

The 2019 Delaware Bay Horseshoe Crab Spawning Survey

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Abstract

Spawning counts of horseshoe crabs were scheduled for 24 beaches in New Jersey and Delaware during the full and new lunar phases in May and June 2019. A total of 288 counts were planned, of which 234 counts were completed with 54 cancelled due to weather (43), no access (9) and no surveyors (2). An additional 60 counts were scheduled on five new/restored beaches in New Jersey with 11 dates cancelled due to weather (7), no access (2) and no surveyors (2).

A single day peak estimate of 724,533 horseshoe crabs (270,382 New Jersey, 454,151 Delaware) was reached on May 20th, two days after the full moon. The 2019 single day peak estimate for the Delaware Bay is the highest estimate in the series for the years 1999-2019. New Jersey's 2019 peak estimate of 270,382 was similar to last year's estimate of 272,954 and is among the highest of the time series. Delaware's peak estimate of 454,151 is the highest estimate in the time series, surpassing last year's record of 381,309 (1999-2019). The peak estimate of 62,113 for the five additional beaches was achieved on June 1st, 2 days prior to the new moon.

The 2019 seasonal activity for the Delaware Bay was 3,397,246 (1,291,799 New Jersey, 2,105,447 Delaware). The seasonal estimate was the greatest estimate in the time series, exceeding the 2018 record estimate of 2,865,087. The seasonal number of horseshoe crabs for the new/restored beaches was estimated to be 335,211, greatly exceeding last year's estimate of 193,943.

The average male to female sex ratio for the entire Bay was 5.38 during the 12 survey nights and is lower than last year's ratio of 5.54. The sex ratio of 4.74 for the New Jersey side was considerably lower than Delaware's ratio of 6.05. The sex ratio combined with the seasonal estimate for 2019 equated to estimates of 532,484 female spawners and 2,864,762 males. For the five additional New Jersey beaches, the sex ratio of 5.34 was considerably higher than the average sex ratio of 4.74 for the 11 New Jersey beaches.

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 their time and 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 2019 along the shores of the Delaware Bay. Twenty-four beaches were represented in this year's count (13 along the state of Delaware's coast and 11 along the coast of New Jersey). The 13 Delaware beaches from south to north were Cape Henlopen, Broadkill, Primehook, Fowler, Slaughter, Big Stone, Bennetts Pier, South Bowers North Bowers, Ted Harvey Wildlife Management Area (WMA), Kitts Hummock, Pickering and Woodland. New Jersey's 11 beaches included Higbees, North Cape May, Townbank, Villas, Norburys Landing, South Cape Shore Lab, Highs, Pierces Point, Kimbles, Reeds and Fortescue. Gandys Beach was removed from the survey list due to lack of beach area to survey, access issues and unsafe conditions for access and surveying.

The counts were coordinated with the tidal progression along the 24 beaches encompassing the new and full moons on the dates of May 2nd, 4th, 6th, 16th, 18th, 20th and June 1st, 3rd, 5th, 15th, 17th and 19th. Times of high tides ranged from 7:50pm to 11:14pm 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. If incomplete counts of less than 100 quadrats occurred, they were calculated and utilized the same way as complete counts.

Five additional beaches in New Jersey were surveyed after beach restoration/replenishment during the last few years. The beaches listed south to north were 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 spawning crabs on these beaches.

Results

Along the 24 beaches, 288 surveys were scheduled, 156 in Delaware and 132 in New Jersey over 12 dates. Of these, 234 surveys (81%) were conducted with 54 cancellations due to weather (43), no access (9) and no surveyors (2). The majority of the weather cancellations occurred on two dates, May 2nd and June 17th. On May 2nd, the first survey date of 2019, six counts in Delaware and nine counts in New Jersey were cancelled due to weather. And on June 17th, the full moon date, nine counts in Delaware and seven counts in New Jersey were cancelled due to weather. (Table 1A, 1B and 1C)

Seven incomplete counts were recorded in Delaware and no incomplete counts were recorded on the 11 New Jersey beaches. Surveys were incomplete if fewer than 100 quadrats were counted. Severe weather and abnormally high tides

are typically responsible for the incomplete counts. The incomplete counts in Delaware occurred June 5th at Cape Henlopen (66 quadrats), June 17th at North Bowers (33 quadrats), June 5th and June 19th at Ted Harvey WMA (37 and 45 quadrats respectively), June 5th and June 17th at Kitts Hummock (98 and 33 quadrats respectively) and May 16th at Woodland Beach (36 quadrats).

Sixty counts were scheduled for the five new/restored beaches in New Jersey. Of the 60 counts, a total of 49 surveys (82%) were performed and 11 dates were cancelled due to weather (7), no access (2) and no surveyors (2). Nine incomplete counts (29, 37, 31, 25, 28, 34, 34, 33 and 32 quadrats) occurred at North Pierces Point on the dates of May 6th, 16th, 18th, 20th and June 1st, 3rd, 15th, 17th and 19th respectively, and were due to lack of accessible beach area. (Table 1C)

The May 20th estimate of 724,533 spawners along the 13 Delaware and the 11 New Jersey beaches is the greatest in the time series (1999-2019). The 2019 estimate is higher than last year's record estimate of 654,263. The peak spawning estimate can be attributed to 63% spawning in Delaware and 37% in New Jersey. Spawning estimates in New Jersey were greatest during two dates, May 20th and June 1st, contributing 38% to the seasonal estimate. The two dates of May 20th and June 5th contributed 40% to Delaware's seasonal estimate. (Table 1A and 1B and Figure 1.) The peak spawning estimate of 62,113 for the five additional beaches was achieved on June 1st and a lesser number of 60,010 was estimated for May 20th (Table 1C and Figure 1 C).

The greatest densities of the season in New Jersey were observed at Pierces Point of 36.81 and 40.04 horseshoe crabs per square meter on May 20th and June 1st respectively, and at Highs of 38.61 crabs per square meter on May 20th (Table 1A). In Delaware, the highest densities of 45.21, 41.77 and 37.59 crabs per square meter were recorded at Pickering on May 20th, June 1st and June 5th, respectively (Table 1B).

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 square meter, moderate activity equals 5 to 10 crabs per square meter, and high activity equals greater than 10 crabs per square meter. The data is analyzed in percentages since the number of dates and/or beaches may change yearly.

The majority of the dates surveyed (33% in DE and 37% in NJ) recorded densities lower than five horseshoe crabs per square meter, however these percentages were the lowest on record. Dates with zero horseshoe crabs totaled zero in New Jersey, the only time this occurred during the time series (1999-2019). The percentage of dates with zero crabs in Delaware was 3%, the same as last year and the lowest on record. High densities (greater than 10 crabs per square meter) were the greatest on record, 29% in Delaware and 27% in New Jersey. Also, the highest on record were dates with moderate spawning (5 to 10 horseshoe crabs per square meter), 17% in both Delaware and New Jersey. (Figure 3B). The percentage

of dates missed was among the highest due to the number of weather cancellations (Figure 3B). (Table 3)

The seasonal activity of 1,291,799 for the New Jersey side of the Bay replaced the 2016 record estimate of 1,271,102 and last year's estimate of 1,189,246 for the highest in the time series (1999-2019). Delaware's seasonal estimate of 2,105,447 is the highest of the series (1999-2019) surpassing last year's record estimate of 1,675,841. (Table 4 and Figure 4). Big Stone (due to its beach expanse), Slaughter and Pickering beaches in Delaware and Reeds, Norburys Landing and Pierces Point beaches in New Jersey had the greatest estimates of spawning crabs. (Table 1A and 1B and Table 2).

