The 2016 Delaware Bay Horseshoe Crab Spawning Survey

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Abstract

Spawning counts of horseshoe crabs were scheduled for 25 beaches in New Jersey and Delaware during moon phases in May and June. The schedule included 300 events of which 286 counts were completed with 14 dates cancelled due to no access/flooding (6), weather (5) and no surveyors (3). An additional 60 counts were scheduled on five restored/replenished beaches in New Jersey with five dates canceled due to no access/flooding.

A single day peak estimate of 534,511 horseshoe crabs (279,678 New Jersey, 254,833 Delaware) was reached on June 6th, two days after the new moon. The 2016 peak estimate was second only to 2009 (586,298). The peak estimate for the five additional beaches of 46,396 was also achieved on June 6th. Delaware's peak number occurred on June 4th with 256,536 spawning individuals.

The grand total of seasonal activity for the Delaware Bay was 2,461,704 (1,271,102 New Jersey, 1,190,602 Delaware). The seasonal spawning estimate for Delaware ranked sixth of 18 years in the time series. For the third time since 1999 and the second year in a row, New Jersey's seasonal estimate surpassed Delaware's estimate. New Jersey's estimate was the greatest estimate of the time series surpassing other years, in some cases by double or triple. The seasonal number of horseshoe crabs for the new/restored beaches was estimated to be 186,778.

The average male to female sex ratio of 4.54 (4.41 for New Jersey and 4.68 for Delaware) was slightly higher than last year (4.47) with more males counted in relation to females. The sex ratio of 2016 was the fifth highest of the 18 year time series; only 2007 (4.90), 2008 (4.90), 2009 (5.04) and 2011 (5.36) were greater. A sex ratio of 4.95 for the five additional New Jersey beaches was higher than the 2016 average sex ratio. However, it was much lower than last year's estimate of 6.83 for the additional beaches.

The 2016 sex ratio combined with the high seasonal estimate equated to estimates of 444,351 female spawners and 2,017,353 males. Both the female and the male estimates were the greatest estimates in the time series , 112,464 females and 534,814 males greater than last year's estimates.

Introduction

Since its inception in 1999, our survey has made tremendous strides and is considered the premier method of estimating the spawning population of horseshoe crabs. To continue with this undertaking each year we rely on many eager and energetic groups and volunteers who generously give of their time and their efforts to learn, count, enter and analyze the data acquired from the survey.

Methods

Horseshoe crabs were enumerated in the months of May and June 2016 along the shores of the Delaware Bay. Twenty-five beaches were represented in this year's count (13 along the state of Delaware's coast and 12 along the coast of New Jersey). Delaware's beaches were the standard 13 beaches with counting resumed at Broadkill after last year's restoration and at Fowlers after road repair. The 13 Delaware beaches from north to south were Woodland, Pickering, Kitts Hummock, Ted Harvey Wildlife Management Area (WMA), North Bowers, South Bowers, Bennetts Pier, Big Stone, Slaughter, Fowler, Primehook, Broadkill and Cape Henlopen. New Jersey's 12 beaches included Gandys, Fortescue, Reeds, Kimbles, Pierces Point, Highs, South Cape Shore Lab, Norburys Landing, Villas, Townbank, North Cape May and Higbees.

The counts were taken simultaneously along the 25 beaches during the high tides encompassing the new and full moons on the dates of May 4th, 6th, 8th, 19th, 21st, 23rd and June 2nd, 4th, 6th, 18th, 20th, 22nd. Times of high tides ranged from 7:13pm to 11:05pm with the high tide approaching the northern beaches later into the night. Counts begin with the onset of the changing tide from peak high to beginning ebb on one kilometer of preset beach. Where one contiguous kilometer of beach was not available, adjustments were made to randomly place 100 quadrats within the amount of contiguous beach available. Incomplete counts of less than 100 quadrats were calculated and utilized the same way as complete counts.

Dyers Cove was added to the replenished/restored beaches in New Jersey, resulting in five beaches that were surveyed: north Pierces Point, Cooks, Moores, Thompsons, and Dyers Cove. The survey/beach lengths were 450 meters for North Pierces Point, 350 meters for Cooks Beach, 1000 meters for Moores Beach, 900 meters for Thompsons, and 300 meters for Dyers Cove. The survey/beach lengths were used to calculate the approximate number of horseshoe crabs spawning on these beaches.

Results

Three hundred and sixty surveys were scheduled, 156 in Delaware, 144 in New Jersey, and an additional 60 counts from the five beaches in New Jersey. A total of 341 surveys (95%) were conducted. The 19 cancellations were due to no access/flooding (11), weather (5) and volunteer unavailability (3).

Eleven surveys were canceled due to no access, nine occurred on May 6th in New Jersey at North Cape May, Kimbles, Gandys, North Pierces Point, Cooks, Moores, Thompsons and Dyers Cove, and in Delaware at South Bowers. The remaining two cancellations for no access happened in New Jersey at Gandys Beach on May 4th and 8th. Five weather cancellations were documented, three in Delaware on May 21st at Broadkill, Primehook and Slaughter beaches and two in New Jersey at Reeds Beach on May 21st and at Pierces Point on May 23rd. (Table 1A, 1B, 1C)

Fifteen counts were incomplete, three in Delaware and 12 in New Jersey. Surveys were incomplete if fewer than 100 quadrats were counted, with an exception at Gandys Beach where a complete count is 66 quadrats. The incomplete counts in Delaware were at Big Stone Beach on May 6th (66 quadrats) and June 6th (60 quadrats), and at Broadkill on May 19th (quadrat number not specified). Out of the 12 New Jersey incomplete counts, nine were at Gandys, May 19th (34 quadrats), May 21st (22 quadrats), May 23rd (20 quadrats), June 2nd (27 quadrats), June 4th (25 quadrats), June 6th (33 quadrats), June 18th (31 quadrats), June 20th (32 quadrats) and June 22nd (18 quadrats). The remaining three incomplete counts occurred at Higbees on May 19th (92 quadrats) and at Norburys and North Cape May on May 21st (50 and 25 quadrats respectively).

This year's (2016) peak estimate of spawners along Delaware and New Jersey's shores of 534,511 was the second greatest estimate of the time series with only the 2009 estimate of 586,298 being greater (Table 2). The peak spawning estimate was evenly distributed between New Jersey (52%) and Delaware (48%). Spawning estimates were greatest during four dates, May 19th, May 23rd, June 4th and June 6th, contributing 77% to Delaware's seasonal estimate and 67% to New Jersey's seasonal estimate. In New Jersey, the greatest densities were achieved on May 23rd, 29.65 crabs per meter at South Cape Shore Lab and 31.06 at Highs Beach. In Delaware, the greatest densities were at Pickering on June 2nd of 35.01 crabs per meter and on June 4th of 37.25 crabs per meter. Horseshoe crabs were observed June 2nd, 4th and 6th on the most northern beach in Delaware, Woodland beach. (Table 1A and 1B and Figure 1)

