



Atlantic States Marine Fisheries Commission

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MEMORANDUM

TO: Horseshoe Crab Management Board

FROM: Delaware Bay Ecosystem Technical Committee and Adaptive Resource Management Subcommittee

DATE: October 2, 2023

SUBJECT: Delaware Bay Horseshoe Crab Harvest Recommendation for 2024

This memo describes the 2024 harvest recommendation for Delaware Bay region horseshoe crabs using the methods from the Adaptive Resource Management, or ARM Framework (ASMFC 2022a). Since 2013, horseshoe crabs in the Delaware Bay Region (New Jersey, Delaware, Maryland, and Virginia) have been managed under the ARM Framework to set harvest levels with consideration of the needs of migratory shorebirds. The ARM was developed jointly by the Commission, U.S. Fish and Wildlife Service, and U.S. Geological Survey in recognition of the importance of horseshoe crab eggs to migratory shorebirds stopping over in the Delaware Bay region. In particular, horseshoe crab eggs are an important food source for the *rufa* red knot, which is listed as threatened under the Endangered Species Act.

Under Addendum VIII (ASMFC 2022b), the 2022 ARM Revision is 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. The maximum number of male and female horseshoe crabs the ARM Revision can recommend is 500,000 males and 210,000 females. The ARM Revision was used for the first time to set harvest for the 2023 fishing year and the recommended harvest levels were 475,000 male and 125,000 female horseshoe crabs. Acknowledging public concern about the status of the red knot population in the Delaware Bay, the Board elected to implement harvest limits of zero female and 475,000 male horseshoe crabs for the 2023 season. To make up for the lost harvest of female crabs, the Board agreed to increase Maryland and Virginia's male harvest quotas with an offset ratio of 2:1 males to females.

1. 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.

2. Population estimates

Red knot abundance estimates used to make harvest recommendations under the ARM Revision are based on mark-resight total stopover population estimates (Figure 1; Lyons 2023). The 2022 red knot population estimate was 39,800.

In the ARM Revision, all quantifiable sources of mortality (i.e., bait harvest, coastwide biomedical mortality, and commercial dead discards; Figure 2 - Figure 3) were used in the catch multiple survey analysis (CMSA) to estimate male and female horseshoe crab population estimates. Population estimates for horseshoe crabs were made using the coastwide biomedical data or no biomedical data which provide upper and lower bounds for the public. The harvest recommendation is based on the results using confidential biomedical data from the region. The Virginia Tech Trawl Survey estimates are used in the CMSA along with the New Jersey Ocean Trawl and the Delaware Fish and Wildlife Adult Trawl Surveys (ASMFC 2022a; Wong et al. 2023; Figure 4 -Figure 5).

In 2021, the number of newly mature female horseshoe crabs estimated in the Virginia Tech Trawl survey was zero (Table 1). This data point is lagged forward to represent 2022, the terminal year of the current model, and poses an issue for the CMSA. The CMSA is a simple, stage-based model that essentially sums the newly mature and mature crabs, subtracts harvest and accounts for natural mortality, and predicts the next year's population. The model will not run with an estimate of zero newly mature horseshoe crabs and has struggled to reconcile the high mature female horseshoe crab population estimates in the Virginia Tech Trawl Survey with the low newly mature population estimates for the last few years. The ARM Subcommittee and Delaware Bay Ecosystem Technical Committee (DBETC) previously discussed three hypotheses for the low newly mature horseshoe crabs in the Virginia Tech Trawl Survey: 1) a catchability issue where newly mature crabs are not in the same location as mature crabs, 2) a multi-year recruitment failure beginning in 2010 that began to show up 9 years later (the length of time to maturity) in 2019, the first year of low newly mature crabs, or 3) an identification issue where the onboard technicians since 2019 have been misclassifying newly mature horseshoe crabs as mature or immature.

To gap-fill the newly mature female horseshoe crab time series so there are no zeros, the ARM Subcommittee and DBETC decided to use an average ratio of newly mature to mature females from previous years. For 2002-2018, newly mature female horseshoe crabs comprised 19.9% of the total mature crabs (newly mature plus mature) in the Virginia Tech Trawl data. Additionally, the Delaware Adult Trawl Survey is used in the CMSA as an index of abundance and has been collecting staged data since 2017 (Figure 6). While the Delaware Adult Trawl has fewer years of stage data, the two stages have tracked each other also with an average of 19.9% of the female horseshoe crabs being newly mature for 2017-2022 (Figure 7). Using the average of 19.9%, the years of 2019-2022 in the Virginia Tech Trawl were adjusted where the observed newly mature and mature female horseshoe crabs were added together and then 19.9% were attributed to the newly mature stage. This method did not increase the number of total female horseshoe crabs in the model, but rather re-proportioned them between the two stages of newly mature and mature. This approach is supported by the biology of horseshoe crabs since it is hard to reconcile the high number of mature female and low newly mature female horseshoe crabs in recent years given the single year time step. This approach also resulted in CMSA estimates of total females that were closer to swept area estimates from the Virginia Tech trawl survey. If

the trend of low newly mature female horseshoe crabs continues in the future, the ARM and DBETC will re-evaluate gap-filling methods as needed.