The peak estimate for the five additional New Jersey beaches was achieved on the date of June 1st and along with the May 20th estimate contributed 36% to the seasonal estimate. The greatest densities were achieved at North Pierces Point, May 18th (28.16 horseshoe crabs per square meter) and May 20th (38.04 horseshoe crabs per square meter), and at Thompsons June 3rd (28.40 crabs per square meter). Similar to the 11 New Jersey beaches, the percentages of dates with moderate and high densities were great, and no survey dates recorded zero horseshoe crabs on the additional beaches. (Table 1C)

The 2019 average sex ratio of 5.38 for the entire Delaware Bay combined with the seasonal estimate equated to 532,484 females spawning along the survey beaches. The estimate of female spawners is the highest estimate in the time series (1999-2019), exceeding last year's estimate of 438,087 and the 2016 record estimate of 444,351 (Table 5 and Figure 5A. and 5B.). The average sex ratio for Delaware was 6.05 while the ratio for New Jersey was 4.74. The average sex ratio for the five additional New Jersey beaches at 5.34 was higher than the average sex ratio (4.74) of the 11 beaches in New Jersey. (Table 6)

The average sex ratio for each beach was calculated by dividing the total number of males by the total number of females recorded during the survey counts (Table 6 and Figure 6). The total number of horseshoe crabs counted was plotted against the sex ratio for 234 dates (Figure 7).

The sex ratios were categorized according to percentage of occurrence for the 11 New Jersey beaches, the 13 Delaware beaches and the five new/restored New Jersey beaches during the 12 nights. 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. (Figure 7A.) In Delaware, the highest sex ratios (male/female) recorded were 14.14 at North Bowers on June 1st, 11.59 at Ted Harvey WMA on June 3rd and 10.28 at Kitts Hummock on June 5th. In New Jersey, the highest sex ratio was 9.00 at Townbank on June 1st and 12.50 at North Pierces Point, a new/restored beach on June 19th.

Average sex ratios were also calculated for each survey night for the 13 Delaware beaches, the 11 New Jersey beaches and the additional five New Jersey beaches. For all three, the percentage of dates with no sex ratio increased noticeably due to the number of weather cancellations. The percentage of ratios with 1 female to 1 to less than 3 males dropped considerably from last year, the percentage of 1 to 3 less than 5 increased and the sex ratios of 1 female surrounded by more than 7 males decreased with the greatest decrease on the 11 New Jersey beaches. (Table 7)

Observations of tagged horseshoe crabs during the survey counts numbered 322, mainly from New Jersey (245) where tagging took place during the season. The majority of the tagged animals were alive (296) and encountered outside the quadrats (268). Many of the tagged animals were observed at Kimbles (75), Reeds (59) and Fortescue (20) as well as the new/restored beaches, Thompsons (25) and Moores (21). At Slaughter Beach in Delaware, 17 of the 27 tagged horseshoe crabs were dead which is not common. (Table 8) (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.)

Summary

This year's estimates set new records, exceeding many of the records established in 2018, within the time series 1999-2019.

The table below summarizes the records established in 2019.

Greatest on Record	2019 Estimate	Record Number	Previous Record	Record Number
Delaware Bay (24 beaches)	Peak Day	724,533	2018	654,263
Delaware (13 beaches)	Peak Day	454,151	2018	381,309
Delaware Bay (24 beaches)	Seasonal	3,397,246	2018	2,865,087
Delaware (13 beaches)	Seasonal	2,105,447	2018	1,675,841
New Jersey (11 beaches)	Seasonal	1,291,799	2016	1,271,102
Female Spawners	Seasonal	532,484	2016	444,351
Male Spawners	Seasonal	2,864,762	2018	2,427,000
Percentage of High Densities (>10) - Delaware	Seasonal	29%	2018	24%
Percentage of High Densities (>10) - New Jersey	Seasonal	27%	2015	19%
Percentage of Moderate Densities (5-10) - Delaware	Seasonal	17%	2008	17%
Percentage of Moderate Densities (5-10) - New Jersey	Seasonal	17%	2012	16%
Lowest on Record	2019 Estimate	Record Number	Previous Record	Record Number
Percentage of Dates with Zero Horseshoe Crabs - Delaware	Seasonal	3%	2018	3%
Percentage of Dates with Zero Horseshoe Crabs - New Jersey	Seasonal	0%	2016	2%

Discussion

The horseshoe crab numbers along the Delaware Bay shore have been increasing over the last few years with many of the estimates being the highest encountered over the entire time period. The weather was favorable for conducting the 2019 survey and although there were many weather cancellations, they occurred at the beginning and the end of the season when spawners were not as abundant. And while weather is a major factor influencing spawning activity, another reason for the sustained increase could be due to stringent management measures. However, the greater densities of horseshoe crabs may be linked to decreasing spawning habitat along the accessible beaches and may not result in an actual increase in spawning numbers.

Lessening spawning habitat along the Delaware Bay shore could also explain the differences in the sex ratios between the 13 Delaware beaches and the 11 beaches in New Jersey. The 2019 sex ratio for the 11 New Jersey beaches decreased to 4.74 males per one female while Delaware's ratio increased to 6.05 males per one female. The deteriorating spawning habitat due to erosion and the sand replenishment of beaches could be a deterrent to female spawners. The difference in the sex ratios could also be a result of the great increase in spawners along the Delaware shores in 2019, an increase of 500,000 from the year 2018, which is skewed toward males due to spawning behavior.

A sincere thank you to the volunteers!

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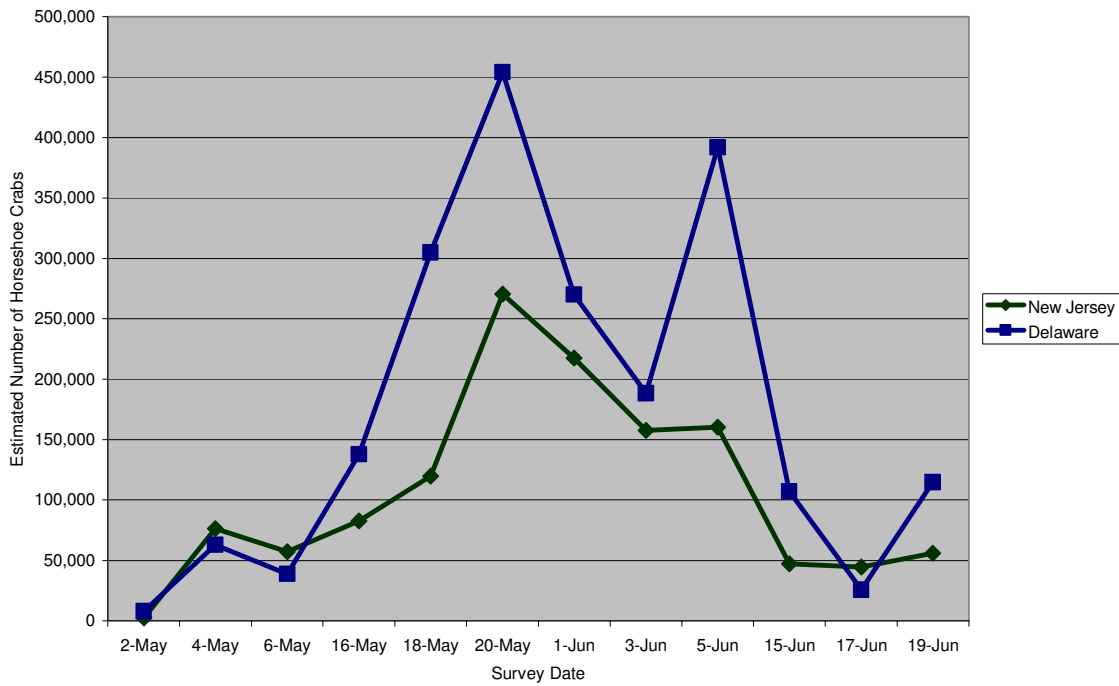


