

HORSESHOE CRAB CONSERVATION ON CAPE COD

An Interactive Qualifying Project Report

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Introduction

The horseshoe crab, *Limulus polyphemus*, is a natural resource benefiting humans and the environment alike. In its natural habitat the horseshoe contributes to the environment in a number of ways, from irrigating the soil of the shores, acting as a home for a number of organisms, to providing food for a number of species. Humans make use of horseshoe crabs in many ways. The horseshoe crab is used as a model for optical studies due to their complex system of eyes and light sensors. There are commercial uses for the horseshoe crab, in the bait and biomedical industry (Lord, 2000). The demand for the horseshoe crab has increased in the past years and as a result could be causing new stresses on the horseshoe crab population. There has been little assessment of the current threat to the horseshoe crab population. The horseshoe crab population needs to be studied to assure the continuation of the species. There may be a need to place regulations on the uses and harvest of the horseshoe crab. In this study the general public was surveyed to assess over all concerns and opinions regarding the horseshoe crab population, uses and possible solution.

Natural History

The horseshoe crab is in the Phylum Arthropoda along with other crabs, but is actually more closely related to spiders and scorpions. Its physical features, such as size, condition and color of shell, and the presences of mating characteristics can determine the age and sex of the horseshoe crab. Female horseshoe crabs can be identified by their larger size and mating scars found on the carapace. A male horseshoe crab that has mated will display inflamed claspers, or “boxing gloves” which are used to attach to the female during mating (Shuster, 1982).

The horseshoe crab's mating depends on environmental factors. The mating season is during the new and full moons from mid May to early July. At this time horseshoe crabs come to the shore about 1 hour before high tide, returning to deeper water about 1 hour after the tide begins to recede. Once on the shore the female will lay 4,000 eggs that were fertilized by the males, in nests which she has dug in the intertidal. A female will lay eggs up to three times a year. Out of 130,000 eggs only one will survive. The spawning habitat for horseshoe crabs on Massachusetts's beaches consists of coarse-grained, well-drained sand (ASMFC, 1998).

Commercial Uses

The horseshoe crab is used by the bait industry as bait for conch, eel bait and at certain places along the east coast, catfish. Horseshoe crabs are killed and placed in bait "pots" and left as bait. This process results in a 100% mortality rate (Writer, 2000). The bait industry is responsible for the capture and ultimate death of up to two million horseshoe crabs per year (Alternatibe Bait, 1999). The closure of Delaware Bay to Horseshoe crab fishing has put more pressure on Massachusetts resulting in the tripling of price of crabs for bait. Another concern brought forth by the bait industry is that eel fisheries prefer female horseshoe crabs with eggs, which adds stress to gender ratios and spawning rates (ASMFC, 1998).

Associates of Cape Cod, a Falmouth based biomedical company, uses the horseshoe crab blood to produce Limulus Amebocyte Lysate, a product that is used to detect bacterial contamination in pharmaceuticals. ACC is the second largest producer of Lysate and one of four licensed by the FDA. Lysate was discovered in 1971, replacing chemical test on animals such as rabbits (Fraser, 2001). When horseshoe crabs are bled

for lysate, 30% of their blood is extracted (Sargent, 2000). Although the biomedical industry is required to return the animals after use reports show a 10% death rate from harvest to release (Writer, 2000). Horseshoe crab blood, which is blue due to its copper base, can sell for up to \$5,000 a quart (Sargent, 2000). ACC, which is only one of the companies utilizing horseshoe crabs for lysate, harvests around 250,000 horseshoe crabs per year (Writer, 2000). Although surviving horseshoe crabs are released, they are not necessarily released in the same area from where they were taken.

