

Delaware Bay Horseshoe Crab Management Stakeholder Survey Report



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Sustainable and Cooperative Management of Atlantic Coastal Fisheries

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EXECUTIVE SUMMARY

The Atlantic States Marine Fisheries Commission (Commission) has maintained primary management authority for horseshoe crabs in state and federal waters since it adopted the Interstate Fishery Management Plan for Horseshoe Crabs (FMP) in 1998. The Delaware Bay population of horseshoe crabs has been managed under the Adaptive Resource Management (ARM) Framework since 2012. The ARM Framework considers the abundance levels of horseshoe crabs and shorebirds in determining the optimal harvest level for the Delaware Bay states of New Jersey, Delaware, Maryland, and Virginia (east of the COLREGS). Since 2013 the Horseshoe Crab Management Board (Board) has set bait harvest limits for the Delaware Bay region based on the ARM Framework recommendations.

In 2023 the Board undertook an effort to better understand stakeholder values regarding horseshoe crab management in the Delaware Bay region. This initiative was in response to widespread public concern about the adoption of the 2021 ARM Revision, which updated the ARM model to include additional data on shorebirds and horseshoe crabs and advancements in modeling software and techniques. In large part this public concern was focused on the potential for female horseshoe crab harvest under the Revised ARM and its impact on the rufa red knot, which is listed as threatened under the Endangered Species Act, and depends on horseshoe crab eggs as a major food source in the Delaware Bay during its migration.

A survey was developed by a work group of Board members from the Delaware Bay states and distributed to Delaware Bay stakeholders, including bait harvesters and dealers, fishermen who use horseshoe crab as bait, biomedical fishery and industry participants, environmental conservation groups, and researchers. The survey results reflect diverging values across stakeholder groups. Commercial industry participants indicated they still value the harvest of female horseshoe crabs, though it has not been permitted in the region since 2012. Researchers and environmental groups tended to value the protection of female horseshoe crabs and the ecological role of horseshoe crabs as a food source for shorebirds over the fishery.

The survey results will be considered by the Board to provide guidance on whether to consider future changes to horseshoe management for the Delaware Bay region.

Table of Contents

1. INTRODUCTION.....	3
2. METHODS.....	4
Survey Development.....	4
Survey Dissemination.....	4
3. RESULTS.....	5
Response Rate.....	5
3.1 Questions 1-2. State of Residence and Occupation	5
3.2 Questions for Harvesters and Dealers	5
Question 3. What are the horseshoe crabs that you harvest or sell used for?.....	5
Question 4. Have you ever harvested or sold female horseshoe crabs for bait in the past?	6
Question 5. How important is it to you to be able to harvest/sell female horseshoe crabs for bait in the future?	6
Question 6. Value and demand for female horseshoe crabs	6
Question 7. Preferences for female versus male harvest	7
3.3 Perspectives on the Delaware Bay system	7
Question 8. Delaware Bay Perceptions	7
Question 9. Impacts on Horseshoe Crab Population.....	8
Question 10. Impacts on Red Knot Stopover Population	9
Question 11. Importance of Management Objectives	10
Question 12. Ranking management goals	12
3.4 Perspectives on the Adaptive Resource Management (ARM) Model and Female Harvest.....	13
Questions 13-14. Should the ARM model be modified?	13
Questions 15-16. Should a limited amount of female harvest be allowed?	14
Question 17. Use of female horseshoe crabs by the biomedical industry.....	15
3.5 Question 18. What do you think is most important for managers to consider when making decisions about the management of the Delaware Bay horseshoe crab population?	16
4. DISCUSSION.....	16
Appendix A. Survey Questionnaire	18
Appendix B. Open-Ended Survey Responses	30
Appendix C. Additional Figures.....	34

1. INTRODUCTION

The Delaware Bay population of horseshoe crabs has been managed under the Adaptive Resource Management (ARM) Framework since 2012 in recognition of public concern regarding the horseshoe crab population and its ecological role of horseshoe crabs in the Delaware Bay. The Framework considers the abundance levels of horseshoe crabs and shorebirds in determining the optimal harvest level for the Delaware Bay states of New Jersey, Delaware, Maryland, and Virginia (east of the COLREGS). Since 2013, the Board has annually reviewed recommended harvest levels from the ARM model, and specified harvest levels for the following year in New Jersey, Delaware, Maryland, and Virginia.

In 2021, a revision to the ARM Framework was completed. The revision updated the ARM model with an additional decade of data on shorebirds and horseshoe crabs in the Delaware Bay region, and advancements in modeling software and techniques. Changes to the ARM Framework are described in detail in the [2021 Revision to the Adaptive Resource Management Framework and Peer Review Report](#), and include:

- Catch multiple survey analysis (CMSA) to estimate male and female horseshoe crab population estimates using all quantifiable sources of mortality (i.e., natural mortality, bait harvest, coastwide biomedical mortality, and commercial dead discards) and several abundance indices from the Delaware Bay Region
- Integrated population model (IPM) to quantify the effects of horseshoe crab abundance on red knot survival and recruitment based on data collected in the Delaware Bay
- Transition to new modeling approach which can be implemented through readily available R software and incorporates uncertainty on all life history parameters for both horseshoe crabs and red knots
- Harvest recommendations based on a continuous scale rather than discrete harvest packages as in the previous Framework
- Female harvest decoupled from the harvest of males

Following the recommendations of the ARM Revision independent peer review panel that endorsed the ARM Revision as the best and most current scientific information for the management of Delaware Bay horseshoe crabs, the Horseshoe Crab Management Board (Board) reviewed and accepted the ARM Framework Revision in January 2022. The Board adopted use of the ARM Revision for management under Addendum VIII, approved in November 2022. During the public comment period on Addendum VIII, there was significant public concern about the status of the red knot population in the Delaware Bay. Over 30,000 comments were submitted by the public opposing the adoption of the ARM Revision, in large part due to the fact that the revised model allowed for a limited amount of female horseshoe crab harvest by the bait fishery. In response to the widespread public concern, the Board elected to implement a zero female horseshoe crab harvest for the 2023 season, despite the 2022 ARM model run recommending a female harvest limit of 125,000 horseshoe crabs for the 2023 season.

The Board expressed interest in evaluating the current goals and objectives for the Delaware Bay horseshoe crab fishery and ecosystem, given the apparent differences in stakeholder opinions on female harvest. After reviewing information on available resources and possible approaches, in May of 2023 the Board agreed to form a work group to develop a survey that would be distributed to stakeholders including bait harvesters and dealers, biomedical fishery and industry participants, and environmental groups. The goal of the survey is to provide insight into stakeholder perspectives to help inform the Board on whether to consider future changes to horseshoe management for the Delaware Bay region.

2. METHODS

Survey Development

The Delaware Bay Management Objectives Work Group (DBMO WG) met via webinar four times between June and September 2023 to develop the survey questionnaire. The WG members identified the following overarching research questions:

- Is there demand for harvest of female horseshoe crabs?
- Under what conditions would stakeholders be comfortable allowing female harvest?
- What management goals for the Delaware Bay region are important to stakeholders?
- Should the Board consider changes to the management program for setting Delaware Bay bait harvest specifications?

A survey questionnaire was developed to provide insight into these research questions. The questionnaire was reviewed by an external social science researcher to identify potential sources of bias and recommend changes. The final survey was created using online SurveyMonkey software. Survey logic was incorporated into the survey design to present certain questions to a respondent based on a previous response. Specifically, one set of questions was only administered to those who indicated their field of work was commercial fisheries. A copy of the final survey questionnaire is provided in Appendix A.

Survey Dissemination

This survey effort was aimed at better understanding stakeholder values regarding the Delaware Bay horseshoe crab fishery and population; therefore, the survey participants were limited to stakeholders from the Delaware Bay region. The DBMO WG aimed to survey individuals from various stakeholder groups with an interest in horseshoe crab management, including environmental conservation groups, commercial fishermen and dealers, biomedical industry, academics and researchers, and coastal community members.

The WG members identified specific individuals from New Jersey, Delaware, Maryland, and Virginia to participate in the survey representing the various stakeholder groups. Contacts were also collected from organizations that submitted public comments to the Management Board on Addendum VIII. A total of 107 individuals with available contact information were identified to receive the survey. Table 1 details the number of contacts provided by each state, and by stakeholder group.

Table 1. Survey contacts provided by states and stakeholder groups.

Group	Harvesters	Dealers	Other Fishermen	Environmental NGO	Biomedical	Towns	Other
#	26	4	39	25	4	3	6
State	NJ	DE	MD	VA			
#	53	15	18	17			

Using SurveyMonkey, the survey was disseminated via email to the recipients on August 22, 2023 and two reminder emails were sent to those that had not completed the survey (September 11 and 18, 2023). Each survey recipient was informed their responses would be anonymous.

3. RESULTS

Response Rate

Of the 106 individuals who received the survey invitation, 83 opened the survey (78.3%), 17 did not open the survey (16.0%), and 4 email invitations bounced (3.8%). A total of 40 responses to the survey were received, resulting in a 38% response rate.

The following sections provide the results of the survey, grouped by sets of related questions. Open-ended responses are provided in Appendix B, and additional figures are provided in Appendix C.

3.1 Questions 1-2. State of Residence and Occupation

The first two questions of the survey asked the respondents to indicate which state they lived in, and their primary field of work. The majority of respondents identified New Jersey as their state of residence (22 of 40, 55%), followed by Delaware (7, 18%), Virginia (6, 15%), and Maryland (3, 8%). One respondent each answered New York and Pennsylvania.

Of 11 possible multiple-choice options, the 40 respondents represented five occupational groups. The groups in descending order by number of respondents are: Commercial fisheries (harvesters and dealers) (21, 53%), Environmental conservation (8, 20%), Biomedical industry (4, 10%), Academia or research (4, 10%), and Unemployed or retired (3, 8%).

3.2 Questions for Harvesters and Dealers

Questions 3-7 in the survey was only administered to respondents who answered that their primary field of work is “Commercial fisheries (harvesters and dealers).” These questions were targeted at the fishing industry to better understand the makeup of the fishery and value of horseshoe crabs by sex. A total of 19 individuals responded to these questions.

Question 3. What are the horseshoe crabs that you harvest or sell used for?

The possible responses to this question were: bait, biomedical, both bait and biomedical, I do not know, and I do not harvest horseshoe crabs. Ten respondents harvest or sell horseshoe crabs for bait, five for both bait and biomedical, three do not harvest horseshoe crabs, and one does not

know what the horseshoe crabs are used for. No respondents indicated that they only harvest or sell horseshoe crabs for biomedical purposes.

Question 4. Have you ever harvested or sold female horseshoe crabs for bait in the past?

The majority of respondents to this question indicated that they have harvested or sold female horseshoe crabs in the past (74%). Five responded that they have not (26%).

Question 5. How important is it to you to be able to harvest/sell female horseshoe crabs for bait in the future?

The possible responses to this question included: Not Important at All, Of Little Importance, Of Average Importance, Very Important, and Absolutely Essential. Respectively, these responses were selected by 1, 1, 6, 7, and 4 individuals. The most common responses were “Very Important” (37%), “Of Average Importance (32%), and “Absolutely Essential” (21%) (Figure 1). By applying a numeric value to each of the above responses from one to five (1=Not Important at All, 5=Absolutely Essential) the average response across the 19 respondents is equal to 3.63. This indicates that on average, more commercial fishermen and dealers do think it is important to harvest/sell female horseshoe in the future than do not.

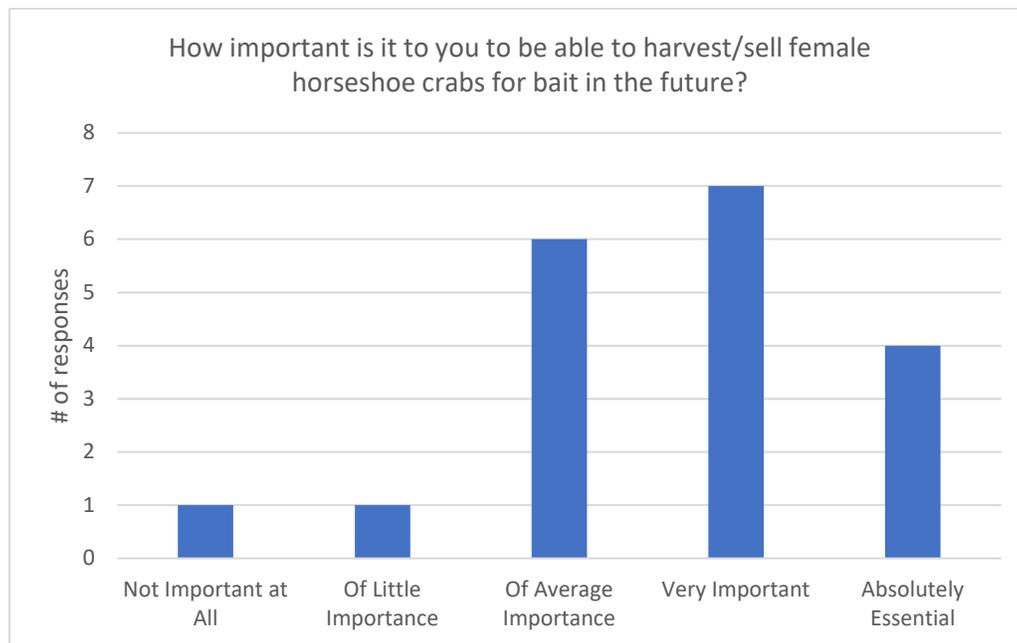


Figure 1. Importance of future female harvest.

Question 6. Value and demand for female horseshoe crabs

Question 6 asked respondents to express their level of agreement to two separate statements: “Female horseshoe crabs are worth more money than male horseshoe crabs” and “There is no market demand for female horseshoe crabs.” Responses were given on a scale of 1 to 5, where 1 is “strongly agree” and 5 is “strongly disagree.” The responses to each statement were significantly skewed, with the large majority in agreement that female horseshoe crabs are worth more money than males, and in disagreement that there is no market demand for female

horseshoe crabs (Figure 2). A single respondent disagreed with the first statement, and one respondent agreed with the second statement.