Figure 1C. New Jersey Spawning Estimates During 2019 Survey
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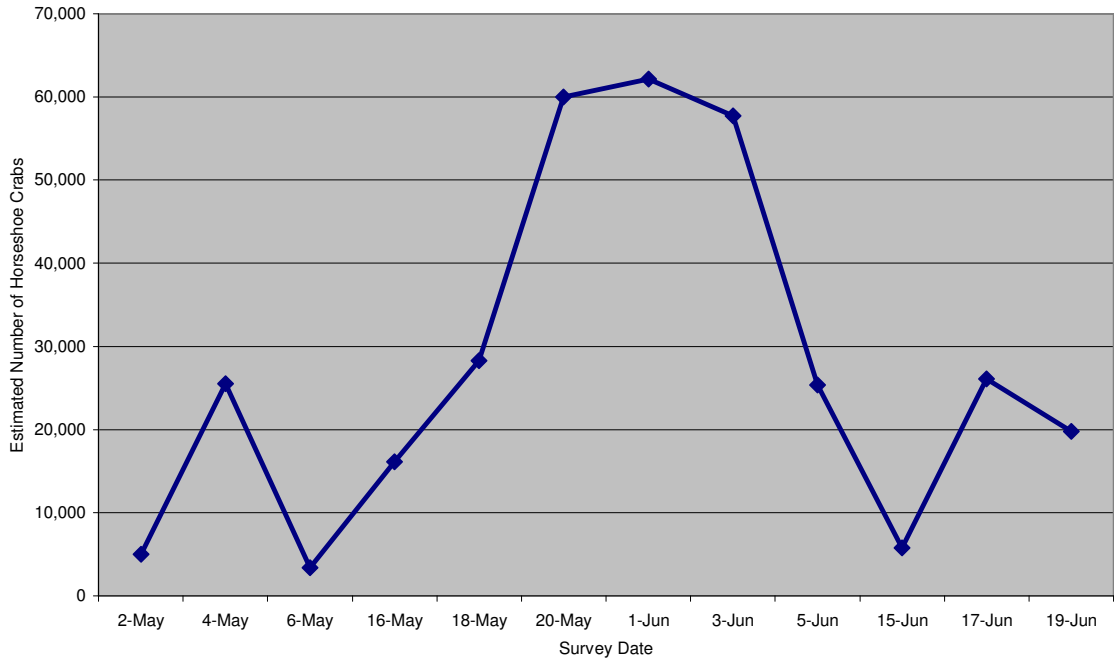


