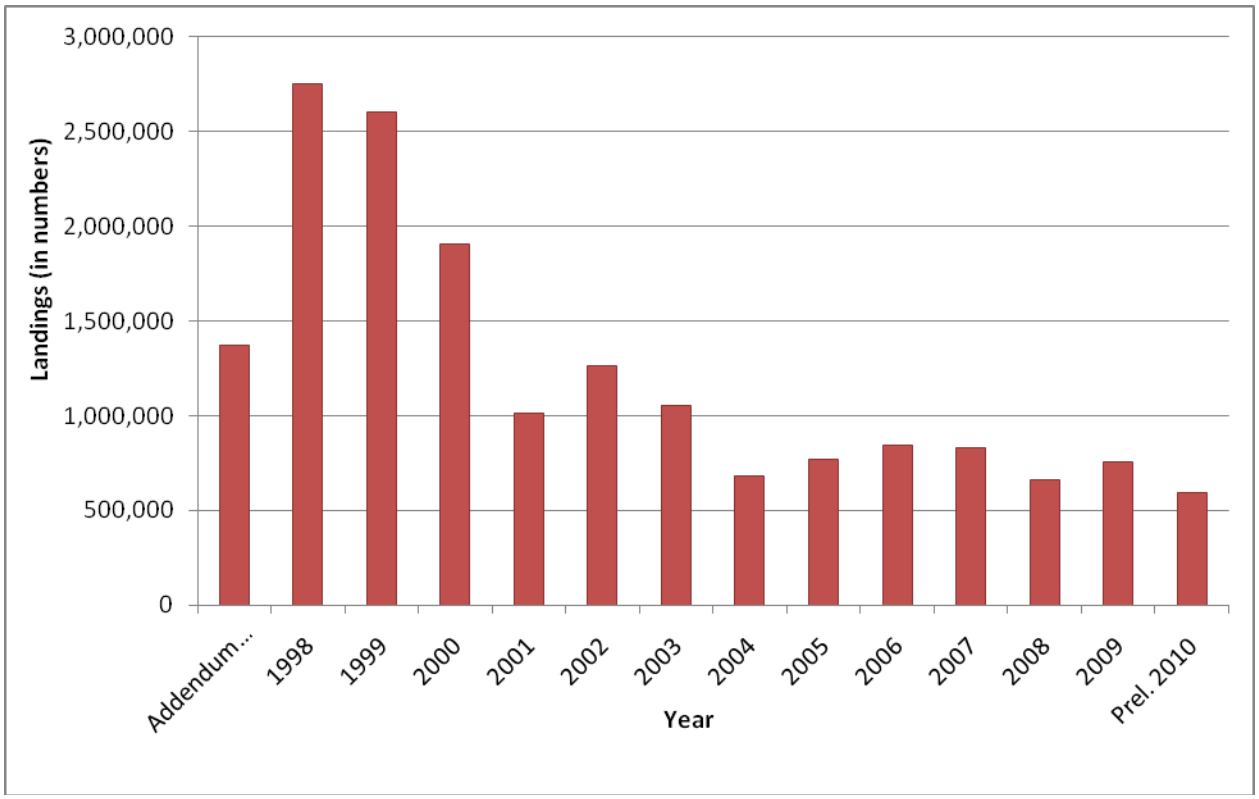

Figure 1. Coastwide horseshoe crab landings for bait expressed as number of crabs.