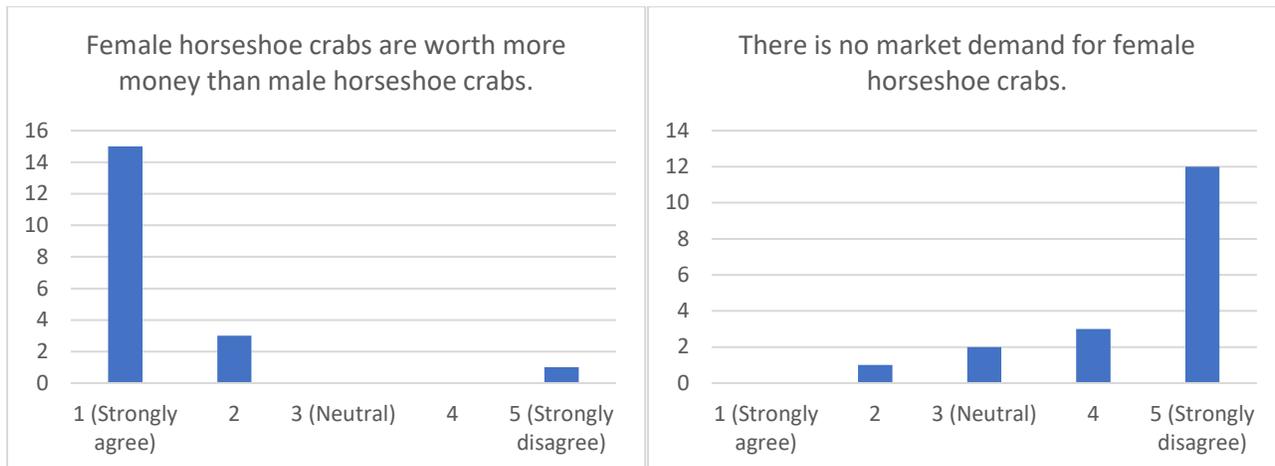


Figure 2. Perceived value (left) and demand for (right) of female horseshoe crabs.

Question 7. Preferences for female versus male harvest

Question 7 aimed to further understand the value of female harvest. Respondents were asked “Of the following two options, which do you prefer?” and only two possible choices were provided: 1) A larger overall quota of all male horseshoe crabs, or 2) A smaller overall quota including some female horseshoe crabs. The responses to this question were evenly split, with nine responses for each choice.

When the responses were broken down by state, two notable results are that all of the respondents from Virginia (n=4) prefer a smaller quota including some females, and the majority (70%) of respondents from New Jersey (n=10)—which currently has a moratorium on bait harvest—prefer a larger overall quota of all males. Table 2 provides responses by state.

Table 2. Question 7 responses by state.

State	A larger overall quota of all male horseshoe crabs	A smaller overall quota including some female horseshoe crabs
Delaware	2	1
Maryland		1
New Jersey	7	3
Virginia		4
Total	9	9

3.3 Perspectives on the Delaware Bay system

Question 8. Delaware Bay Perceptions

Question 8 was designed to elicit information on how stakeholders perceive different components of the Delaware Bay ecosystem, including the horseshoe crab population, bait

fishery, and interactions with red knots. Participants were asked to respond to six statements with their level of agreement on a scale of 1 to 5, where 1 is "strongly agree" and 5 is "strongly disagree." The six statements are listed below:

- A. The Delaware Bay population of horseshoe crabs is healthy.
- B. The horseshoe crab bait fishery is negatively impacting the Delaware Bay population of horseshoe crabs.
- C. The number of horseshoe crabs in the Delaware Bay population is increasing.
- D. The horseshoe crab bait fishery is negatively impacting red knots in the Delaware Bay.
- E. Fishermen should be allowed to harvest female horseshoe crabs from the Delaware Bay population if it is at a healthy level.
- F. Fishermen should not be allowed to harvest male horseshoe crabs from the Delaware Bay population if it is at a healthy level.

There were 36 responses to this question. The responses to each statement tended to show bipolar trends, where the largest number of responses were divided between the two extremes, and fewer responses fell in the middle of the range. This seems to be primarily explained by diverging perspectives among different stakeholder groups (Table 3).

Table 3. Average responses to Question 8 by occupational group. Cells are color coded such that averages falling on the side of agreement are shaded in green, and averages falling on the side of disagreement are shaded in red, and averages in the neutral range are white.

Statement	Commercial fisheries (harvesters and dealers) (n=18)	Environmental conservation (n=7)	Unemployed or retired (n=3)	Biomedical industry (n=4)	Academia or research (n=4)
A	1.22	4.43	3.00	1.00	4.00
B	4.61	1.57	1.00	5.00	2.00
C	1.65	3.40	3.00	2.00	3.00
D	4.29	2.83	1.00	4.33	2.25
E	1.44	5.00	3.33	3.00	3.25
F	4.88	2.83	2.33	3.67	4.00

Question 9. Impacts on Horseshoe Crab Population

This question asked respondents to rank three issues by the level of impact they are thought to have on the Delaware Bay population of horseshoe crabs: climate change, horseshoe crab harvest, and human development of the shoreline.

There was a total of 35 responses to this question. The responses varied across occupational groups. When all responses from each occupational group were averaged, the ranking order of the three issues varied from group to group (Table 4, Figure 3). Higher average values equate to a higher level of perceived impact on the horseshoe crab population.

Table 4. Average rank value of horseshoe crab threats by occupational group. Higher value = higher impact.

Occupational Group	Average of Climate change	Average of Horseshoe crab harvest	Average of Human development of the shoreline
Academia or research (n=3)	2.00	2.25	1.75
Biomedical industry (n=4)	1.75	1.25	3.00
Commercial fisheries (harvesters and dealers) (n=18)	1.89	1.33	2.78
Environmental conservation (n=7)	1.50	2.50	2.00
Unemployed or retired (n=3)	1.67	2.00	2.33
Average of all responses (n=35)	1.80	1.69	2.51

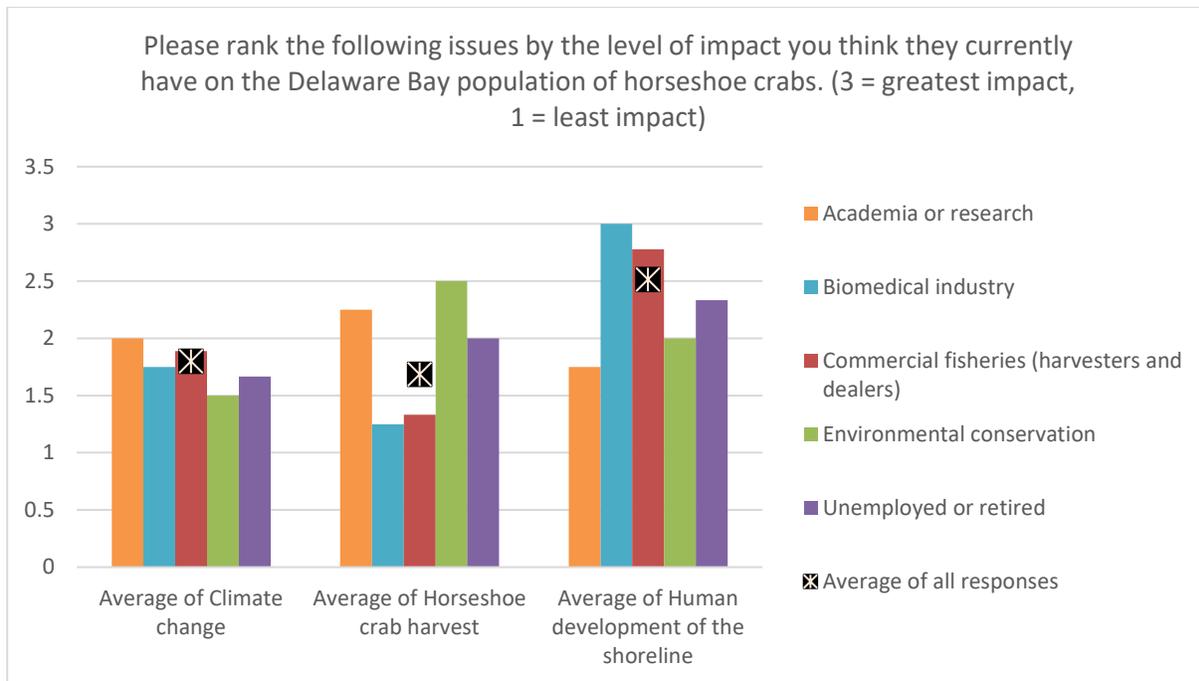


Figure 3. Perceived impacts of individual threats to horseshoe crab population. Higher average values equate to a higher level of perceived impact on the horseshoe crab population.

Question 10. Impacts on Red Knot Stopover Population

This question asked respondents to rank three issues by the level of impact they are thought to have on the red knots that stopover in the Delaware Bay during their migration: climate change, reduced food availability (horseshoe crab eggs) due to horseshoe crab harvest, and human development of the shoreline.

Similar to Question 9, there was substantial variation in the responses across different occupational groups (Table 5, Figure 4). Higher average values equate to a higher level of perceived impact on the red knot stopover population.

Table 5. Average rank value of red knot threats by occupational group. Higher value = higher impact.

Occupational Group	Average of Climate change	Average of Reduced food availability (horseshoe crab eggs) due to horseshoe crab harvest	Average of Human development of the shoreline
Academia or research (n=3)	2.00	2.33	1.67
Biomedical industry (n=4)	2.00	1.00	3.00
Commercial fisheries (harvesters and dealers) (n=18)	2.28	1.11	2.61
Environmental conservation (n=7)	1.43	2.57	2.00
Unemployed or retired (n=3)	2.00	2.00	2.00
Average across all responses (n=35)	2.03	1.57	2.40

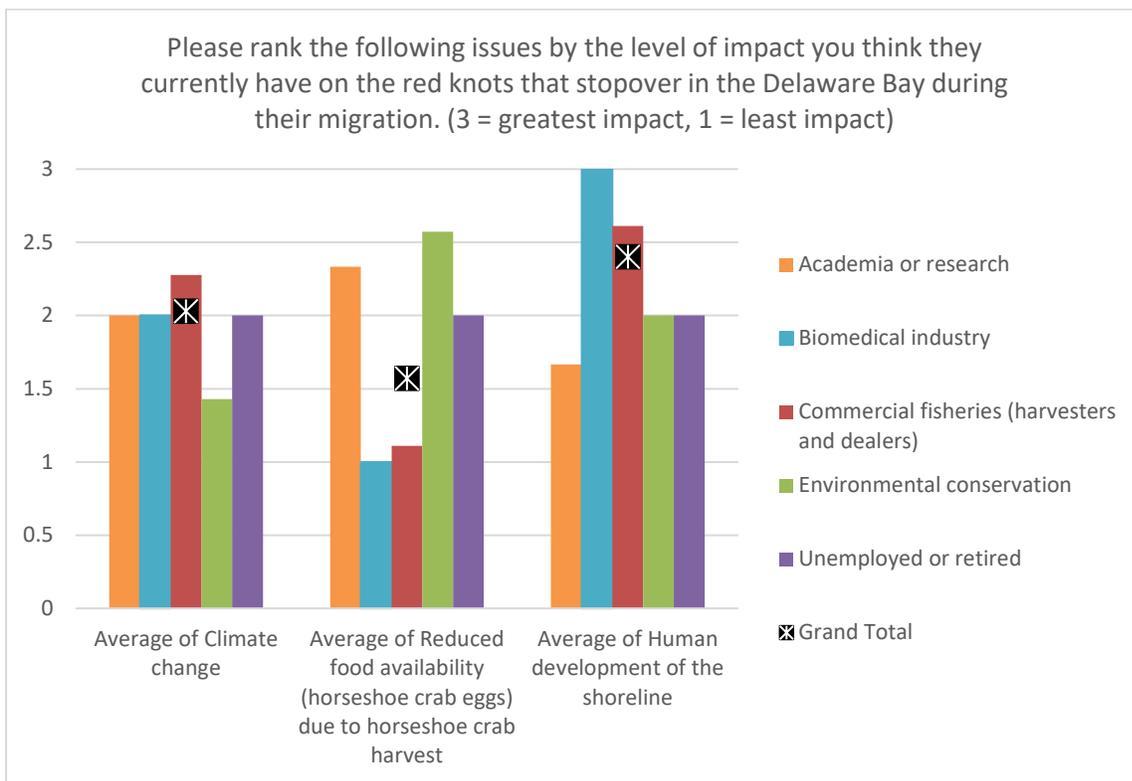


Figure 4. Perceived impacts of individual threats to red knot stopover population. Higher average values equate to a higher level of perceived impact on the red knot population.

Question 11. Importance of Management Objectives

Question 11 was designed to provide insight into the importance to stakeholders of various management objectives for the Delaware Bay horseshoe crab fishery. Participants were asked to indicate the level of importance of seven different management objectives. Possible responses included: Not Important at All, Of Little Importance, Of Average Importance, Very Important, and Absolutely Essential. The seven management objectives presented are listed below:

1. Maintaining a healthy population of horseshoe crabs
2. Maximizing forage (horseshoe crab eggs) for migrating shorebirds
3. Maximizing horseshoe crab bait harvest
4. Allowing horseshoe crabs to be used in the biomedical industry for human health
5. Protecting female horseshoe crabs
6. Using the best available science to inform management
7. Using a multi-species management approach that uses data on horseshoe crabs and shorebirds to recommend harvest levels

Thirty-four responses were received. For analysis, the responses were weighted as follows: Not Important at All = 1, Of Little Importance = 2, Of Average Importance = 3, Very Important = 4, and Absolutely Essential = 5. The average importance of each management objective was calculated across all responses and by occupational group (Figure 5, Table 6). Average values above 3.00 indicate that a management objective is perceived as above average importance, while average values below 3.00 indicate that an objective is perceived as below average importance.

