

The 2018 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 2018. This year, the schedule included 15 dates, not the usual 12. Three counts, April 27th, April 29th and May 1st were added surrounding the full moon date in late April. A total of 375 counts were planned, of which 310 counts were completed with 65 cancelled due to weather (41), no access (9), no surveyors (8) and other (7). An additional 75 counts were scheduled on five new/restored beaches in New Jersey with 12 dates cancelled due to weather (5), no access (4), no surveyors (1) and other (2).

A single day peak estimate of 654,263 horseshoe crabs (272,954 New Jersey, 381,309 Delaware) was reached on May 31st, two days after the full moon. The 2018 single day peak estimate for the Delaware Bay is the highest estimate in the series from the years 1999-2018. New Jersey's 2018 peak estimate of 272,954 was lower than last year's estimate of 308,938, but is among the highest of the estimates. Delaware's peak estimate of 381,309 set a record as the highest estimate in the time series (1999-2018). Delaware's estimate surpasses previous years by 100,000 to 200,000 spawners and was similar to two previous estimates, 351,090 recorded in 2007 and 340,854 in 2009. The peak estimate of 48,177 for the five additional beaches was achieved on May 31st as well.

The 2018 seasonal activity for the Delaware Bay was 2,865,087 (1,189,246 New Jersey, 1,675,841 Delaware). The seasonal estimate was the greatest estimate in the time series, exceeding the 2016 estimate of 2,461,704. The seasonal number of horseshoe crabs for the new/restored beaches was estimated to be 193,943.

The average male to female sex ratio for the entire Bay was 5.54 during the 12 survey nights and is the highest in the time series (1999-2018). The sex ratio of 5.16 for the New Jersey side was considerably lower than Delaware's ratio of 5.90. The sex ratio combined with the seasonal estimate for 2018 equated to estimates of 438,087 female spawners and 2,427,000 males. Even with the high sex ratio, the number of female spawners was similar to the record established in 2016 of 444,351 female spawners. For the five additional New Jersey beaches, the sex ratio of 6.37 was considerably higher than the average sex ratio of 5.16 for the 12 New Jersey beaches.

Spawning activity surrounding the full moon date of April 29th was minimal in New Jersey with an estimate of 7,558 and was greater in Delaware with an estimate of 59,128. During the April counts, horseshoe crabs were observed on 32 of the scheduled 39 dates in Delaware and 14 of the 36 dates in New Jersey.

Computed from the April dates, the sex ratio of 7.01 in New Jersey was higher and the sex ratio of 5.53 in Delaware was lower than the average ratios for the 12 dates.

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 2018 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). 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 12 beaches included Higbees, North Cape May, Townbank, Villas, Norburys Landing, South Cape Shore Lab, Highs, Pierces Point, Kimbles, Reeds, Fortescue and Gandys.

The counts were taken simultaneously along the 25 beaches during the high tides encompassing the new and full moons on the dates of April 27th, 29th, May 1st, 13th, 15th, 17th, 27th, 29th, 31st and June 11th, 13th, 15th, 26th, 28th and 30th. Times of high tides ranged from 7:34pm 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: 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 spawning on these beaches.

Results

Along the 25 beaches, 375 surveys were scheduled, 195 in Delaware and 180 in New Jersey over 15 dates. Of these, 310 surveys (83%) were conducted with 65 cancellations due to weather (41), no access (9), no surveyors (8) and other (7).

The majority of the weather cancellations occurred on two dates, May 15th and May 27th. On May 15th, the new moon date, all 13 counts in Delaware and nine of the 12 counts in New Jersey were cancelled. And on May 27th, two days before the full moon, seven counts were cancelled in Delaware and six counts were cancelled in New Jersey. (Table 1A, 1B and 1D)

Eight incomplete counts were recorded in Delaware and none in New Jersey. Surveys were incomplete if fewer than 100 quadrats were counted, with Gandys Beach being the exception where a complete count is 66 quadrats. The incomplete counts in Delaware occurred April 27th (34 quadrats) and April 29th (63 quadrats) at Woodland Beach, May 27th and June 11th (51 quadrats both dates) at Broadkill, May 31st at North Bowers (42 quadrats), at South Bowers (78 quadrats) and at Ted Harvey WMA (68 quadrats) and lastly, June 30th at North Bowers (50 quadrats). At Gandys Beach in New Jersey, in past years, many incomplete and/or cancellations due to flooding/access were noted, however this year none were recorded. This was due in part to volunteers intentionally arriving to count approximately 30 minutes past high tide to avoid flooding/access issues. (This is noted on the Beach Site Sheet).

Seventy-five counts were scheduled for the five new/restored beaches in New Jersey, 60 in May and June and 15 in April. Of the 60 counts scheduled in May and June, a total of 49 surveys (82%) were performed and 11 dates were cancelled due to weather (4), no access (4), no surveyors (1) and other (2). During the April counts, one count was cancelled due to weather and the remaining 14 counts recorded few horseshoe crabs. (Table 1C and 1E)

This year's (2018) peak estimate of spawners along Delaware and New Jersey's shores of 654,263 is the greatest in the time series (1999-2018). The 2018 estimate is higher than previous high estimates of 581,872 recorded last year and 586,298 recorded in the year 2009. The peak spawning estimate can be attributed to 58% spawning in Delaware and 42% in New Jersey. Spawning estimates were greatest during two dates, May 29th and May 31st, contributing 44% to the seasonal estimate. Three estimates from the dates of May 17th, June 13th and June 15th added another 41% to the seasonal estimate. (Table 1A and 1B and Figure 1)

The greatest densities of the season were reached May 29th and May 31st, at South Cape Shore Lab in New Jersey of 34.04 and 34.56 horseshoe crabs per square meter, respectively (Table 1A) and at Pickering in Delaware of 35.52 and 33.73 crabs per square, respectively (Table 1B). At Woodland beach, the most northern beach in Delaware, the majority of the counts were cancelled due to no access and the three counts that were performed recorded zero horseshoe crabs. (Table 1B and 1D)

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 counts in April were categorized separately from the 12 dates.

The majority of the dates surveyed (44% in DE and 49% in NJ) recorded densities lower than five horseshoe crabs per square meter. Dates with high densities were most notable in 2018 with 24% in Delaware and 17% in New Jersey (Figure 3B). Percentages with zero counts were among the lowest of the series (1998-2018), 3% in both Delaware and New Jersey. Many dates were cancelled due to weather in 2018 and the percentage of dates missed was the among the highest in the time series (Figure 3A). (Table 3)

During the April counts in New Jersey, few horseshoe crabs were observed and 50% of the counts recorded zero horseshoe crabs. In Delaware, more horseshoe crabs were estimated in April than New Jersey, with fewer counts with zero crabs (13%). Only one count exceeded five crabs per square meter and that was 10.33 crabs per square meter recorded at Ted Harvey WMA. (Table 1D)

The seasonal activity of 1,189,246 for the New Jersey side of the Bay replaced the last year's estimate of 997,715 for the second highest in the time series (1999-2018). It is slightly lower than the 2016 record estimate of 1,271,102. Delaware's seasonal estimate of 1,675,841 is the highest of the series (1999-2018) replacing the 2007 estimate of 1,450,837. (Table 4 and Figure 4). In Delaware, Slaughter, Big Stone (due to its beach expanse) and South Bowers had the highest estimates of spawning crabs. In New Jersey, Norburys Landing, South Cape Shore Lab and Fortescue had the highest spawning estimates. (Table 1A and 1B and Table 2).

The peak estimate for the five additional New Jersey beaches was achieved on the date of May 31st and along with the May 29th estimate contributed 45% to the seasonal estimate. These results were similar to the results of the 25 dates, however unlike the other beaches that had good numbers June 13th and 15th, little activity was recorded on the new/restored beaches during these two dates. The peak date of May 31st along with three dates (May 13th, May 17th and May 29th) contributed to the majority of the seasonal estimate (74%). The greatest densities were achieved at Thompsons beach May 13th (23.98 horseshoe crabs per square meter) and May 17th (25.50 horseshoe crabs per square meter). The majority of the densities (58%), however, were low densities (less than 5 crabs per square meter). (Table 1C)

The 2018 average sex ratio of 5.54 for the entire Delaware Bay is the highest on record, but when combined with the seasonal estimate, it equated to 438,087 females spawning along the survey beaches. The estimate of female spawners is the second highest estimate in time series (1999-2018), slightly less than the 2016 record estimate of 444,351 (Table 5 and Figure 5). The average sex ratio for the five additional New Jersey beaches was 6.37 and was higher than the average sex ratio of the 12 surveyed beaches in New Jersey (5.16). (Table 6)

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 counted was plotted against the sex ratio for 270 dates (Figure 7). The sex ratio of 22 males surrounding one female observed June 26th at North Pierces Point and the sex ratio of 50 males surrounding two females on June 30th at Dyers Cove were not plotted as they were viewed as extreme outliers.

The sex ratios were categorized according to percentage of occurrence for the 12 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. Two high sex ratios, of 22 males surrounding one female and 50 males surrounding two females, were observed at two new/restored beaches in New Jersey. In Delaware, the highest sex ratios (male/female) recorded were 14.33 horseshoe crabs per square meter at South Bowers on June 15th and 17.05 crabs per square meter at North Bowers on June 30th. In New Jersey, at Fortescue, sex ratios of 10.95 and 10.54 horseshoe crabs per square meter were recorded on May 17th and on May 29th, respectively. (Figure 7A)

Average sex ratios were also calculated for each survey night for the 13 Delaware beaches, the 12 New Jersey beaches and the additional five New Jersey beaches. The ratios were graphed by survey date (Figure 7B) and also graphed by State separating the May and June counts (Figure 7C and 7D). Sex ratios were also graphed for the years 2015, 2016, 2017 and 2018 at New Jersey beaches, Delaware beaches and the restored/ replenished New Jersey beaches (Figures 7E, 7F and 7G). In New Jersey, the percentage of sex ratios greater than 7 rose from the previous three years' percentages. In Delaware, the percentage of sex ratios greater than seven as well as the ratios in the range of 5 to 7 males per one female rose steadily over the last four years and the lesser sex ratios of 1 to 3 and 3 to 5 males per one female decreased. At the new/restored beaches, ratios greater than seven were steady in 2016 and 2017, but rose considerably in 2018. Percentages of 1 to 3 males and 5 to 7 males per one female increased slightly while the percentages of sex ratios from 3 to 5 males per one female decreased.