Figure 2. Peak Estimates of Spawning Horseshoe Crabs Years 1999-2019

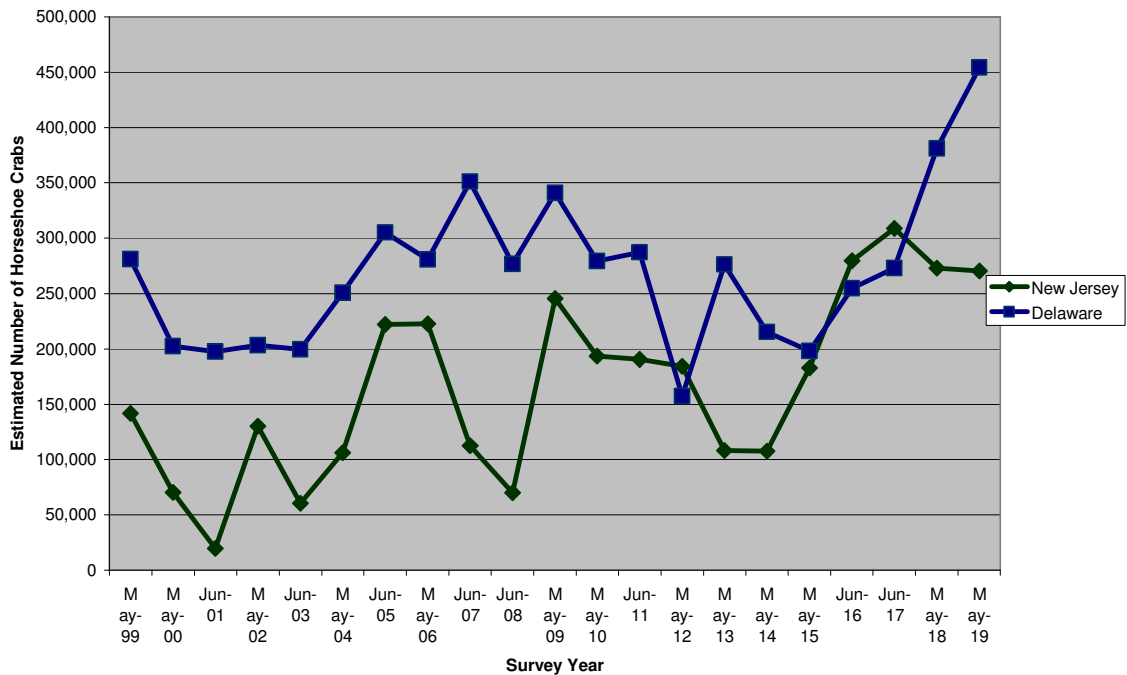


Figure 3. A. Percentages of Dates Missed by Year 1999-2019

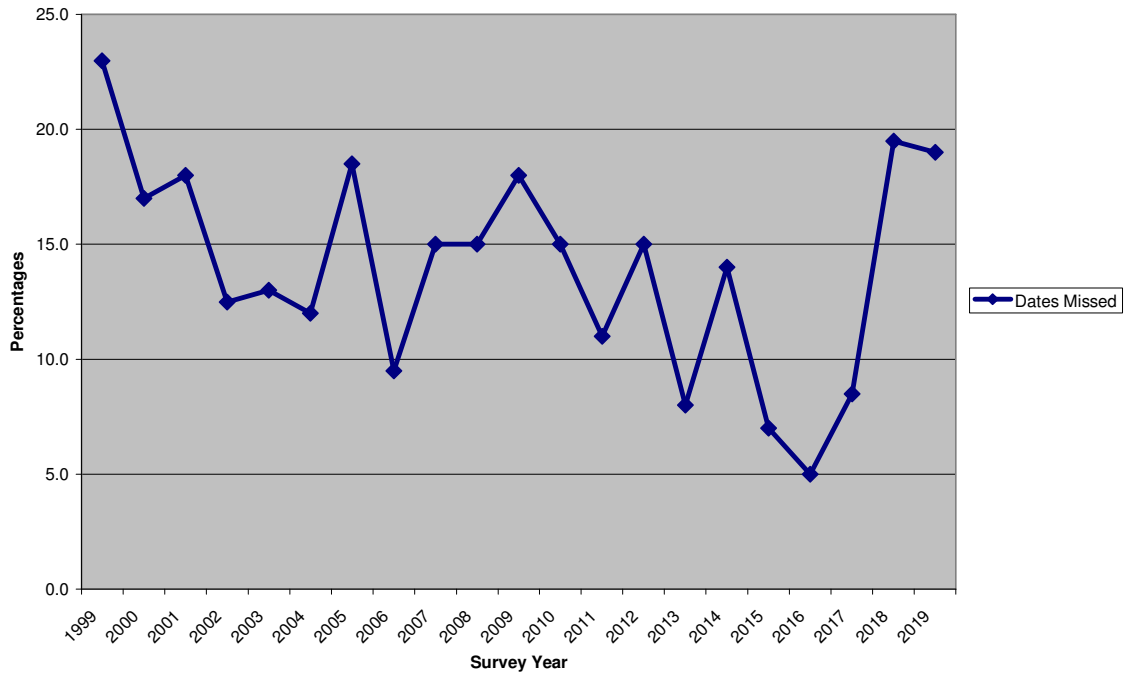


Figure 3.B. Percentages of High Densities by Year 1999-2019

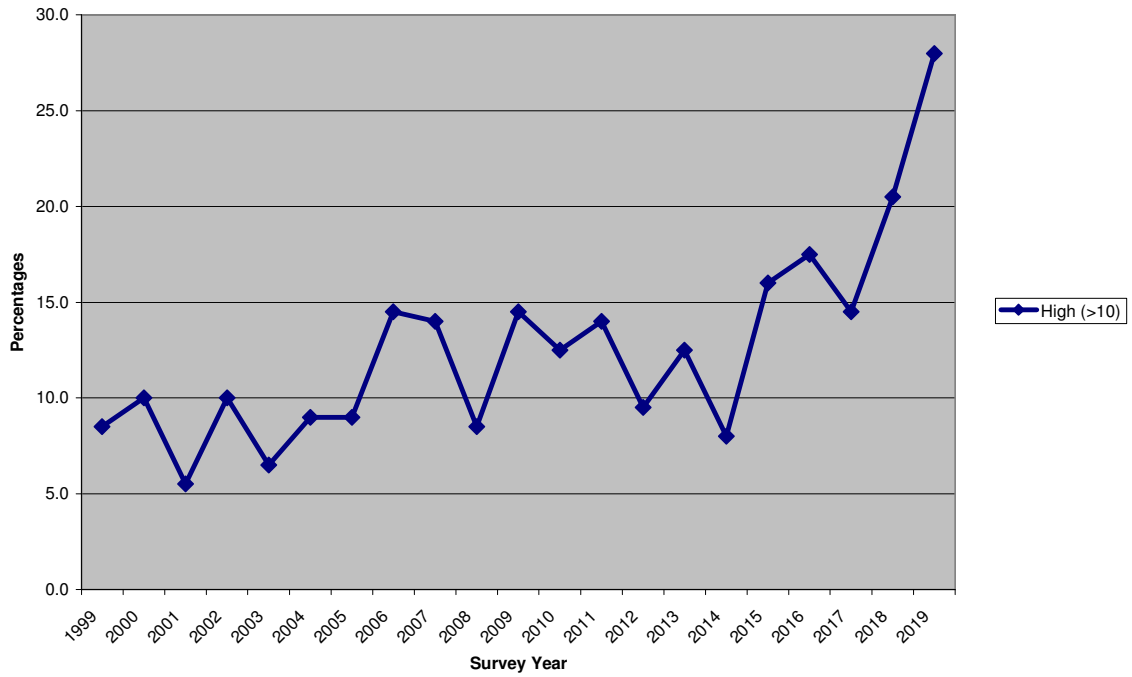


Figure 4. Seasonal Estimates of Horseshoe Crabs 1999-2019

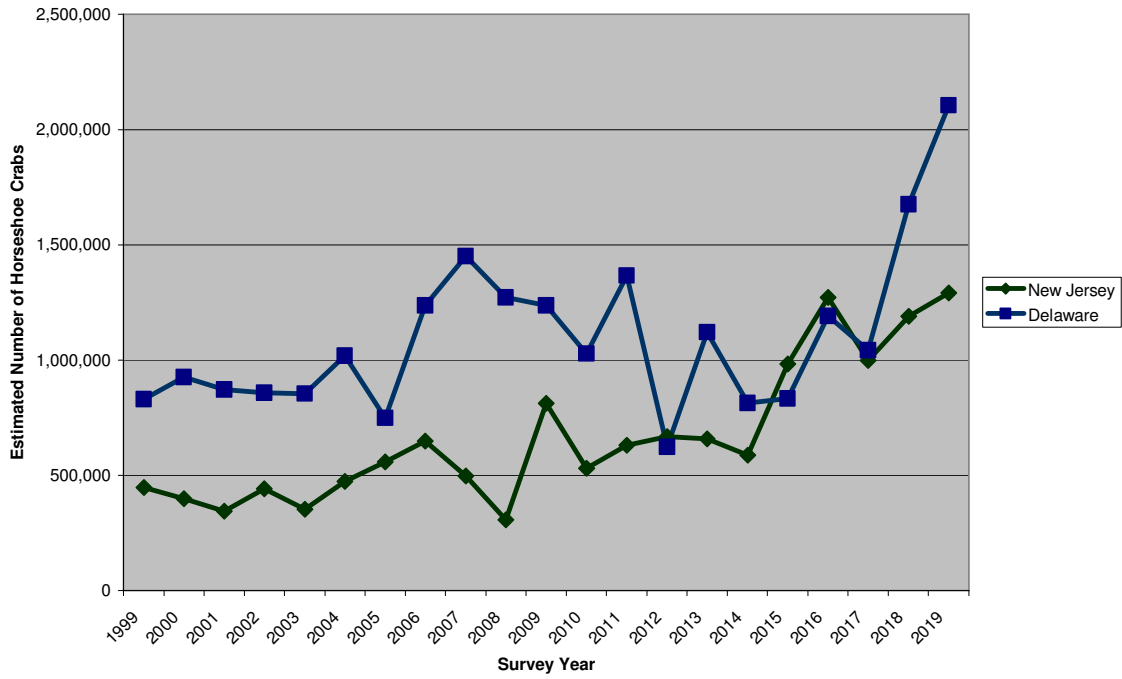
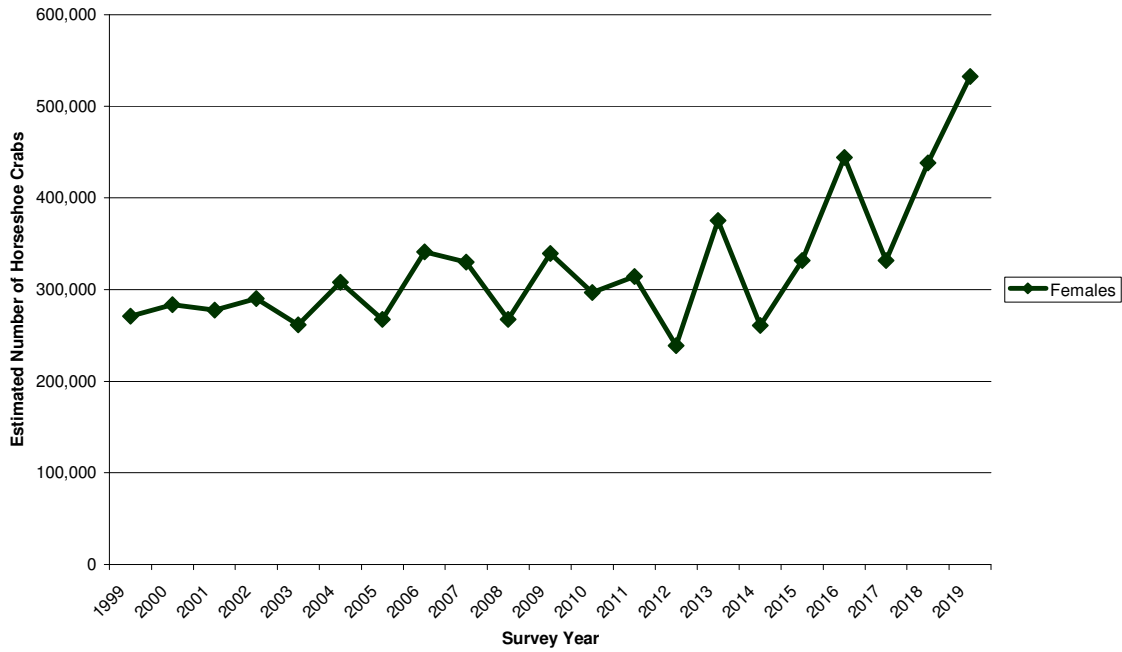