No adjustments had to be made for the male horseshoe crab model.

Using the CMSA model, there were approximately 40.3 million mature male and 16.1-16.2 million mature female horseshoe crabs in the Delaware Bay region in 2022, depending on the use of coastwide or no biomedical data (Figure 8 - Figure 9). The Virginia Tech Trawl population estimates were 44.9 million male and 15.5 million female mature horseshoe crabs for comparison (Table 1).

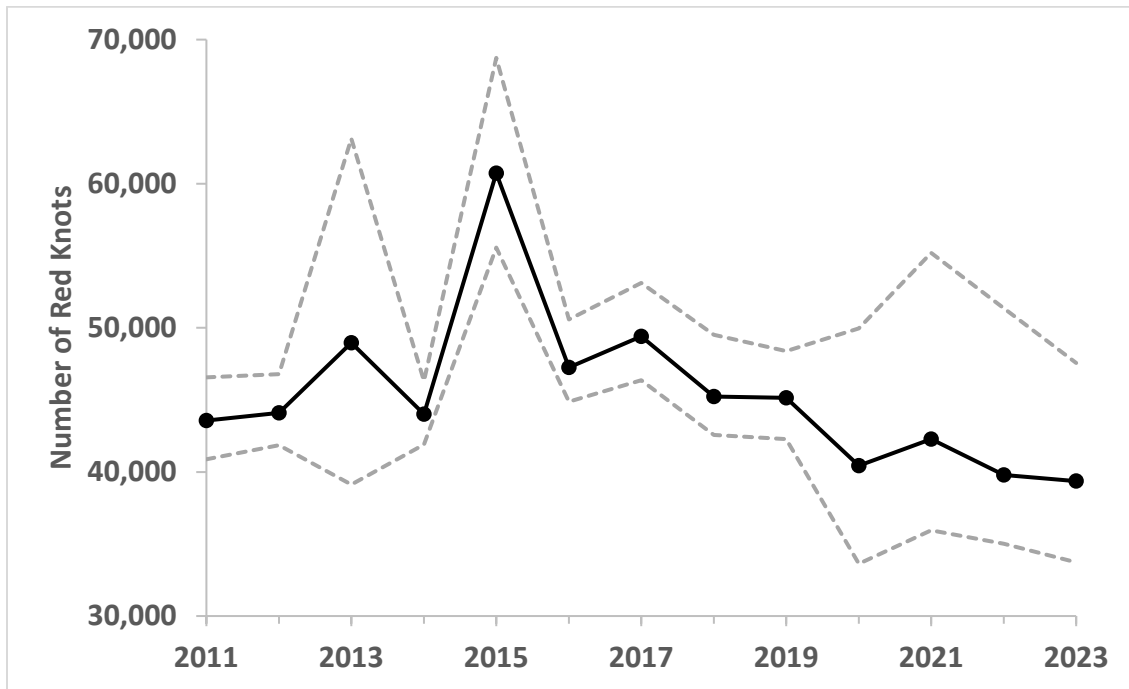


Figure 1. Mark-resight abundance estimates for the red knot stopover population with 95% confidence intervals, 2011-2023.