Observations of tagged horseshoe crabs during the survey counts numbered 260, mainly from New Jersey (205) where tagging took place during the season. The majority of the tagged animals were alive (240) and encountered outside the quadrats (218). Many of the tagged animals were observed at Kimbles (35), Fortescue (30) and Reeds (22) as well as the replenished beaches, Thompsons (55), North Pierces Point (20) and Moores (12). (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

The 2018 peak estimate and the 2018 seasonal estimate were the highest encountered over the time series (1999-2018). Spawning estimates were good despite many weather cancellations that occurred during peak spawning times. New Jersey's peak estimate was the second highest, slightly lower than last year's peak and Delaware's estimate was among the highest peak estimates encountered. During the April counts, spawning horseshoe crabs were recorded in Delaware and few numbers were observed in New Jersey. This year, the average sex ratio for the Delaware Bay increased to 5.54. Delaware's sex ratio of 5.90 males per female was greater than the sex ratio of 5.17 for the New Jersey side. The average sex ratio for the restored/ replenished beaches was the greatest at 6.37 male horseshoe crabs per one female.

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. This year's estimates were again some if not the highest on record. The estimates would have been much greater if many of the counts weren't cancelled due to weather during optimum spawning times May 15th and May 27th. The male numbers seem to be increasing at a greater rate, most likely related to spawning behavior as males tend to stay along the beaches for a longer period of time than the females.

The 2018 sex ratio of 5.54 increased from last year's ratio of 5.15 and the sex ratios between the 12 New Jersey, 13 Delaware and five new/restored beaches show a wide variation. The difference between the sex ratio of the 12 New Jersey beaches and the higher ratio of the five new/restored beaches may be an indication of the attributes of the beach habitat. The females may sense the different (replenished) sand and avoid the beach, lessening the number of females on the beach. The male horseshoe crabs are attracted to the females and congregate around the less numerous females on these beaches, thus still increasing the number of males.

If the spawning habitat sand is important to the female spawners, the erosion along the surveyed beaches of the Delaware Bay may deter the females from spawning on these once prime beaches. This may explain in part the increasing sex ratio along the Delaware Bay and possibly the difference in the sex ratio between the two shores of the Bay. Other environmental factors that may create localized differences in the spawning habitat and conditions along the shoreline include local weather, wind direction and speed, and fresh water flow to name a few.

Densities greater than 10 horseshoe crabs per square meter are increasing as well, which may also be an indication of the limiting space available for spawning due to eroding beaches. The beaches for the Delaware Bay Survey were selected by accessibility. It is likely that the newly formed, perhaps more favorable spawning

sites have developed along the Delaware Bay shore and the females may be spawning outside of the standard accessible beaches and thus outside our counting range.

Acknowledgements

A special THANK YOU is extended to Sherry Bennett, a New Jersey State Fisheries Biologist with a special focus on the Delaware Bay Spawning Survey. Ms. Bennett enters all the data collected from the survey counts. She also manages to survey two beaches in New Jersey with one of them being Gandys Beach which is challenging due to flooding issues. Sherry Bennett is an unsung hero of the Delaware Bay Horseshoe Crab Spawning Survey and we greatly appreciate her hard work over the last 20 years.

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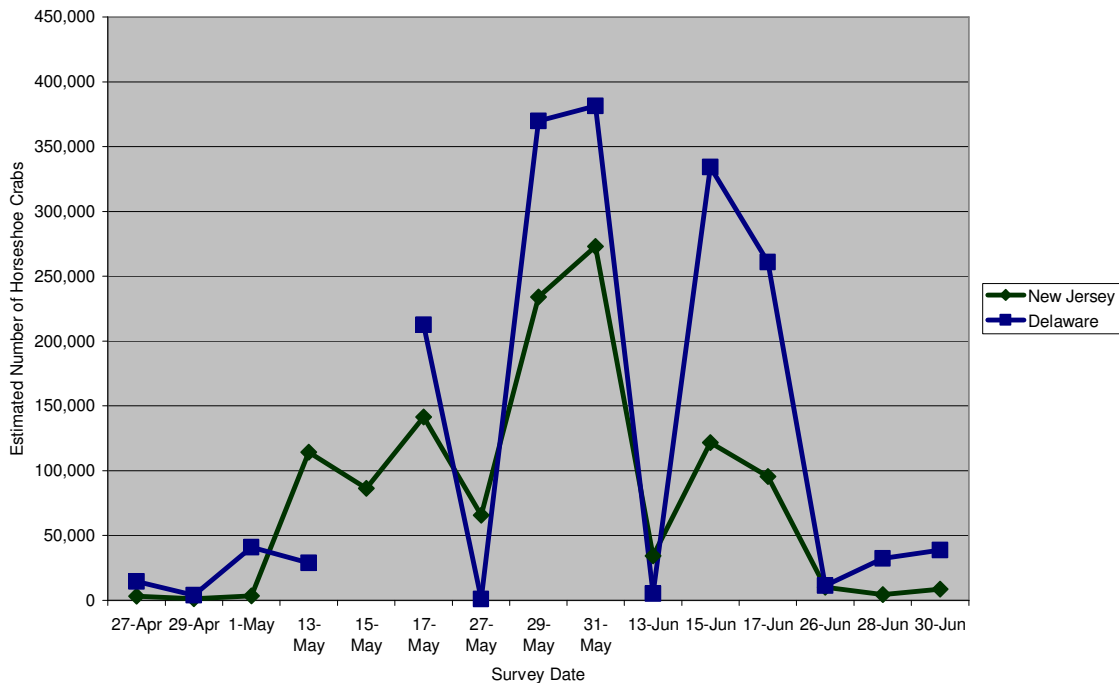


Figure 1C. New Jersey Spawning Estimates During 2018 Survey
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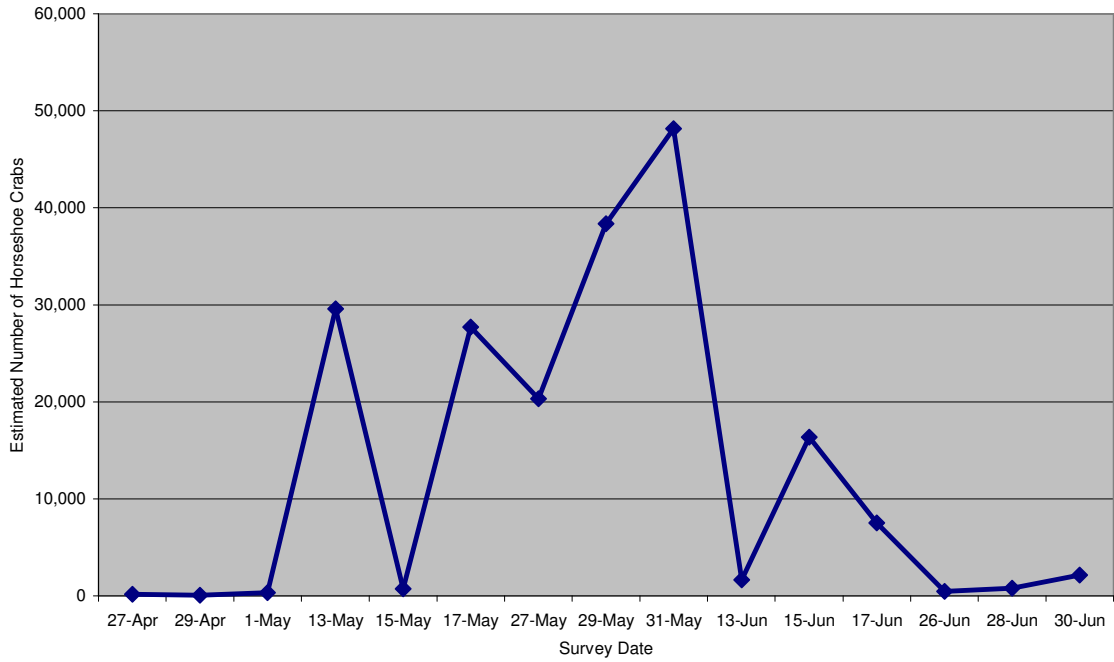