We observe and utilize four levels of spawning activity to categorize the densities for each count. No spawning activity equals 0 crabs, low activity equals less than 5 crabs per meter, moderate activity equals 5 to 10 crabs per meter, and high activity equals greater than 10 crabs per meter. The data is analyzed in percentages since the number of dates and/or beaches may change yearly. As in previous years, the majority of the dates surveyed (56% in DE and 58% in NJ) recorded densities lower than five horseshoe crabs per meter. Similar to 2015, 2016 dates with high densities were numerous with 17% in Delaware and 18% in New Jersey. Only three zero counts were recorded in New Jersey, May 4th at Kimbles, May 8th at Higbees and June 18th at Gandys. Delaware's zero counts were similar to other years (21 dates, 13.5%). Contributing to Delaware's 21 counts, nine were recorded at Woodland beach and six at various beaches on May 4th, the first

count of the season. Few dates (7% in New Jersey and 3% in Delaware) were missed during the 2016 season. (Table 1A and 1B and Table 3 and Figure 3)

The seasonal activity for the New Jersey side of the Bay (1,271,102) was the greatest estimate encountered during the times series. It doubled or in some cases tripled many of the other years' estimates with the exception of the 2009 estimate (811,724) and the 2015 estimate (982,487). Delaware's seasonal estimate (1,190,602) was the sixth highest in the 18 year time series (Table 4 and Figure 4). In 2016, Big Stone (due to its beach expanse), South Bowers and Pickering had the highest estimated number of spawning crabs. In New Jersey, Norburys Landing and South Cape Shore Lab had the highest estimated number of crabs (Table 2).

The peak spawning date for the five additional beaches was June 6th and four dates (May 21st, May 23rd, June 4th and June 6th) contributed to 77% of the seasonal estimate. The greatest densities were achieved on June 6th at Moores of 17.88 crabs per meter and at Thompsons of 22.48. The percentages of dates with zero crabs was 3%, with low activity was 53%, with moderate activity was 13% and with high activity was 22%. The percentage of dates missed was 8%. (Table 1 C and Figure 1C)

The average male to female sex ratio for both shores (4.54) combined with the seasonal estimate equated to 444,351 females spawning along the survey beaches. The number of female spawners was the greatest of all years with only the 2013 estimate of 375,304 a close second. The 2016 estimate surpassed the other years by 103,419 to 205,614 more females. (Table 5 and Figure 5)

The 2016 average sex ratio was 4.54 for the entire Delaware Bay. Sex ratios averaged 3.66 males to one female from the years 1999-2005, then increased to a 4.83 average from the years 2006-2011, and decreased to an average of 4.31 for the past years 2012 to 2016. The average sex ratio for the five additional New Jersey beaches was 4.95, lower than last year's ratio of 6.83 and higher than the average sex ratio of the other surveyed beaches (4.54).

The average sex ratio for each beach was calculated by dividing the total number of males by the total number of females counted during the survey counts (Table 6 and Figure 6). The total number of horseshoe crabs counted was plotted against the sex ratio for each of the 341 dates. Sex ratios seem to be more variable when horseshoe crab numbers are low and as the horseshoe crab numbers increase, the sex ratio becomes more stable (Figure 7).

Sex ratios (males per female) were also categorized according to percentage of occurrence for the 12 New Jersey beaches, the 13 Delaware beaches and the five new/restored New Jersey beaches. The categories were less than 1 (more females were observed than males), 1 male to less than 3 males per female, 3 to less than 5 males per female, 5 to less than 7 males per female and greater than 7 males per female. In New Jersey, more sex ratios (38%) were in the 3 to less than 5 males per

female range compared to last year (26%) and fewer ratios (15%) in the category 5 to 7 males per female than last year (23%). In Delaware, the percentage of sex ratios from 5 to less than 7 males per female increased, 17% compared to 8% in 2015 and ratios from 3 to less than 5 males per female increased slightly, 28% compared to 26% in 2015. The 1 to less than 3 males per female ratios decreased, from 33% to 28% in 2016. For the New Jersey restored/replenished beaches, the percentage of sex ratios greater than 7 males per female was 7%, much less than 31% last year. (Table 7 and Figure 7A).

Observations of tagged horseshoe crabs during the survey counts numbered 348, mainly from New Jersey (285) where tagging took place during the season. The majority of the tagged animals were alive (19 recorded dead) and encountered outside the quadrats (77%). Most of the tagged animals were observed on New Jersey beaches where the majority of the crabs were initially tagged: Kimbles (55), Reeds (31), North Pierces Point (27), Moores (33) and Thompsons (37). (On the back of the Tally Sheets, tag information is recorded: the tag number, the type of tag, if the tagged horseshoe crab was observed in the quadrat or outside and if the crab was dead or alive.) (Table 8)

Discussion

The 2016 horseshoe crab activity was exceptional with a record seasonal estimate of 2,461,704. New Jersey's seasonal estimate was the greatest on record and surpassed Delaware's for the third time in the 18 year time series. The 2016 record numbers were due in part to ideal weather conditions and few counts missed. Only five counts were canceled due to weather and the proportion of dates missed was the lowest of the time series, 10% for this 2016 compared to an average of 28% calculated from the previous years.

Both densities and estimates for each night at each beach are reported in Table 1. The densities are multiplied by the beach length to yield estimates of horseshoe crabs. The length for each beach was established years ago based on United States Geological Survey Topographic maps. Although the shoreline changed over the years, the beach lengths were not adjusted from year to year which enabled comparisons to be made.

The established beach lengths for the Delaware beaches and the New Jersey beaches with two exceptions are comparable to the actual lengths, yielding reasonable estimates. Over the last few years at South Cape Shore Lab and Gandys beach, erosion has decreased the accessible sandy beach area for counting and optimum spawning. At South Cape Shore Lab, the beach length used for extrapolating is 2.2 kilometers and the counting length is 100 meters, and at Gandys, the beach length is 1.2 kilometers and 66 meters is surveyed. Multiplying using the established beach length may overestimate the length of spawning activity, thus overestimating the number of horseshoe crabs.

The 100 meter surveyed section of South Cape Shore Lab also resulted in one of the highest densities. Horseshoe crabs may crowd into the smaller area, increasing the density. Extrapolating using the high density may further inflate the numbers at this beach. Interestingly, the limiting space may also be affecting the sex ratio. The eroding beach area may limit the space females have to bury in but not limit the number of males that surround the female, increasing the ratio of males to females.

Summary

Great numbers of horseshoe crabs and exceptional beach coverage made 2016 a record year. Thirty beaches were covered along the Delaware Bay Shore adding to our knowledge of the Delaware Bay population. Broadkill and Fowlers beaches were surveyed in 2016 after being inaccessible for the prior two annual surveys. The continuation of surveying at these beaches helps bolster the data set, reduces variability, and aids in making historical comparisons between years. The restored/replenished beaches add another facet to the Delaware Bay spawning survey and provide an expanded geographical view of the results.

Acknowledgements

We sound like a "broken record" (assuming everyone knows what a record is) but sincerely thank you for your years of dedication, enthusiasm and support.

