

## **Delaware Bay Horseshoe Crab Millennium Survey**

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### **Abstract**

The 11th annual Delaware Bay Spawning Survey was conducted during the 2000 spawning season. Horseshoe crabs were enumerated on twelve dates surrounding the moon phases in May and June. Eleven beaches in both New Jersey and Delaware were surveyed.

Three peaks were found in New Jersey and Delaware on May 6th (2 days after the new moon), May 18th (full moon) and June 4th (2 days after new moon) with the maximum peak estimate occurring on May 18th. Peak numbers were similar to the two peak 1999 estimates both in New Jersey and Delaware. The maximum peak estimate was 272,770 which included surveys of 22 beaches and is much lower than previous years' estimates. The low estimate may be due in part to the beaches surveyed. When a comparison of the estimates during the 12 survey dates from the same 6 "fixed" beaches in Delaware and New Jersey was made, the 2000 total spawner estimate was comparable to 1999.

The male to female ratio during the 12 survey dates was 3.67 during the 2000 spawning season. The ratio throughout the years (1990-1999) has been variable but the overall trend in the male to female ratio is increasing.

### **Introduction**

The Atlantic States Marine Fisheries Commission (ASMFC) Horseshoe Crab Management Plan adopted in October 1998 included a yearly spawning survey to be conducted along the shores of Delaware Bay. Since a Delaware Bay volunteer spawning survey has existed since 1990, the ASMFC opted for continuing this volunteer based survey with additional statistical guidance from the United States Geological Service (USGS). The survey was then modified to incorporate the statistical needs for the ASMFC horseshoe crab monitoring program. The modified survey was successfully implemented in 1999. The 2000 survey was conducted in the same manner as the 1999 survey with only a few minor changes.

### **Methods**

Horseshoe crabs were counted along the Delaware and New Jersey beaches of Delaware Bay. Twelve beaches (6 beaches on each side of the Bay) are "fixed" beaches, meaning they will be surveyed every year. The 12 beaches are North Cape May, Cape Shore Lab (Green Creek), Highs, Reeds, Gandys and Seabreeze in New Jersey and Primehook, Fowler, Big Stone,

North Bowers, Kitts Hummock and Woodland in Delaware. Eight additional beaches were randomly selected for the 2000 survey. These additional beaches were Higbees, Townbank, Pierces Point and Kimbles for New Jersey and Broadkill, Bennetts Pier, South Bowers and Pickering in Delaware. East Point, NJ and Slaughter Beach, DE were also surveyed, for a total of 11 beaches surveyed on the New Jersey side and the Delaware side.

The survey was conducted on 12 dates during the horseshoe crab's spawning season, which occurs in May and June along the Delaware Bay. These dates were in groups of three: two days before the new or full moon, the day of the moon and two days after the new or full moon. No additional dates were surveyed during the 2000 survey. In 1999, additional dates or "off" dates were scheduled, but after reviewing the data, the USGS determined that surveying around the moons provided the statistical validity needed for the survey.

Horseshoe crabs were enumerated by using a 1 meter quadrat. The number of male and female horseshoe crabs within each quadrat were counted. The quadrat was randomly placed 100 times along the water's edge, parallel to the beach. Each time the survey was conducted a coin was flipped. Depending if the coin was heads or tails, the count would begin on the north or south end of the counting area.

The survey was performed by approximately 281 trained volunteers. Many of the volunteers have participated in the survey since its inception. Training workshops were given in Delaware and New Jersey prior to the survey. The survey's printed materials and the quadrats were distributed at the workshop.