Figure 5. A. Seasonal Estimates of Female Horseshoe Crabs 1999-2019



**Figure 5. B. Seasonal Estimates of Male Horseshoe Crabs
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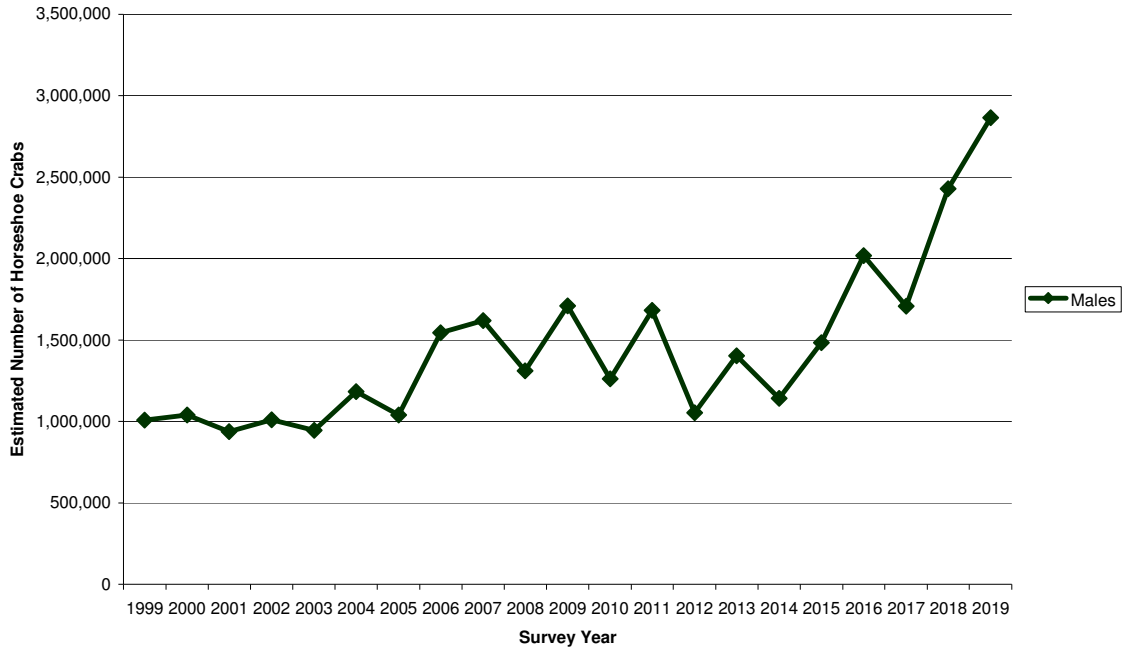