Since the horseshoe crab is not considered fish or shellfish they are classified as wildlife under park jurisdiction (Writer, 2000). With such classifications there is little regulation on the harvest of horseshoe crabs. Along the East Coast, each state has its own regulation on harvest and commercial sales, although there are no regulations for federal waters (ASMFC, 1998). As the largest breeding ground for horseshoe crabs, Delaware was the first state to place regulations on their harvest. The first regulation in the state of Massachusetts was implemented in October 1999, when Monomoy Bay was first closed to horseshoe crab fishing. Heading into the 1999 harvest season Massachusetts only regulated the commercial sale of horseshoe crabs by requiring a license, meanwhile not regulating the harvest at all.

The one regulation that Massachusetts has had in place for years is that license is required to harvest horseshoe crabs. During the 1999 season, only 95 licenses were being used in Massachusetts, with a limit of 200 pots per fisherman. As for federal regulations, the only FDA requirements of the biomedical industry are that animals used must be returned to the ocean alive. Prior to the 2000 harvest season the Atlantic States Marine Fisheries Commission called for a 25% reduction in harvest number but did not apply to

the biomedical industry (ASMFC, 2000). Since regulations are based mainly on a state-by-state basis, the Massachusetts Audubon Society attempts to regulate interstate trade of horseshoe crabs.

The change in populations of any species has an impact not only on that species but also all species with an ecosystem. “The loss of biodiversity would result in the loss of ecosystem functions and the many services they provide to society.” (Duarte, 2000) A species’ contribution to the ecosystem and useful resources are correlated to abundance of the population. Since a species is related to an ecosystem, the conservation of biodiversity should not be directed to a specific species but to the overall ecosystem and all species involved (Duarte, 2000).

The common indicators for population status are numbers, sex and age ratios, all of which are poorly understood in the horseshoe crab populations on Cape Cod. The release of horseshoe crabs to “random sites”, instead of the sites of harvest, after bleeding causes the mixing of populations and increases the possibility of transferring disease and the disruption of gene pools. Such release procedures have an unknown effect on the overall population. “We don’t have a clue what happens to these crabs once they’re put back into the environment” says Jamie Geiger, assistant regional director for fisheries for fish and wildlife. The improper release of harvested horseshoe crabs may to be blamed for reports that large numbers of females have been released in Pleasant Bay that were originally captured in Narragansett Bay. If these reports were true, they would be violations of state law prohibiting the release of out-of-state predators into state waters and ultimately changing the surrounding ecosystem (Olson, 2000).

The horseshoe crab has a great impact on the overall marine food chain. Although no as much of an issue on Cape Cod as it is in Delaware Bay, the horseshoe crab egg is an important food source for many shore birds that feed on the freshly laid eggs as the birds migrate from South America to the Arctic. Shore bird species such as the Red knot (*Calidris canutus*), sanderling (*Calidris alba*), ruddy turnstone (*Arenaria interpres*) and the semipalmated sandpiper (*Calidris pusilla*) along with many species of juvenile fishes feed on the horseshoe crab eggs. The loggerhead sea turtle, which is threatened itself, also depends on the horseshoe crab for food (USGS, 2000).

Due to slow maturing, and ease of harvest, populations are highly sensitive to harvest pressures (ASMFC, 1998). Since the horseshoe crab requires 9 to 11 years to mature the harvest of juvenile horseshoe crabs may cause a drop in population numbers. The fact that female horseshoe crabs are significantly larger in size than males, bait harvesters prefer harvesting females, which could cause a drop in females and reduce spawning rates. Such changes in local populations will alter the gene pool of that population and result in a decrease in genetic diversity. Over periods of time there will be the loss of genetic diversity, which is also influenced by reduction of spawning population, such as a large change in the gender ratio (Auster, 2000).

One possible solution to reduce harvest numbers is that of alternative methods for both the biomedical and bait industries. Attempts at alternative baits, such as synthetics and fish and clam waste mixtures have proved to be unsuccessful heading into the 2000 season. It has been estimated that bait bags could reduce the use of horseshoe crabs by up to 50%, along with reducing bait lost to non-targeted species. Bait bags for conch can consist of surf clam waste and horseshoe crab components, such as hemolymph

byproducts from the biomedical industry. A bait extender using isolated compounds from the horseshoe crabs can be used for eel bait (O'Connell et al, 2000). The biomedical industry has researched the possibility of synthetic or chemical replacements for lysate with not success.