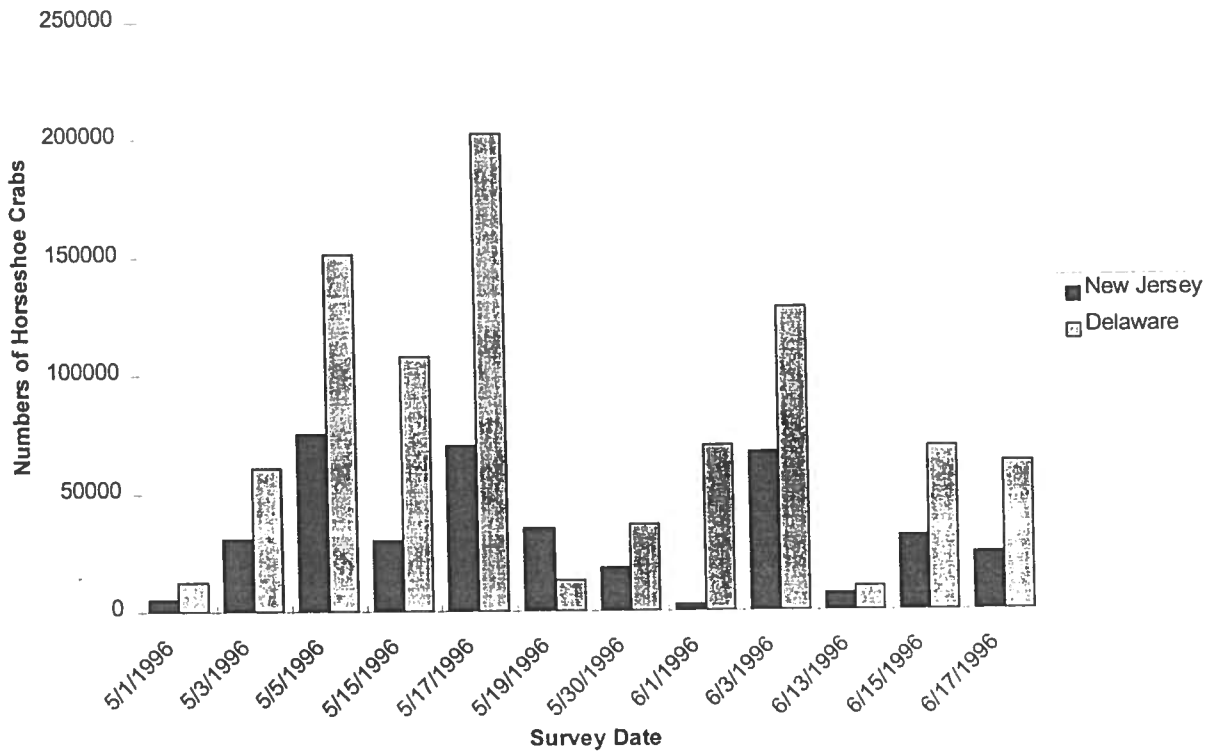
The counts were conducted during the night time high tide. Counts began when the tide was just starting to recede. The times of the counts this year were similar to last year, falling in the evening hours, 7:00-10:00PM at the reference station, Breakwater Harbor, DE. The time of arrival, the start time and end time of the survey was recorded. Data collected also included weather conditions, wave height and the relative amount of light.

## Results

Table 1-A and table 1-B (see attached) and Figure 1 summarize the survey data during the year 2000. The table lists the beaches surveyed, the density of horseshoe crabs and the estimated number of horseshoe crabs on each of the twelve dates. Three peaks were identified in each state during the survey period. The peaks on each side were on the same dates, May 6th, May 18th and June 4th. The maximum peak occurred during the full moon date on May 18th.

Weather plays a critical role, greatly affecting the spawning activity of the horseshoe crabs. Weather conditions during the 2000 spawning season were favorable for spawning with the exception of June 2nd (the new moon date). A severe thunderstorm occurred during the night high tide on June 2nd adversely affecting both volunteers and horseshoe crabs. Many of the volunteers could not conduct the count due to the dangerous lightening and high amplitude waves kept the horseshoe crabs from spawning in great numbers.