Figure 6. Average Sex Ratios by Beach 2019

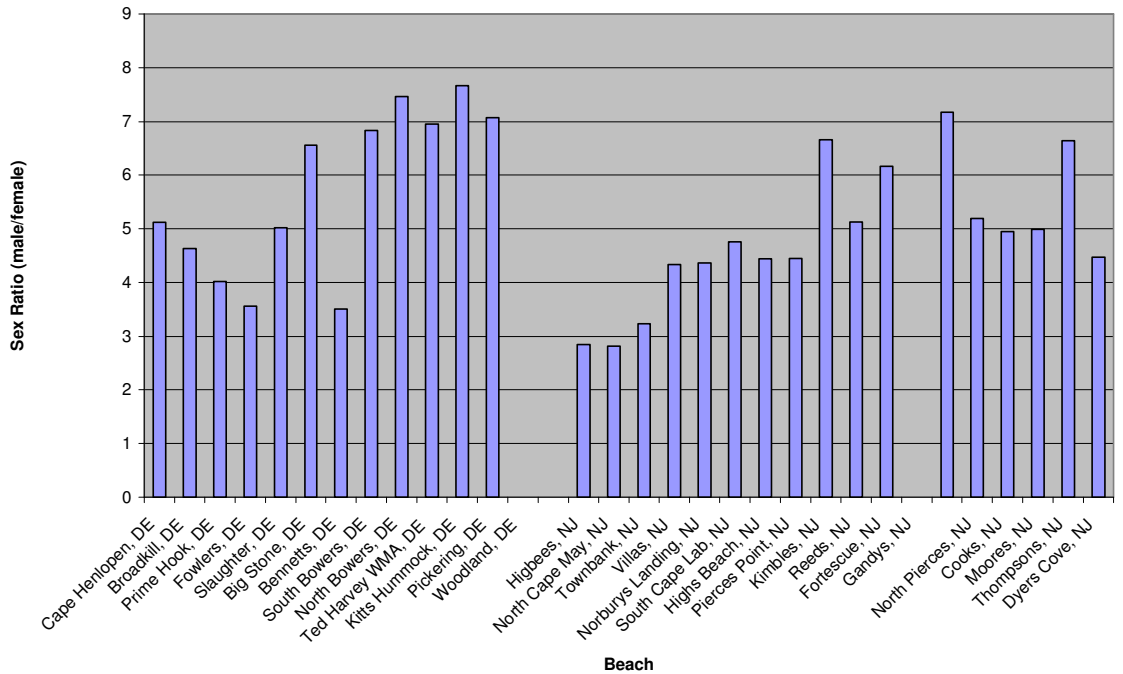


Figure 7. Numbers of Horseshoe Crabs versus Sex Ratios 2019

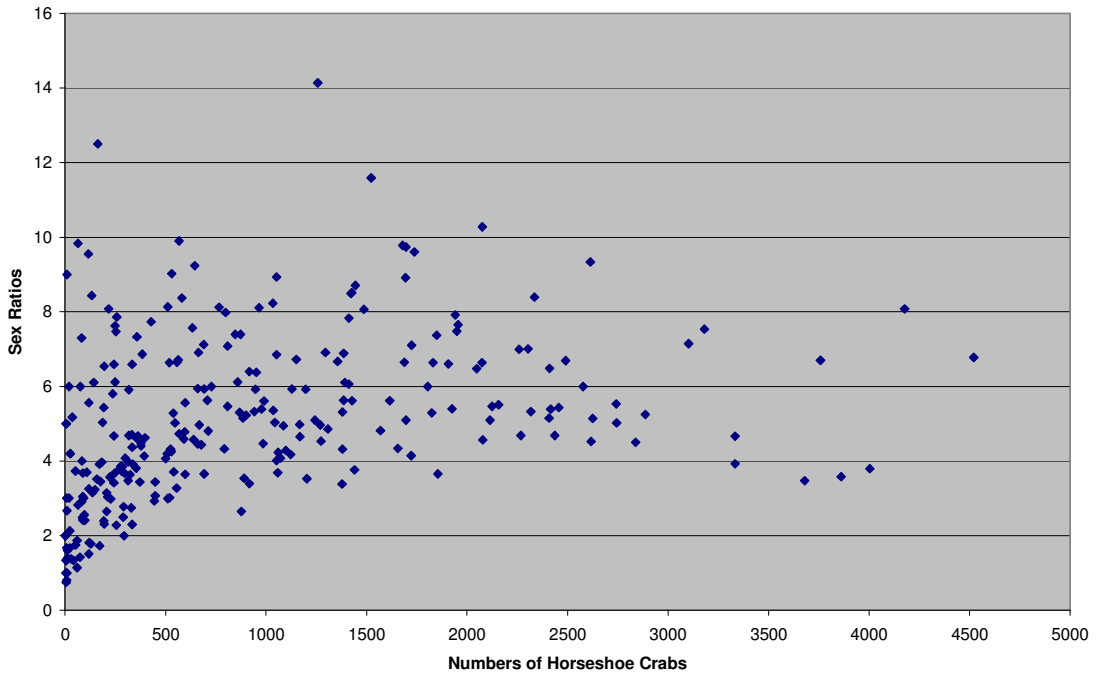


Figure 7A. Sex Ratio Categories 2019

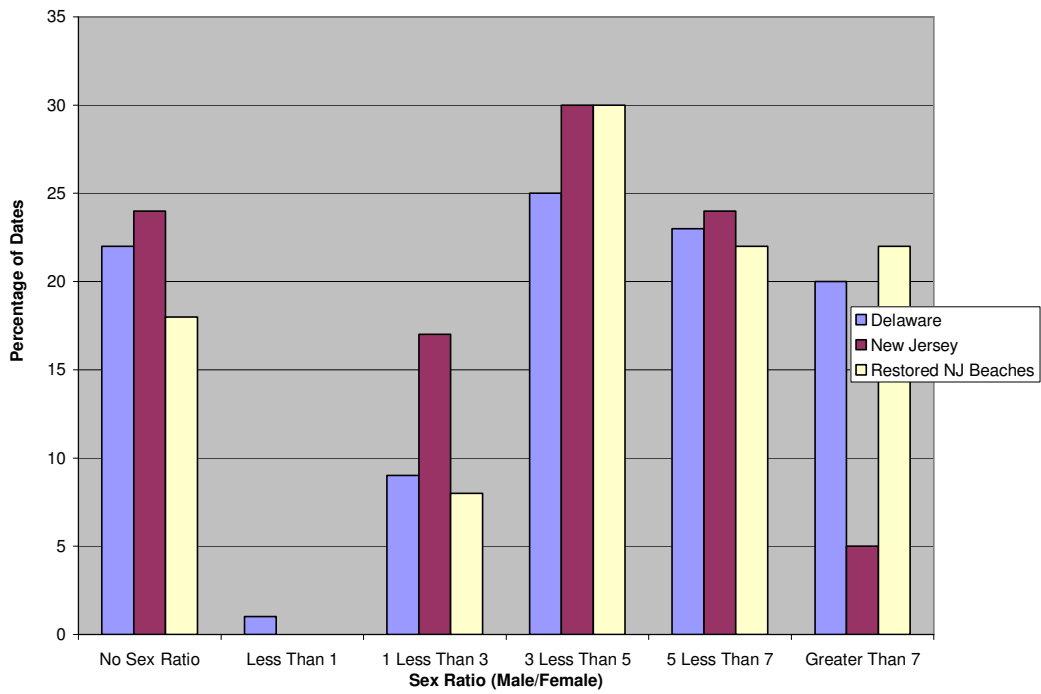


Table 1A. 2019 Survey Results – Densities and Estimates -New Jersey Beaches (2 pages)

Moon Phase	New-2	New	New+2	Full-2	Full	Full+2
Date	2-May	4-May	6-May	16-May	18-May	20-May
Higbees * (0.98 km)						
Density of HSC, Crabs/m	cc-weath	0.01	0.01	0.04	0.60	0.12
Estimated Number of HSC		10	10	39	588	118
North Cape May * (3 km)						
Density of HSC, Crabs/m	cc-weath	cc-ns	0.01	0.01	0.03	0.06
Estimated Number of HSC			30	30	90	180
Townbank (2.3 km)						
Density of HSC, Crabs/m	cc-weath	0.03	0.03	0.08	0.07	2.24
Estimated Number of HSC		69	69	184	161	5,152
Villas (2 km)						
Density of HSC, Crabs/m	cc-weath	5.40	0.77	0.52	2.48	21.15
Estimated Number of HSC		10,800	1,540	1,040	4,960	42,300
Norburys Landing (2.43 km)						
Density of HSC, Crabs/m	cc-weath	6.59	6.59	5.30	10.72	24.36
Estimated Number of HSC		16,014	16,014	12,879	26,050	59,195
South CSL * (2.2 km)						
Density of HSC, Crabs/m	0.89	0.89	0.89	2.86	10.87	13.81
Estimated Number of HSC	1,958	1,958	1,958	6,292	23,914	30,382
Highs * (0.8 km)						
Density of HSC, Crabs/m	cc-weath	7.28	5.63	9.18	5.26	38.61
Estimated Number of HSC		5,824	4,504	7,344	4,208	30,888
Pierces Point (0.7 km)						
Density of HSC, Crabs/m	cc-weath	23.18	18.24	33.34	cc-weath	36.81
Estimated Number of HSC		16,226	12,768	23,338		25,767
Kimbles (1 km)						
Density of HSC, Crabs/m	cc-weath	5.81	4.28	14.27	19.56	21.56
Estimated Number of HSC		5,810	4,280	14,270	19,560	21,560
Reeds * (1.53 km)						
Density of HSC, Crabs/m	cc-weath	9.48	8.69	8.77	20.79	24.56
Estimated Number of HSC		14,504	13,296	13,418	31,809	37,577
Fortescue (2.6 km)						
Density of HSC, Crabs/m	0.11	1.96	1.08	1.48	3.31	6.64
Estimated Number of HSC	286	5,096	2,808	3,848	8,606	17,264
Totals	2,244	76,311	57,276	82,682	119,945	270,382
Moon Phase	New-2	New	New+2	Full-2	Full	Full+2
Date	2-May	4-May	6-May	16-May	18-May	20-May

Table 1A. 2019 Survey Results – Densities and Estimates -New Jersey Beaches (2 pages)

Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	1-Jun	3-Jun	5-Jun	15-Jun	17-Jun	19-Jun	Totals
Higbees * (0.98 km)							
Density of HSC, Crabs/m	1.21	2.93	cc-weath	0.10	5.55	9.18	
Estimated Number of HSC	1,186	2,871		98	5,439	8,996	19,355
North Cape May * (3 km)							
Density of HSC, Crabs/m	0.65	0.60	2.14	0.24	1.95	3.14	
Estimated Number of HSC	1,950	1,800	6,420	720	5,850	9,420	26,490
Townbank (2.3 km)							
Density of HSC, Crabs/m	0.10	0.75	cc-weath	0.42	cc-weath	5.42	
Estimated Number of HSC	230	1,725		966		12,466	21,022
Villas (2 km)							
Density of HSC, Crabs/m	10.99	5.98	14.41	3.78	cc-weath	cc-weath	
Estimated Number of HSC	21,980	11,960	28,820	7,560			130,960
Norburys Landing (2.43 km)							
Density of HSC, Crabs/m	12.73	8.92	cc-weath	4.48	cc-weath	cc-weath	
Estimated Number of HSC	30,934	21,676		10,886			193,647
South CSL * (2.2 km)							
Density of HSC, Crabs/m	11.66	9.02	13.07	3.39	5.92	3.00	
Estimated Number of HSC	25,652	19,844	28,754	7,458	13,024	6,600	167,794
Highs * (0.8 km)							
Density of HSC, Crabs/m	18.31	3.33	26.17	1.28	cc-weath	2.43	
Estimated Number of HSC	14,648	2,664	20,936	1,024		1,944	93,984
Pierces Point (0.7 km)							
Density of HSC, Crabs/m	40.04	33.33	24.09	16.16	28.87	8.85	
Estimated Number of HSC	28,028	23,331	16,863	11,312	20,209	6,195	184,037
Kimbles (1 km)							
Density of HSC, Crabs/m	13.86	14.12	20.48	2.27	cc-weath	cc-weath	
Estimated Number of HSC	13,860	14,120	20,480	2,270			116,210
Reeds * (1.53 km)							
Density of HSC, Crabs/m	19.26	18.05	24.90	2.56	cc-weath	6.68	
Estimated Number of HSC	29,468	27,617	38,097	3,917		10,220	219,922
Fortescue (2.6 km)							
Density of HSC, Crabs/m	19.08	11.50	cc-weath	0.37	cc-weath	cc-weath	
Estimated Number of HSC	49,608	29,900		962			118,378
Totals	217,544	157,508	160,370	47,173	44,522	55,842	1,291,799
Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	1-Jun	3-Jun	5-Jun	15-Jun	17-Jun	19-Jun	Totals