Figure 2. Peak Estimates of Spawning Horseshoe Crabs Years 1999-2018

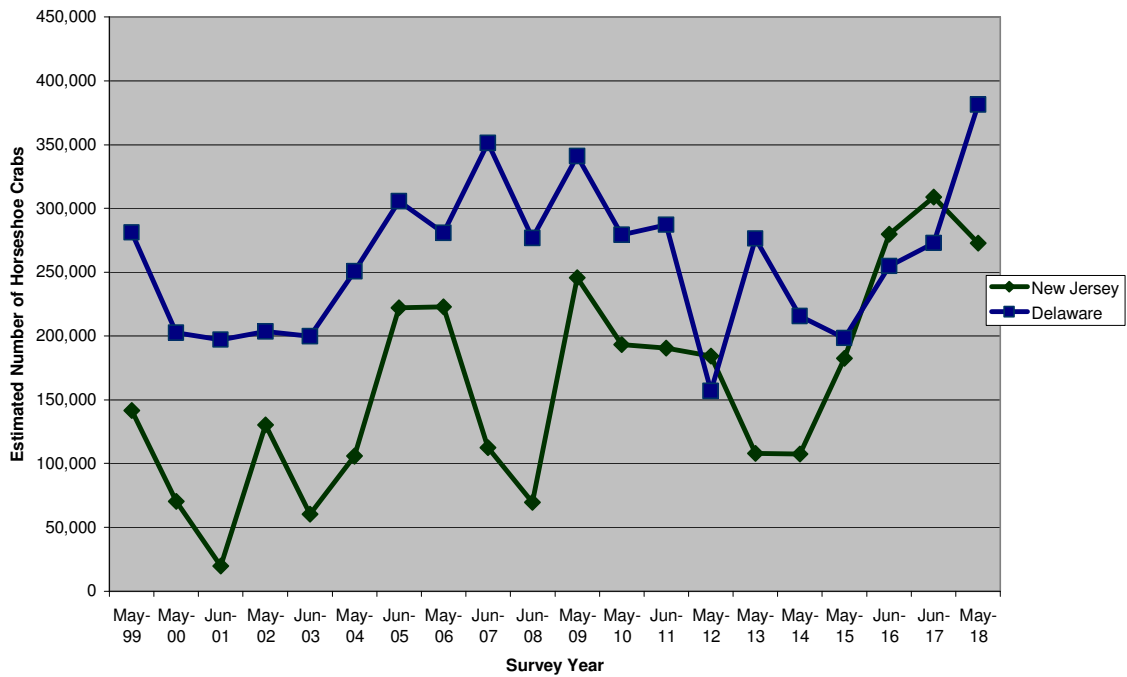


Figure 3. A. Percentages of Dates Missed by Year 1999-2018

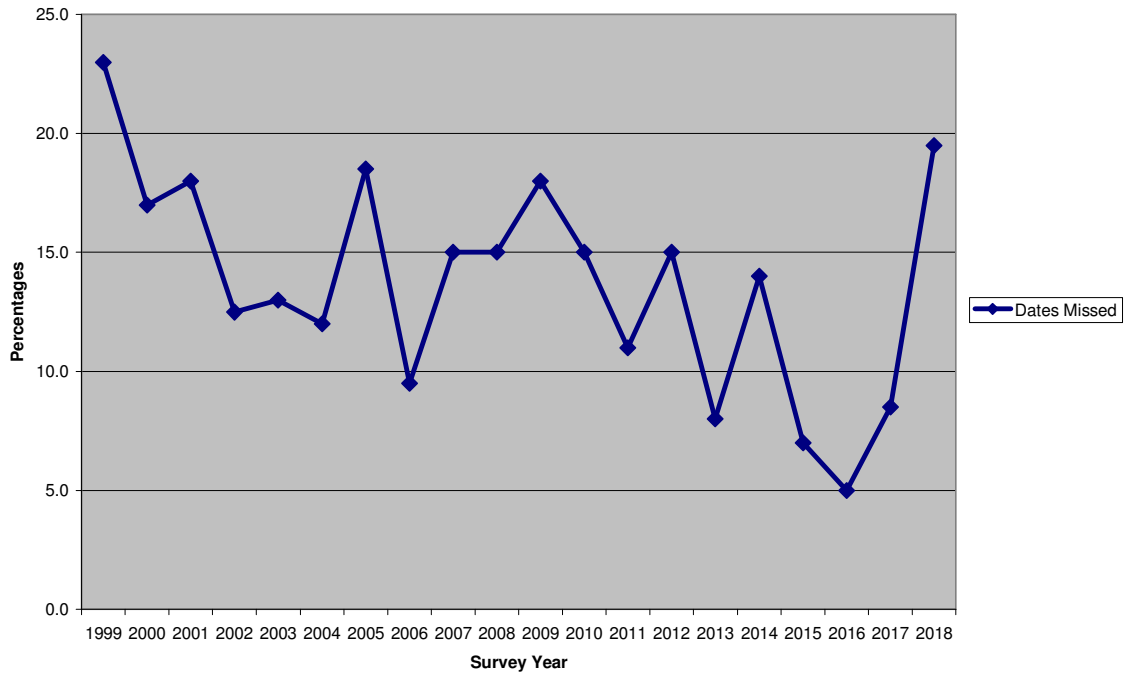


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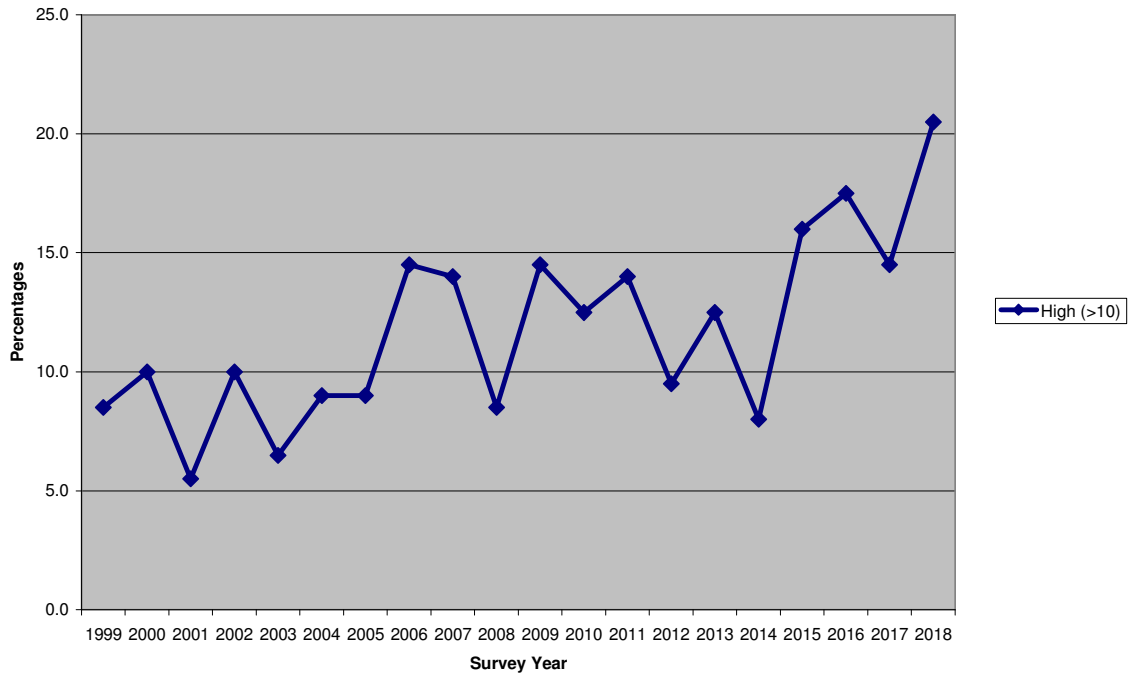


Figure 4. Seasonal Estimates of Horseshoe Crabs 1999-2018

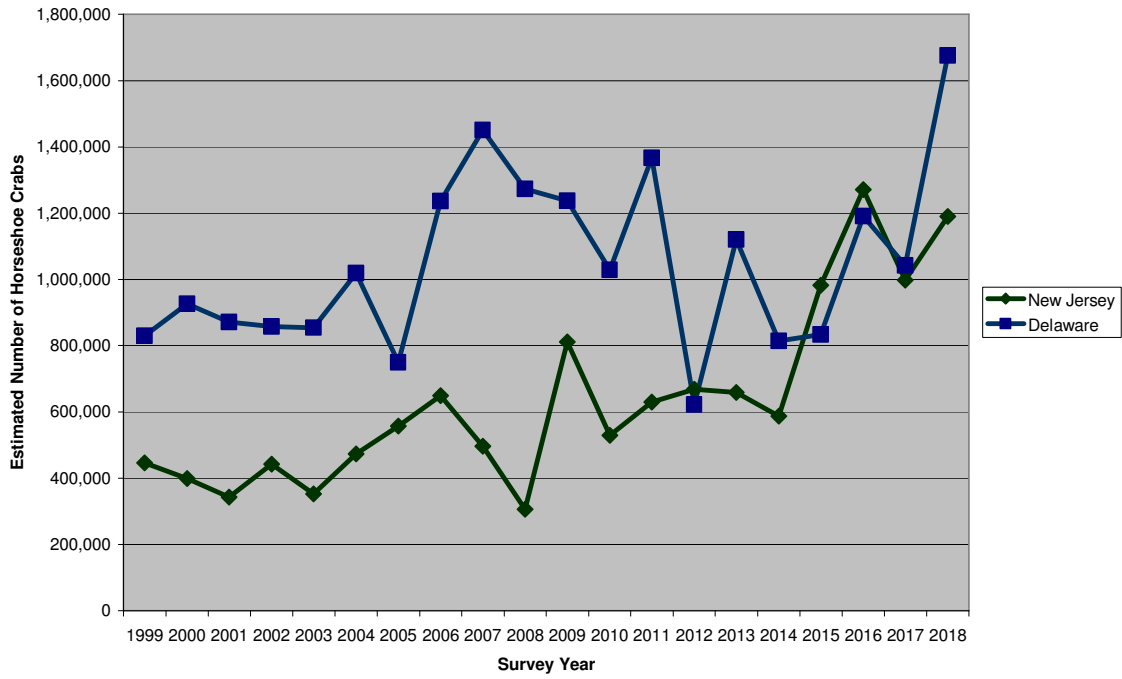
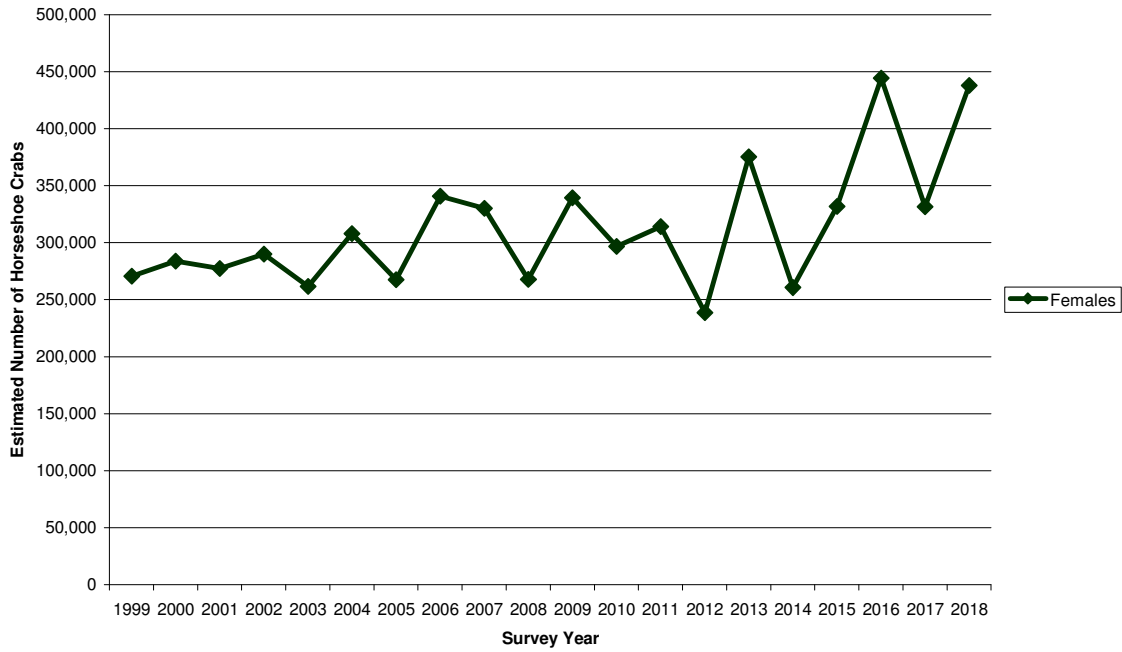