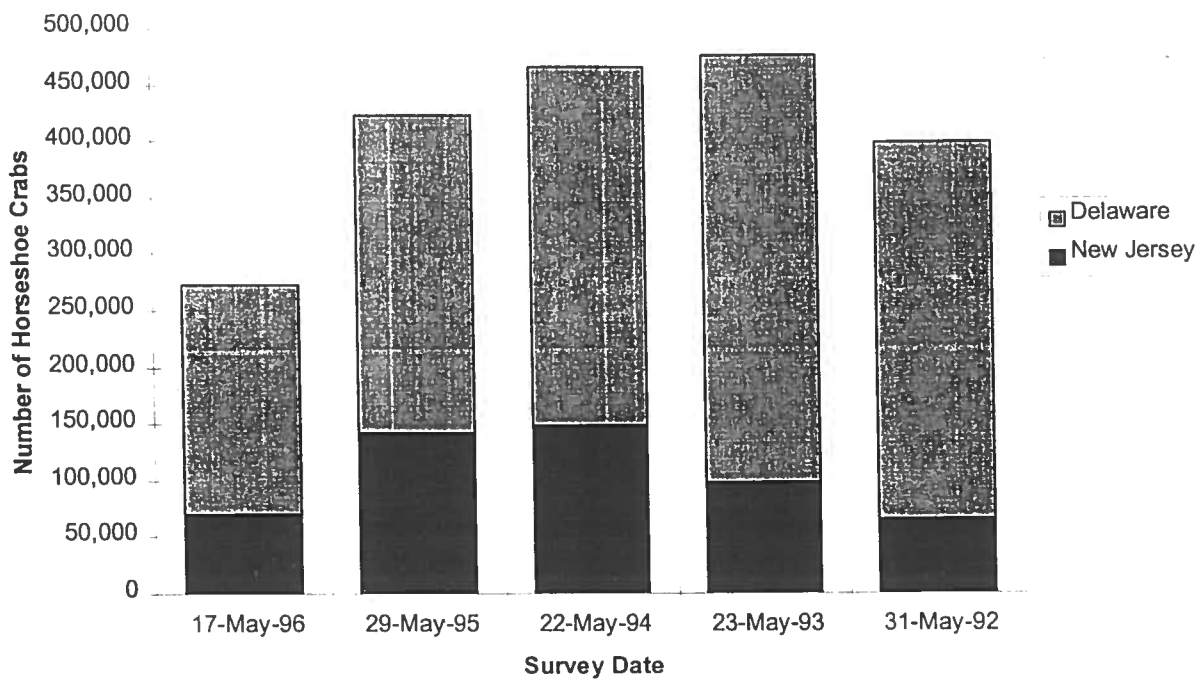
Figure 1. Spawning Estimates for New Jersey and Delaware During 2000 Survey



The South Cape Shore lab beach supported the majority of the spawners from all the New Jersey beaches, 37%. The highest density of horseshoe crabs was recorded on Highs Beach on May 6th (2 days after the new moon) with a density of 15.91. In Delaware, 25% of the spawners were found on Slaughter Beach. The highest density of crabs in Delaware was 27.21 on Pickering Beach on May 18th (full moon).

The maximum peak estimate for 2000 was 272,770 during the full moon date, May 18th. This estimate is the total of the estimates on 11 beaches both in New Jersey and Delaware. In Delaware, 202,477 spawners were estimated during the May 18th, 2000 peak count and the total estimate for New Jersey was 70,293 spawners. This year's estimate is much lower than previous years' estimates Figure 2; (Table 2 see attached). It was equivalent, however, to the numbers reported for the 1977 peak spawning (= 222,000 males and 51,000 females) by Shuster and Botton (1985).

Figure 2. Horseshoe Crab Estimates



The 2000 estimate from the 6 “fixed” beaches was compared to last year’s estimate both in New Jersey and Delaware (Figure 3. A and B). The estimates from the twelve dates for each beach in 1999 and 2000 were added and the number compared between the two years. In New Jersey, fewer crabs (8%) were found during the 2000 spawning season than during the 1999 season on the “fixed” beaches. During the 1999 counts, 80% of the total number of spawners surrounding the moon phase were found on the 6 New Jersey “fixed” beaches. During the 2000 survey, 65% of the total spawners were found on these beaches.

The estimates from the 6 “fixed” beaches in Delaware were compared between the two years. The numbers remained relatively the same (447,756 in 1999 and 450,114 in 2000). In 1999, 77% of the total number of horseshoe crabs were found on the “fixed” beaches whereas in 2000 only 49% were found on these beaches.

Male to female ratios were calculated based on the actual number of males and females counted during all the survey dates. The overall male to female ratio this year was 3.67, in Delaware the ratio was 3.87 and in New Jersey, 3.38. This ratio is similar to last year’s ratio of 3.72. The ratios from the previous years 1990 -1998 were 2.19, 2.64, 3.13, 2.49, 2.46, 2.74, 2.45, 3.48, and 4.66 respectively.