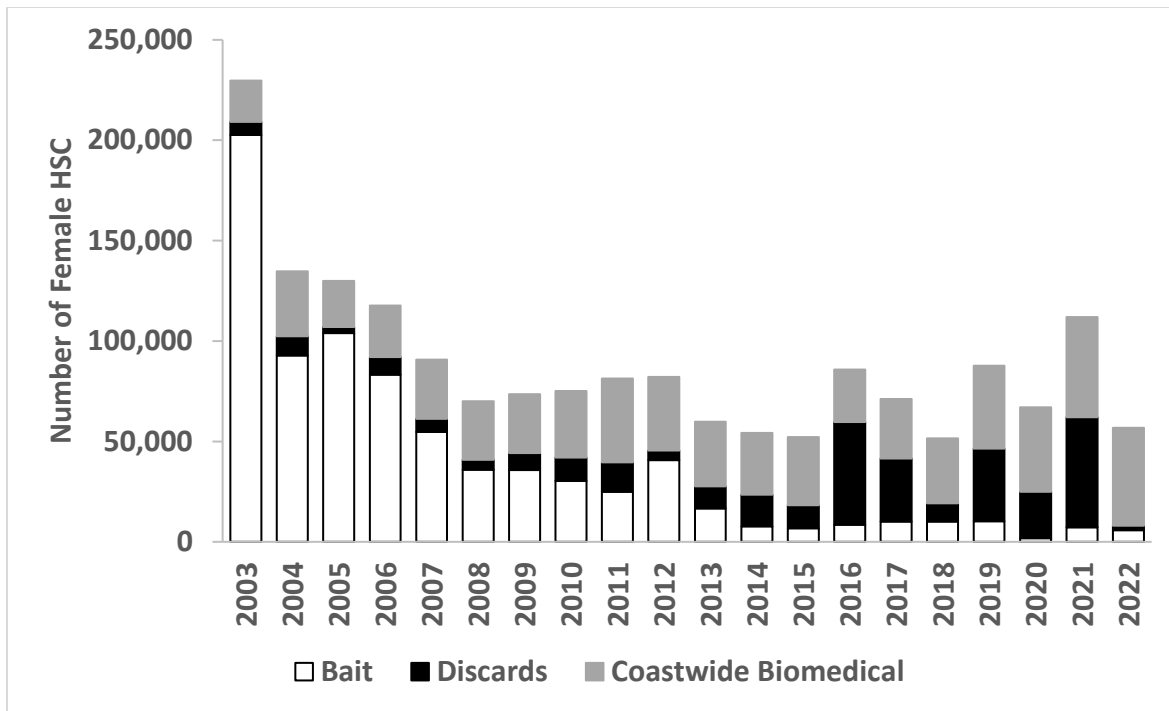


Figure 2. Total female horseshoe crab harvest by source in the Delaware Bay, 2003-2022.

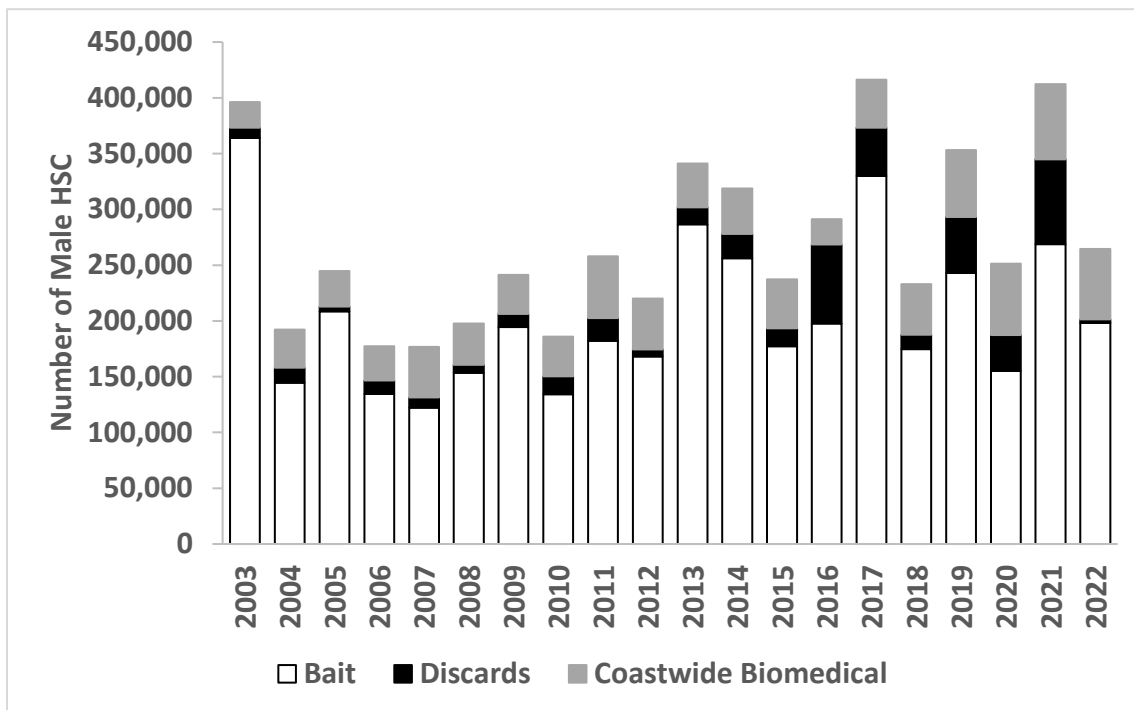


Figure 3. Total male horseshoe crab harvest by source in the Delaware Bay, 2003-2022.