Table 1B. 2019 Survey Results – Densities and Estimates - 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
Cape Henlopen (1.5 km)						
Density of HSC, Crabs/m	cc-weath	0.07	0.21	0.05	0.20	2.43
Estimated Number of HSC		105	315	75	300	3,645
Broadkill (1.5 km)						
Density of HSC, Crabs/m	cc-weath	0.00	0.85	0.07	2.90	9.78
Estimated Number of HSC		0	1,275	105	4,350	14,670
Primehook * (2.0 km)						
Density of HSC, Crabs/m	cc-weath	5.10	4.44	2.77	9.85	12.43
Estimated Number of HSC		10,200	8,880	5,540	19,700	24,860
Fowler * (3 km)						
Density of HSC, Crabs/m	cc-weath	cc-weath	0.26	1.74	3.99	5.11
Estimated Number of HSC			780	5,220	11,970	15,330
Slaughter * (3 km)						
Density of HSC, Crabs/m	cc-weath	5.95	0.08	3.13	17.23	27.45
Estimated Number of HSC		17,850	240	9,390	51,690	82,350
Big Stone * (5.0 km)						
Density of HSC, Crabs/m	0.09	0.96	0.13	6.93	14.86	19.42
Estimated Number of HSC	450	4,800	650	34,650	74,300	97,100
Bennetts Pier (2.6 km)						
Density of HSC, Crabs/m	0.00	0.00	1.37	2.07	5.21	13.79
Estimated Number of HSC	0	0	3,562	5,382	13,546	35,854
South Bowers (2.3 km)						
Density of HSC, Crabs/m	1.32	0.99	1.84	9.66	16.88	22.60
Estimated Number of HSC	3,036	2,277	4,232	22,218	38,824	51,980
North Bowers * (1.3 km)						
Density of HSC, Crabs/m	cc-weath	3.63	3.78	3.55	10.34	23.04
Estimated Number of HSC		4,719	4,914	4,615	13,442	29,952
Ted Harvey WMA (1.0 km)						
Density of HSC, Crabs/m	2.54	8.60	8.47	16.81	24.10	27.42
Estimated Number of HSC	2,540	8,600	8,470	16,810	24,100	27,420
Kitts Hummock * (1.0 km)						
Density of HSC, Crabs/m	0.92	6.34	2.18	16.96	20.74	25.78
Estimated Number of HSC	920	6,340	2,180	16,960	20,740	25,780
Pickering (1 km)						
Density of HSC, Crabs/m	1.18	8.08	3.34	16.94	31.82	45.21
Estimated Number of HSC	1,180	8,080	3,340	16,940	31,820	45,210
Woodland * (0.5 km)						
Density of HSC, Crabs/m	0.00	cc-acc	cc-acc	0.00	cc-acc	cc-acc
Estimated Number of HSC	0			0		
Totals	8,126	62,971	38,838	137,905	304,782	454,151
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

Table 1B. 2019 Survey Results – Densities and Estimates - Delaware Beaches (2 pages)

Moon Phase Date	New-2 1-Jun	New 3-Jun	New+2 5-Jun	Full-2 15-Jun	Full 17-Jun	Full+2 19-Jun	Totals
Cape Henlopen (1.5 km)							
Density of HSC, Crabs/m	3.18	4.48	18.14	1.87	cc-weath	2.57	
Estimated Number of HSC	4,770	6,720	27,210	2,805		3,855	49,800
Broadkill (1.5 km)							
Density of HSC, Crabs/m	9.42	5.01	6.79	0.82	cc-weath	8.08	
Estimated Number of HSC	14,130	7,515	10,185	1,230		12,120	65,580
Primehook * (2.0 km)							
Density of HSC, Crabs/m	10.53	6.93	2.91	1.94	cc-weath	6.40	
Estimated Number of HSC	21,060	13,860	5,820	3,880		12,800	126,600
Fowler * (3 km)							
Density of HSC, Crabs/m	12.03	0.52	7.92	0.08	cc-weath	1.72	
Estimated Number of HSC	36,090	1,560	23,760	240		5,160	100,110
Slaughter * (3 km)							
Density of HSC, Crabs/m	10.36	13.86	22.67	13.92	cc-weath	7.13	
Estimated Number of HSC	31,080	41,580	68,010	41,760		21,390	365,340
Big Stone * (5.0 km)							
Density of HSC, Crabs/m	10.52	3.54	14.29	0.25	cc-weath	5.19	
Estimated Number of HSC	52,600	17,700	71,450	1,250		25,950	380,900
Bennetts Pier (2.6 km)							
Density of HSC, Crabs/m	cc-ns	1.93	16.56	3.73	cc-weath	3.29	
Estimated Number of HSC		5,018	43,056	9,698		8,554	124,670
South Bowers (2.3 km)							
Density of HSC, Crabs/m	5.11	5.97	14.23	7.09	cc-weath	cc-weath	
Estimated Number of HSC	11,753	13,731	32,729	16,307			197,087
North Bowers * (1.3 km)							
Density of HSC, Crabs/m	12.57	6.45	17.39	3.95	2.52	2.38	
Estimated Number of HSC	16,341	8,385	22,607	5,135	3,276	3,094	116,480
Ted Harvey WMA (1.0 km)							
Density of HSC, Crabs/m	17.25	15.23	28.46	11.22	cc-weath	12.60	
Estimated Number of HSC	17,250	15,230	28,460	11,220		12,600	172,700
Kitts Hummock * (1.0 km)							
Density of HSC, Crabs/m	23.37	26.14	21.18	3.24	9.64	3.85	
Estimated Number of HSC	23,370	26,140	21,180	3,240	9,640	3,850	160,340
Pickering (1 km)							
Density of HSC, Crabs/m	41.77	31.03	37.59	10.44	12.96	5.48	
Estimated Number of HSC	41,770	31,030	37,590	10,440	12,960	5,480	245,840
Woodland * (0.5 km)							
Density of HSC, Crabs/m	cc-acc	cc-acc	cc-acc	cc-acc	cc-acc	cc-weath	
Estimated Number of HSC							0
Totals	270,214	188,469	392,057	107,205	25,876	114,853	2,105,447
Moon Phase Date	New-2 1-Jun	New 3-Jun	New+2 5-Jun	Full-2 15-Jun	Full 17-Jun	Full+2 19-Jun	Totals

Table 1C. 2019 Survey Results - Densities and Estimates - New/Restored Beaches

Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	2-May	4-May	6-May	16-May	18-May	20-May	
N Pierces Point (0.45 km)							
Density of HSC, Crabs/m	cc-weath	cc-ns	2.24	21.59	28.16	38.04	
Estimated Number of HSC			1,008	9,716	12,672	17,118	
Cooks (0.35 km)							
Density of HSC, Crabs/m	cc-weath	3.58	2.73	9.90	13.57	cc-weath	
Estimated Number of HSC		1,253	956	3,465	4,750		
Moores (1 km)							
Density of HSC, Crabs/m	cc-weath	6.90	cc-acc	0.31	cc-acc	16.96	
Estimated Number of HSC		6,900		310		16,960	
Thompsons (0.9 km)							
Density of HSC, Crabs/m	5.58	18.50	1.58	2.83	11.69	26.26	
Estimated Number of HSC	5,022	16,650	1,422	2,547	10,521	23,634	
Dyers Cove (0.30km)							
Density of HSC, Crabs/m	cc-ns	2.39	0.07	0.26	1.18	7.66	
Estimated Number of HSC		717	21	78	354	2,298	
Totals	5,022	25,520	3,407	16,116	28,297	60,010	
Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	2-May	4-May	6-May	16-May	18-May	20-May	
Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	1-Jun	3-Jun	5-Jun	15-Jun	17-Jun	19-Jun	Totals
N Pierces Point (0.45 km)							
Density of HSC, Crabs/m	18.96	9.79	cc-weath	4.18	3.52	5.06	
Estimated Number of HSC	8,532	4,406		1,881	1,584	2,277	
Cooks (0.35 km)							
Density of HSC, Crabs/m	12.70	13.81	cc-weath	2.98	2.44	2.50	
Estimated Number of HSC	4,445	4,834		1,043	854	875	
						22,474	
Moores (1 km)							
Density of HSC, Crabs/m	24.17	18.55	10.61	1.78	14.12	11.29	
Estimated Number of HSC	24,170	18,550	10,610	1,780	14,120	11,290	
						104,690	
Thompsons (0.9 km)							
Density of HSC, Crabs/m	21.24	28.40	15.69	1.19	10.59	5.67	
Estimated Number of HSC	19,116	25,560	14,121	1,071	9,531	5,103	
						134,298	
Dyers Cove (0.30km)							
Density of HSC, Crabs/m	19.50	14.45	2.08	0.06	cc-weath	0.87	
Estimated Number of HSC	5,850	4,335	624	18		261	
						14,556	
Totals	62,113	57,684	25,355	5,793	26,089	19,806	
						335,211	
Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	1-Jun	3-Jun	5-Jun	15-Jun	17-Jun	19-Jun	Totals