### Comparison of NJ "Fixed" Beaches

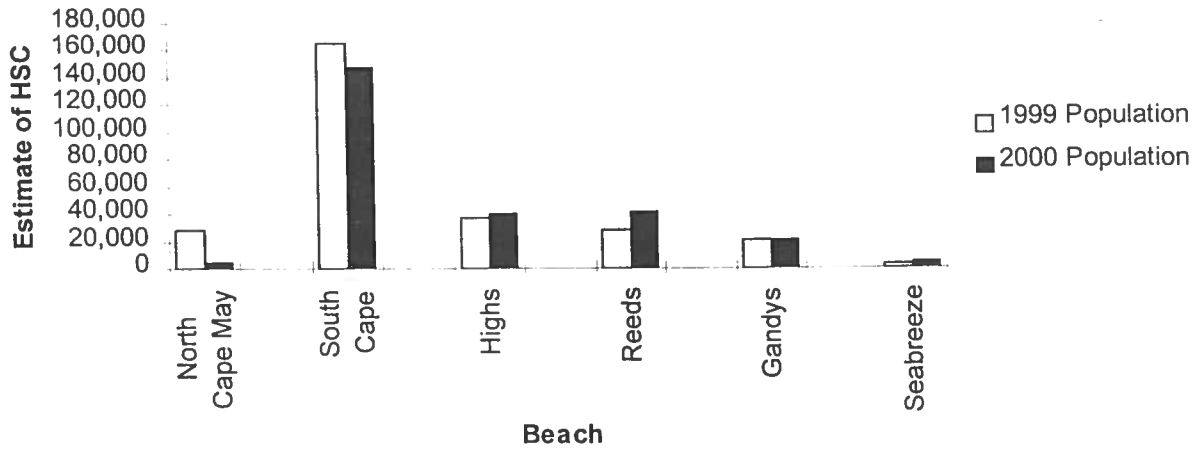


Figure 3A.

### Comparison of DE "Fixed" Beaches

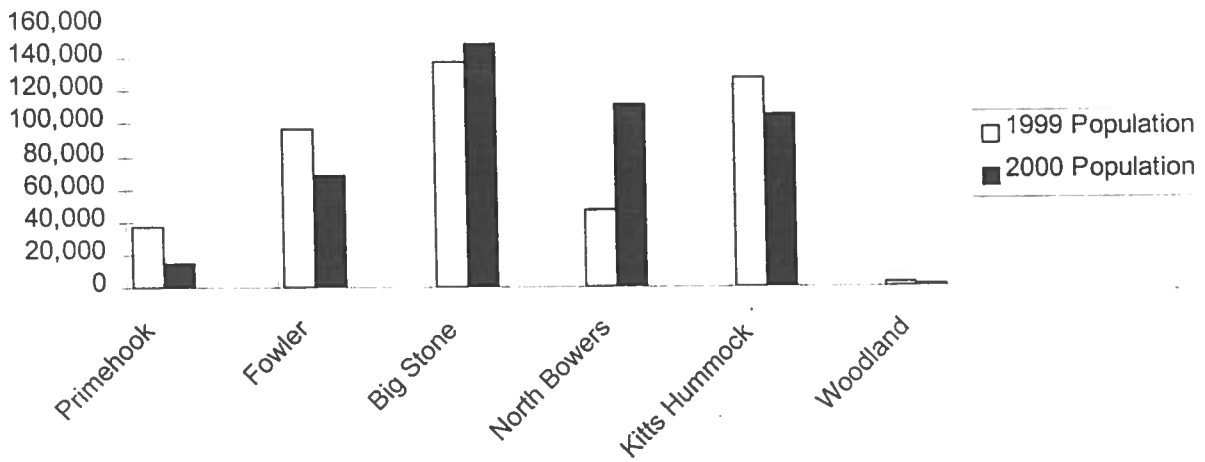


Figure 3B.

## Discussion

The peak numbers were similar to the 1999 counts, with the peaks in New Jersey totaling 75,033, 70,293 and 67,092 on May 6th, May 18th and June 4th respectively and in Delaware, 151,376, 202,477 and 128,583. Last year (1999) only two peaks were identified. This year, the moon phase in May was early, May 4th, whereas last year (1999), the first moon related count started on the 13th of May. This may in part explain the three peaks determined during the 2000 survey. During these three peak days, 53% of the total number of spawners were estimated in New Jersey and 52% were estimated in Delaware.