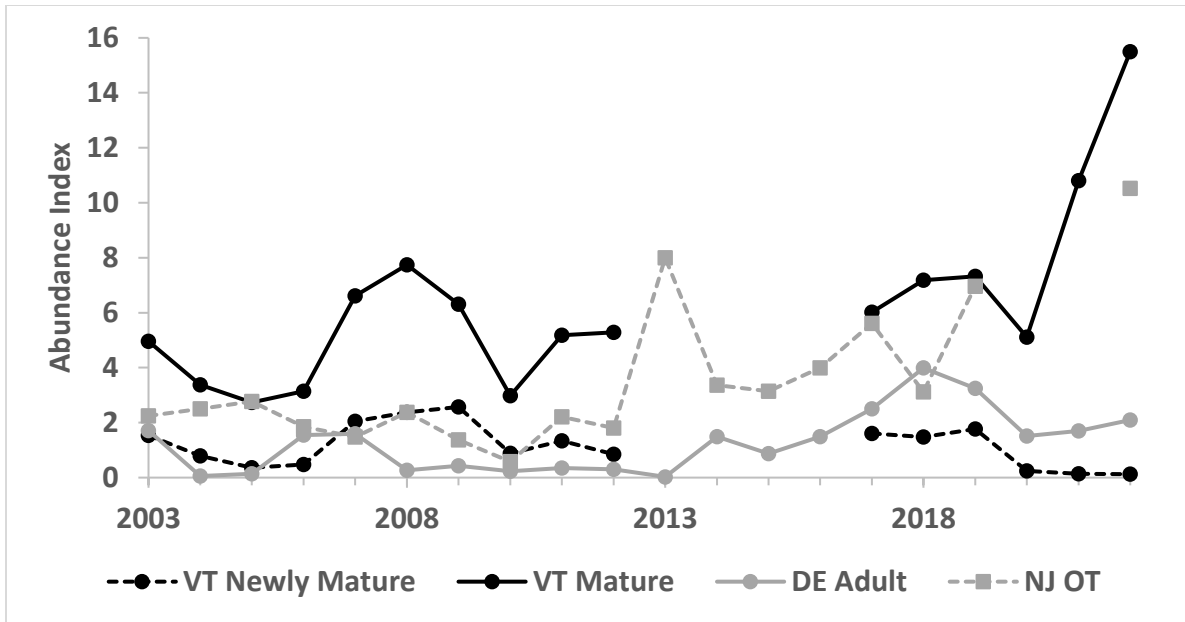


Figure 4. Female horseshoe crab abundance indices used in the CMSA. The Virginia Tech (VT) indices are in millions of newly mature and mature crabs while the Delaware Adult (DE Adult) and New Jersey Ocean Trawl (NJ OT) are in catch-per-tow.