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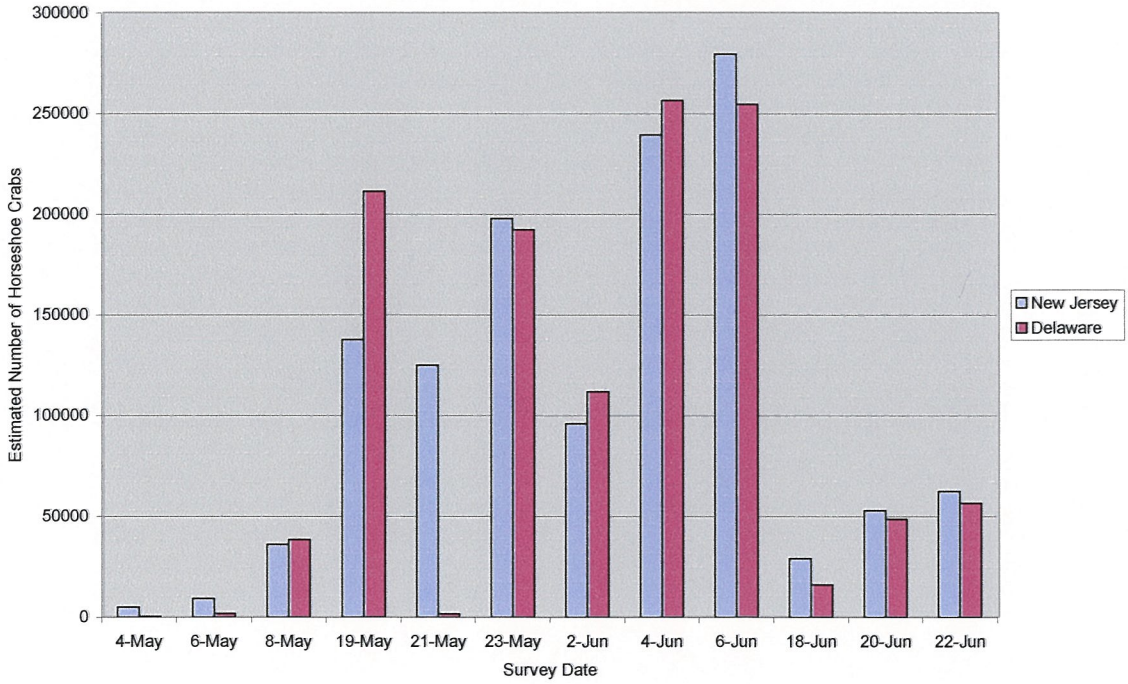

Figure 1C. New Jersey Spawning Estimates During 2016 Survey
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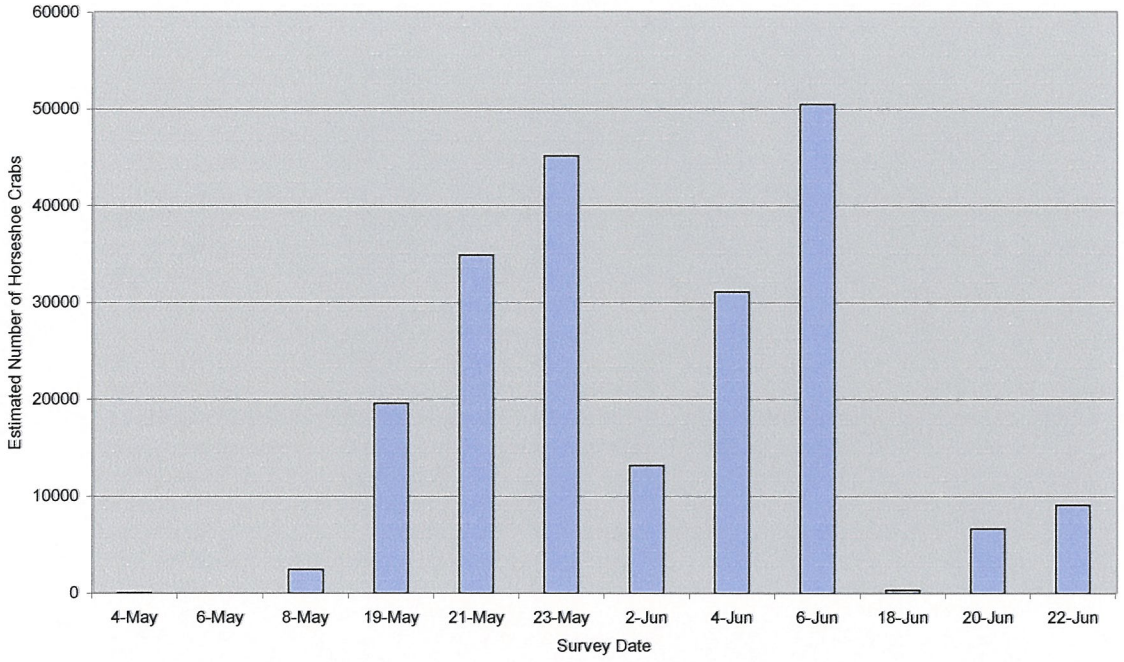