The 2000 estimate was 272,770 for the 11 beaches surveyed in Delaware and New Jersey. This estimate is much lower than the 1999 estimate of 422,775, which was comprised of estimates from 13 beaches in New Jersey and 8 Delaware beaches. New Jersey's low estimate of 70,293 spawners could be explained in part due to sampling fewer beaches and sampling beaches with less spawning activity. In 1999, three beaches which historically exhibit good spawning activity, Sunray, Fortescue and Moores beaches, were sampled, contributing 40,176 individuals to the total estimate. In the 2000 survey, these three beaches were not surveyed and Higbees beach, a beach with low spawning activity was surveyed.

The Delaware count of May 30th, on the full moon date in 1999 was 281,056 for 9 beaches. Most of the Delaware beaches surveyed in both 1999 and 2000 had lower estimates in 2000. The two additional beaches surveyed in Delaware for the 2000 survey were South Bowers and Bennetts Pier. Big Stone beach, due to its long expanse (7.6 km), was divided for the 2000 spawning survey to ensure that an accurate sample was taken. Therefore, Big Stone beach was split to include a 5.6 km stretch on the south end and a 2.6 km stretch, Bennetts Pier, on the north end.

Comparing the total estimates from the two years poses some problems since not all of the same beaches surveyed, therefore estimates from the 6 "fixed" beaches were compared. The NJ beach estimate was slightly lower, 8%, in 2000 than in 1999. On the Delaware side, the numbers were comparable in 1999 and 2000.

The selection of beaches for surveying is critical for obtaining the peak overall estimate. Horseshoe crabs do not utilize the whole Delaware bay shore similarly. Horseshoe crab spawning activity is greatest along the middle beaches of the bay. The abundance of horseshoe crabs, if plotted along the axis of the Delaware Bay, creates a bell shaped curve. Historically this is the case and during the 11 years of the volunteer spawning survey, this generalization has still proven to be correct. In past years, surveying was scheduled first and foremost on the middle beaches. If additional help was available, the outlying beaches were surveyed. The selection of beaches under the direction of the USGS is random, although beaches are somewhat categorized based on geographic location and historical spawning activity. This random process may not be the best methodology to use for the selection of beaches. Slaughter Beach was not one of the beaches randomly selected for surveying this year, however it produced the the greatest number of spawners.

The beaches were covered more extensively this year with fewer survey dates missed. New Jersey missed 16.7% of the dates in 1999 and 9.7% dates in 2000. In Delaware, 29% of the dates were missed in 1999 and 18% in 2000. The June 2nd date was missed on almost all of the beaches due to a severe thunderstorm. Additional dates were missed because of shortages in volunteer help or last minute emergencies.

Male to female ratios can be instructive in assessing a population. The ratio of males to females during the spawning season usually results in more male spawners than females, which is a behavioral aspect of the horseshoe crab's spawning activity. This ratio is also affected by weather conditions, calm weather allows more males to congregate around a female and rough weather allows just the attached male to hang on. Since 1997, the ratio of males to females has climbed considerably. One factor which negatively affects this ratio is the collection of female horseshoe crabs as the preferred bait for eel and conch (whelk) traps.

### **Conclusion**

The Delaware Bay Spawning Survey continues to be a proven methodology to be an extremely useful tool in estimating the spawning population of horseshoe crabs. The project is supported by many dedicated non-governmental organizations (NGOs) and volunteers who brave the dark, the bugs, the water, the weather and sleepless nights to assist in the count. As always, thank you, thank you, thank you to all the volunteers!!!

### **References**

Shuster, C.N. Jr. and M. L. Botton. 1985. A contribution to the population biology of horseshoe crabs, *Limulus polyphemus* (L.), in Delaware Bay. *Estuaries* 8 (4): 363-372.