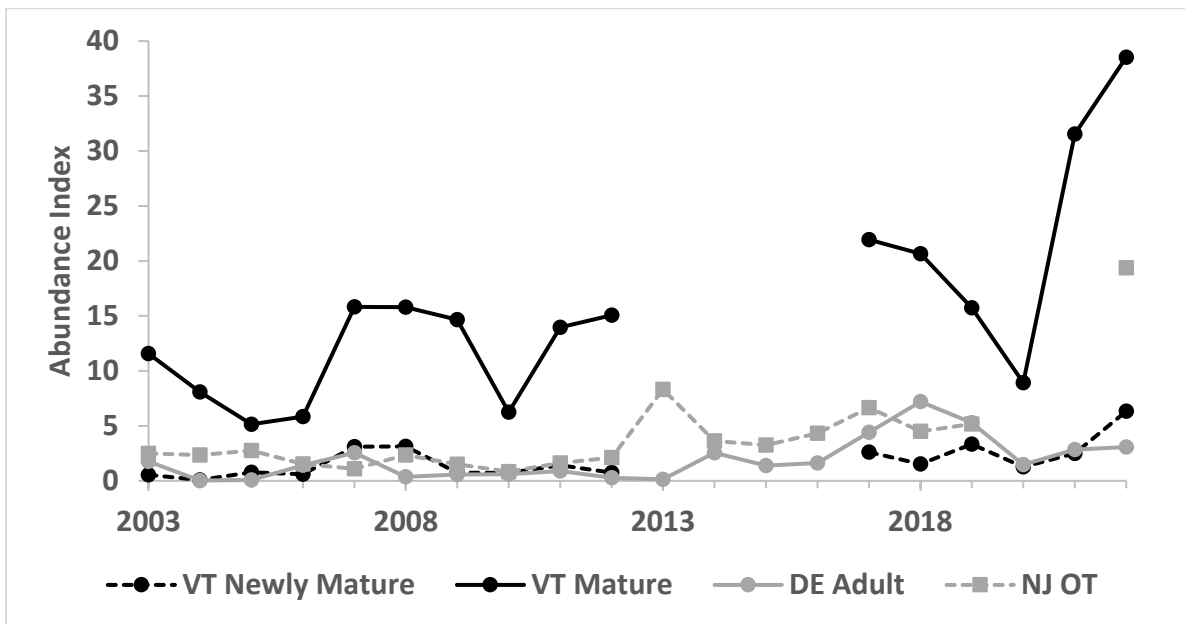


Figure 5. Male horseshoe crab abundance indices used in the CMSA. The Virginia Tech (VT) indices are in millions of newly mature and mature crabs while the Delaware Adult (DE Adult) and New Jersey Ocean Trawl (NJ OT) are in catch-per-tow.

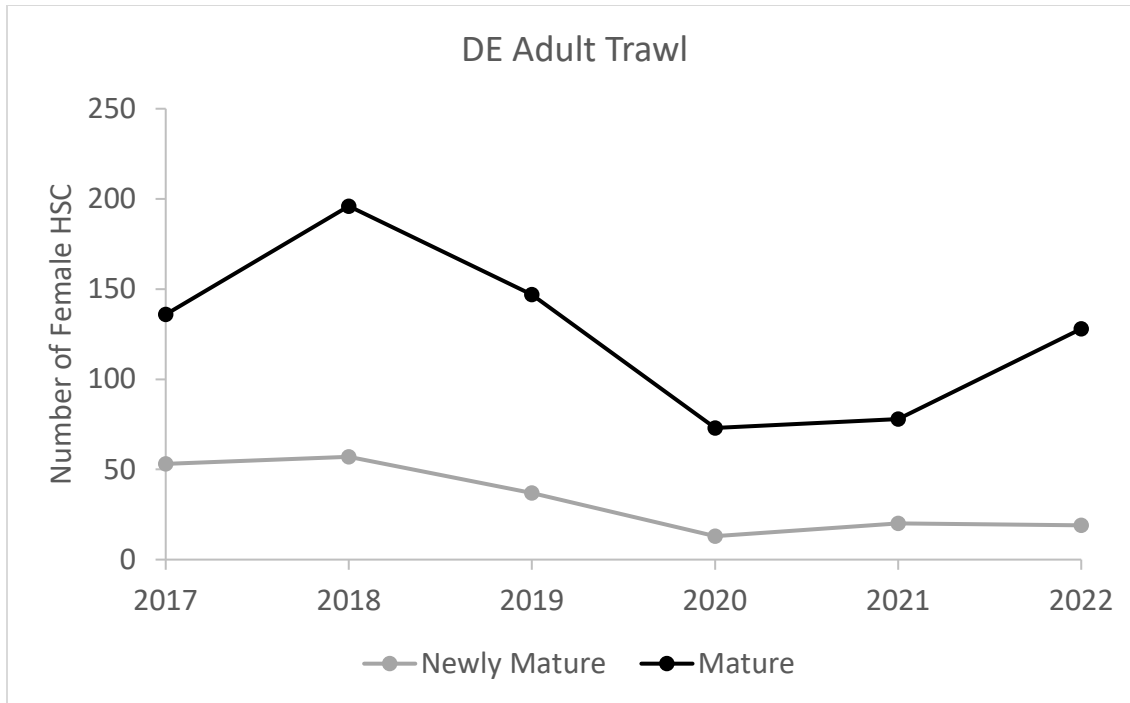


Figure 6. Mature and newly mature female horseshoe crabs caught in the Delaware Adult (30 foot) Trawl, 2017-2022.