Figure 5. A. Seasonal Estimates of Female Horseshoe Crabs 1999-2018



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1999-2018**

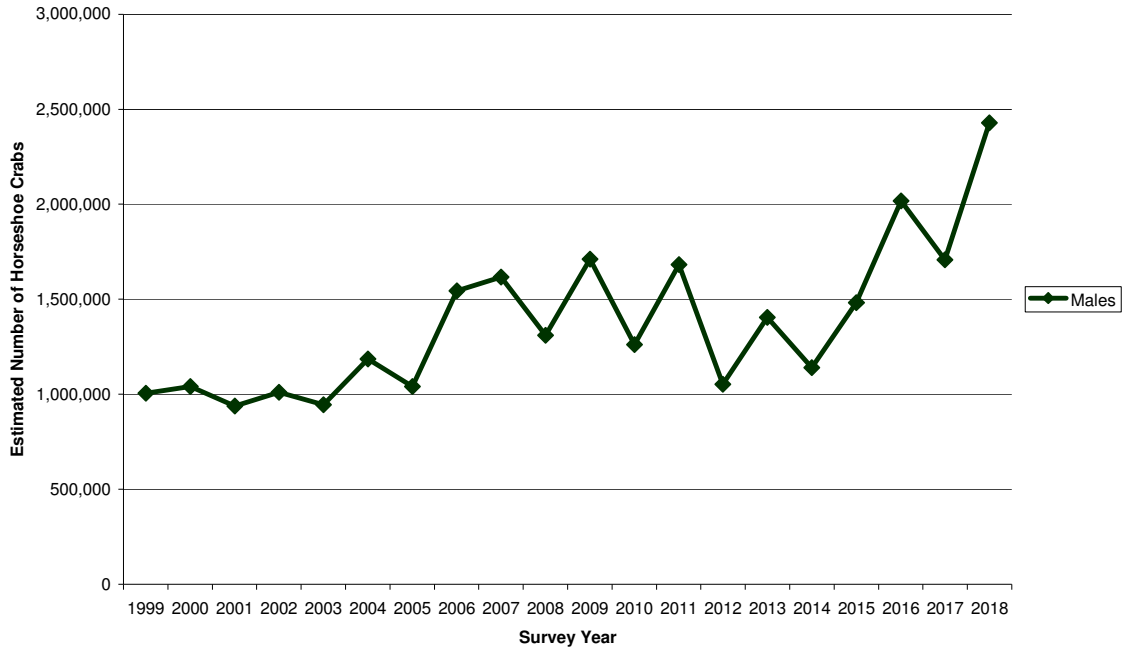


Figure 6. Average Sex Ratios by Beach 2018

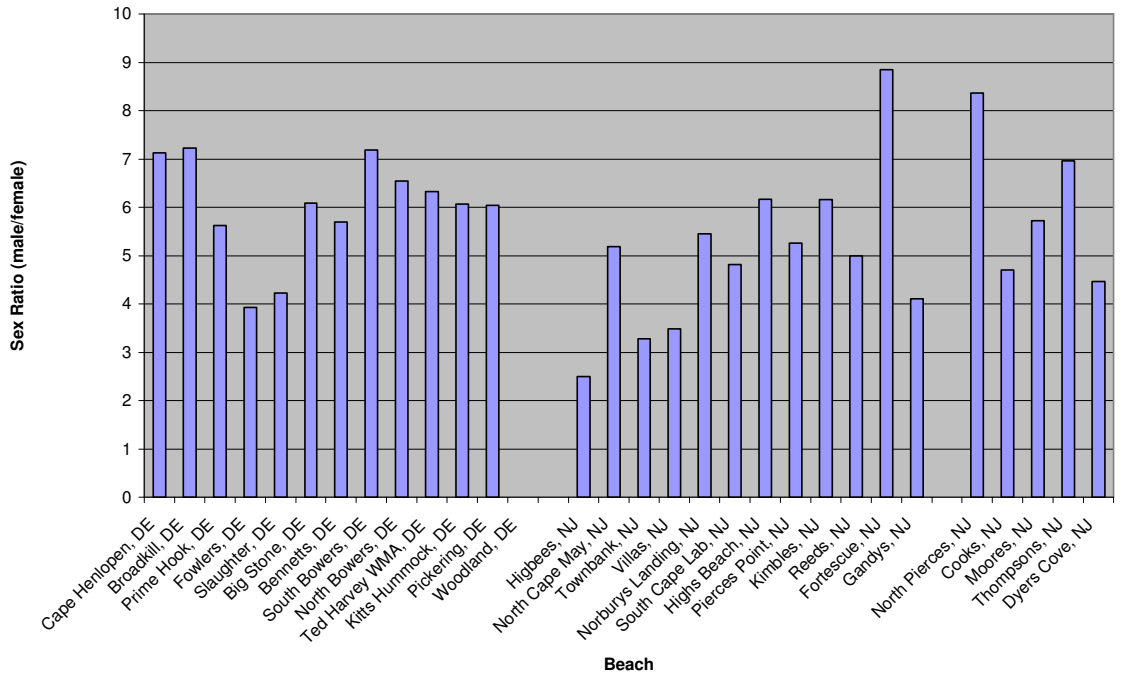


Figure 7. Numbers of Horseshoe Crabs versus Sex Ratios 2018