**Table 1. 2000 Survey Results - Densities and Estimates**  
**A. New Jersey Beaches (2 pages)**

Moon Phase Date	New -2 2-May	New 4-May	New +2 6-May	Full -2 16-May	Full 18-May	Full +2 20-May
<b>Higbees (0.98 km)</b>						
Density of HSC, Crabs/m	0	0	0.01	0	0	0
Estimated Number of HSC	0	0	10	0	0	0
<b>North Cape May* (3 km)</b>						
Density of HSC, Crabs/m	0	0	0	0	0	0
Estimated Number of HSC	0	0	0	0	0	0
<b>Townbank (2.3 km)</b>						
Density of HSC, Crabs/m	0.10	0.03	2.18	0.89	0.25	1.47
Estimated Number of HSC	230	69	5,014	2,047	575	3,381
<b>South CSL* (2.2 km)</b>						
Density of HSC, Crabs/m	1.39	7.36	14.29	3.72	12.67	6.67
Estimated Number of HSC	3,058	16,192	31,438	8,184	27,874	14,674
<b>Highs* (0.8 km)</b>						
Density of HSC, Crabs/m	0.96	7.06	15.91	2.53	14.57	3.01
Estimated Number of HSC	768	5,648	12,728	2,024	11,656	2,408
<b>Pierces Point (0.7 km)</b>						
Density of HSC, Crabs/m	0.63	4.83	no survey	5.23	10.20	no survey
Estimated Number of HSC	441	3,381	no survey	3,661	7,140	no survey
<b>Kimbles (1 km)</b>						
Density of HSC, Crabs/m	no survey	3.03	10.85	5.20	9.27	4.53
Estimated Number of HSC	no survey	3,030	10,850	5,200	9,270	4,530
<b>Reeds* (1.53 km)</b>						
Density of HSC, Crabs/m	0.56	1.70	7.84	5.49	4.48	3.27
Estimated Number of HSC	857	2,601	11,995	8,400	6,854	5,003
<b>East Point (1 km)</b>						
Density of HSC, Crabs/m	0.00	0.03	1.51	0.32	4.44	2.12
Estimated Number of HSC	0	30	1,510	320	4,440	2,120
<b>Gandys* (1.2 km)</b>						
Density of HSC, Crabs/m	0.00	0.00	1.24	0.02	0.86	1.10
Estimated Number of HSC	0	0	1,488	24	1,032	1,320
<b>Sea Breeze* (1.65 km)</b>						
Density of HSC, Crabs/m	0.00	0.00	0.00	0.28	0.88	0.88
Estimated Number of HSC	0	0	0	462	1,452	1,452
<b>Totals</b>	<b>5,354</b>	<b>30,951</b>	<b>75,033</b>	<b>30,322</b>	<b>70,293</b>	<b>34,888</b>
Moon Phase	New -2	New	New +2	Full -2	Full	Full +2

\* Beaches Surveyed Every Year



**Table 1. 2000 Survey Results - Densities and Estimates**  
**A. New Jersey Beaches (2 pages)**

Moon Phase Date	New -2 31-May	New 2-Jun	New +2 4-Jun	Full -2 14-Jun	Full 16-Jun	Full +2 18-Jun	Totals
<b>Higbees (0.98 km)</b>							
Density of HSC, Crabs/m	0	cancelled	0.14	0	0.38	0.32	
Estimated Number of HSC	0	cancelled	137	0	372	314	833
<b>North Cape May* (3 km)</b>							
Density of HSC, Crabs/m	0.01	cancelled	1.17	0	no survey	0.28	
Estimated Number of HSC	30	cancelled	3,510	0	no survey	840	4,380
<b>Townbank (2.3 km)</b>							
Density of HSC, Crabs/m	0.31	cancelled	7.06	2.13	8.48	6.81	
Estimated Number of HSC	713	cancelled	16,238	4,899	19,504	15,663	68,333
<b>South CSL* (2.2 km)</b>							
Density of HSC, Crabs/m	3.50	1.40	10.04	0.50	3.92	1.58	
Estimated Number of HSC	7,700	3,080	22,088	1,100	8,624	3,476	147,488
<b>Higs* (0.8 km)</b>							
Density of HSC, Crabs/m	3.78	cancelled	1.44	0.34	0.39	0.78	
Estimated Number of HSC	3,024	cancelled	1,152	272	312	624	40,616
<b>Pierces Point (0.7 km)</b>							
Density of HSC, Crabs/m	3.63	cancelled	1.18	0.09	0.31	no survey	
Estimated Number of HSC	2,541	cancelled	826	63	217	no survey	18,270
<b>Kimbles (1 km)</b>							
Density of HSC, Crabs/m	no survey	cancelled	2.20	0.61	0.34	0.15	
Estimated Number of HSC	no survey	cancelled	2,200	610	340	150	36,180
<b>Reeds* (1.53 km)</b>							
Density of HSC, Crabs/m	1.02	cancelled	2.07	0.01	0.36	0.19	
Estimated Number of HSC	1,561	cancelled	3,167	15	551	291	41,295
<b>East Point (1 km)</b>							
Density of HSC, Crabs/m	0.16	cancelled	5.93	0.20	1.32	cancelled	
Estimated Number of HSC	160	cancelled	5,930	200	1,320	cancelled	16,030
<b>Gandys* (1.2 km)</b>							
Density of HSC, Crabs/m	1.58	0.12	9.87	0.35	0.11	2.47	
Estimated Number of HSC	1,896	144	11,844	420	132	2,964	21,264
<b>Sea Breeze* (1.65 km)</b>							
Density of HSC, Crabs/m	0.48	0.00	0.00	no survey	no survey	cancelled	
Estimated Number of HSC	792	0	0	no survey	no survey	cancelled	4,158
							<b>398,847</b>
<b>Totals</b>	<b>18,417</b>	<b>3,224</b>	<b>67,092</b>	<b>7,579</b>	<b>31,372</b>	<b>24,322</b>	<b>398,847</b>
Moon Phase	New -2	New	New +2	Full -2	Full	Full +2	