Currently there are many possible threats to the horseshoe crab population. These threats come from nature and from humans. The human threats can be regulated, where as threats from other species are difficult to assess and control. Since the biomedical and bait industries both result in the loss of some number of horseshoe crabs regulations on the uses and harvest can curb the over all effects on the populations. Another threat posed by humans comes from the use of mobile bottom fishing gear, which may capture horseshoe crabs as unintentional by-catch. Mobile bottom fishing gear also has a negative effect on the physical structures on the ocean bottom, and chemical exchanges between sediment and water in the horseshoe crab's habitat. (DeAlteris et al, 2000) Although there are no single obvious predators in nature the threat still remains. One group of organisms that does directly effect the horseshoe crab population is migrating shore birds. Many species of shore birds feed on freshly laid horseshoe crab eggs. This threat is not as serious of an issue on Cape Cod as it is in locations such as Delaware Bay. As for environmental threats, shoreline erosion has caused a reduction in spawning habitat for horseshoe crabs. Development of structures and infrastructures cause degradation, while structures, such as jetties reduce the erosion and create better spawning habitats for the horseshoe crab (ASMFC, 1998).

The horseshoe crab population on Cape Cod may indeed be decreasing, but that will be determined by the environmental and government agencies involved. Until the

point where regulations are implemented, it is the public's actions which will help conserve the horseshoe crabs. Without the knowledge and understanding of possible threats to the horseshoe crab population no actions will be taken to protect the resource. The support for regulations on commercial harvest will come from the public. In order to assess the public's awareness and concern with the issues surrounding commercial horseshoe crab use a questionnaire was administered. Questions found on this questionnaire dealt with the commercial uses of, decrease in population numbers, and future actions to protect the horseshoe crab on Cape Cod.

Methodology

Surveys are used to measure four aspects of a population: the prevalence of attitudes, beliefs and behavior; change over time; differences within a group; and the propositions of the source of the attitudes, beliefs and behavior (Weisberg, pp 25-27). There are a number of survey platforms, one of which was used in the study is the questionnaire. Through the use of the questionnaire, data were obtained to review the opinion of the public relating to the horseshoe crab population on Cape Cod. Questions on the questionnaire were aimed to determine the awareness and concern about the horseshoe crab population along with the options for commercial uses and possible changes to state harvest regulations.

The questionnaire used in this study was administered to a sample population of subjects with some connection to Cape Cod, either residents or visitors. This population was targeted since the horseshoe crab population should most directly affect those in close contact with the animals. Although the goal was to have wide range of respondents,

due to the placement of questionnaires for random responses, an unintentional sampling bias of subjects who reside on Cape Cod with an interest in the topic formed. Questions contained in a questionnaire were in one of two forms, that of closed-ended questions or opened-ended questions. Opened-ended questions allow for the subject to respond in any form they choose. Closed-ended questions on the other hand call for a response determined by the questionnaire design (Weisberg, pp 77-79). On the questionnaire closed-ended questions use rating scales to access responses, the scale used was a 1-5 scale. Questions were be presented in a simple manner to assist in accessibility. Using closed-ended questions provided unbiased responses and reduced the complexity of questions and responses.

The order of questions on the questionnaire was set in a manner which provided a smooth flow, and in which earlier questions do not influence following questions (Weisberg, p. 101). Each question on the questionnaire was designed to provide a response that was reliable and valid (Weisberg, pp. 94-95).