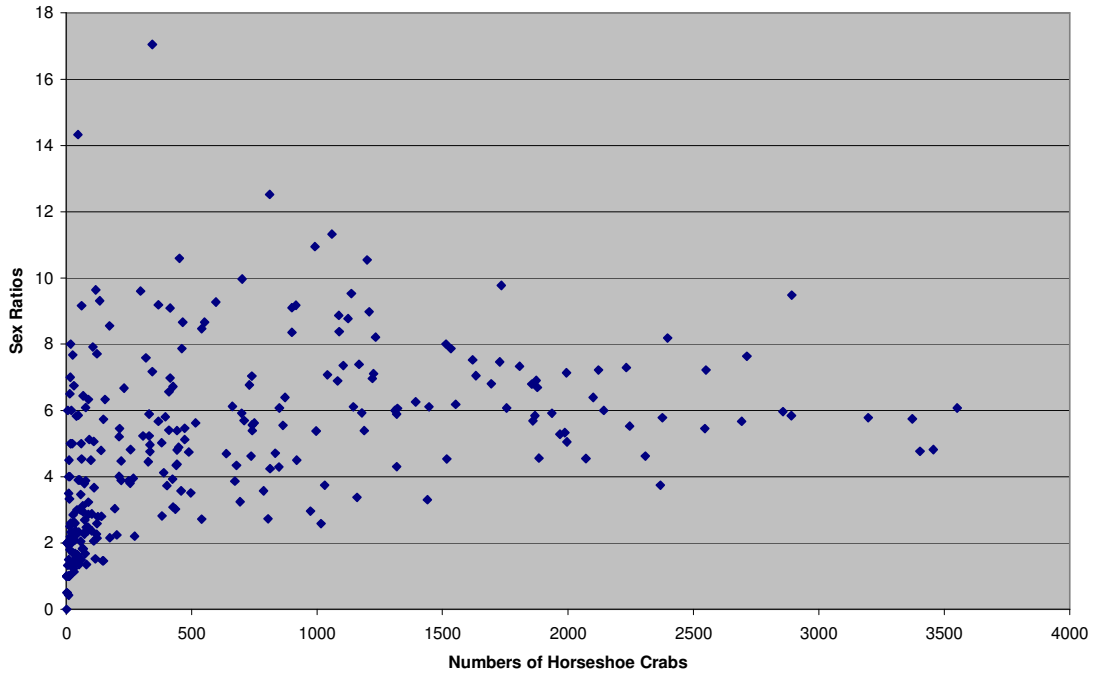


Figure 7A. Sex Ratio Categories 2018

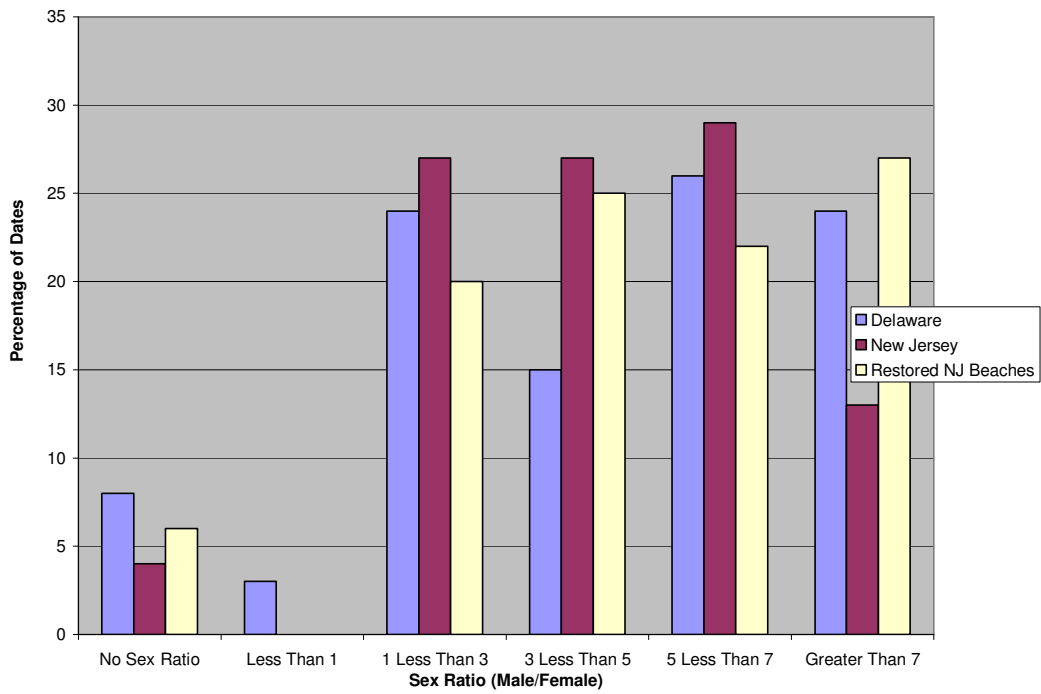


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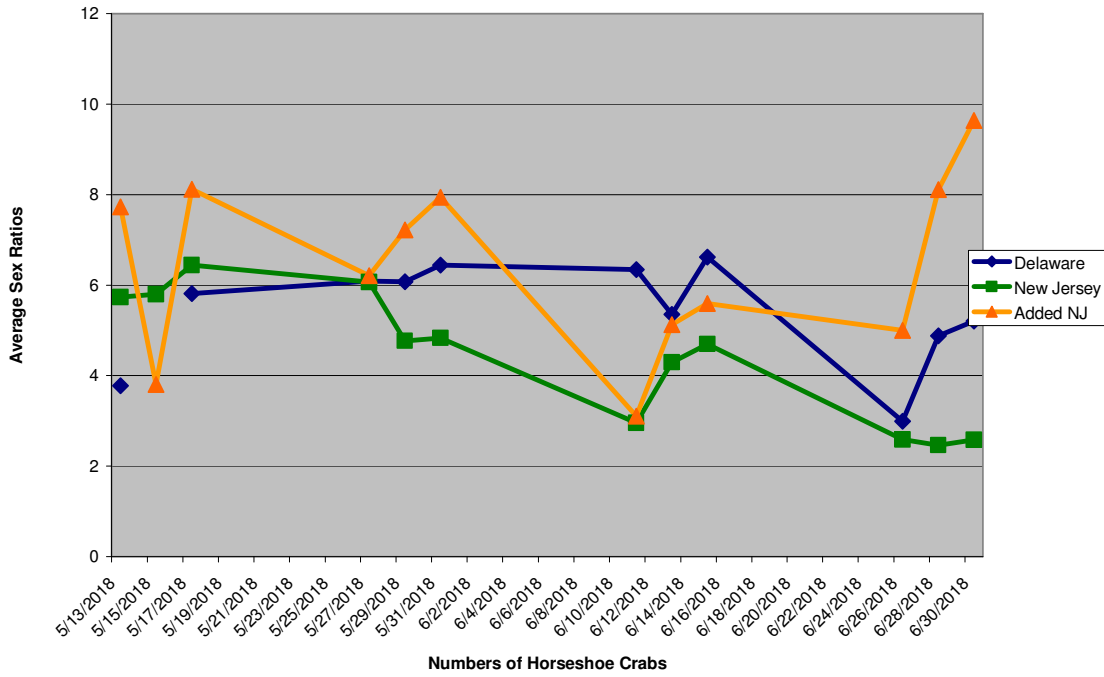


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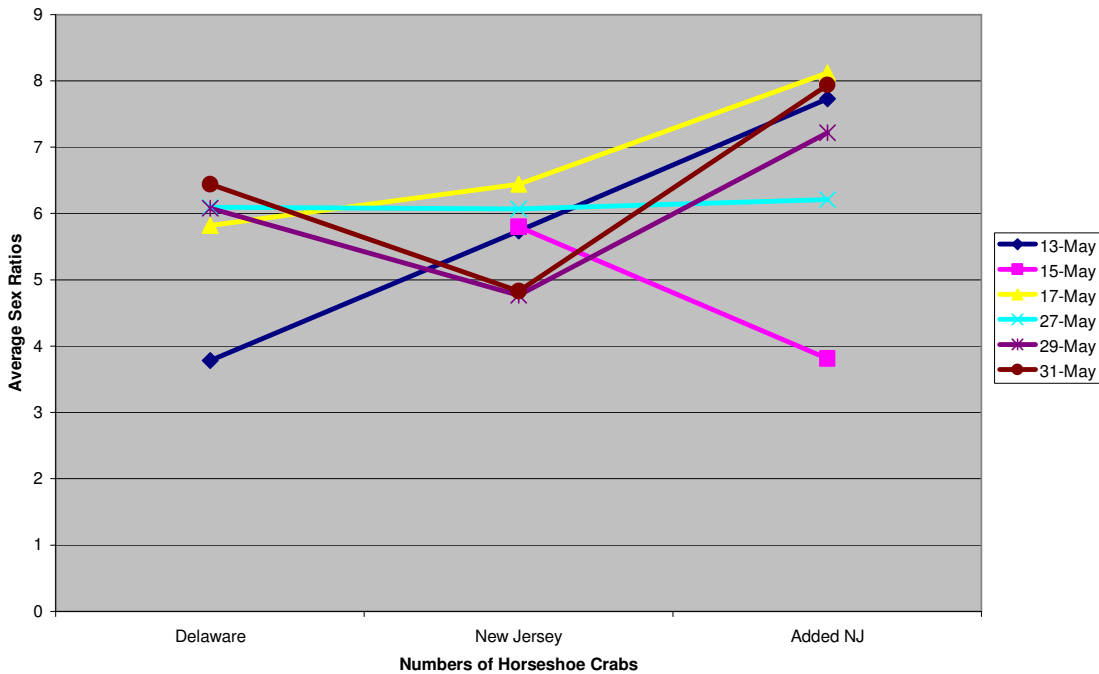