\* Beaches Surveyed Every Year

**Table 1. 2000 Survey Results - Densities and Estimates**  
**B. Delaware Beaches (2 pages)**

Moon Phase Date	New -2 2-May	New 4-May	New +2 6-May	Full -2 16-May	Full 18-May	Full +2 20-May
<b>Broadkill (1.5 km)</b>						
Density of HSC, Crabs/m	0.08	0.04	0.89	0.08	0.48	0.01
Estimated Number of HSC	120	60	1,335	120	720	15
<b>Primehook* (2.0 km)</b>						
Density of HSC, Crabs/m	0.00	0.68	5.87	0.09	0.43	no survey
Estimated Number of HSC	0	1,360	11,740	180	860	no survey
<b>Fowler* (3 km)</b>						
Density of HSC, Crabs/m	0.00	0.00	8.74	0.00	2.24	0.01
Estimated Number of HSC	0	0	26,220	0	6,720	30
<b>Slaughter (3 km)</b>						
Density of HSC, Crabs/m	2.66	15.09	13.91	15.19	19.84	0.00
Estimated Number of HSC	7,980	45,270	41,730	45,570	59,520	0
<b>Big Stone* (5.0 km)</b>						
Density of HSC, Crabs/m	0.00	0.03	7.56	1.89	7.51	0.01
Estimated Number of HSC	0	150	37,800	9,450	37,550	50
<b>Bennetts Pier (2.6 km)</b>						
Density of HSC, Crabs/m	no survey	no survey	no survey	0.05	0.98	no survey
Estimated Number of HSC	no survey	no survey	no survey	130	2,548	no survey
<b>South Bowers (2.3 km)</b>						
Density of HSC, Crabs/m	no survey	no survey	no survey	6.41	10.65	1.80
Estimated Number of HSC	no survey	no survey	no survey	14,743	24,495	4,140
<b>North Bowers* (1.3 km)</b>						
Density of HSC, Crabs/m	2.20	6.50	7.57	9.61	15.98	6.78
Estimated Number of HSC	2,860	8,450	9,841	12,493	20,774	8,814
<b>Kitts Hummock* (1.0 km)</b>						
Density of HSC, Crabs/m	no survey	3.08	8.81	16.50	21.99	no survey
Estimated Number of HSC	no survey	3,080	8,810	16,500	21,990	no survey
<b>Pickering (1 km)</b>						
Density of HSC, Crabs/m	1.11	2.19	13.89	9.27	27.21	no survey
Estimated Number of HSC	1,110	2,190	13,890	9,270	27,210	no survey
<b>Woodland* (0.5 km)</b>						
Density of HSC, Crabs/m	0.00	0.00	0.02	0.00	0.18	0.00
Estimated Number of HSC	0	0	10	0	90	0
<b>Totals</b>	<b>12,070</b>	<b>60,560</b>	<b>151,376</b>	<b>108,456</b>	<b>202,477</b>	<b>13,049</b>
Moon Phase	New -2	New	New +2	Full -2	Full	Full +2

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\* Beaches Surveyed Every Year