In order to show that the responses of each subject were reliable, question 1, which asked the respondent to identify a picture of a horseshoe crab, was designed to show that the subject had the basic knowledge needed to answer the following questions. The demographics for this questionnaire are found on questions 2-4. These questions asked for respondent's gender, age, and whether or not they were residents of Cape Cod. Although normally found at the end of a questionnaire, these questions were placed at the beginning for format reasons. Questions 5-14 and 16 on this questionnaire are in a closed-ended format with a 5-point scale. These question were all designed to gain the over all opinion of the pubic on certain topics regarding the uses of the Horseshoe crab,

with the exception of 6 and 7. Questions 6 and 7 were designed to obtain data that could show if the public noticed a decrease in the Horseshoe crab population without directly asking. This was accomplished by asking first, “How often, during a typically year, were you on the shore prior to the spring of 2000?” and “During that time how often did you see horseshoe crabs?”. Follow was the same question, pertaining to the time spent on the shore during the 2000 season. Question 15 is the one question that is somewhat opened-ended. This question uses the idea of rank orders to assess the importance of proposed harvest regulation. The respondent was asked to rank horseshoe crab sex, age, size, and limits during spawning season in order of most to least important. The final question asked the respondent to agree or disagree with the statement, “I am concerned about horseshoe crab population on Cape Cod and believe biomedical and bait harvest regulations should be improved.” This question provided insight into the overall view on the horseshoe crabs population issue as a whole, where as questions 5-14 all looked into different aspects of the issue.

In order to sample the population in a non-aggressive manner, questionnaires were placed at three public places on Cape Cod. Two of the places were local town halls in Eastham and Orleans. These locations were used with the understanding that there would be a large response from Cape Cod residents. The third location was the Wellfleet Audubon Society. This location was to receive responses from visitors to Cape Cod. It was also understood that this group might include subjects that were environmentally aware and may respond accordingly. At each of the locations 150 copies of the questionnaire were left out in clear sight, in close proximity to the main reception areas.

After two months, mid-September to mid-November the questionnaire were collected. Since there was a mailing address on the questionnaire a small number of surveys were mailed over the course of the two months. Over the two months a total of 45 questionnaires were collected.

In order to increase the number of non-residents of Cape Cod the questionnaire was placed at <http://www.wpi.edu/~nolanlll/questionnaire.htm>. The web site was linked to an email account that collected the responses in a numeric code. Due to a lack of publicity there were few responses to the web-based questionnaire. Due to email service failure, the results from the web based questionnaire were not excisable, and there for were not use for any analysis.

The data collected from the questionnaires was entered into a database for analysis. SPSS 10.1 for Windows (2000 SPSS INC.) was used for the analysis of the data. Non-parametric tests were used throughout the analysis of the questionnaire. Although most questions were answered using a 5-point scale, responses were often changed to a 2-point for analysis. When this was done, responses of 1 and 2 were pooled and coded as the same response, 4 and 5 were coded as the same response, and a response of 3 was omitted as a neutral response.

Results

In order to examine public understanding of the commercial uses of horseshoe crabs two tests were used. The first showed that there was no difference in level of understanding between residents of Cape Cod and non-residents. The number of respondents which reside on Cape Cod out numbered the non-residents by 37 to 8, which

may have affected the significance of this test. With the possibility that a lack of available information may ultimately affect what the public understands, the results were tested for such a correlation. The questions used were 5a, “How well do you understand the harvest and commercial use of horseshoe crabs?” and 5b, “How well has information relating to horseshoe crabs been made available to you?”. The responses from these displayed a direct correlation between the available information and the respondent’s understanding of the commercial uses of horseshoe crabs. (Spearman correlation test, correlation value=0.742, $p < 0.001$)

In regards to the possible decline of the horseshoe crab population on Cape Cod, the question of the seriousness of the issue was addressed. When asked about the seriousness of the issues regarding the horseshoe crab population on Cape Cod a significantly larger group of respondents described the issue as serious to extremely serious. (Q: 5c) (Goodness of fit, $\chi^2 = 15.7$, $df = 1$, $p < 0.01$).