Figure 7. D. Sex Ratios By State During June 2018

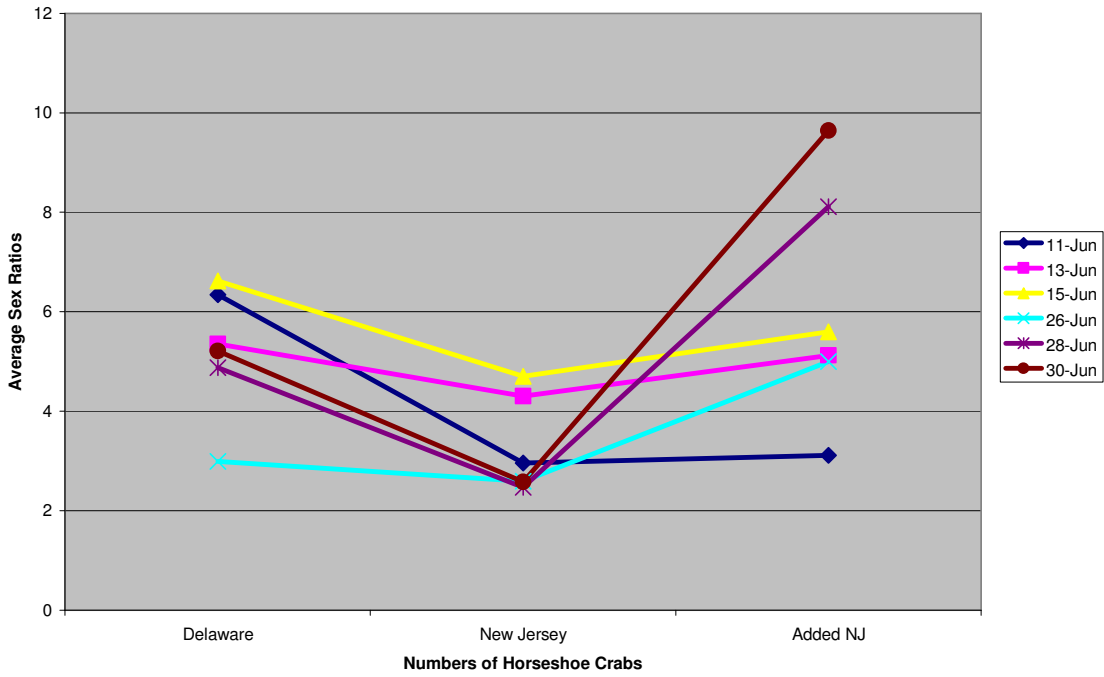


Figure 7.E. Percentages of Sex Ratios at New Jersey Beaches 2015 -2018

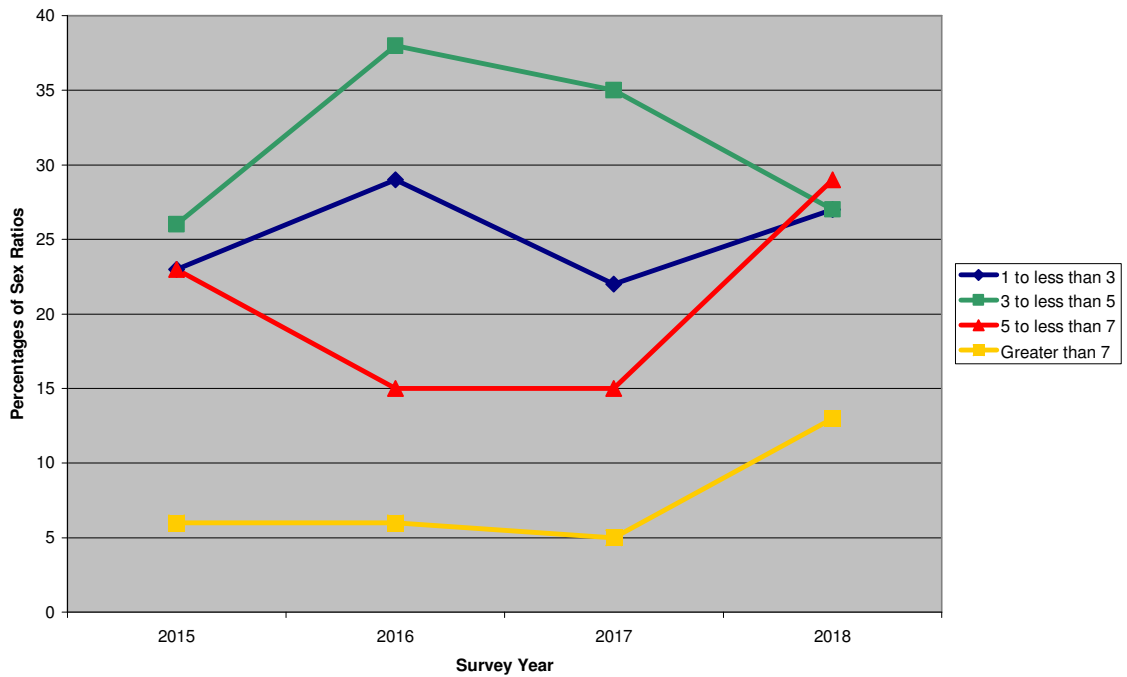


Figure 7.F. Percentages of Sex Ratios at Delaware Beaches 2015 -2018

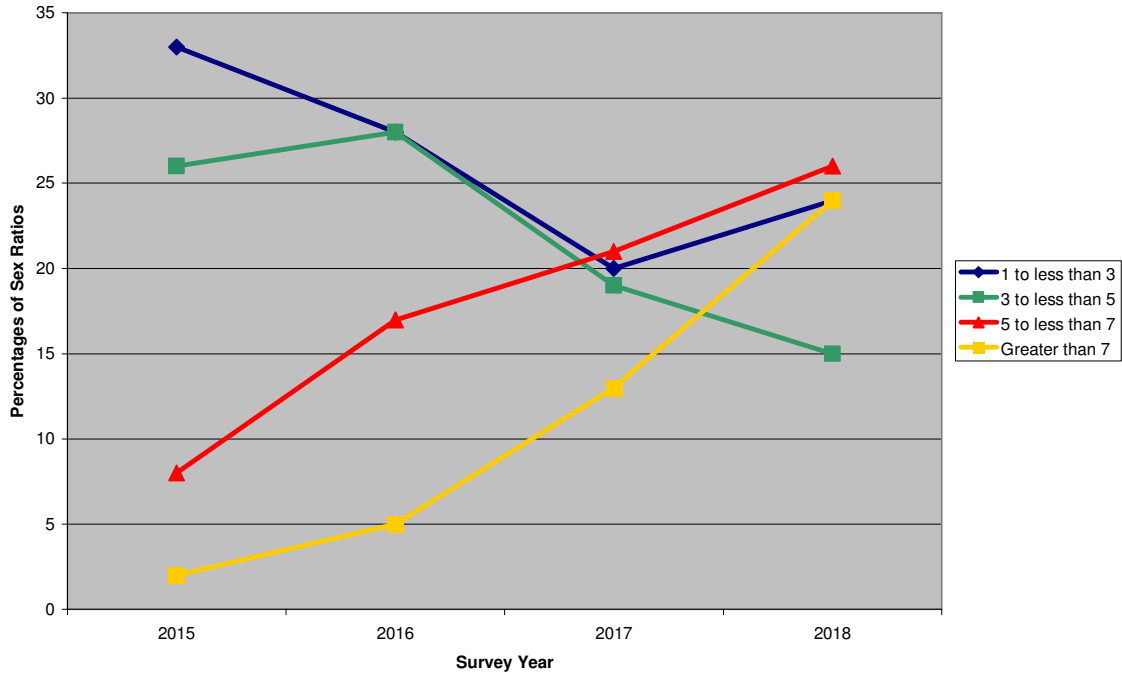


Figure 7.G. Percentages of Sex Ratios at Restored/Replenished Beaches 2015 -2018

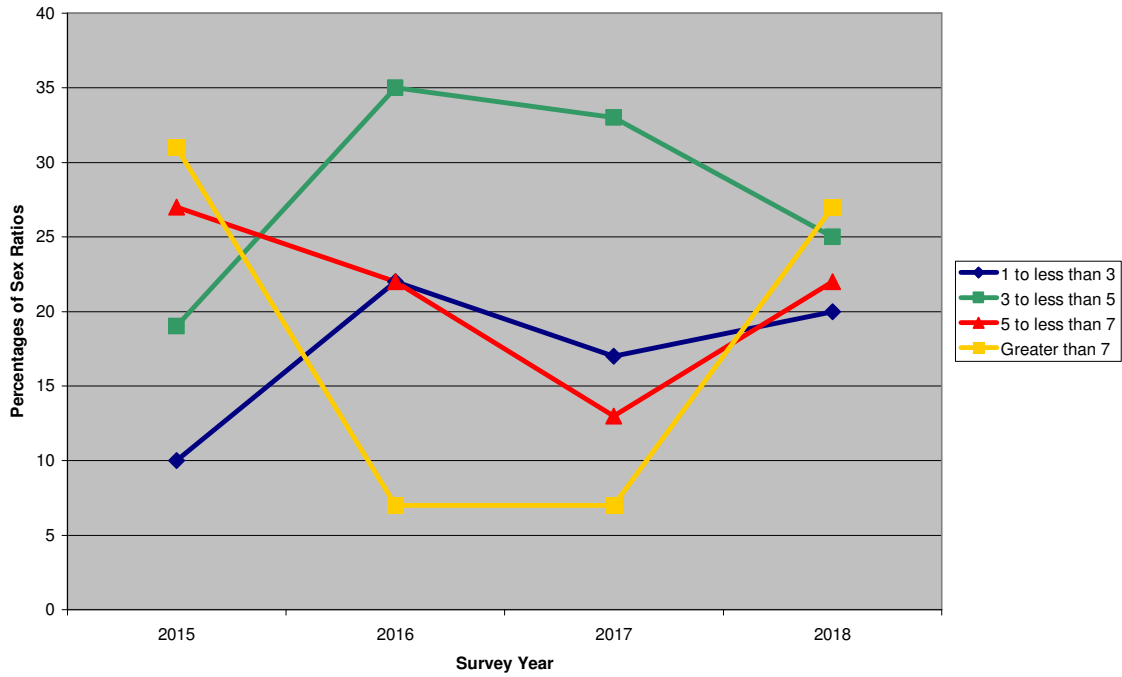


Table 1A. 2018 Survey Results – Densities and Estimates -New Jersey Beaches (2 pages)