Figure 2. Peak Estimates of Spawning Horseshoe Crabs Years 1999-2016

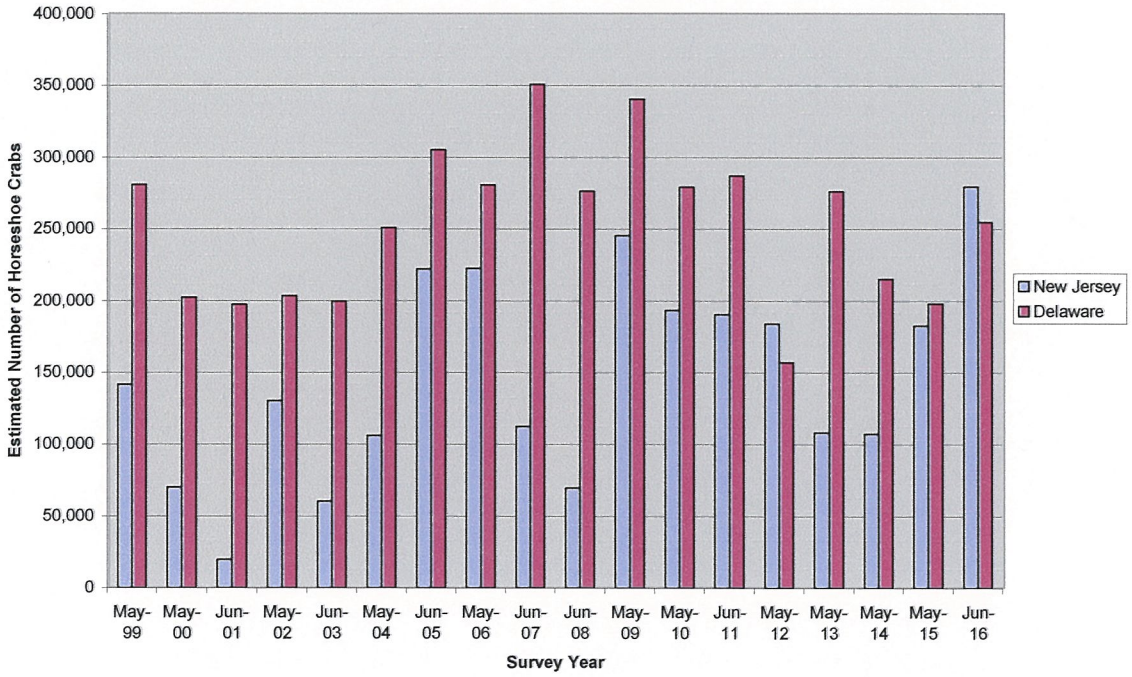

Figure 3. Percentages of Horseshoe Crab Densities by Year 1999-2016

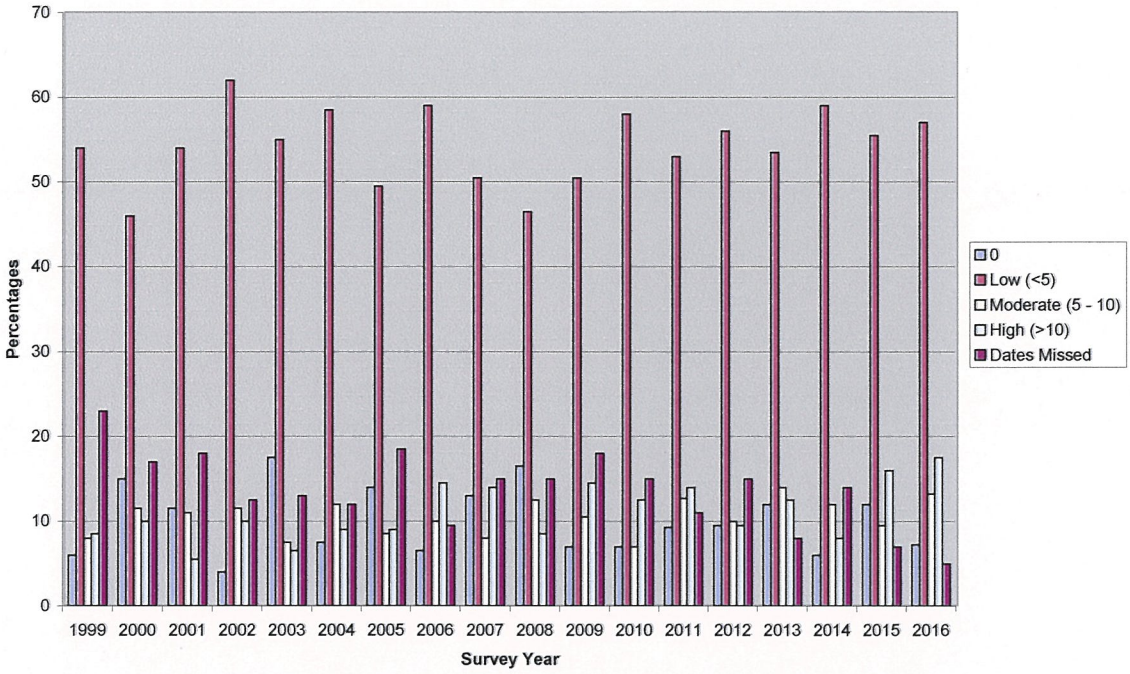

Figure 4. Seasonal Estimates of Horseshoe Crabs 1999-2016

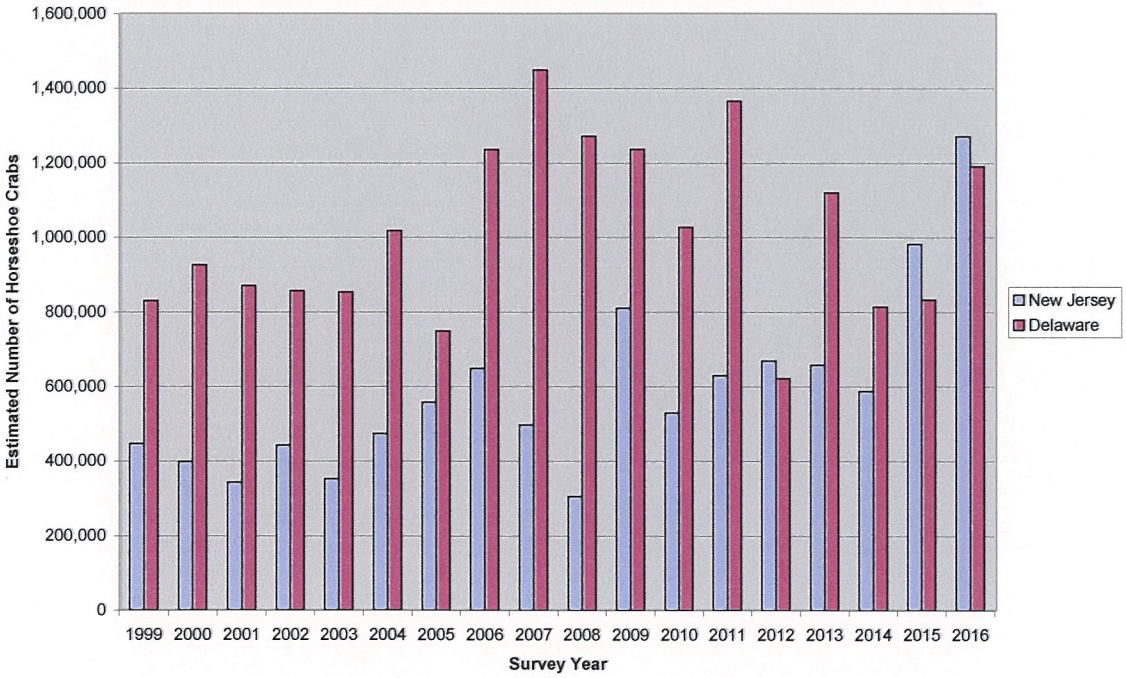

Figure 5. Seasonal Estimates of Male and Female Horseshoe Crabs 1999-2016

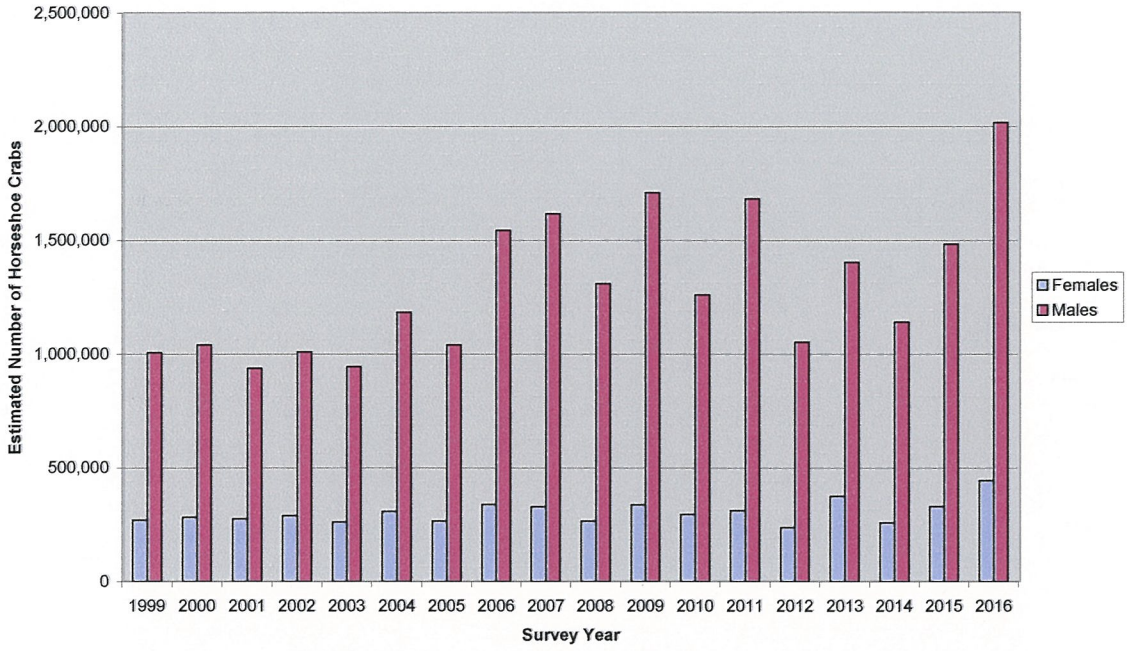

Figure 6. Average Sex Ratios by Beach

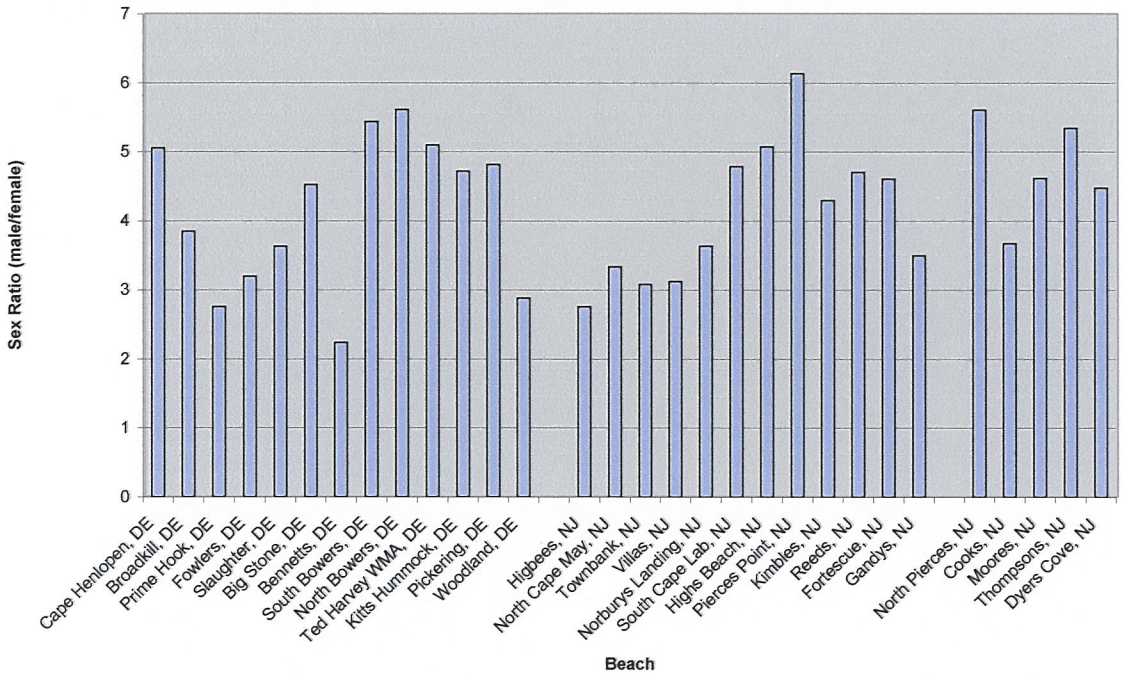

Figure 7. Numbers of Horseshoe Crabs versus Sex Ratios 2016

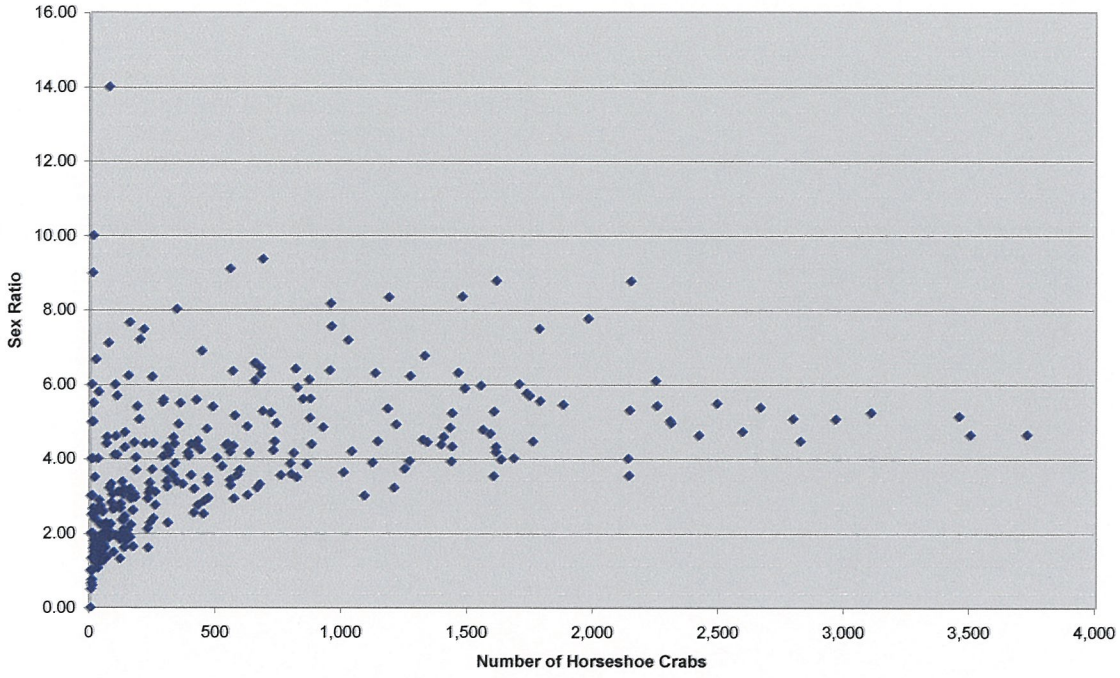

Figure 7A. Sex Ratio Categories 2016

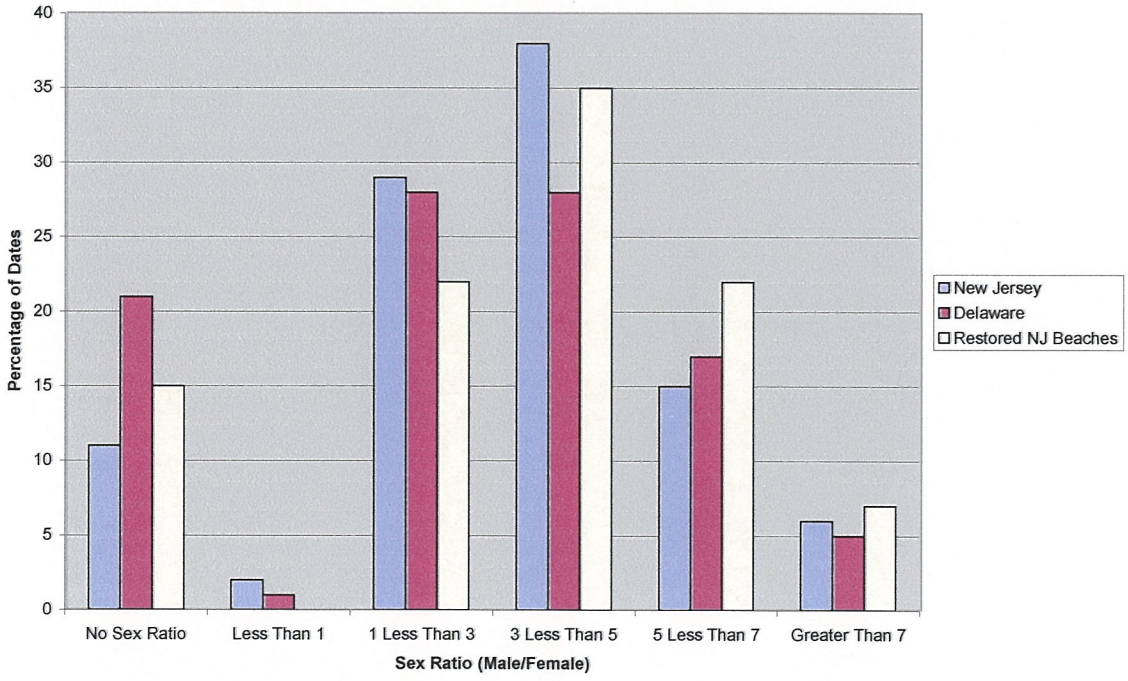

Table 1. 2016 Survey Results- Densities and Estimates

A. New Jersey Beaches (*Indicates beaches surveyed every year)

Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	New-2	New	New+2	Full-2	Full	Full+2	
Date	**4-May**	**6-May**	**8-May**	**19-May**	**21-May**	**23-May**	**2-Jun**	**4-Jun**	**6-Jun**	**18-Jun**	**20-Jun**	**22-Jun**	**Totals**
Higbees * (0.98 km)													
Density of HSC, Crabs/m	0.03	0.01	0.00	0.04	0.07	0.17	0.30	4.28	4.40	0.22	1.36	2.51	
Estimated Number of HSC	29	10	0	39	69	167	294	4,194	4,312	216	1,333	2,460	13,122
North Cape May * (3 km)													