In order to evaluate the population decline of horseshoe crabs on Cape Cod the respondents were asked to agree with the idea that the population was indeed decreasing. The results showed that 94% of the respondents agreed in noticing a decrease in population. Of these Respondents who had noticed a population decrease of horseshoe crabs also felt that this population decrease was an issue of concern. (Fisher’s exact test, $N = 25$, $\chi^2 = 25$, $df = 1$, $p < 0.04$)

With such a high percent of respondents noticing a decrease in horseshoe crab population, the responses to questions 7 and 8 were used to assess the frequency of sightings of horseshoe crabs on the shore of Cape Cod before the 2000 season verse the 2000 season. These questions were each two part questions, which first asked for the

frequency of time on Cape Cod shores and then asked the frequency of horseshoe crabs sightings during the time spent on the shore. Question 7 asked for times prior to the 2000 season, and question 8 asked for responses in regards to the 2000 season. Although there was a slightly higher response showing that the frequency of sighting prior to the 2000 season were greater than those during the 2000 season this difference was not significant.

Whether or not the commercial uses of horseshoe crabs are sociologically acceptable was addressed through questions 9a and 9b. Question 9 asked for the respondent to agree or disagree with two statements, A, "It is an acceptable commercial use to harvest horseshoe crabs for bait", and B, "it is an acceptable commercial use to harvest horseshoe crabs for biomedical uses". The majority, 27 of 32, of respondents do agree that the biomedical industry is an acceptable use for horseshoe crabs, whereas less than 10% agreed with the bait industry (fig 1). The responses were skewed towards biomedical uses being more acceptable than the uses for bait; there were no responses, however, that would indicate total approval for current commercial uses by either the biomedical or bait industries.

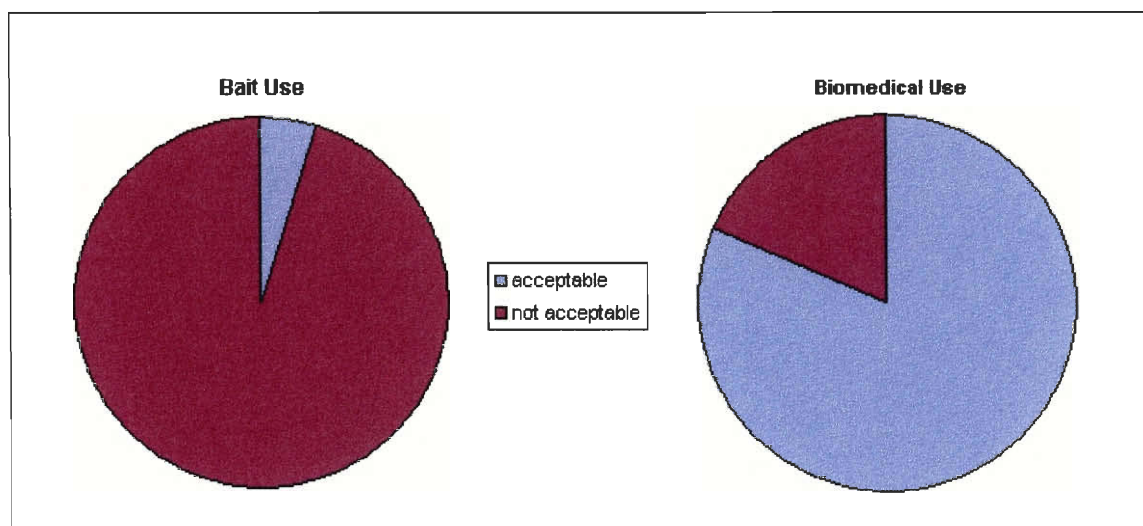


Figure 1: Acceptance of commercial Horseshoe crab uses. The results of questions 9a and 9b. Graph displays those responses that either believed that the commercial uses were acceptable or not, all neutral responses were excluded.