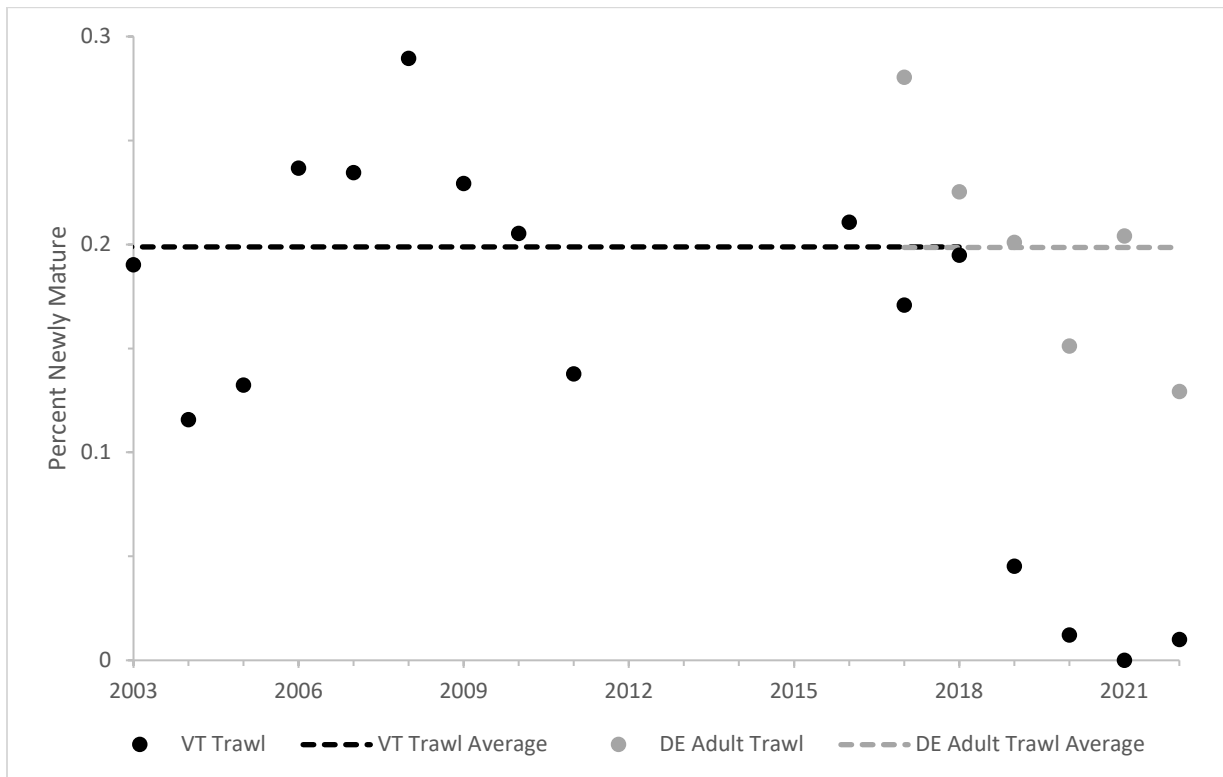


Figure 7. Percent of newly mature female horseshoe crabs in the Virginia Tech and Delaware Adult Trawls. The low years of newly mature female horseshoe crabs (2019-2022) were not included in the average for the Virginia Tech Trawl.