Across all groups, Objective 1, Maintaining a healthy population of horseshoe crabs, was consistently considered to be above average importance (> 4.00) by all five groups. Maximizing forage (horseshoe crab eggs) for migrating shorebirds was considered above average importance for four of the five occupational groups. Maximizing horseshoe crab bait harvest was considered above average importance for two of the five groups (“commercial harvesters” and “unemployed or retired”) and below average importance for the other three. Allowing horseshoe crabs to be used in the biomedical industry for human health was considered above average importance for four of five groups, with values generally falling closer to 3 (average importance) and showing greater variance than the responses for the other objectives (range: 2.57-5). For the last three objectives, all five groups considered them to be above average importance on average (> 3), but there was variation in the degree of importance across groups.

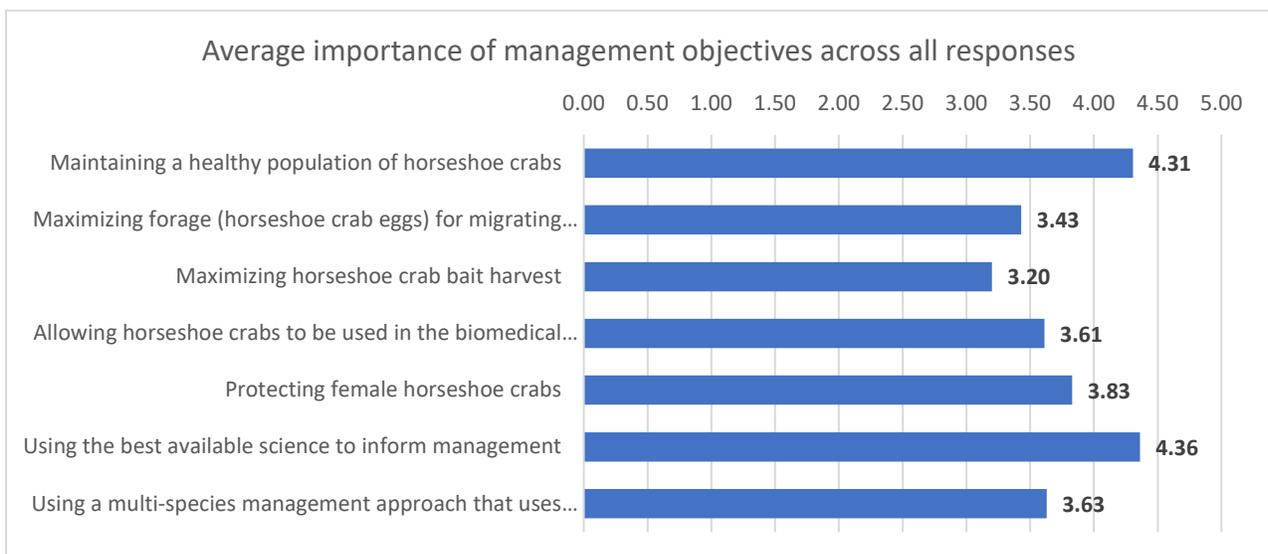


Figure 5. Average importance of management objectives across all responses.

Table 6. Average responses to Question 11 by occupational group. 1=Not important At All, 5=Absolutely Essential. Cells are color coded by column to indicate levels of importance assigned to each objective by each group, where the highest importance is shaded green and the lowest importance is shaded red.

Management Objectives	Academia or research (n=4)	Biomedical industry (n=3)	Commercial fisheries (harvesters and dealers) (n=18)	Environmental conservation (n=6)	Unemployed or retired (n=3)
Maintaining a healthy population of horseshoe crabs	5.00	4.75	4.00	4.43	4.33
Maximizing forage (horseshoe crab eggs) for migrating shorebirds	4.25	3.25	2.78	4.67	4.00
Maximizing horseshoe crab bait harvest	2.00	2.75	4.24	1.14	4.33
Allowing horseshoe crabs to be used in the biomedical industry for human health	3.25	5.00	3.78	2.57	3.67
Protecting female horseshoe crabs	4.50	3.33	3.28	5.00	4.00
Using the best available science...	4.75	3.33	3.17	4.00	4.33
Using a multi-species management approach...	4.75	3.33	3.17	4.00	4.33

Question 12. Ranking management goals

To provide additional insight into stakeholder priorities, Question 12 asked respondents to rank the first five management goals from the previous question by their level of importance. For analysis, responses were weighted with the most important item assigned a value of 5, and the least important assigned a value of 1. Consistent with the previous question, the results indicate that on average across all responses (n=36), maintaining a healthy population of horseshoe crabs is viewed as the most important management objective (Figure 6). Similar to previous issues, there is more variation among the responses when broken down by occupational group (Table 7).

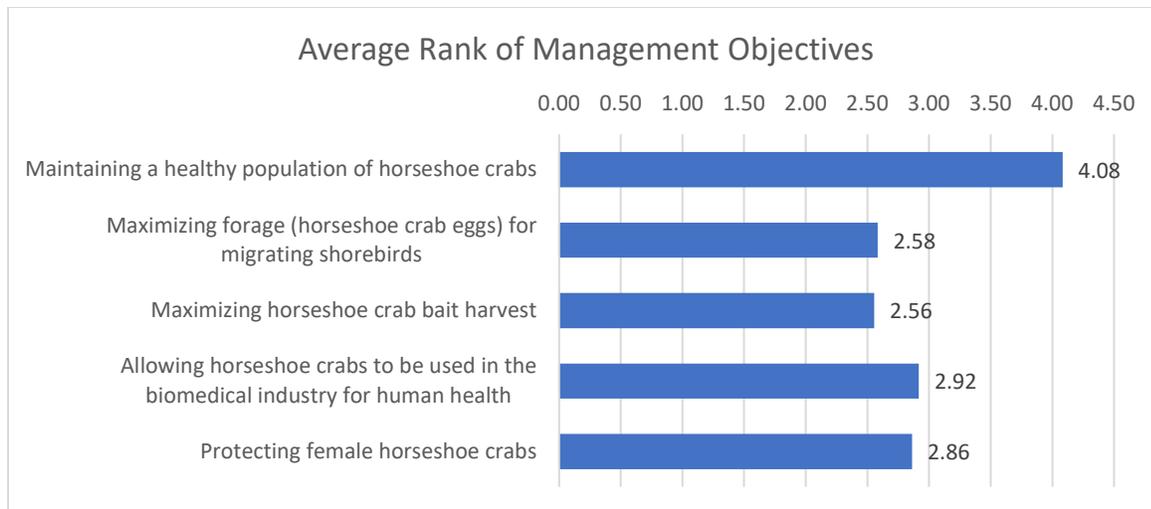


Figure 6. Average rank of management objectives based on importance across all responses. Higher value = higher rank.

Table 7. Average rank of management objectives based on importance, by occupational group. Cells are color coded by column to indicate average ranks assigned to each objective by each group, where the highest rank is shaded green and the lowest rank is shaded red.

Management Objectives	Academia or research (n=4)	Biomedical industry (n=3)	Commercial fisheries (harvesters and dealers) (n=18)	Environmental conservation (n=6)	Unemployed or retired (n=3)
Maintaining a healthy population of horseshoe crabs	4.75	4.25	4.17	4.00	2.67
Maximizing forage (horseshoe crab eggs) for migrating shorebirds	4.00	1.75	1.61	4.14	4.00
Maximizing horseshoe crab bait harvest	1.00	1.25	3.56	1.29	3.33
Allowing horseshoe crabs to be used in the biomedical industry for human health	2.00	4.25	3.39	2.00	1.67
Protecting female horseshoe crabs	3.25	3.50	2.28	3.57	3.33

3.4 Perspectives on the Adaptive Resource Management (ARM) Model and Female Harvest

Questions 13-14. Should the ARM model be modified?

Question 13 specifically asked survey participants if they think the ARM Model, as revised in 2021, should be modified. Of the 36 responses, 47% said yes, 20% said no, and 33% said “I don’t know” (Figure 7). Among most occupational groups, there was not a clear tendency toward any particular response.

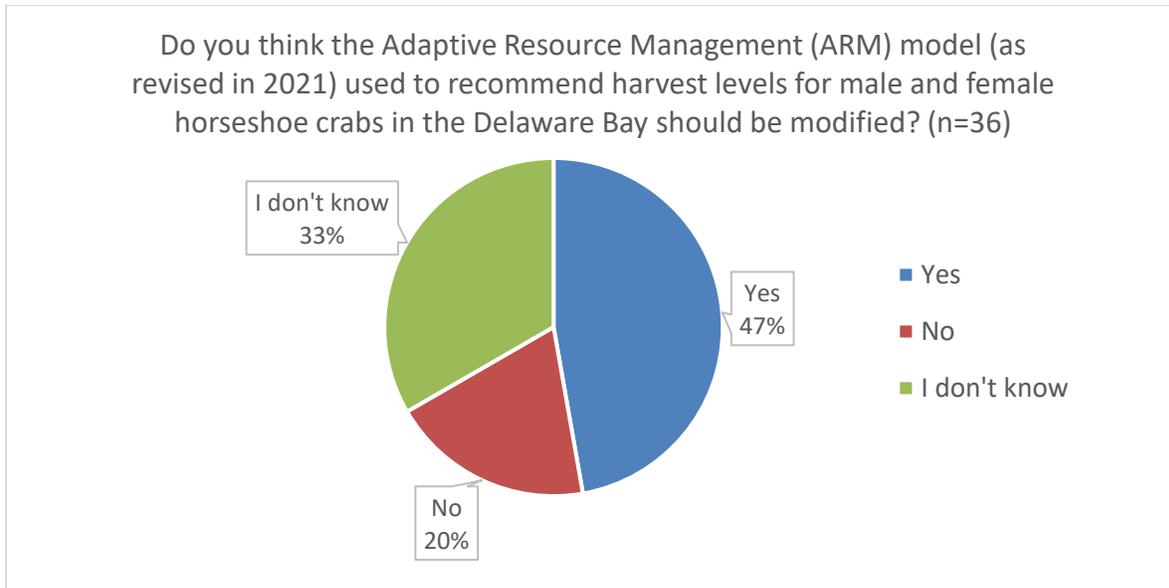


Figure 7. Opinion on whether the current ARM Model should be revised.

Respondents who answered “Yes” to Question 13 were presented with another question: “Why do you think ARM model used to recommend harvest levels for male and female horseshoe crabs in the Delaware Bay should be modified?” Sixteen open-ended responses were provided. Among the commercial fishery members who responded, a prevailing theme in the responses is that there are more horseshoe crabs than what is estimated in the ARM. A few responses stated that New Jersey should be given some opportunity for harvest. One commercial industry member advocated for Delaware Bay horseshoe crabs to be used only for biomedical purposes and not for bait because of the low mortality rate and the greater value of biomedical crabs. Seven responses, mostly from academic or environmental conservation respondents, referenced issues with the model and the built-in assumptions in the framework. For example, some stated that the model underestimates the relationship between horseshoe crabs and red knots, that the model population estimates do not accurately reflect the conditions of either species, and that it underestimates the impact of biomedical removals. Two comments stated that there should be a larger horseshoe crab population before increased harvest is allowed. All open-ended responses to this question are provided in Appendix B.

Questions 15-16. Should a limited amount of female harvest be allowed?

Question 15 specifically asked survey participants if they think a limited amount of female horseshoe crab bait harvest should be allowed at this point in time. Of 35 total responses, 49% said yes (n=17), 37% said no (n=13), and 14% said “I don’t know” (n=5). The distribution of responses varied between occupational groups. For the “academia and research” group responses were split evenly between “No” and “I don’t know.” The majority (14 of 18) of commercial fisheries group answered “Yes,” while 100% of the environmental conservation group answered “No.” The “biomedical industry” group responses included two “Yes” and one “I don’t know.” The responses from the “unemployed or retired” group were split evenly among all three answers (Figure 8).

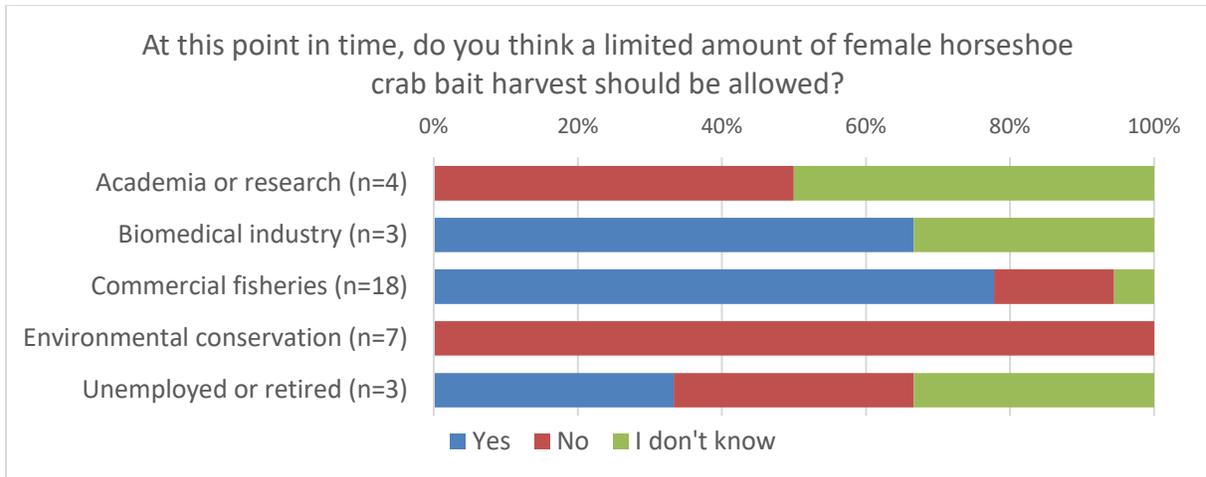


Figure 8. Opinion on allowing female bait harvest within occupational groups.