Density of HSC, Crabs/m	0.01	cancel	0.16	0.13	0.16	0.58	1.35	5.83	8.08	0.07	1.22	4.01	
Estimated Number of HSC	30	no access	480	390	480	1,740	4,050	17,490	24,240	210	3,660	12,030	64,800
Townbank (2.3 km)													
Density of HSC, Crabs/m	0.02	0.05	0.43	0.52	0.47	cancel	1.42	14.34	6.73	2.28	2.37	3.42	
Estimated Number of HSC	46	115	989	1,196	1,081	surveyors	3,266	32,982	15,479	5,244	5,451	7,866	73,715
Villas (2 km)													
Density of HSC, Crabs/m	0.17	0.09	2.28	4.12	2.29	4.69	5.70	12.07	16.82	0.66	3.08	3.13	
Estimated Number of HSC	340	180	4,560	8,240	4,580	9,380	11,400	24,140	33,640	1,320	6,160	6,260	110,200
Norburys Landing (2.43 km)													
Density of HSC, Crabs/m	0.10	0.75	4.52	13.21	9.36	16.02	6.23	16.12	21.41	1.48	2.58	2.38	
Estimated Number of HSC	243	1,823	10,984	32,100	22,745	38,929	15,139	39,172	52,026	3,596	6,269	5,783	228,809
South CSL * (2.2 km)													
Density of HSC, Crabs/m	0.83	0.47	4.14	14.37	28.24	29.65	5.67	24.91	27.95	0.44	5.73	4.42	
Estimated Number of HSC	1,826	1,034	9,108	31,614	62,128	65,230	12,474	54,802	61,490	968	12,606	9,724	323,004
Highs * (0.8 km)													
Density of HSC, Crabs/m	1.38	3.04	1.61	16.04	14.29	31.06	6.77	14.87	26.65	0.78	3.91	2.35	
Estimated Number of HSC	1,104	2,432	1,288	12,832	11,432	24,848	5,416	11,896	21,320	624	3,128	1,880	98,200
Pierces Point (0.7 km)													