**Table 2. Comparison of Date on Horseshoe Crabs Spawning on Delaware Bay Shores
Years 1999-2019 (2 pages)**

Peak Estimate	May 20	May 31	Jun 11	Jun 06	May 16	May 26	May 23	May 22	Jun 03	May 29	May 24	Jun 03
Year	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
Number of Horseshoe Crabs	724,533	654,263	581,872	534,511	380,936	322,672	384,548	341,062	477,715	472,759	586,298	346,319
New Jersey Estimate	270,382	272,954	308,938	279,678	182,671	107,278	108,194	184,046	190,449	193,463	245,444	69,669
Delaware Estimate	454,151	381,309	272,934	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	13	13	13	11	13	13	13	13	13	13	13
Number of Beaches Surveyed in NJ	11	12	12	12	12	12	12	12	12	12	13	12
Main Beaches in DE	Big Stone	Big Stone	Slaughter	Big Stone	Big Stone	Kitts Hummock	Slaughter	Pickering	Big Stone	Big Stone	Big Stone	Big Stone
	Slaughter	Slaughter	Big Stone	South Bowers	Slaughte	Pickering	Pickering	Ted Harvey	Slaughter	Slaughter	Slaughter	Slaughter
	Pickering	South Bowers	Pickering	Pickering	South Bowers	Big Stone	Big Stone	S. Bowers	S. Bowers	S. Bowers	S. Bowers	Pickering
		Pickering						Big Stone	Pickering	Pickering	Pickering	
Main Beaches in NJ	Reeds	South CSL	Norburys	Norburys	Norburys	Norburys	Fortescue	Fortescue	South CSL	South CSL	South CSL	South CSL
	Norburys	Fortescue	South CSL	South CSL	South CSL	Reeds	Norburys	South CSL	Norburys	Norburys	Norburys	Norburys
	Pierces Point	Norburys	Fortescue		Fortescue	Fortescue		Gandys	Fortescue	Gandys	Reeds	

**Table 2. Comparison of Date on Horseshoe Crabs Spawning on Delaware Bay Shores
Years 1999-2019 (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 1999-2019

Survey Year	State	Percentage				Dates Missed
		0	Low (<5)	Moderate (5-10)	High (>10)	
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
2017	New Jersey	4	63	6	15	11
	Delaware	17	47	15	14	6
2018	New Jersey	3	49	13	17	17
	Delaware	3	44	8	24	22
2018 Apr	New Jersey	50	39	0	0	11
	Delaware	13	79	0	3	5
2019	New Jersey	0	37	17	27	20
	Delaware	3	33	17	29	18

Table 4. Seasonal Estimates of Horseshoe Crabs 1999-2019

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
2017	997,715	1,041,994	2,039,709
2018	1,189,246	1,675,841	2,865,087
2019	1,291,799	2,105,447	3,397,246

Table 5. Sex Ratios and Estimates of Male and Female Horseshoe Crabs 1999-2019

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
2017	5.15	331,660	1,708,049
2018	5.54	438,087	2,427,000
2019	5.38	532,484	2,864,762

Table 6. Sex Ratios by Beach 2019

Beach	2016	2017	2018	2019
	Avg Sex Ratio Male to Female	Avg Sex Ratio Male to Female	Avg Sex Ratio Male to Female	Avg Sex Ratio Male to Female
Cape Henlopen, DE	5.06	5.96	6.94	5.12
Broadkill, DE	3.85	3.76	6.71	4.63
Prime Hook, DE	2.76	3.29	5.46	4.02
Fowlers, DE	3.20	3.03	3.75	3.56
Slaughter, DE	3.63	4.14	4.30	5.02
Big Stone, DE	4.53	5.66	6.07	6.56
Bennetts, DE	2.24	2.08	5.70	3.51
South Bowers, DE	5.44	6.57	7.21	6.83
North Bowers, DE	5.62	6.73	6.60	7.46
Ted Harvey WMA, DE	5.10	5.90	6.27	6.95
Kitts Hummock, DE	4.72	6.14	6.02	7.67
Pickering, DE	4.82	6.95	6.28	7.07
Woodland, DE	2.88	2.81	-	-
Average Sex Ratio		4.85	5.88	6.05
Higbees, NJ	2.76	3.35	2.50	2.85
North Cape May, NJ	3.34	2.43	3.71	2.82
Townbank, NJ	3.09	3.85	3.31	3.23
Villas, NJ	3.12	3.57	3.51	4.34
Norburys Landing, NJ	3.64	4.74	5.46	4.37
South Cape Lab, NJ	4.79	4.58	5.11	4.76
Highs Beach, NJ	5.08	5.72	6.51	4.44
Pierces Point, NJ	6.14	4.03	5.26	4.45
Kimbles, NJ	4.30	5.58	6.19	6.66
Reeds, NJ	4.71	4.68	5.58	5.13
Fortescue, NJ	4.61	7.03	8.85	6.17
Gandys, NJ	3.50	4.10	4.11	Not Surveyed
Average Sex Ratio			5.17	4.74
North Pierces, NJ	5.61	6.50	8.29	7.17
Cooks, NJ	3.67	4.57	4.69	5.20
Moores, NJ	4.62	4.73	5.72	4.95
Thompsons, NJ	5.35	5.35	6.94	4.99
Dyers Cove, NJ	4.48	6.05	4.48	6.64
Average Sex Ratio			6.38	5.34

Table 7. Percentages of Sex Ratios During 2019 Survey

Delaware

Sex Ratio	% 2015	% 2016	% 2017	% 2018	% 2019
No Sex Ratio	24	21	24	8	22
Less Than 1	6	1	3	3	1
1 to less than 3	33	28	20	24	9
3 to less than 5	26	28	19	15	25
5 to less than 7	8	17	21	26	23
Greater than 7	2	5	13	24	20

New Jersey

Sex Ratio	% 2015	% 2016	% 2017	% 2018	% 2019
No Sex Ratio	20	11	22	4	24
Less Than 1	1	2	1	0	0
1 to less than 3	23	29	22	27	17
3 to less than 5	26	38	35	27	30
5 to less than 7	23	15	15	29	24
Greater than 7	6	6	5	13	5

Additional New Jersey Beaches

Sex Ratio	% 2015	% 2016	% 2017	% 2018	% 2019
No Sex Ratio	13	15	30	6	18
Less Than 1	0	0	0	0	0
1 to less than 3	10	22	17	20	8
3 to less than 5	19	35	33	25	30
5 to less than 7	27	22	13	22	22
Greater than 7	31	7	7	27	22

Table 8. Tagged Horseshoe Crabs Observed During Surveys 2007-2019

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
2017	321	39	282	70	251	306	15	1
2018	260	55	205	42	218	240	20*	0
2019	322	77	245	54	268	296	26	0
Totals	2476	842	1634	547	1929	2316	160	50

* Tallied as dead, not reported as alive or dead.