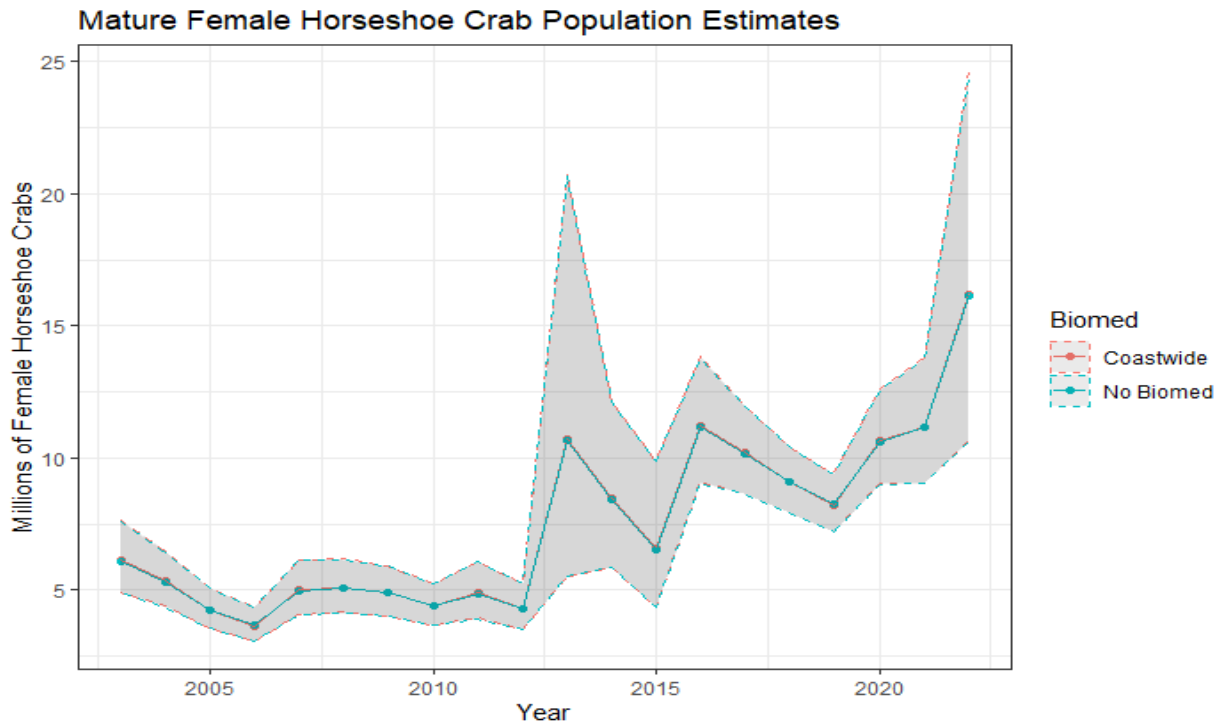


Figure 8. Population estimates from the CMSA for mature female horseshoe crabs with 95% confidence intervals. Delaware Bay biomedical data is confidential so population estimates using coastwide and zero biomedical data provide upper and lower bounds, although there is very little difference between the two and the time series overlap on the figures.

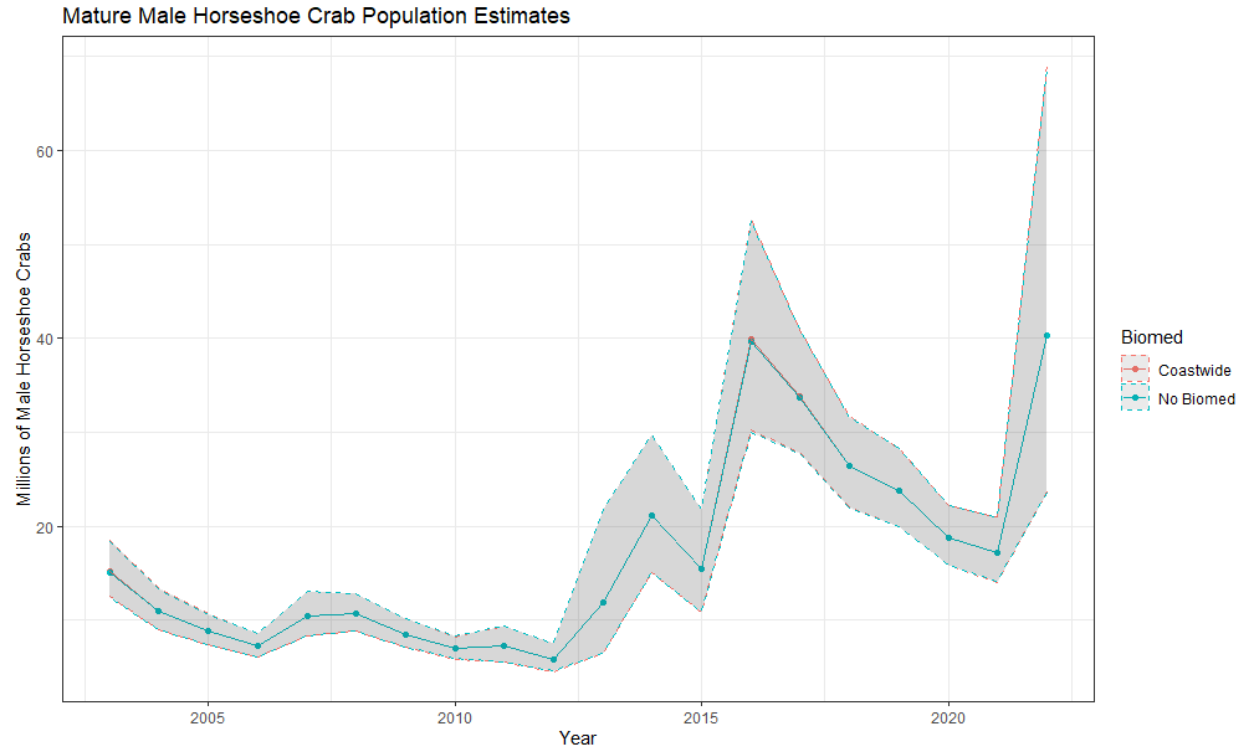


Figure 9. Population estimates from the CMSA for male horseshoe crabs with 95% confidence intervals. Delaware Bay biomedical data is confidential so population estimates using coastwide and zero biomedical data provide upper and lower bounds, although there is very little difference between the two and the time series overlap on the figures.