Moon Phase Date	New-2 13-May	New 15-May	New+2 17-May	Full-2 27-May	Full 29-May	Full+2 31-May
Higbees * (0.98 km)						
Density of HSC, Crabs/m	cc-weath			cc-weath	1.48	1.45
Estimated Number of HSC		0	0		1,450	1,421
North Cape May * (3 km)						
Density of HSC, Crabs/m	cc-ns	cc-weath	cc-weath	cc-weath	1.41	cc-ns
Estimated Number of HSC					4,230	
Townbank (2.3 km)						
Density of HSC, Crabs/m	0.16	cc-weath	0.54	cc-ns	3.82	8.05
Estimated Number of HSC	368		1,242		8,786	18,515
Villas (2 km)						
Density of HSC, Crabs/m	0.99	cc-weath	2.11	cc-weath	9.73	11.60
Estimated Number of HSC	1,980		4,220		19,460	23,200
Norburys Landing (2.43 km)						
Density of HSC, Crabs/m	4.41	cc-weath	4.09	cc-weath	18.61	19.88
Estimated Number of HSC	10,716		9,939		45,222	48,308
South CSL * (2.2 km)						
Density of HSC, Crabs/m	8.34	28.91	26.92	22.46	34.04	34.56
Estimated Number of HSC	18,348	63,602	59,224	49,412	74,888	76,032
Highs * (0.8 km)						
Density of HSC, Crabs/m	12.34	28.57	8.99	8.73	11.78	18.69
Estimated Number of HSC	9,872	22,856	7,192	6,984	9,424	14,952
Pierces Point (0.7 km)						
Density of HSC, Crabs/m	23.09	cc-weath	19.37	13.11	7.41	8.64
Estimated Number of HSC	16,163		13,559	9,177	5,187	6,048
Kimbles (1 km)						
Density of HSC, Crabs/m	2.30	cc-weath	3.06	cc-weath	11.88	15.34
Estimated Number of HSC	2,300		3,060		11,880	15,340
Reeds * (1.53 km)						
Density of HSC, Crabs/m	15.14	cc-weath	5.16	cc-weath	14.46	18.84
Estimated Number of HSC	23,164		7,895		22,124	28,825
Fortescue (2.6 km)						
Density of HSC, Crabs/m	10.86	cc-weath	12.00	cc-ns	9.92	12.08
Estimated Number of HSC	28,236		31,200		25,792	31,408
Gandys * (1.2 km)						
Density of HSC, Crabs/m	2.49	cc-weath	3.31	cc-ns	4.72	7.42
Estimated Number of HSC	2,988		3,972		5,664	8,904
Totals	114,136	86,458	141,503	65,573	234,108	272,954
Moon Phase Date	New-2 13-May	New 15-May	New+2 17-May	Full-2 27-May	Full 29-May	Full+2 31-May

Table 1A. 2018 Survey Results – Densities and Estimates -New Jersey Beaches (2 pages)

Moon Phase Date	New-2 11-Jun	New 13-Jun	New+2 15-Jun	Full-2 26-Jun	Full 28-Jun	Full+2 30-Jun	Totals
Higbees * (0.98 km)							
Density of HSC, Crabs/m	0.80	4.25	6.93	0.87	0.74	2.73	
Estimated Number of HSC	784	4,165	6,791	853	725	2,675	18,865
North Cape May * (3 km)							
Density of HSC, Crabs/m	0.21	0.58	4.89	0.11	0.10	cc-ns	
Estimated Number of HSC	630	1,740	14,670	330	300		21,900
Townbank (2.3 km)							
Density of HSC, Crabs/m	1.12	4.97	8.48	0.34	0.04	0.35	
Estimated Number of HSC	2,576	11,431	19,504	782	92	805	64,101
Villas (2 km)							
Density of HSC, Crabs/m	4.35	10.31	7.10	2.01	0.27	0.65	
Estimated Number of HSC	8,700	20,620	14,200	4,020	540	1,300	98,240
Norburys Landing (2.43 km)							
Density of HSC, Crabs/m	1.25	6.38	4.64	0.27	0.12	0.18	
Estimated Number of HSC	3,038	15,503	11,275	656	292	437	145,387
South CSL * (2.2 km)							
Density of HSC, Crabs/m	0.66	4.39	0.72	0.80	0.72	0.58	
Estimated Number of HSC	1,452	9,658	1,584	1,760	1,584	1,276	358,820
Highs * (0.8 km)							
Density of HSC, Crabs/m	0.78	7.40	1.07	0.88	0.24	0.67	
Estimated Number of HSC	624	5,920	856	704	192	536	80,112
Pierces Point (0.7 km)							
Density of HSC, Crabs/m	0.29	9.19	3.34	0.14	0.16		
Estimated Number of HSC	203	6,433	2,338	98	112	0	59,318
Kimbles (1 km)							
Density of HSC, Crabs/m	0.14	3.30	0.31	0.36	0.13	0.48	
Estimated Number of HSC	140	3,300	310	360	130	480	37,300
Reeds * (1.53 km)							
Density of HSC, Crabs/m	0.18	2.11	2.20	0.10	0.15	0.56	
Estimated Number of HSC	275	3,228	3,366	153	230	857	90,117
Fortescue (2.6 km)							
Density of HSC, Crabs/m	3.67	11.68	5.96	0.09	0.03	cc-other	
Estimated Number of HSC	9,542	30,368	15,496	234	78		172,354
Gandys * (1.2 km)							
Density of HSC, Crabs/m	5.40	7.87	4.24		0.16	cc-other	
Estimated Number of HSC	6,480	9,444	5,088	0	192		42,732
Totals	34,444	121,811	95,479	9,950	4,466	8,367	1,189,246
Moon Phase Date	New-2 11-Jun	New 13-Jun	New+2 15-Jun	Full-2 26-Jun	Full 28-Jun	Full+2 30-Jun	Totals

Table 1B. 2018 Survey Results – Densities and Estimates - Delaware Beaches (2 pages)

Moon Phase	New-2	New	New+2	Full-2	Full	Full+2
Date	13-May	15-May	17-May	27-May	29-May	31-May
Cape Henlopen (1.5 km)						
Density of HSC, Crabs/m	0.78	cc-weath	3.43	cc-weath	4.25	5.40
Estimated Number of HSC	1,170		5,145		6,375	8,100
Broadkill (1.5 km)						
Density of HSC, Crabs/m		cc-weath	8.13		18.78	28.93
Estimated Number of HSC	0		12,195	0	28,170	43,395
Primehook * (2.0 km)						
Density of HSC, Crabs/m	2.19	cc-weath	6.78	cc-weath	13.21	10.82
Estimated Number of HSC	4,380		13,560		26,420	21,640
Fowler * (3 km)						
Density of HSC, Crabs/m	1.74	cc-weath	10.15	cc-weath	6.72	13.17
Estimated Number of HSC	5,220		30,450		20,160	39,510
Slaughter * (3 km)						
Density of HSC, Crabs/m	0.01	cc-weath	0.81	cc-weath	23.68	14.39
Estimated Number of HSC	30		2,430		71,040	43,170
Big Stone * (5.0 km)						
Density of HSC, Crabs/m	0.03	cc-weath	13.17	cc-weath	16.95	18.56
Estimated Number of HSC	150		65,850		84,750	92,800
Bennetts Pier (2.6 km)						
Density of HSC, Crabs/m	0.20	cc-weath	0.89	cc-weath	0.92	cc-weath
Estimated Number of HSC	520		2,314		2,392	
South Bowers (2.3 km)						
Density of HSC, Crabs/m	4.48	cc-weath	7.30	cc-weath	17.34	20.77
Estimated Number of HSC	10,304		16,790		39,882	47,771
North Bowers * (1.3 km)						
Density of HSC, Crabs/m	4.41	cc-weath	5.51	0.12	12.20	21.81
Estimated Number of HSC	5,733		7,163	156	15,860	28,353
Ted Harvey WMA (1.0 km)						
Density of HSC, Crabs/m	0.68	cc-weath	10.88	0.44	18.07	22.84
Estimated Number of HSC	680		10,880	440	18,070	22,840
Kitts Hummock * (1.0 km)						
Density of HSC, Crabs/m	0.10	cc-weath	18.74	0.18	21.22	cc-weath
Estimated Number of HSC	100		18,740	180	21,220	
Pickering (1 km)						
Density of HSC, Crabs/m	0.41	cc-weath	27.13	0.12	35.52	33.73
Estimated Number of HSC	410		27,130	120	35,520	33,730
Woodland * (0.5 km)						
Density of HSC, Crabs/m	cc-acc	cc-weath	cc-acc	cc-acc	cc-acc	cc-weath
Estimated Number of HSC						
Totals	28,697		212,647	896	369,859	381,309
Moon Phase	New-2	New	New+2	Full-2	Full	Full+2
Date	13-May	15-May	17-May	27-May	29-May	31-May

Table 1B. 2018 Survey Results – Densities and Estimates - Delaware Beaches (2 pages)

Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	11-Jun	13-Jun	15-Jun	26-Jun	28-Jun	30-Jun	Totals
Cape Henlopen (1.5 km)							
Density of HSC, Crabs/m	2.13	4.15	1.48	1.22	0.26	1.34	
Estimated Number of HSC	3,195	6,225	2,220	1,830	390	2,010	36,660
Broadkill (1.5 km)							
Density of HSC, Crabs/m		8.49	12.25	0.22	1.01	1.21	
Estimated Number of HSC	0	12,735	18,375	330	1,515	1,815	118,530
Primehook * (2.0 km)							
Density of HSC, Crabs/m	0.10	7.36	17.28	0.30	0.39	1.16	
Estimated Number of HSC	200	14,720	34,560	600	780	2,320	119,180
Fowler * (3 km)							
Density of HSC, Crabs/m	0.01	3.89	3.95	0.07	0.75	0.45	
Estimated Number of HSC	30	11,670	11,850	210	2,250	1,350	122,700
Slaughter * (3 km)							
Density of HSC, Crabs/m	0.03	20.72	23.77	1.01	0.49	2.68	
Estimated Number of HSC	90	62,160	71,310	3,030	1,470	8,040	262,770
Big Stone * (5.0 km)							
Density of HSC, Crabs/m	0.03	11.44	7.02	cc-ns	0.52	0.60	
Estimated Number of HSC	150	57,200	35,100		2,600	3,000	341,600
Bennetts Pier (2.6 km)							
Density of HSC, Crabs/m	0.32	8.99	1.10		0.02	0.02	
Estimated Number of HSC	832	23,374	2,860	0	52	52	32,396
South Bowers (2.3 km)							
Density of HSC, Crabs/m	cc-other	19.68	8.11	1.23	3.18	3.43	
Estimated Number of HSC		45,264	18,653	2,829	7,314	7,889	196,696
North Bowers * (1.3 km)							
Density of HSC, Crabs/m	0.35	19.96	11.24	1.09	1.72	0.92	
Estimated Number of HSC	455	25,948	14,612	1,417	2,236	1,196	103,129
Ted Harvey WMA (1.0 km)							
Density of HSC, Crabs/m	0.02	25.46	19.95	0.84	4.10	4.52	
Estimated Number of HSC	20	25,460	19,950	840	4,100	4,520	107,800
Kitts Hummock * (1.0 km)							
Density of HSC, Crabs/m	0.01	17.55	15.17	0.02	1.94	2.97	
Estimated Number of HSC	10	17,550	15,170	20	1,940	2,970	77,900
Pickering (1 km)							
Density of HSC, Crabs/m	0.03	31.97	16.34	0.07	7.49	3.67	
Estimated Number of HSC	30	31,970	16,340	70	7,490	3,670	156,480
Woodland * (0.5 km)							
Density of HSC, Crabs/m	cc-other	cc-acc	cc-acc	cc-acc	cc-acc		
Estimated Number of HSC						0	0
Totals	5,012	334,276	261,000	11,176	32,137	38,832	1,675,841
Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	11-Jun	13-Jun	15-Jun	26-Jun	28-Jun	30-Jun	Totals