Density of HSC, Crabs/m	1.33	2.59	5.37	18.79	13.28	cancel	6.29	17.84	21.49	19.80	5.45	4.22	
Estimated Number of HSC	931	1,813	3,759	13,153	9,296	weather	4,403	12,488	15,043	13,860	3,815	2,954	81,515
Kimbles (1 km)													
Density of HSC, Crabs/m	0.00	cancel	1.34	7.94	1.11	10.38	4.30	5.92	8.16	0.39	0.98	cancel	
Estimated Number of HSC	0	no access	1,340	7,940	1,110	10,380	4,300	5,920	8,160	390	980	surveyors	40,520
Reeds * (1.53 km)													
Density of HSC, Crabs/m	0.18	1.07	1.83	7.98	cancel	14.03	3.57	8.69	11.32	cancel	1.33	1.61	
Estimated Number of HSC	275	1,637	2,800	12,209	weather	21,466	5,462	13,296	17,320	surveyors	2,035	2,463	78,963
Fortescue (2.6 km)													
Density of HSC, Crabs/m	0.07	0.10	0.34	6.62	3.28	8.20	7.17	3.29	9.58	1.01	1.86	1.97	
Estimated Number of HSC	182	260	884	17,212	8,528	21,320	18,642	8,554	24,908	2,626	4,836	5,122	113,074
Gandys * (1.2 km)													
Density of HSC, Crabs/m	cancel	cancel	cancel	0.76	3.05	3.80	9.22	12.12	1.45	0.00	2.31	4.94	
Estimated Number of HSC	no access	no access	no access	912	3,660	4,560	11,064	14,544	1,740	0	2,772	5,928	45,180
Totals	5,007	9,303	36,192	137,838	125,108	198,019	95,910	239,478	279,678	29,054	53,045	62,471	1,271,102

Table 1. 2016 Survey Results - Densities and Estimates
B. Delaware Beaches (*Indicates Beaches Surveyed Every Year)

Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	New-2	New	New+2	Full-2	Full	Full+2	
Date	**4-May**	**6-May**	**8-May**	**19-May**	**21-May**	**23-May**	**2-Jun**	**4-Jun**	**6-Jun**	**18-Jun**	**20-Jun**	**22-Jun**	**Totals**
Cape Henlopen (1.5 km)													
Density of HSC, Crabs/m	0.01	0.05	1.07	0.11	0.25	1.52	5.56	8.78	5.55	0.23	2.16	1.74	
Estimated Number of HSC	15	75	1,605	165	375	2,280	8,340	13,170	8,325	345	3,240	2,610	40,545
Broadkill (1.5 km)													
Density of HSC, Crabs/m	0.00	0.07	0.01	0.07	cancel	0.08	0.00	3.99	7.26	0.04	0.84	1.21	
Estimated Number of HSC	0	105	15	105	weather	120	0	5,985	10,890	60	1,260	1,815	20,355
Primehook * (2.0 km)													
Density of HSC, Crabs/m	0.01	0.03	0.03	1.69	cancel	1.20	0.25	7.56	4.27	0.38	1.19	1.59	
Estimated Number of HSC	20	60	60	3,380	weather	2,400	500	15,120	8,540	760	2,380	3,180	36,400
Fowler * (3 km)													
Density of HSC, Crabs/m	0.02	0.04	0.01	0.38	0.00	0.45	0.03	2.87	4.67	0.50	0.31	0.92	
Estimated Number of HSC	60	120	30	1,140	0	1,350	90	8,610	14,010	1,500	930	2,760	30,600
Slaughter * (3 km)													
Density of HSC, Crabs/m	0.01	0.01	0.07	8.59	cancel	1.74	1.70	7.32	5.57	0.18	1.59	0.82	
Estimated Number of HSC	30	30	210	25,770	weather	5,220	5,100	21,960	16,710	540	4,770	2,460	82,800
Big Stone * (5.0 km)													
Density of HSC, Crabs/m	0.00	0.12	1.78	16.11	0.00	12.68	0.45	12.71	10.85	0.18	0.84	3.05	
Estimated Number of HSC	0	600	8,900	80,550	0	63,400	2,250	63,550	54,250	900	4,200	15,250	293,850
Bennetts Pier (2.6 km)													
Density of HSC, Crabs/m	0.00	0.00	0.00	0.60	0.00	0.39	0.72	1.36	4.50	0.03	1.34	0.91	
Estimated Number of HSC	0	0	0	1,560	0	1,014	1,872	3,536	11,700	78	3,484	2,366	25,610
South Bowers (2.3 km)													
Density of HSC, Crabs/m	0.00	cancel	1.27	11.42	0.08	13.39	8.73	8.72	14.78	0.57	3.43	2.12	
Estimated Number of HSC	0	no access	2,921	26,266	184	30,797	20,079	20,056	33,994	1,311	7,889	4,876	148,373
North Bowers * (1.3 km)													
Density of HSC, Crabs/m	0.00	0.05	1.94	13.94	0.08	12.14	6.22	17.03	16.13	1.21	1.56	0.73	
Estimated Number of HSC	0	65	2,522	18,122	104	15,782	8,086	22,139	20,969	1,573	2,028	949	92,339
Ted Harvey WMA (1.0 km)													
Density of HSC, Crabs/m	0.11	0.13	6.53	15.89	0.08	22.53	12.49	23.09	17.35	3.67	6.84	9.54	
Estimated Number of HSC	110	130	6,530	15,890	80	22,530	12,490	23,090	17,350	3,670	6,840	9,540	118,250
Kitts Hummock * (1.0 km)													
Density of HSC, Crabs/m	0.10	0.12	8.45	14.38	0.81	21.44	17.59	21.38	23.05	2.33	3.36	4.21	
Estimated Number of HSC	100	120	8,450	14,380	810	21,440	17,590	21,380	23,050	2,330	3,360	4,210	117,220
Pickering (1 km)													
Density of HSC, Crabs/m	0.00	0.41	7.38	24.19	0.02	25.94	35.01	37.25	34.56	3.05	8.22	6.58	
Estimated Number of HSC	0	410	7,380	24,190	20	25,940	35,010	37,250	34,560	3,050	8,220	6,580	182,610
Woodland * (0.5 km)													
Density of HSC, Crabs/m	0.00	0.00	0.00	0.00	0.00	0.00	0.95	1.38	0.97	0.00	0.00	0.00	
Estimated Number of HSC	0	0	0	0	0	0	475	690	485	0	0	0	1,650
Totals	335	1,715	38,623	211,518	1,573	192,273	111,882	256,536	254,833	16,117	48,601	56,596	1,190,602

Table 1. 2016 Survey Results- Densities and Estimates
C. New and Restored New Jersey Beaches

Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	New-2	New	New+2	Full-2	Full	Full+2	
Date	**4-May**	**6-May**	**8-May**	**19-May**	**21-May**	**23-May**	**2-Jun**	**4-Jun**	**6-Jun**	**18-Jun**	**20-Jun**	**22-Jun**	**Totals**
North Pierces Point (0.45 km)													
Density of HSC, Crabs/m	0.06	cancel	3.13	14.61	15.52	16.32	5.66	11.86	10.24	0.62	3.35	1.81	
Estimated Number of HSC	27	no access	1,409	6,575	6,984	7,344	2,547	5,337	4,608	279	1,508	815	37,431
Cooks (0.35 km)													
Density of HSC, Crabs/m	0.00	cancel	0.06	1.00	1.28	11.21	1.60	5.23	4.64	0.04	0.15	0.14	
Estimated Number of HSC	0	no access	21	350	448	3,924	560	1,831	1,624	14	53	49	8,873
Moores (1 km)													
Density of HSC, Crabs/m	0.01	cancel	0.35	3.87	5.02	10.06	2.89	9.51	17.88	0.02	0.73	1.67	
Estimated Number of HSC	10	no access	350	3,870	5,020	10,060	2,890	9,510	17,880	20	730	1,670	52,010
Thompsons (0.9 km)													
Density of HSC, Crabs/m	0.00	cancel	0.65	9.23	17.45	15.60	2.45	11.80	22.48	0.02	1.37	2.45	
Estimated Number of HSC	0	no access	585	8,307	15,705	14,040	2,205	10,620	20,232	18	1,233	2,205	75,150
Dyers Cove (0.30km)													
Density of HSC, Crabs/m	0.01	cancel	0.10	0.54	7.52	10.89	5.55	4.26	6.84	0.31	3.50	4.86	
Estimated Number of HSC	3	no access	30	162	2,256	3,267	1,665	1,278	2,052	93	1,050	1,458	13,314
Totals	40	n/a	2,395	19,264	30,413	38,635	9,867	28,576	46,396	424	4,573	6,197	186,778

Table 2. Comparison of Data on Horseshoe Crabs Spawning on Delaware Bay Shores Years 1999-2016 (2 pages)

Peak Estimate	Jun 06	May 16	May 26	May 23	May 22	Jun 03	May 29	May 24	Jun 03
Year	2016	2015	2014	2013	2012	2011	2010	2009	2008
Number of Horseshoe Crabs	534,511	380,936	322,672	384,548	341,062	477,715	472,759	586,298	346,319
New Jersey Estimate	279,678	182,671	107,278	108,194	184,046	190,449	193,463	245,444	69,669
Delaware Estimate	254,833	198,265	215,394	276,354	157,016	287,266	279,296	340,854	276,650
Number of Beaches Surveyed in DE	13	11	13	13	13	13	13	13	13
Number of Beaches Surveyed in NJ	12	12	12	12	12	12	12	13	12
Main Beaches in DE	Big Stone	Big Stone	Kitts Hummock	Slaughter	Pickering	Big Stone	Big Stone	Big Stone	Big Stone
	South Bowers	Slaughte	Pickering	Pickering	Ted Harvey	Slaughter	Slaughter	Slaughter	Slaughter
	Pickering	South Bowers	Big Stone	Big Stone	S. Bowers	S. Bowers	S. Bowers	S. Bowers	Pickering
					Big Stone	Pickering	Pickering	Pickering	
Main Beaches in NJ	Norburys	Norburys	Norburys	Fortescue	Fortescue	South CSL	South CSL	South CSL	South CSL
	South CSL	South CSL	Reeds	Norburys	South CSL	Norburys	Norburys	Norburys	Norburys
		Fortescue	Fortescue		Gandys	Fortescue	Gandys	Reeds	

Table 2. Comparison of Data on Horseshoe Crabs Spawning on Delaware Bay Shores Years 1999-2016 (2 pages)