**Table 1. 2000 Survey Results - Densities and Estimates**  
**B. Delaware Beaches (2 pages)**

Moon Phase Date	New -2 31-May	New 2-Jun	New +2 4-Jun	Full -2 14-Jun	Full 16-Jun	Full +2 18-Jun	Totals
<b>Broadkill (1.5 km)</b>							
Density of HSC, Crabs/m	0.00	cancelled	0.34	0.00	0.04	0.32	
Estimated Number of HSC	0	cancelled	510	0	60	480	3,420
<b>Primehook* (2.0 km)</b>							
Density of HSC, Crabs/m	0.19	cancelled	no survey	0.00	0.06	no survey	
Estimated Number of HSC	380	cancelled	no survey	0	120	no survey	14,640
<b>Fowler* (3 km)</b>							
Density of HSC, Crabs/m	0.01	cancelled	4.65	0.00	0.87	6.11	
Estimated Number of HSC	30	cancelled	13,950	0	2,610	18,330	67,890
<b>Slaughter (3 km)</b>							
Density of HSC, Crabs/m	0.54	cancelled	6.51	0.00	3.47	0.00	
Estimated Number of HSC	1,620	cancelled	19,530	0	10,410	0	231,630
<b>Big Stone* (5.0 km)</b>							
Density of HSC, Crabs/m	0.08	6.29	6.40	no survey	no survey	no survey	
Estimated Number of HSC	400	31,450	32,000	no survey	no survey	no survey	148,850
<b>Bennetts Pier (2.6 km)</b>							
Density of HSC, Crabs/m	0.03	cancelled	3.32	no survey	1.20	1.23	
Estimated Number of HSC	78	cancelled	8,632	no survey	3,120	3,198	17,706
<b>South Bowers (2.3 km)</b>							
Density of HSC, Crabs/m	1.26	6.37	4.53	2.28	0.89	no survey	
Estimated Number of HSC	2,898	14,651	10,419	5,244	2,047	no survey	78,637
<b>North Bowers* (1.3 km)</b>							
Density of HSC, Crabs/m	2.61	cancelled	4.24	3.80	18.15	8.89	
Estimated Number of HSC	3,393	cancelled	5,512	4,940	23,595	11,557	112,229
<b>Kitts Hummock* (1.0 km)</b>							
Density of HSC, Crabs/m	10.57	cancelled	18.39	no survey	12.09	13.66	
Estimated Number of HSC	10,570	cancelled	18,390	no survey	12,090	13,660	105,090
<b>Pickering (1 km)</b>							
Density of HSC, Crabs/m	16.92	23.71	19.10	no survey	15.04	15.89	
Estimated Number of HSC	16,920	23,710	19,100	no survey	15,040	15,890	144,330
<b>Woodland* (0.5 km)</b>							
Density of HSC, Crabs/m	0.11	1.40	1.08	0.00	0.00	0.04	
Estimated Number of HSC	55	700	540	0	0	20	1,415
<b>Totals</b>	<b>36,344</b>	<b>70,511</b>	<b>128,583</b>	<b>10,184</b>	<b>69,092</b>	<b>63,135</b>	<b>925,837</b>
Moon Phase	New -2	New	New +2	Full -2	Full	Full +2	

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\* Beaches Surveyed Every Year

Table 2. Comparison of Data on Horseshoe Crabs Spawning on Delaware Bay Shores

	18-May-00	30-May-99	23-May-98	24-May-97	1-Jun-96	18-May-00	30-May-99	23-May-98	24-May-97	1-Jun-96
Estimated Number of HSC During PM Tide	272,770	422,775	464,934	475,810	398,290	New Jersey	141,720	148,444	98,487	65,846
Estimated Number of HSC (PM) - New Jersey Beaches	70,293	141,720	148,444	98,487	65,846	Delaware	281,055	316,490	377,323	332,444
Estimated Number of HSC (PM) - Delaware Beaches	202,477	281,055	316,490	377,323	332,444					
Beaches Surveyed in Delaware	11	9	7	7	7					
Beaches Surveyed in New Jersey	11	13	12	12	10					
Main Spawning Beaches in Delaware	Slaughter Big Stone	Slaughter Big Stone	Slaughter Big Stone	Slaughter Big Stone	Slaughter Big Stone South Bowers					
Main Spawning Beaches in New Jersey	South CSL	Townbank Norburys South CSL	South CSL Reeds Cooks	Norburys South CSL	Norburys South CSL Higgs East Point					

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