Since there is a lack of regulations and by-laws regarding commercial uses of horseshoe crabs in the state of Massachusetts, the public's opinion of possible regulations and by-laws were studied as well. The first possibility questioned was the requirement of research in the biomedical and bait industry into alternative methods. There were no statistically significant trends found in either case, however over 90% of respondents agreed that there should be required research prior to the next harvest season in both industries.

As far as regulation on the harvest of horseshoe crabs the respondents were asked to rank four possible regulation requirements from most to least important. The proposed regulations were that of age, size, sex, and regulations on harvest during spawning season. The results showed that regulations during spawning season were ranked most important. There were no differences statically among the other three regulations (fig 2).

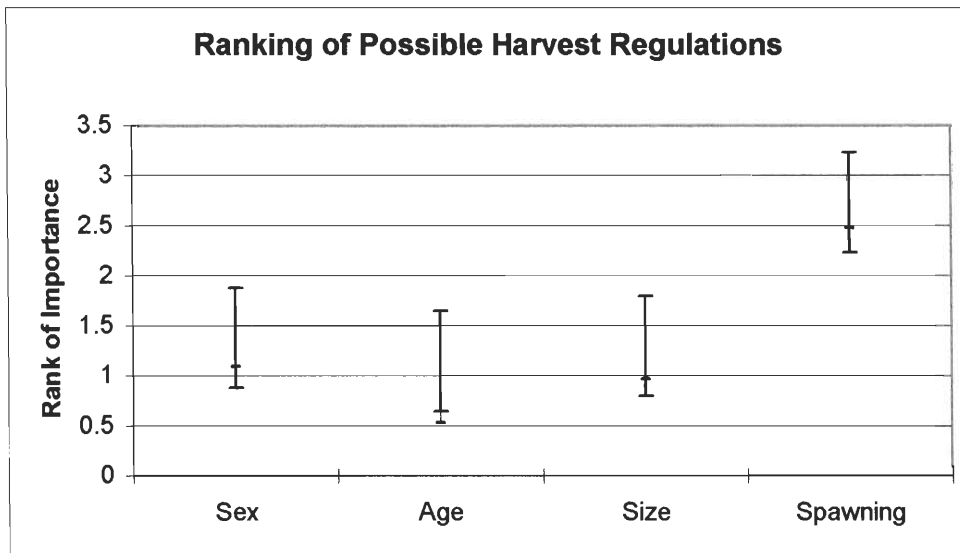


Figure 2: Ranking of possible harvest regulations. Most important (3) to least important (0) results from question 15. For each regulation the bar represents the upper and lower bounds of the mean within a 95% confidence interval.

The final question consolidated all of the questions on the questionnaire and asked if the respondent was concerned with the horseshoe crab population and believed there should be harvest regulations should be improved. The majority, 76%, were concerned and agreed that the regulations should be improved (fig 3).