Participants that answered “No” to Question 15 were presented with another question: “Under what conditions should harvest of female horseshoe crabs be allowed?” Eleven open-ended responses were provided. Three responses indicated that female harvest of horseshoe crabs should not be allowed under any conditions, and another said that female harvest is not necessary. One response said that females should only be used for biomedical purposes. Three responses stated that female harvest should only be allowed once horseshoe crab and/or red knot populations have rebounded to near historic levels. One response argued that females should be harvested according to the original ARM framework until the current framework has been evaluated by multiple stakeholders. All open-ended responses to this question are provided in Appendix B.

Question 17. Use of female horseshoe crabs by the biomedical industry

This question aimed to understand stakeholder opinions about whether female horseshoe crabs should be collected for biomedical purposes. Thirty-five responses were given, and 46% said “Yes,” 43% said “No” and 11% said “I don’t know”. Occupational groups responded differently to this question (Figure 9).

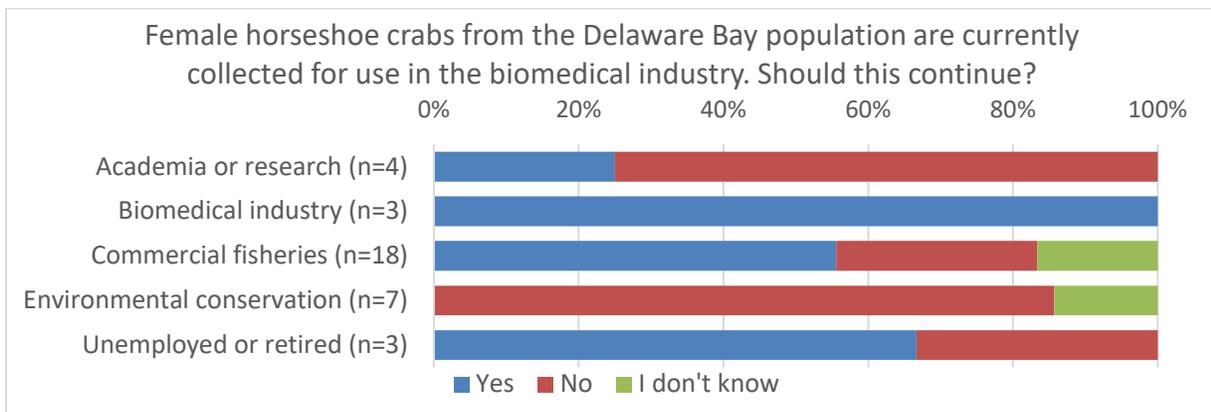


Figure 9. Opinion on biomedical use of female horseshoe crabs within occupational groups.

3.5 Question 18. What do you think is most important for managers to consider when making decisions about the management of the Delaware Bay horseshoe crab population?

The final survey question aimed to allow respondents to add additional information that may not have been considered in the other survey questions. Thirty-two open ended answers were submitted describing what the respondent thinks is the most important issue for managers to consider relative to this issue. A wide variety of topics and perspectives were addressed in these responses. The two most commonly mentioned issues were the health of the horseshoe crab population (n=9), and basing management decisions in robust science (n=5). Four responses focused on allowing sufficient bait harvest, and three responses emphasized the importance of impacts on fishermen and coastal communities. Two responses highlighted the importance of the greater ecosystem, including the role of horseshoe crabs and other species. Two responses specifically mentioned supporting shorebird recovery. Two responses highlighted allowing for biomedical use of horseshoe crabs, while two other responses advocated for switching to synthetic alternatives for bait and limulus amebocyte lysate (LAL). One response focused on the importance of maintaining adequate spawning beaches. One response emphasized the need to improve the data used for management. All open-ended responses to this question are provided in Appendix B.

4. DISCUSSION

The responses to this survey reflect one of the prominent challenges of managing the Delaware Bay horseshoe crab population, of which the Board has long been aware: a variety of stakeholders have an interest in the Delaware Bay population of horseshoe crab, but these stakeholder groups have diverging and sometimes contradictory management goals. The survey results provide some insight on the values and objectives of certain stakeholder groups.

The results clarify that within the commercial industry, including horseshoe crab harvesters and dealers, and fishermen who use horseshoe crab as bait, there is demand for female horseshoe crabs and they are considered more valuable than males. The majority of the commercial industry respondents have harvested females in the past, and indicate that harvesting females in the future is important to them. The majority of commercial industry respondents think a limited amount of female harvest should be allowed at present, but a few do not. Among the biomedical and academic stakeholders there is less certainty on allowing female harvest, and for environmental conservation respondents the unanimous opinion is that no female harvest should be allowed at this time. Among the respondents who do not think any female harvest should be allowed, there is a divide between individuals who think female harvest could be allowed once horseshoe crab and red knot populations have rebounded to near historic levels, and individuals who think it should never be allowed.

Regarding management goals, the results are mixed on which goals are perceived as most important. Researchers and environmental groups tended to value the protection of female horseshoe crabs and the ecological role of horseshoe crabs as a food source for shorebirds over the fishery. Commercial fishery participants attribute greater importance to bait harvest.

One area where almost all stakeholder groups agree is on the importance of maintaining a healthy horseshoe crab population. Across stakeholder groups this remains a top priority for management. However, there are differing opinions on the current state of the Delaware Bay population and the impacts of the bait fishery. While the commercial fishery participants tend to have a more positive perception, the environmental and academic participants tend to disagree with the idea that the Delaware Bay population is healthy, and think the bait fishery is having a negative impact on the horseshoe crab population.

A significant proportion of survey respondents think the ARM Model should be revised. Those respondents belong to various stakeholder groups and have a number of reasons for their opinions. Most commercial fishery respondents think the ARM should be revised because it is underestimating the numbers of horseshoe crabs, whereas other stakeholders argue it is overestimating the populations of horseshoe crabs and red knots. Nevertheless, the survey results are clear that stakeholders highly value the use of the best available science to inform management.

Appendix A. Survey Questionnaire



Delaware Bay Horseshoe Crab Management Survey

The Horseshoe Crab Management Board of the Atlantic States Marine Fisheries Commission (Commission) is seeking input from stakeholders regarding management of the Delaware Bay population of horseshoe crabs. As a stakeholder with an interest in horseshoe crab management, you have been selected to participate in this survey because of the valuable perspective you can provide on this issue. The purpose of the survey is to better understand the value of horseshoe crabs to stakeholders and guide the Board in evaluating the management objectives established in the fishery management plan.

All survey responses will be anonymous, and the results will be generalized such that individual responses will not be discernable. Your participation and engagement in the management process by completing this survey are greatly appreciated.



Delaware Bay Horseshoe Crab Management Survey

Participant Information

* 1. In what state or U.S. territory do you live?

* 2. What is your primary field of work?

- Commercial fisheries (harvesters and dealers)
- Fisheries management
- Environmental conservation
- Biomedical industry
- Academia or research
- Legislature
- Tourism industry
- State government
- Federal government
- Unemployed or retired
- Other (please specify)



Delaware Bay Horseshoe Crab Management Survey

Questions for Commercial Harvesters and Dealers

3. What are the horseshoe crabs that you harvest or sell used for?

- Bait
- Biomedical
- Both bait and biomedical
- I do not know
- I do not harvest horseshoe crabs
- Other (please specify)

4. Have you ever harvested or sold female horseshoe crabs for bait in the past?

- Yes
- No

5. How important is it to you to be able to harvest/sell female horseshoe crabs for bait in the future?

- Not Important at All
- Of Little Importance
- Of Average Importance
- Very Important
- Absolutely Essential
- This does not apply to me

6. On a scale of 1 to 5, where 1 is "strongly agree" and 5 is "strongly disagree," express your level of agreement with the following statements:

	1. Strongly agree	2	3. Neutral	4	5. Strongly disagree
Female horseshoe crabs are worth more money than male horseshoe crabs.	<input type="radio"/>				
There is no market demand for female horseshoe crabs.	<input type="radio"/>				

7. Of the following two options, which do you prefer?

- A larger overall quota of all male horseshoe crabs
- A smaller overall quota including some female horseshoe crabs



Delaware Bay Horseshoe Crab Management Survey

The questions in this survey ask about the Delaware Bay horseshoe crab population, and the management of the fishery in the Delaware Bay region. The Delaware Bay population includes horseshoe crabs within the state waters of New Jersey, Delaware, Maryland, and Virginia and adjacent federal waters.

Horseshoe crabs from the Delaware Bay region (New Jersey-Virginia) have been of particular concern due to their relationship with red knots, a shorebird species currently listed as Threatened by the US Fish and Wildlife Service. The red knot is one of the many shorebird species that feed on horseshoe crab eggs in the Delaware Bay region during their annual migration from South America to the Arctic.

For the purposes of this survey, a "healthy" horseshoe crab population is considered to be one with enough horseshoe crabs to supply enough food for the shorebirds and sustain fishery harvest.

8. On a scale of 1 to 5, where 1 is "strongly agree" and 5 is "strongly disagree," express your level of agreement with the following statements:

	1. Strongly agree	2	3. Neutral	4	5. Strongly disagree
The Delaware Bay population of horseshoe crabs is healthy.	<input type="radio"/>				
The horseshoe crab bait fishery is negatively impacting the Delaware Bay population of horseshoe crabs.	<input type="radio"/>				
The number of horseshoe crabs in the Delaware Bay population is increasing.	<input type="radio"/>				
The horseshoe crab bait fishery is negatively impacting red knots in the Delaware Bay.	<input type="radio"/>				
Fishermen should be allowed to harvest female horseshoe crabs from the Delaware Bay population if it is at a healthy level.	<input type="radio"/>				
Fishermen should not be allowed to harvest male horseshoe crabs from the Delaware Bay population if it is at a healthy level.	<input type="radio"/>				

9. Please rank the following issues by the level of impact you think they currently have on the Delaware Bay population of horseshoe crabs. (1 = greatest impact, 3 = least impact)

<input type="text"/>	Climate change
<input type="text"/>	Horseshoe crab harvest
<input type="text"/>	Human development of the shoreline

10. Please rank the following issues by the level of impact you think they currently have on the red knots that stopover in the Delaware Bay during their migration. (1 = greatest impact, 3 = least impact)

☐
☐
☐

Climate change

Reduced food availability (horseshoe crab eggs) due to horseshoe crab harvest

Human development of the shoreline



Delaware Bay Horseshoe Crab Management Survey

11. How important to you is each of the following management objectives for the Delaware Bay population of horseshoe crabs?

	Not Important at All	Of Little Importance	Of Average Importance	Very Important	Absolutely Essential
Maintaining a healthy population of horseshoe crabs	<input type="radio"/>				
Maximizing forage (horseshoe crab eggs) for migrating shorebirds	<input type="radio"/>				
Maximizing horseshoe crab bait harvest	<input type="radio"/>				
Allowing horseshoe crabs to be used in the biomedical industry for human health	<input type="radio"/>				
Protecting female horseshoe crabs	<input type="radio"/>				
Using the best available science to inform management	<input type="radio"/>				
Using a multi-species management approach that uses data on horseshoe crabs and shorebirds to recommend harvest levels	<input type="radio"/>				

12. Rank these management goals for the Delaware Bay region by their level of importance to you. (1 = most important, 5 = least important)

- ☰ Maintaining a healthy population of horseshoe crabs
- ☰ Maximizing forage (horseshoe crab eggs) for migrating shorebirds
- ☰ Maximizing horseshoe crab bait harvest
- ☰ Allowing horseshoe crabs to be used in the biomedical industry for human health
- ☰ Protecting female horseshoe crabs



Delaware Bay Horseshoe Crab Management Survey

In 2012, the Commission adopted the use of the Adaptive Resource Management (ARM) Framework for setting harvest levels for horseshoe crabs of Delaware Bay-origin given the important ecological role horseshoe crab eggs play in the food web for migrating shorebirds in that region. The ARM Framework considers the abundance levels of horseshoe crabs and red knots, as well as values previously expressed by stakeholders, in determining the optimal harvest level for horseshoe crabs from the Delaware Bay population. The ARM Framework was revised and peer reviewed in 2021.

Abundance surveys are used for both red knots and horseshoe crabs to estimate population sizes. The ARM Revision uses fishery-dependent data for horseshoe crabs from the commercial bait fishery, dead discard estimates from other fisheries, and mortality estimates from the biomedical industry. Based on these population estimates, and stakeholder values, the Framework recommends the appropriate number of male and female horseshoe crabs that can be harvested for the commercial bait fishery without limiting the population growth of red knots.

13. Do you think the Adaptive Resource Management (ARM) model (as revised in 2021) used to recommend harvest levels for male and female horseshoe crabs in the Delaware Bay should be modified?

- Yes
- No
- I don't know



Delaware Bay Horseshoe Crab Management Survey

14. Why do you think ARM model used to recommend harvest levels for male and female horseshoe crabs in the Delaware Bay should be modified? Answer below.



Delaware Bay Horseshoe Crab Management Survey

15. The current management framework allows for the possibility of limited commercial harvest of female horseshoe crabs from the Delaware Bay population based on the number of horseshoe crabs and red knots. At this point in time, do you think a limited amount of female horseshoe crab bait harvest should be allowed?

- Yes
- No
- I don't know



Delaware Bay Horseshoe Crab Management Survey

16. Under what conditions should harvest of female horseshoe crabs be allowed?



Delaware Bay Horseshoe Crab Management Survey

17. Female horseshoe crabs from the Delaware Bay population are currently collected for use in the biomedical industry. Should this continue?

- Yes
- No
- I don't know



Delaware Bay Horseshoe Crab Management Survey

18. What do you think is most important for managers to consider when making decisions about the management of the Delaware Bay horseshoe crab population?