Day	Jun 01	May 27	Jun 08	May 21	Jun 14	May 28	Jun 05	May 18	May 30
Year	2007	2006	2005	2004	2003	2002	2001	2000	1999
Number of Horseshoe Crabs	463,587	503,435	527,520	356,739	259,957	333,553	216,929	272,770	422,775
New Jersey Estimate	112,497	222,653	222,168	105,973	60,272	130,164	19,726	70,293	141,720
Delaware Estimate	351,090	280,782	305,352	250,766	199,685	203,389	197,203	202,477	281,055
Number of Beaches Surveyed in DE	13	13	13	13	13	13	13	11	9
Number of Beaches Surveyed in NJ	11	11	11	11	10	10	10	11	13
Main Beaches in DE	Big Stone	Big Stone	Big Stone	Big Stone	Big Stone	S. Bowers	Slaughter	Slaughter	Slaughter
	Slaughter	Slaughter	S. Bowers	Slaughter	Slaughter	Slaughter	Big Stone	Big Stone	Big Stone
	S. Bowers	S. Bowers	Bennets	Pickering	Pickering	Big Stone			
		Pickering	Slaughter		Ted Harvey	Pickering			
			Pickering						
Main Beaches in NJ	South CSL	South CSL	South CSL	South CSL	South CSL	South CSL	South CSL	South CSL	Townbank
		Norburys	Norburys	Fortescue	Fortescue	Gandys			Norburys
		Fortescue	Villas	Norburys	Norburys	Sea Breeze			South CSL

Table 3. Percentages of Horseshoe Crab Densities 1999-2016

				Percentage		
Survey Year	State	0	Low (<5)	Moderate (5-10)	High (>10)	Dates Missed
1999	New Jersey	4	65	10	6	15
	Delaware	8	43	6	11	31
2000	New Jersey	16	54	10	5	14
	Delaware	14	38	13	15	20
2001	New Jersey	10	63	5	5	17
	Delaware	13	46	11	6	19
2002	New Jersey	3	61	10	8	13
	Delaware	5	63	13	12	7
2003	New Jersey	17	60	7	3	13
	Delaware	18	50	8	10	13
2004	New Jersey	5	63	9	8	14
	Delaware	10	54	15	10	10
2005	New Jersey	14	48	6	10	21
	Delaware	14	51	11	8	16
2006	New Jersey	5	64	8	12	11
	Delaware	8	54	12	17	8
2007	New Jersey	16	58	1	10	15
	Delaware	10	43	15	18	15
2008	New Jersey	21	51	8	0	19
	Delaware	12	42	17	17	11
2009	New Jersey	4	50	8	14	24
	Delaware	10	51	13	15	12
2010	New Jersey	5	60	6	8	20
	Delaware	9	56	8	17	10
2011	New Jersey	10	58	15	7	10
	Delaware	8	49	10	21	12
2012	New Jersey	6	56	16	8	14
	Delaware	13	56	4	11	16
2013	New Jersey	11	56	15	8	10
	Delaware	13	51	13	17	6
2014	New Jersey	5	64	13	6	13
	Delaware	8	55	12	10	16
2015	New Jersey	10	55	9	19	7
	Delaware	14	56	10	13	7
2016	New Jersey	2	58	15	18	7
	Delaware	13.5	56	11.5	17	3

Table 4. Seasonal Estimates of Horseshoe Crabs 1999-2016

Year	New Jersey	Delaware	Total
1999	447,128	830,405	1,277,533
2000	398,847	925,837	1,324,684
2001	343,351	871,375	1,214,726
2002	442,586	857,362	1,299,948
2003	352,800	853,721	1,206,521
2004	474,019	1,019,014	1,493,033
2005	557,956	749,473	1,307,429
2006	648,728	1,236,627	1,885,355
2007	496,535	1,450,837	1,947,372
2008	306,306	1,272,312	1,578,618
2009	811,724	1,237,476	2,049,200
2010	529,606	1,028,611	1,558,217
2011	630,091	1,367,112	1,997,203
2012	668,950	622,619	1,291,569
2013	658,675	1,120,264	1,778,939
2014	587,460	814,120	1,401,580
2015	982,487	832,939	1,815,426
2016	1,271,102	1,190,602	2,461,704

Table 5. Sex Ratios and Estimates of Male and Female Horseshoe Crabs 1999-2016

Year	Sex Ratio	Females	Males
1999	3.72	270,664	1,006,869
2000	3.67	283,658	1,041,026
2001	3.38	277,335	937,391
2002	3.48	290,167	1,009,781
2003	3.61	261,718	944,803
2004	3.85	307,842	1,185,191
2005	3.89	267,368	1,040,061
2006	4.53	340,932	1,544,423
2007	4.90	330,064	1,617,308
2008	4.90	267,562	1,311,056
2009	5.04	339,271	1,709,929
2010	4.25	296,803	1,261,414
2011	5.36	314,026	1,683,177
2012	4.41	238,737	1,052,832
2013	3.74	375,304	1,403,635
2014	4.38	260,517	1,141,063
2015	4.47	331,887	1,483,539
2016	4.54	444,351	2,017,353

Table 6. Sex Ratios by Beach 2016

Beach	Average Sex Ratio
	Male to Female
Cape Henlopen, DE	5.06
Broadkill, DE	3.85
Prime Hook, DE	2.76
Fowlers, DE	3.20
Slaughter, DE	3.63
Big Stone, DE	4.53
Bennetts, DE	2.24
South Bowers, DE	5.44
North Bowers, DE	5.62
Ted Harvey WMA, DE	5.10
Kitts Hummock, DE	4.72
Pickering, DE	4.82
Woodland, DE	2.88
Higbees, NJ	2.76
North Cape May, NJ	3.34
Townbank, NJ	3.09
Villas, NJ	3.12
Norburys Landing, NJ	3.64
South Cape Lab, NJ	4.79
Highs Beach, NJ	5.08
Pierces Point, NJ	6.14
Kimbles, NJ	4.30
Reeds, NJ	4.71
Fortescue, NJ	4.61
Gandys, NJ	3.50
North Pierces, NJ	5.61
Cooks, NJ	3.67
Moores, NJ	4.62
Thompsons, NJ	5.35
Dyers Cove, NJ	4.48

Table 7. Percentages of Sex Ratios 2016 compared to 2015

Sex Ratio	New Jersey Percentage 2015	New Jersey Percentage 2016	Delaware Percentage 2015	Delaware Percentage 2016	Added NJ Percentage 2015	Added NJ Percentage 2016
No Sex Ratio	20	11	24	21	13	15
Less Than 1	1	2	6	1	0	0
1 to less than 3	23	29	33	28	10	22
3 to less than 5	26	38	26	28	19	35
5 to less than 7	23	15	8	17	27	22
Greater than 7	6	6	2	5	31	7

Table 8. Tagged Horseshoe Crabs Observed During Surveys 2007-2016

Year	Total	Delaware	New Jersey	In Quadrat	Outside	Alive	Dead	Unreadable
2007	116	95	21	30	86	102	14	3
2008	73	65	8	16	57	70	3	0
2009	153	62	91	26	127	145	8	10
2010	100	71	29	19	81	94	6	14
2011	191	87	104	31	160	175	16	11
2012	106	42	64	50	56	104	2	4
2013	147	88	59	45	102	130	17	3
2014	104	56	48	22	82	94	10	1
2015	235	42	193	61	174	231	4	1
2016	348	63	285	81	267	329	19	2
Totals	**1573**	**671**	**902**	**381**	**1192**	**1474**	**99**	**49**