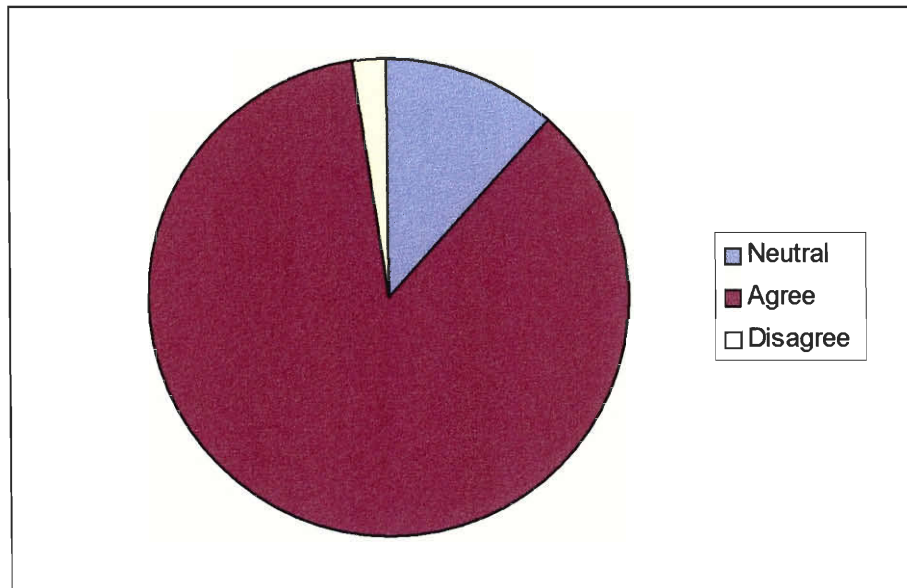


Figure 3: Agreement with the statement, “I am concerned about the horseshoe crab population on Cape Cod and believe biomedical and bait harvest regulation should be improved”.

Discussion

The results obtained through the use of the questionnaire can be used to gain insight into public opinion, but due to the sample population used should be taken with caution and understanding that all responses may be biased. Even with this fact of skewed respondents there were a number of trends worth discussing.

The questions regarding the public’s knowledge and understanding showed that the availability of information would directly affect the understanding about the issue. With this known, one way of promoting awareness of the topics concerning the horseshoe

crab on Cape Cod may be to present the public with the information more frequently or from a different angle. Although the topics of concern are addressed in local newspapers, there seems to be a concentration on the legal problem rather than the information concerning the uses and possible threats on the horseshoe crab. Since it was seen that concern was positively correlated with the respondents understanding, if public concern is to be elevated along with awareness, the information must be presented in a more efficient manner.

When the public's concern was looked at with respect to observed decrease in horseshoe crab population the correlation was significant. Since a decreasing population would spark a concern in the public's eye, the need for population studies, such as the ones performed since 2000 in many areas of Cape Cod, may be necessary to provide the information needed to invoke concern. Even with such a high percent of respondents noticing a decrease in numbers, actual data presented to the public would increase awareness and concern. The over use of any natural resource may present a problem over time. If horseshoe crabs are harvested at a rate greater than that need to reproduce after time the population may begin to decrease, if not already. Studies to assess the population status should provide the knowledge need to determine the need for precautionary actions.

It was obvious from the results that horseshoe crab use in the biomedical industry is accepted, but there is room for improvement. Even if not legally required, research should be constantly conducted to look into alternative methods. If by chance a product were created that could substitute for lysate, there would be that much less stress put on the horseshoe crab population on Cape Cod. As for the bait industry, there is an urgent

need for alternative methods. No population can endure such losses to population numbers without some consequences. Once again, the discovery or development of alternative bait would not only relieve stress, but also may create a bait source that is more obtainable and possibly more cost efficient.

There are many ways that the horseshoe crab population can be protected and conserved without eliminating commercial harvest. Regulations that would limit the harvest of horseshoe crabs during spawning, ranked first by the respondents, would assist in keeping the population at normal numbers. Also, if the female horseshoe crab population was smaller than the males, regulations on both sex and size may be useful to keep the population growing.

Until the horseshoe crab population on Cape Cod is studied the status will not be known. For now the harvest of horseshoe crabs should be looked at to assure that all precautions are taken to avoid any dramatic change in population. The results from the surveys showed that there is a concern about the population and commercial uses of the horseshoe crabs on Cape Cod. The biomedical industry is an accepted use of horseshoe crabs, but should still look into possible alternatives, where as the bait industry should be seeking alternatives to reduce the use of horseshoe crabs.

The survey provided insight into the publics views on the commercial harvesting of horseshoe crabs and possible actions that should be taken. The concern is present and calls for further studies and actions to protect the Horseshoe crab population on Cape Cod. Along with population studies, further surveys could provide a better assessment of the sociological concerns and opinions. Future surveys should attempt to target a wider range of respondents to avoid the bias seen through out this study.

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