Delaware Bay Horseshoe Crab Management Survey

Optional Demographic Information

19. What is your age?

- 17 or younger
- 18-20
- 21-29
- 30-39
- 40-49
- 50-59
- 60 or older
- Choose not to answer

20. What is your gender?

- Female
- Male
- Other
- Choose not to answer

21. Which race/ethnicity best describes you? (Select all that apply)

- American Indian or Alaskan Native
- Asian / Pacific Islander
- Black or African American
- Hispanic
- White / Caucasian
- Choose not to answer
- Multiple ethnicity / Other (please specify)



Delaware Bay Horseshoe Crab Management Survey

Thank you for completing this survey!

The Commission's Horseshoe Crab Management Board greatly appreciates your perspective on this topic. The Management Board will review the results of the survey at its next meeting.

Appendix B. Open-Ended Survey Responses

Question 14. Why do you think ARM model used to recommend harvest levels for male and female horseshoe crabs in the Delaware Bay should be modified?
The horseshoe crab levels should be a lot stronger than they have been because the harvesting have been restrictive.
The ARM model vastly underestimates the importance of horseshoe crabs to red knots and thus recommends dangerously high harvest levels. It also generates estimates and projections of horseshoe crab and red knot abundance that do not accurately reflect the conditions of either species. Considering the precarious state of the ecosystem, ASMFC should take a risk-averse approach.
More crabs now then 2007.
I believe it underestimates the levels of impacts to both horseshoe crabs and shore birds
I think NJ should be allowed to harvest
I feel that female horseshoe crabs should be exclusively utilized for bio-medical purposes. The value per crab and the very low mortality rate by live return to sea, far outweighs the value of females for bait and far outweighs 100% bait mortality. Female survival is essential to sustaining a healthy stock biomass.
Because it sucks
We need more harvest and mortality data from the pharmaceutical industry. They should not be exempt from supplying data. In addition, the model should be giving more weight to the horseshoe crab / shorebird recourses in the Delaware Bay. The bait harvest industry while a worthwhile endeavor should not trump the resources. Female horseshoe crabs should not be harvested until the population recovers to near historic levels.
I feel that there are many more crabs than they think
The numbers of crabs in the Delaware Bay are not yet at a sustainable level. I believe we need a few more years of significant increase not occurring using the current ARM model
Puts too much emphasis on allowing HSC harvest before the populations number have fully rebounded. Also underestimates negative effect of crab bleeding.
You are not taking in consideration the use of one female horseshoe crab for bait will save millions of eggs. We are using the horseshoe crabs to catch everything that is eating the eggs in the water. For instance one horseshoe crab could catch 10 pounds of eels how many eggs do you think 10 pounds of eels can eat in a year?
Crabs are more plentiful and NJ moratorium in place 16 years lifted and NJ and Delaware should be alternate. 1 state every other year to be more equitable
It should be modified to include harvest impacts in a diversity of species, not just red knots.
Many assumptions of the model are problematic and unsupported, likely affecting the inferences being made by model developers with respect to the status of the horseshoe crab populations and their relationship to Red Knot population viability.
Because it doesn't allow for female harvest of local population of female's that are not from the Delaware Bay population

Question 16. Under what conditions should harvest of female horseshoe crabs be allowed?
Given the importance of female horseshoe crabs to the ecosystem and the harm that their removal has caused, it is difficult to imagine a scenario when harvesting them would be justified. At a minimum, both horseshoe crabs and red knots would need to have recovered to their pre-overharvest abundance levels, with enough of a buffer to ensure that a female harvest would not precipitate another decline. Those conditions seem very remote today.
Under no conditions should female horseshoe crabs be harvested
It isn't necessary
Bio-Medical use only
none
After the population recovers to near historic levels.
When fishermen needed them just like it was.
When HSC populations number and egg densities on the spawning beaches are up to earlier documented levels.
ABSOLUTELY NONE
As proposed in the original ARM framework. However, interpretation of the existing data and the outputs of the current ARM framework must be scrutinized and evaluated by multiple stakeholders. To date, this has not been done.
On all occasions

Question 18. What do you think is most important for managers to consider when making decisions about the management of the Delaware Bay horseshoe crab population?
Healthy population so you can have enough for the biomedical research
Managers should prioritize the critical and unique role of horseshoe crabs in the ecosystem, including the many species and processes that depend on them.
The health of the horseshoe crab population, utilizing the best available horseshoe crab population data and ensuring that horseshoe crabs can continue to be collected for the Limulus Amebocyte Lysate (LAL) test that is critical to human health
Make a decision on future harvest or buy the few licenses that are left. People make a living off the water!
Increasing the population of horseshoe crabs and supporting shore bird migration and populations.
I'm in MD there management is working fine
Not sure
In New Jersey the harvest method should be addressed. Many horseshoe permit holders have the ability to harvest crabs in other fisheries that do not require a hand harvest on the beach during the spawn of the horseshoe crab. If a permit holder can harvest horseshoe crabs in another legal fishery it will eliminate the interaction of harvesters and horseshoe crabs spawning on the shoreline as our current regulation requires that method to collect them. As an example such as a winter dredge fishery or spring Gillnet, the horseshoe crab that could be harvested in that manner would not be pulled from the sandy shorelines during the time when the crab spawns. The beach collection is not favorable due to the fact that that crab is there to

spawn. If it's harvest in another fishery other than hand/beach harvest it's not collecting a spawning crab which may or may not make it to the shoreline due to other environmental reasons or threats.
Whether horseshoe crabs have the ability to change sex depending on the lesser of one or the other sex
The use of existing alternative to HSC blood is now possible HSC should be phased out Bait alternatives also exist
Keeping the resource strong and robust. Create the greatest use benefit to human population in mortality estimates and calculations. The Red Knot need for the eggs is essential, although should not be arbitrary in reasoning to limit Horseshoe Crab usage. How will having a Wind Energy Farm located on top of the Schuster Sanctuary, effect the long-term viability of the resource?
Ecological interrelationships between horseshoe crabs and other species including shorebirds
That Delaware's season is after the bulk of the crabs have already laid their eggs.
Use scientifically-robust data and models, including analyses and interpretation by scientists not affiliated with affected states.
Maintain a balance of both the female and male population to their percentage so they can reproduce sufficiently. We do not want to overharvest to prevent their reproduction. Our main goal is to not only preserve the red knots but also the horseshoe crabs also.
Current population and collection data is extremely important, especially data from the pharma industry. Without this data the current model does not work as well as it could.
Having real science done and not made up science like all the science in the past for the birds..!!
The stock of the crabs
When making the decisions managers should take the actual science for what it's worth and not change the method once it doesn't meet their agenda.
I think they need to push for additional use of synthetic baits for the fishing industry and synthetic blood substitutes for the medical industry. They need to look at overall impacts, not just horseshoe crab population size.
Data. Full stop.
Make a reasonable amount of horseshoe crabs available for bait.
That HSC population numbers haven't fully rebounded and is not producing an overabundance of eggs needed to sustain shorebird foraging needs.
Recovery of the Red Knot
Using horseshoe crabs for bait and catching what is eating their eggs we help the population. Less predators more prey Simple
NJ license permit holders should be the ones to harvest these biomedical crabs currently NJ has established monopoly should be investigated anti trust violations
Horseshoe crab population
The current population of horseshoe crabs is just a fraction of its historic numbers. Any management decisions should be to increase their population numbers not just maintain current levels.

Use ecological endpoints for recovery of horseshoe crab populations. Consider the importance of horseshoe crabs as a keystone species in near shore inter tidal communities, not only for migratory shorebirds, but fishes and other marine organisms.

The fisherman

Financial and cultural impact on small coastal communities.

It is very important to keep the spawning beaches from becoming over developed and not having anywhere for the Horseshoe Crabs to spawn

Appendix C. Additional Figures

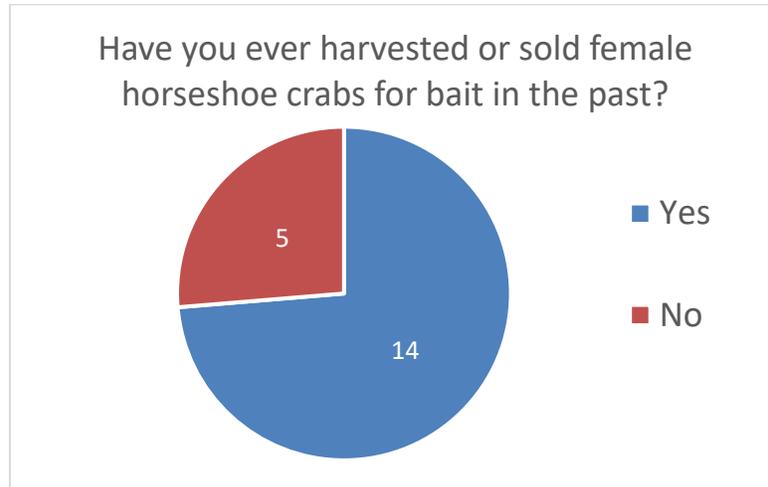


Figure A1. Past female horseshoe crab harvest.

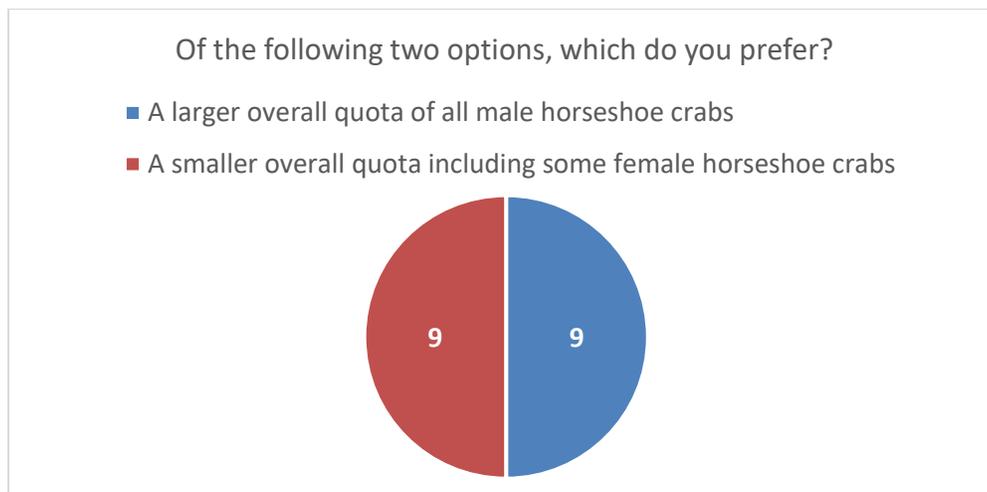


Figure A2. Preferences for harvest quota makeup.

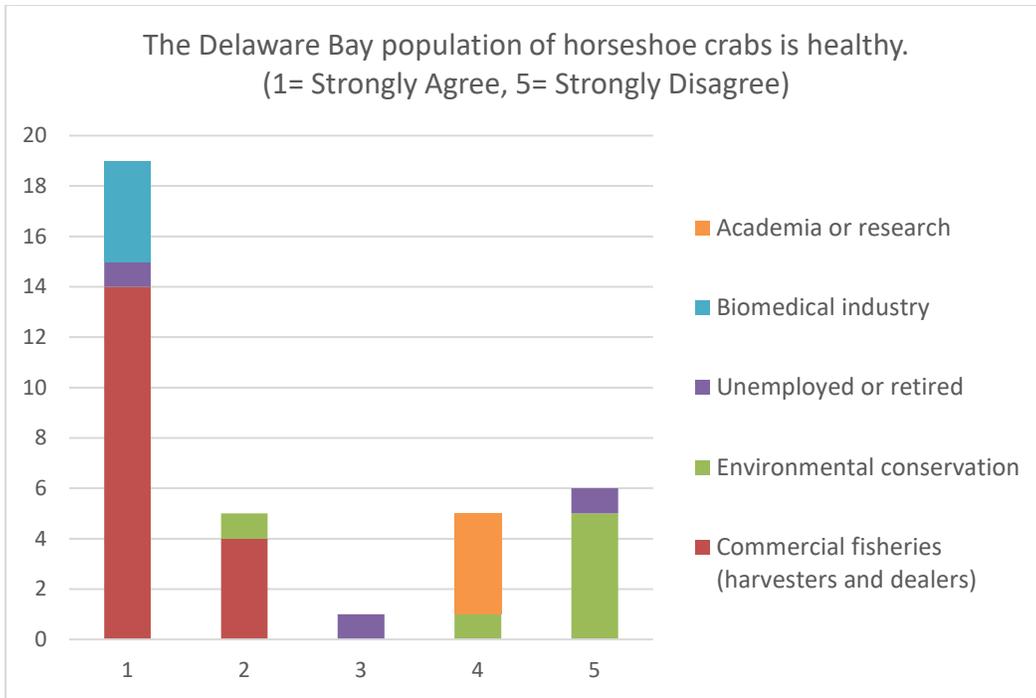


Figure A3. Perception of Delaware Bay horseshoe crab population health.

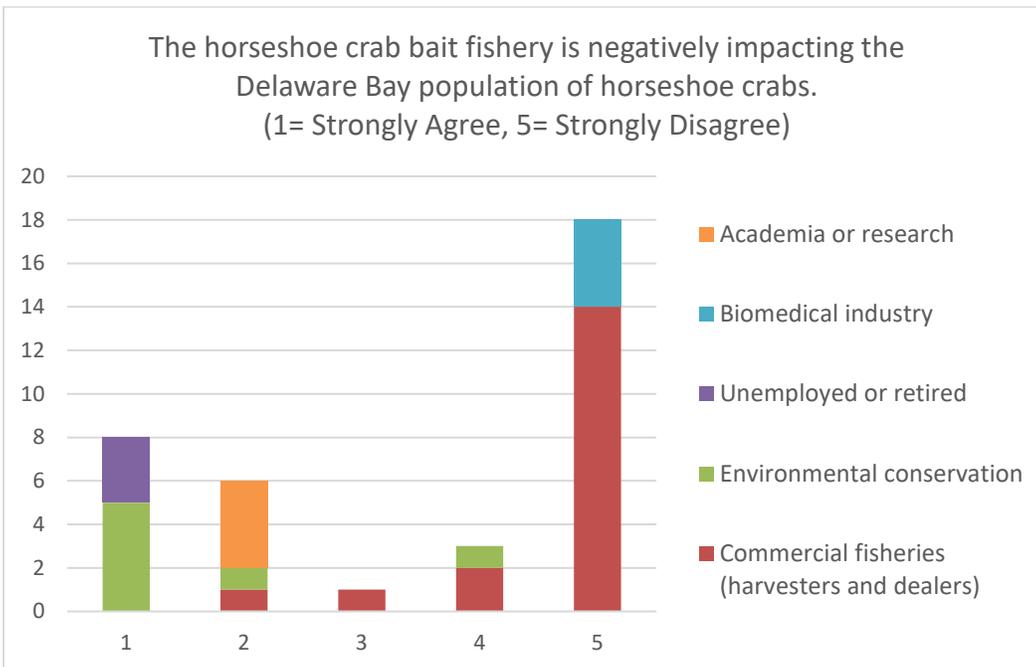


Figure A4. Perception of bait fishery impacts on horseshoe crab population.