Table 1. Total mature (newly mature plus mature) horseshoe crab population estimates in millions by sex and estimation method (catch multiple survey model or Virginia Tech Trawl Survey), 2003-2022.

	Females (in millions)			Males (in millions)		
Biomedical Data:	Zero	Coastwide	N/A	Zero	Coastwide	N/A
Estimation Method:	CMSA		VT Trawl	CMSA		VT Trawl
2003	6.1	6.1	6.5	15.1	15.2	12.1
2004	5.3	5.3	4.2	11	11	8.1
2005	4.2	4.2	3.1	8.9	8.9	5.9
2006	3.7	3.7	3.6	7.3	7.3	6.4
2007	5	5	8.7	10.4	10.5	18.9
2008	5.1	5.1	10.1	10.7	10.7	18.9
2009	4.9	4.9	8.9	8.5	8.5	15.4
2010	4.4	4.4	3.9	7	7	7
2011	4.9	4.9	6.5	7.2	7.3	15.4
2012	4.3	4.3	6.1	5.9	5.9	15.8
2013	10.7	10.7		11.9	11.9	
2014	8.4	8.5		21.1	21.2	
2015	6.5	6.6		15.4	15.4	
2016	11.2	11.2		39.7	39.9	
2017	10.2	10.2	7.6	33.7	33.8	24.5
2018	9.1	9.1	8.7	26.4	26.4	22.2
2019	8.2	8.2	9.1	23.7	23.8	19.1
2020	10.6	10.7	5.4	18.8	18.8	10.2
2021	11.2	11.2	10.9	17.2	17.2	34
2022	16.1	16.2	15.5	40.3	40.3	44.9

3. Harvest Recommendation

Harvest recommendations for the 2024 fishing year made using the ARM Revision are based on CMSA estimates of horseshoe crab abundance and the red knot mark-resight abundance estimates. ARM harvest recommendations are based on a continuous scale rather than the discrete harvest packages in the previous ARM Framework. Therefore, a 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 is determined separately. The maximum possible harvests for both females and males are maintained from the previous ARM Framework at 210,000 and 500,000, respectively.

The annual recommendation of allowable Delaware Bay horseshoe crab harvest is based on current state of the system (abundances of both species in the previous calendar year) and the optimal harvest policy functions from the ARM Revision. Annual estimates of horseshoe crab and red knot abundances are used as input to the harvest policy functions, which then output the optimal horseshoe crab harvest to be implemented. As per Addendum VIII, the optimal recommended harvest is rounded down to the nearest 25,000 crabs to uphold data confidentiality.

The harvest recommendation based on the ARM Framework for 2024 is 175,000 female and 500,000 male horseshoe crabs.

4. Quota Allocation

Allocation of allowable harvest was conducted in accordance with the methodology in Addendum VIII (Table 2).

Table 2. Delaware Bay-origin and total horseshoe crab quota for 2024 by state. Virginia total quota only refers to the amount that can be harvested east of the COLREGS line.

State	Delaware Bay-Origin Quota		Total Quota	
	Male	Female	Male	Female
Delaware	173,014	60,555	173,014	60,555
New Jersey	173,014	60,555	173,014	60,555
Maryland	132,865	46,503	126,410	44,243
Virginia	21,107	7,387	40,667	20,331
TOTAL	500,000	175,000	513,106	185,684

5. References

ASMFC. 2022a. Revision to the Framework for Adaptive Management of Horseshoe Crab Harvest in the Delaware Bay Inclusive of Red Knot Conservation and Peer Review Report. Arlington, VA. 302 pp.

ASMFC. 2022b. Addendum VIII to the Fishery Management Plan for Horseshoe Crab. Washington D.C. 12pp.

Lyons, J.E. 2023. Red Knot Stopover Population Estimate for 2023. Memorandum to the Delaware Bay ARM Working Group. U.S. Geological Survey Patuxent Wildlife Research Center, Laurel, Maryland. 13 pp.

Wong, C. Y. Jiao, and E. Hallerman. 2023. Results of the 2022 Horseshoe Crab Trawl Survey: Report to the Atlantic States Marine Fisheries Commission Horseshoe Crab and Delaware Bay Ecology Technical Committees. 28 pp.