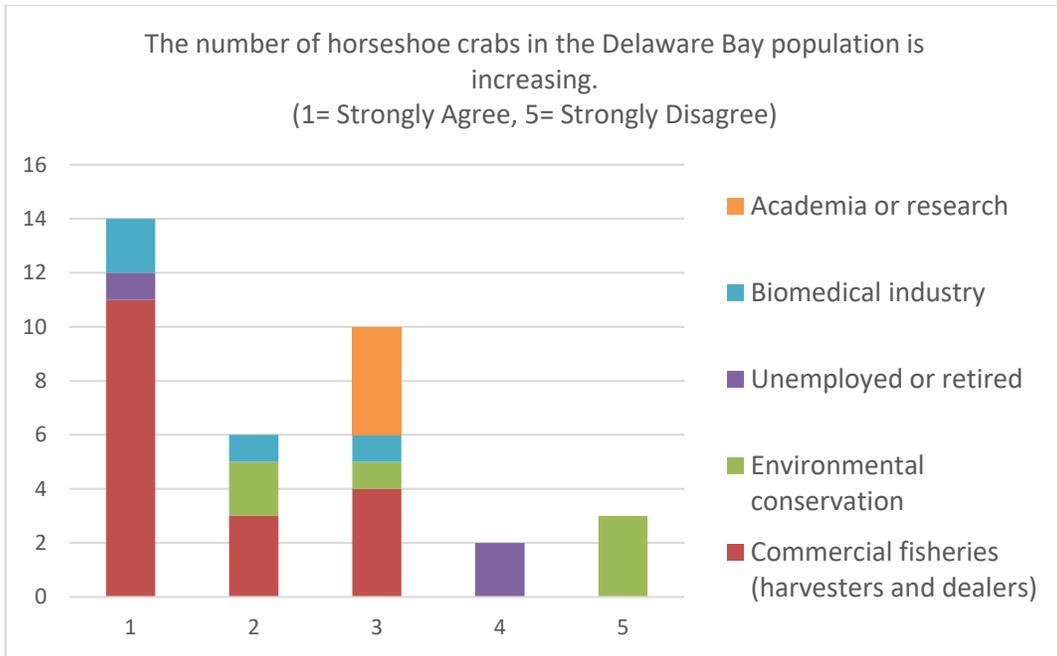


Figure A5. Perception of Delaware Bay horseshoe crab population growth.

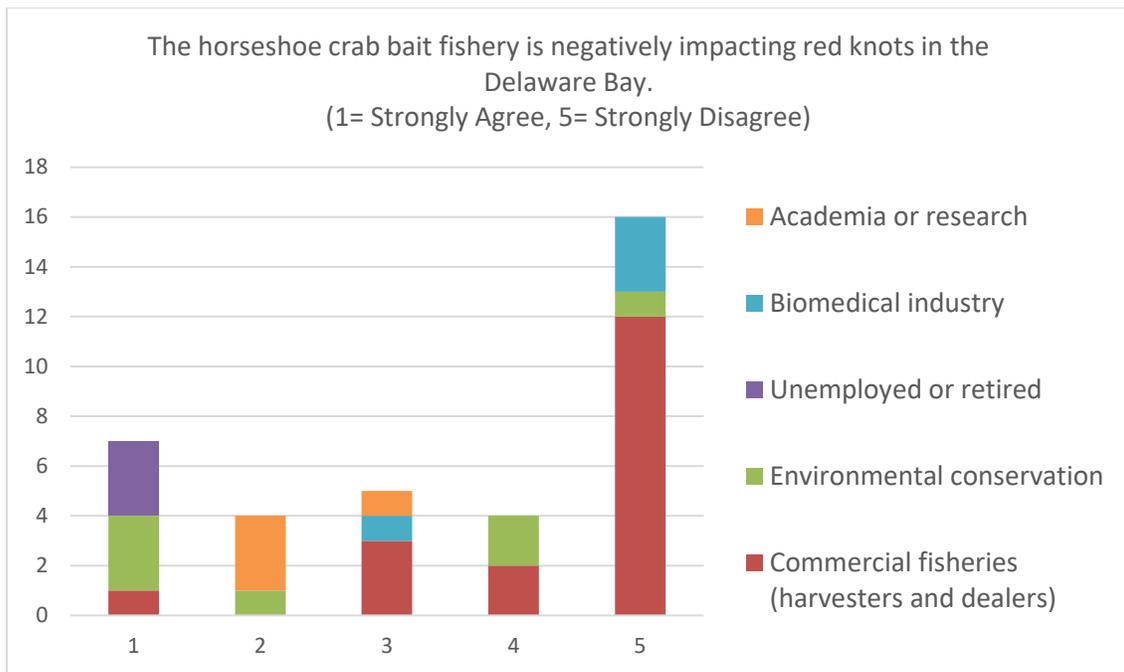


Figure A6. Perception of bait fishery impacts on red knots.

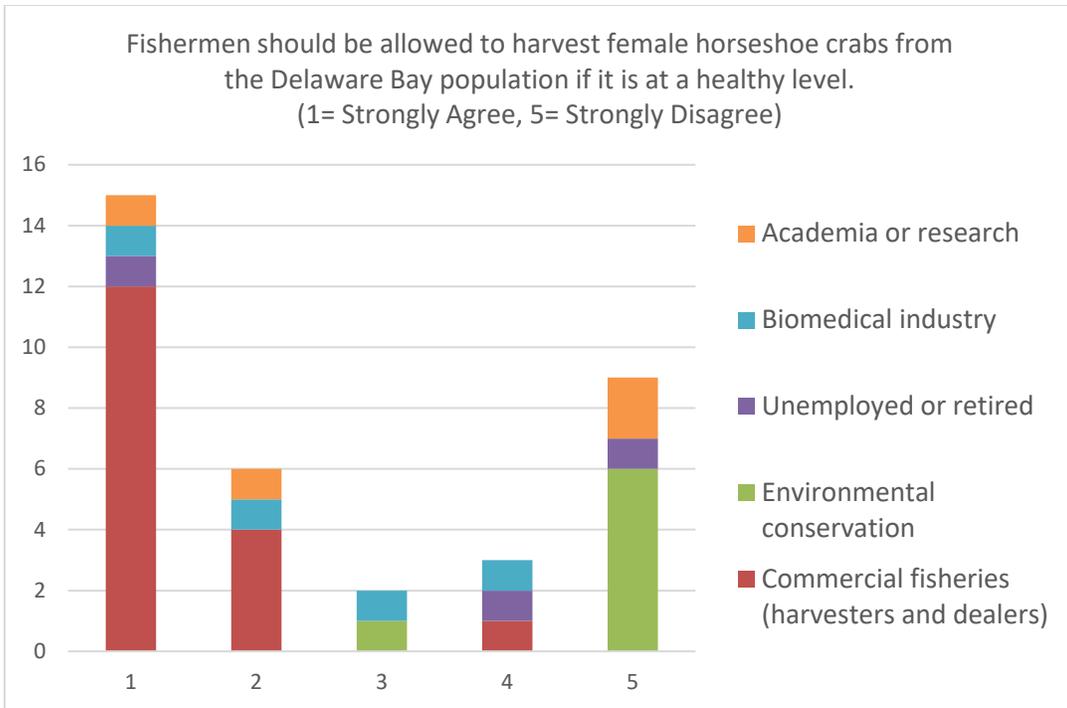


Figure A7. Opinion on female harvest allowance.

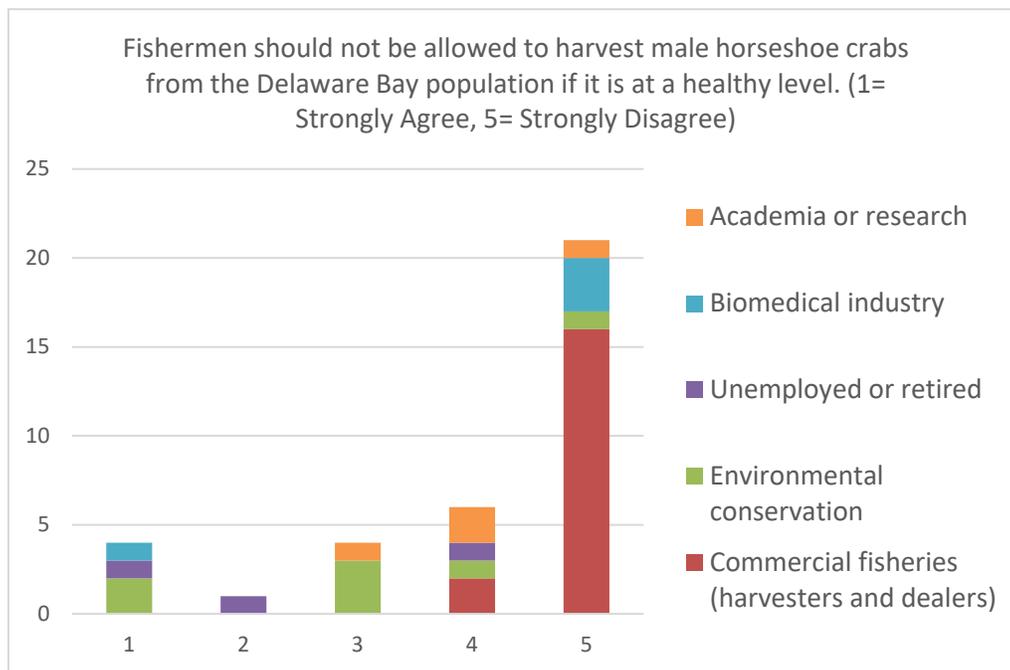


Figure A8. Opinion on male harvest allowance.

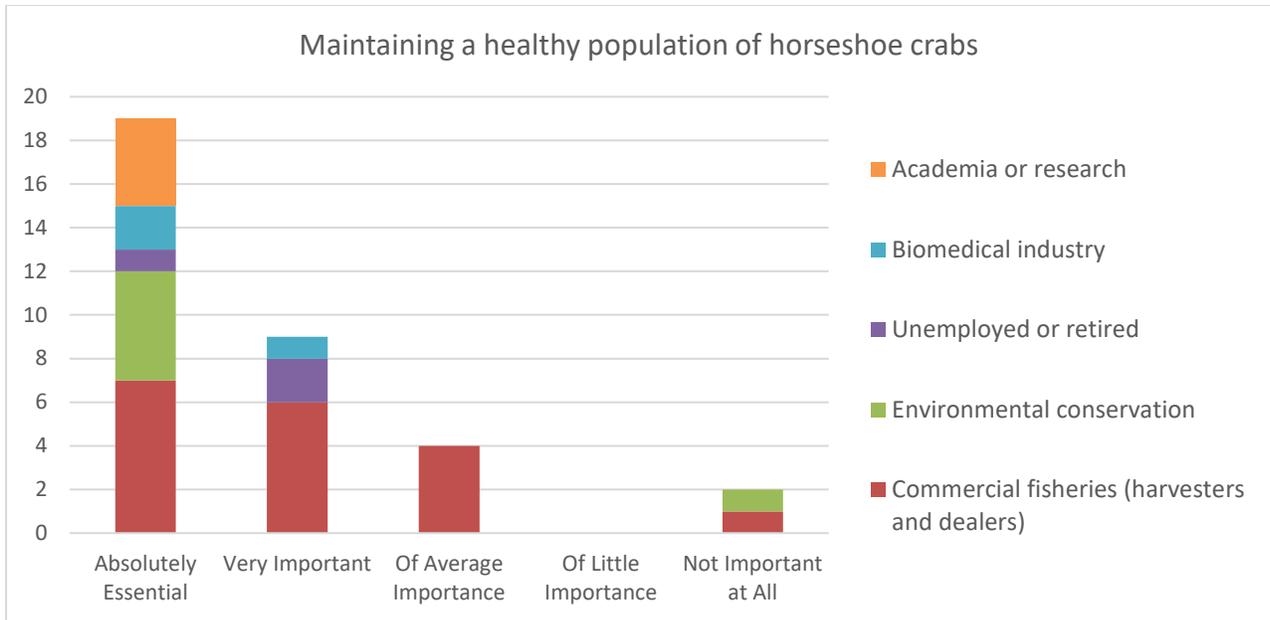


Figure A9. Importance of maintaining a healthy population of horseshoe crabs.

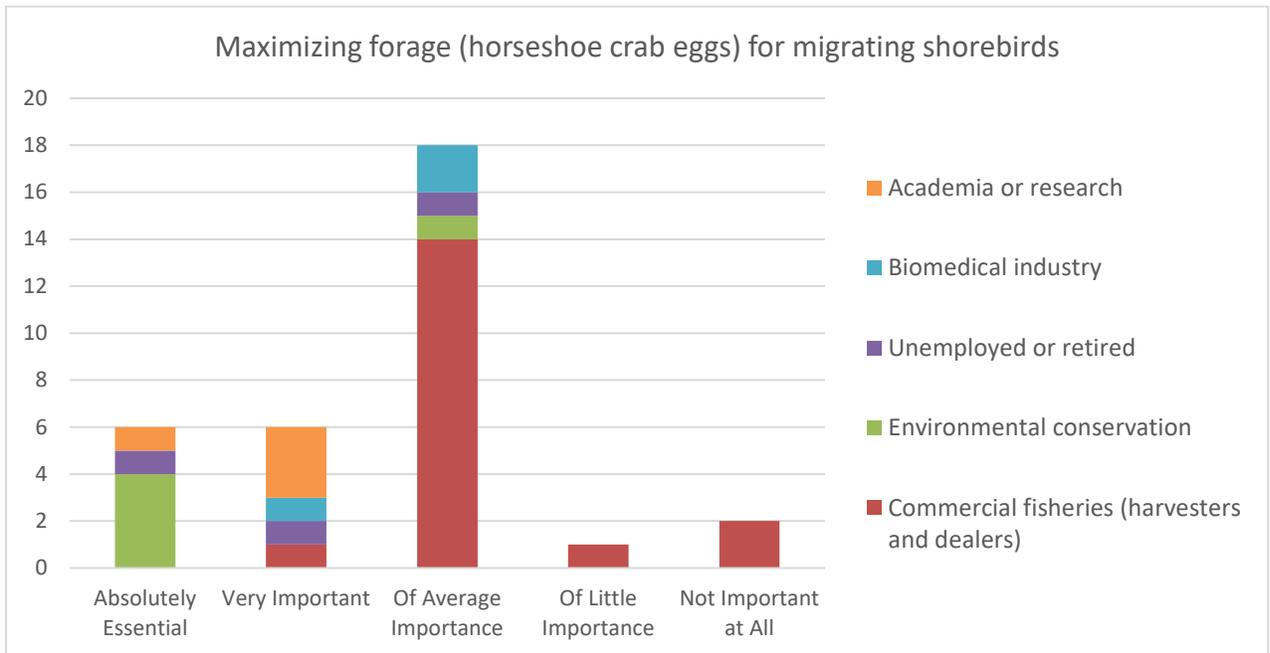


Figure A10. Importance of maximizing forage (horseshoe crab eggs) for migrating shorebirds.

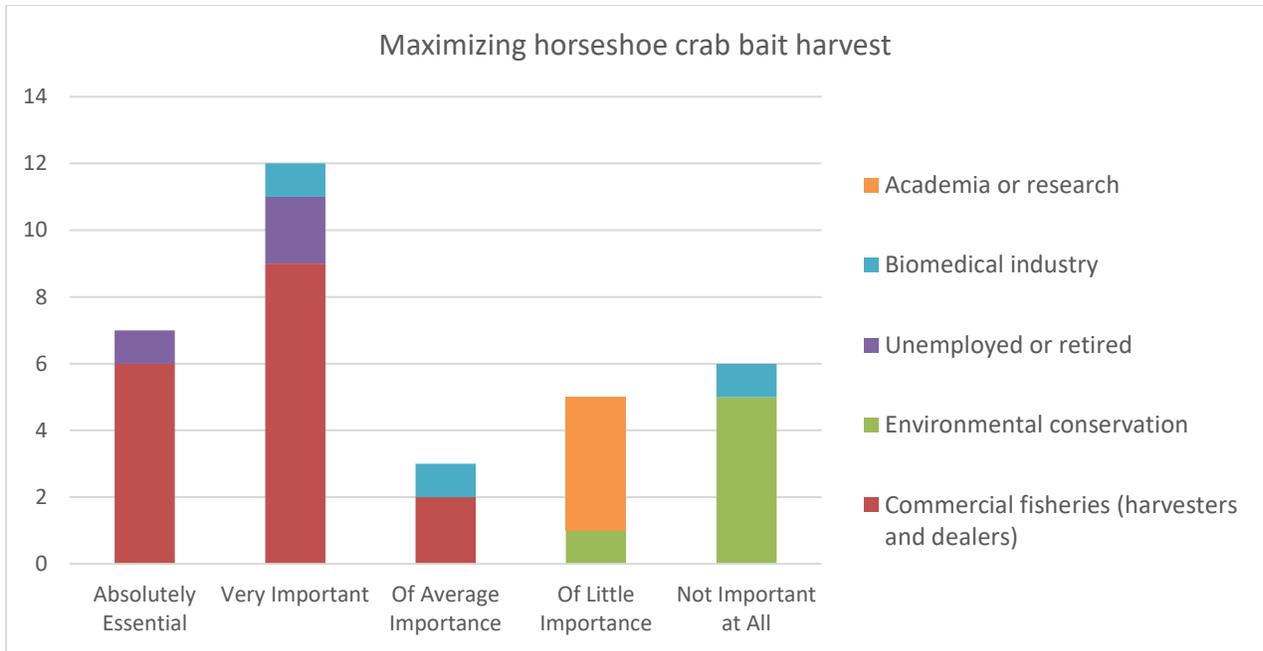


Figure A11. Importance of maximizing horseshoe crab bait harvest.

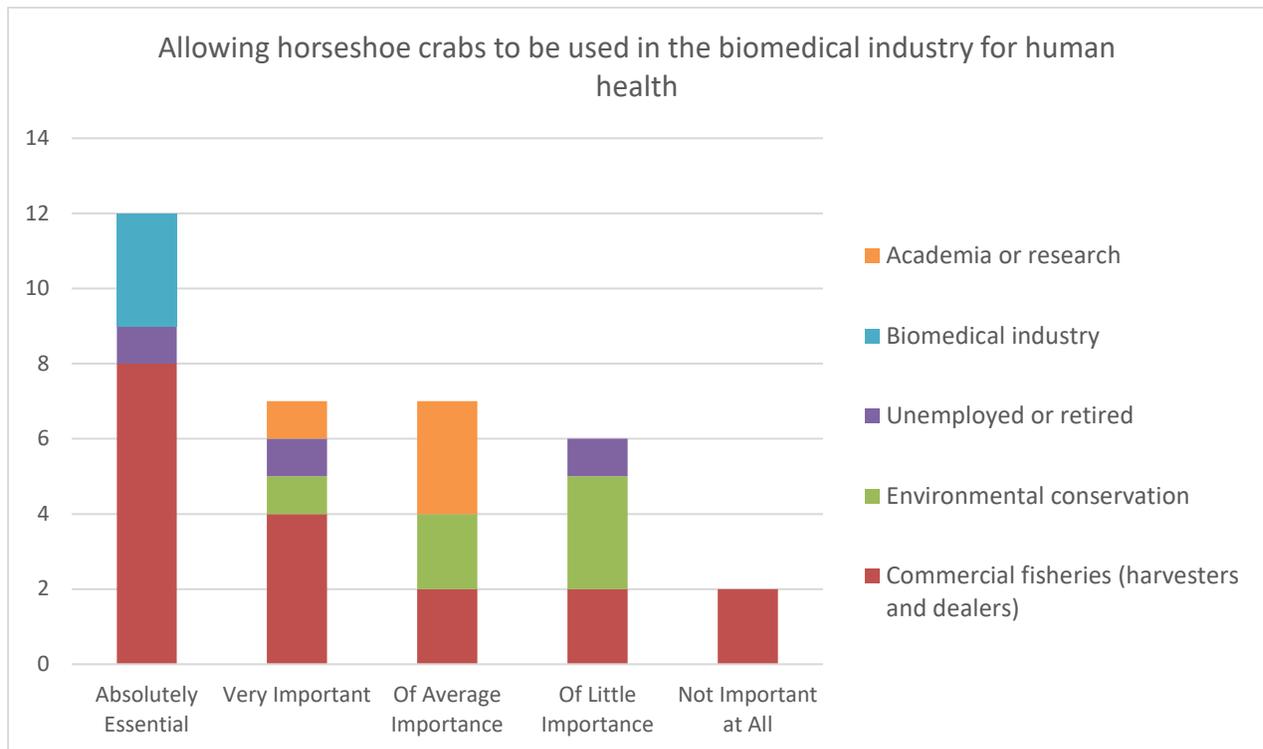


Figure A12. Importance of allowing horseshoe crabs to be used in the biomedical industry.

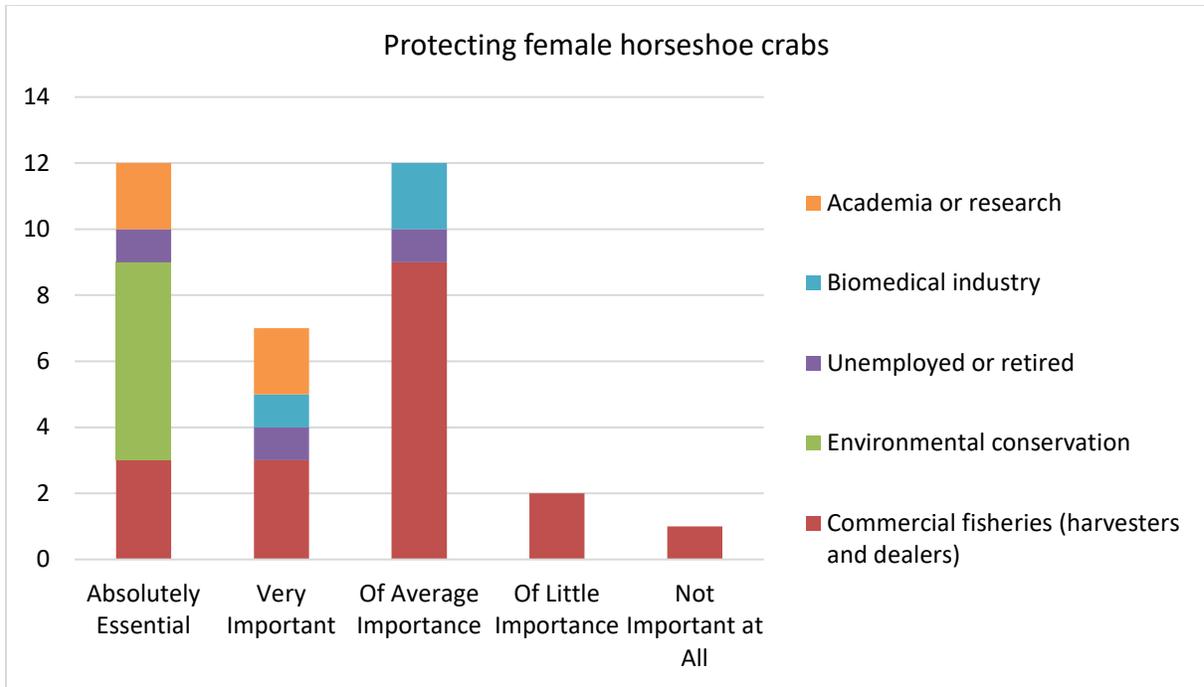


Figure A13. Importance of protecting female horseshoe crabs.

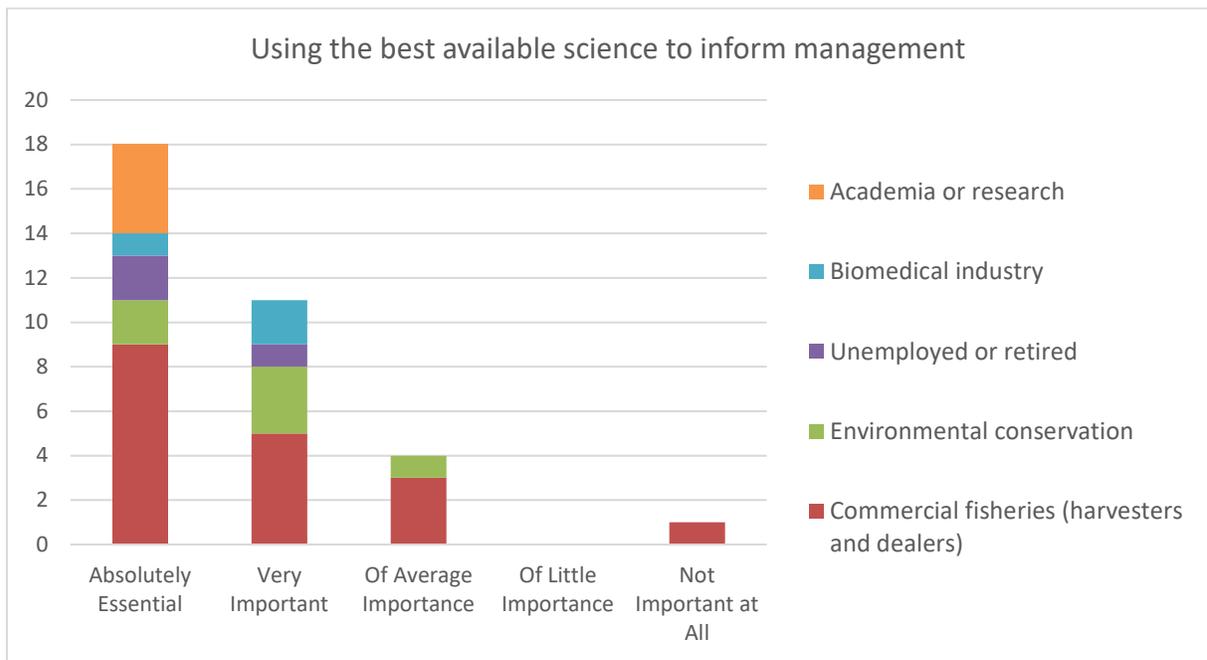


Figure A14. Importance of using the best available science to inform management.

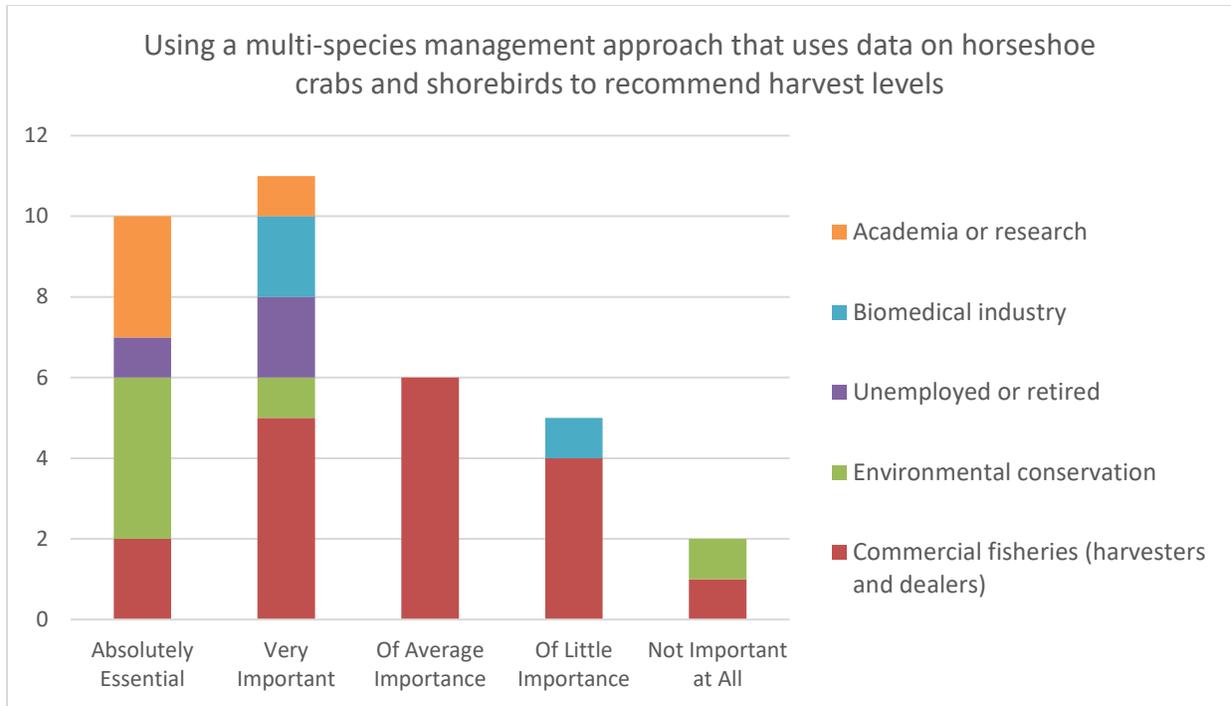


Figure A15. Importance of using a multi-species management approach.

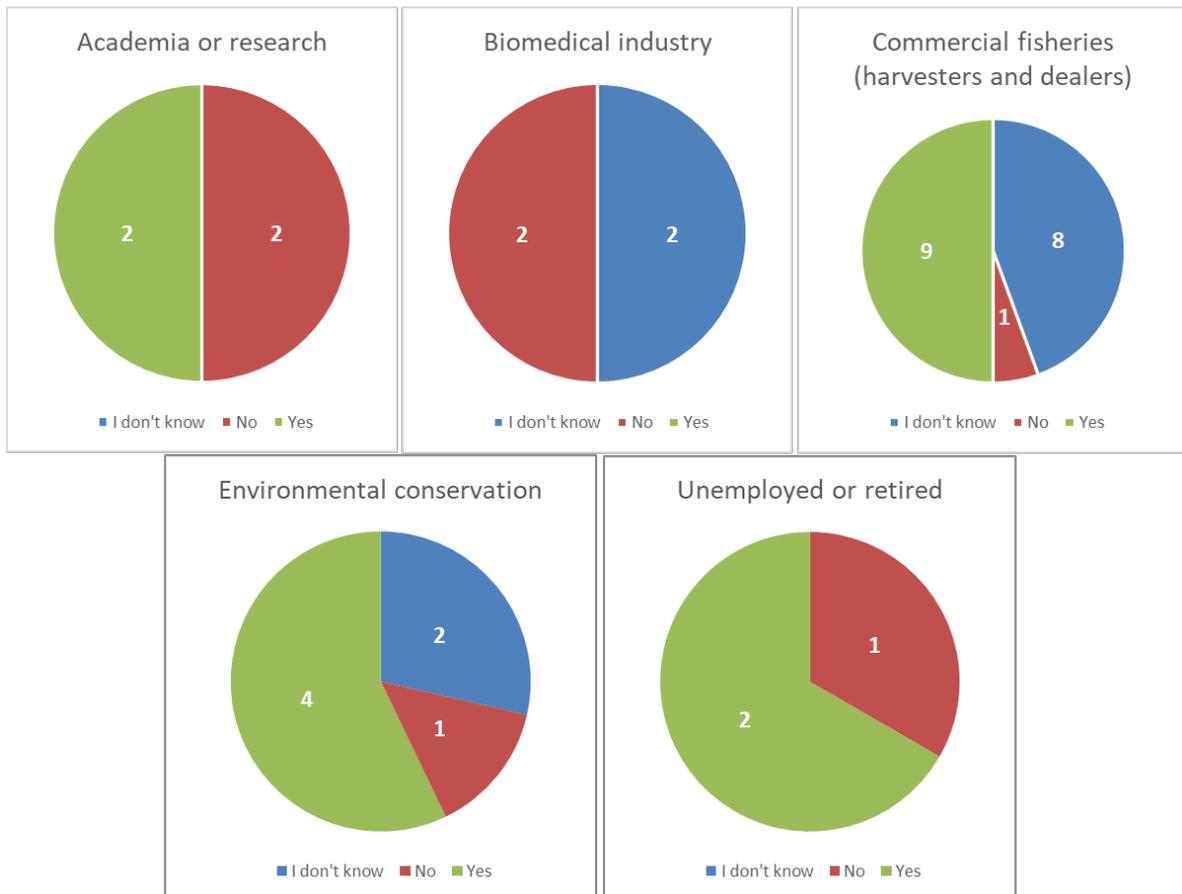


Figure A16. Opinion on whether the current ARM Model should be revised by occupational group.

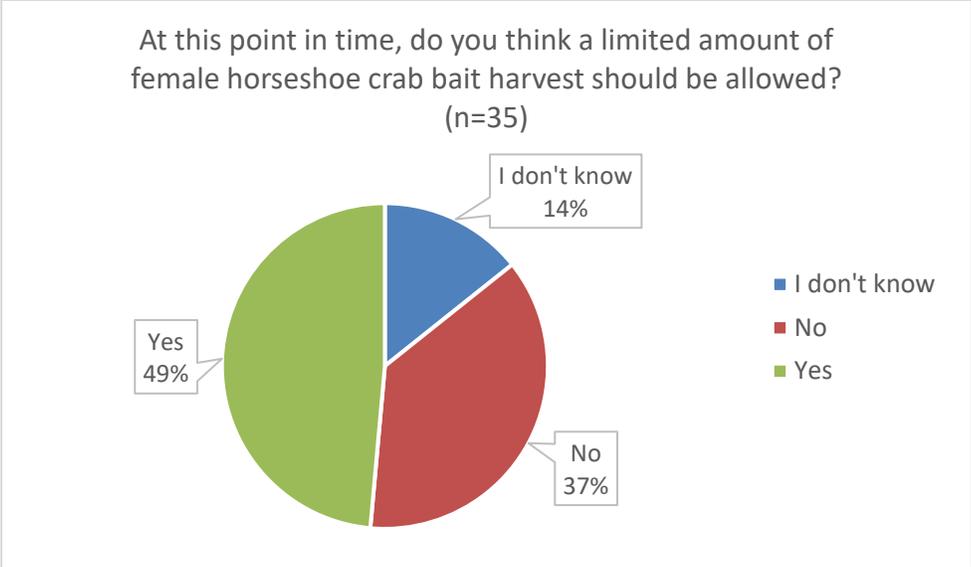


Figure A17. Opinion on allowing female bait harvest.

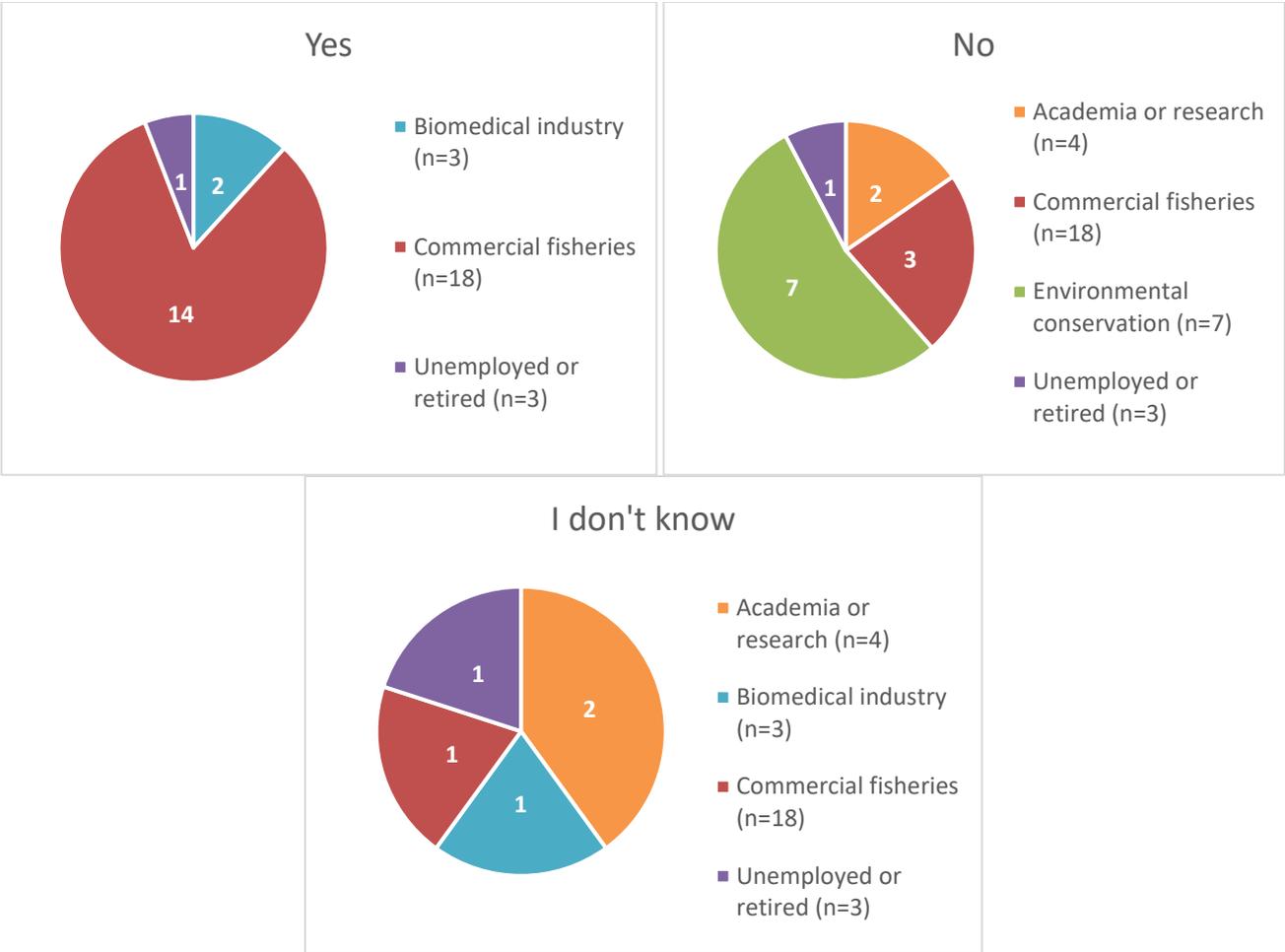


Figure A18. Makeup of respondents to Question 15 by answer provided.

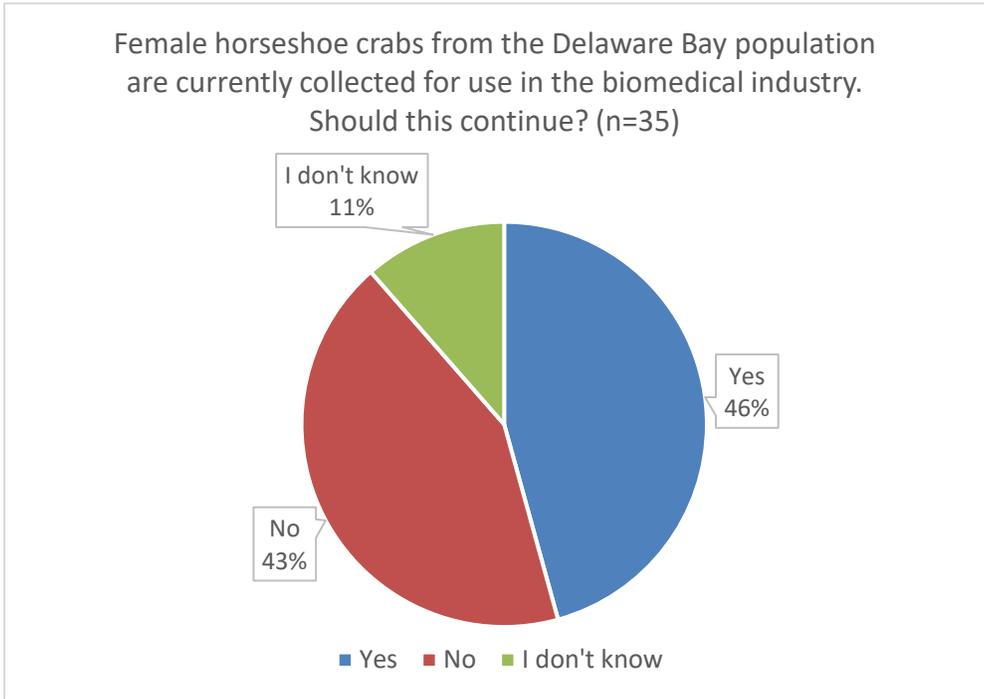


Figure A19. Opinion on use of female horseshoe crabs in the biomedical industry.