Table 1C. 2018 Survey Results - Densities and Estimates - New/Restored Beaches

Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	13-May	15-May	17-May	27-May	29-May	31-May	
N Pierces Point (0.45 km)							
Density of HSC, Crabs/m	4.14 cc-weath		10.60 cc-other		10.42	11.37	
Estimated Number of HSC	1,863		4,770		4,689	5,117	
Cooks (0.35 km)							
Density of HSC, Crabs/m	1.54 cc-weath		cc-acc	cc-weath	3.80	4.41	
Estimated Number of HSC	539				1,330	1,544	
Moores (1 km)							
Density of HSC, Crabs/m	4.61 cc-acc		cc-acc	13.93	21.00	21.42	
Estimated Number of HSC	4,610			13,930	21,000	21,420	
Thompsons (0.9 km)							
Density of HSC, Crabs/m	23.98 cc-weath		25.50	6.63	11.04	22.33	
Estimated Number of HSC	21,582		22,950	5,967	9,936	20,097	
Dyers Cove (0.30km)							
Density of HSC, Crabs/m	3.34	2.55 cc-other		1.39	4.72 cc-ns		
Estimated Number of HSC	1,002	765		417	1,416		
Totals	29,596	765	27,720	20,314	38,371	48,177	
Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	13-May	15-May	17-May	27-May	29-May	31-May	
Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	11-Jun	13-Jun	15-Jun	26-Jun	28-Jun	30-Jun	Totals
N Pierces Point (0.45 km)							
Density of HSC, Crabs/m	0.01	3.27	0.61	0.23	0.61	1.17	
Estimated Number of HSC	5	1,472	275	104	275	527	16,439
Cooks (0.35 km)							
Density of HSC, Crabs/m	0.01	0.43	0.59	0.18	0.15	0.10	
Estimated Number of HSC	4	151	207	63	53	35	3,413
Moores (1 km)							
Density of HSC, Crabs/m	0.67	4.58 cc-acc		0.29	0.33	1.22	
Estimated Number of HSC	670	4,580		290	330	1,220	60,960
Thompsons (0.9 km)							
Density of HSC, Crabs/m	0.89	9.96	6.99	0.02	0.06	0.27	
Estimated Number of HSC	801	8,964	6,291	18	54	243	80,532
Dyers Cove (0.30km)							
Density of HSC, Crabs/m	0.60	4.02	2.56		0.21	0.52	
Estimated Number of HSC	180	1,206	768	0	63	156	3,600
Totals	1,659	16,372	7,540	475	774	2,181	193,943
Moon Phase	New-2	New	New+2	Full-2	Full	Full+2	
Date	11-Jun	13-Jun	15-Jun	26-Jun	28-Jun	30-Jun	Totals

Table 1D. 2018 Survey Results - Densities and Estimates - New Jersey and Delaware during April

Moon Phase	Full-2	Full	Full+2		Moon Phase	Full-2	Full	Full+2	
Date	27- Apr	29-Apr	1-May		Date	27- Apr	29- Apr	1-May	
Higbees * (0.98 km)					Cape Henlopen (1.5 km)				
Density of HSC, Crabs/m					Density of HSC, Crabs/m	0.01		0.08	
Estimated Number of HSC	0	0	0		Estimated Number of HSC	15	0	120	
North Cape May * (3 km)					Broadkill (1.5 km)				
Density of HSC, Crabs/m		cc-weath			Density of HSC, Crabs/m	0.02	0.04	0.36	
Estimated Number of HSC	0		0		Estimated Number of HSC	30	60	540	
Townbank (2.3 km)					Primehook * (2.0 km)				
Density of HSC, Crabs/m					Density of HSC, Crabs/m	0.32	0.26	2.85	
Estimated Number of HSC	0	0	0		Estimated Number of HSC	640	520	5,700	
Villas (2 km)					Fowler * (3 km)				
Density of HSC, Crabs/m	0.02				Density of HSC, Crabs/m	0.02	0.18	0.71	
Estimated Number of HSC	40	0	0		Estimated Number of HSC	60	540	2,130	
Norburys Landing (2.43 km)					Slaughter * (3 km)				
Density of HSC, Crabs/m	0.01	0.02	0.06		Density of HSC, Crabs/m	0.04	0.04	4.59	
Estimated Number of HSC	24	49	146		Estimated Number of HSC	120	120	13,770	
South CSL * (2.2 km)					Big Stone * (5.0 km)				
Density of HSC, Crabs/m	0.56	0.49	0.58		Density of HSC, Crabs/m	cc-ns	0.03	0.09	
Estimated Number of HSC	1,232	1,078	1,276		Estimated Number of HSC		150	450	
Highs * (0.8 km)					Bennetts Pier (2.6 km)				
Density of HSC, Crabs/m	1.20	cc-other	0.28		Density of HSC, Crabs/m	0.07			
Estimated Number of HSC	960		224		Estimated Number of HSC	182	0	0	
Pierces Point (0.7 km)					South Bowers (2.3 km)				
Density of HSC, Crabs/m	0.92		0.33		Density of HSC, Crabs/m	2.04	0.09	0.29	
Estimated Number of HSC	644	0	231		Estimated Number of HSC	4,692	207	667	
Kimbles (1 km)					North Bowers * (1.3 km)				
Density of HSC, Crabs/m					Density of HSC, Crabs/m	0.21	0.21	2.63	
Estimated Number of HSC	0	0	0		Estimated Number of HSC	273	273	3,419	
Reeds * (1.53 km)					Ted Harvey WMA (1.0 km)				
Density of HSC, Crabs/m	0.10		0.93		Density of HSC, Crabs/m	3.18	1.96	10.33	
Estimated Number of HSC	153	0	1,423		Estimated Number of HSC	3,180	1,960	10,330	
Fortescue (2.6 km)					Kitts Hummock * (1.0 km)				
Density of HSC, Crabs/m	0.03	cc-other			Density of HSC, Crabs/m	1.22	0.03	1.13	
Estimated Number of HSC	78		0		Estimated Number of HSC	1,220	30	1,130	
Gandys * (1.2 km)					Pickering (1 km)				
Density of HSC, Crabs/m		cc-other			Density of HSC, Crabs/m	3.82	0.04	2.74	
Estimated Number of HSC	0		0		Estimated Number of HSC	3,820	40	2,740	
					Woodland * (0.5 km)				
					Density of HSC, Crabs/m				cc-acc
					Estimated Number of HSC	0	0		
Totals	3,131	1,127	3,300	7,558	Totals	14,232	3,900	40,996	59,128
Moon Phase	Full-2	Full	Full+2	Totals	Moon Phase	Full-2	Full	Full+2	Totals
Date	27- Apr	29-Apr	1-May		Date	27- Apr	29- Apr	1-May	

Table 1E. 2018 Survey Results - Densities and Estimates - New/Restored Beaches during April

Moon Phase	Full-2	Full	Full+2	
Date	27-Apr	29-Apr	1-May	
N Pierces Point (0.45 km)				
Density of HSC, Crabs/m	0.05	0.12	0.06	
Estimated Number of HSC	23	54	27	
Cooks (0.35 km)				
Density of HSC, Crabs/m	0.04			
Estimated Number of HSC	14	0	0	
Moores (1 km)				
Density of HSC, Crabs/m	0.06			
Estimated Number of HSC	60	0	0	
Thompsons (0.9 km)				
Density of HSC, Crabs/m	0.08	0.01	0.34	
Estimated Number of HSC	72	9	306	
Dyers Cove (0.30km)				
Density of HSC, Crabs/m	0.02		cc-weath	
Estimated Number of HSC	6	0		
Totals	175	63	333	571
Moon Phase	Full-2	Full	Full+2	Totals
Date	27-Apr	29-Apr	1-May	

**Table 2. Comparison of Date on Horseshoe Crabs Spawning on Delaware Bay Shores
Years 1999-2018 (2 pages)**

Peak Estimate	May 31	Jun 11	Jun 06	May 16	May 26	May 23	May 22	Jun 03	May 29	May 24	Jun 03
Year	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008
Number of Horseshoe Crabs	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	272,954	308,938	279,678	182,671	107,278	108,194	184,046	190,449	193,463	245,444	69,669
Delaware Estimate	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	11	13	13	13	13	13	13	13
Number of Beaches Surveyed in NJ	12	12	12	12	12	12	12	12	12	13	12
Main Beaches in DE	Big Stone	Slaughter	Big Stone	Big Stone	Kitts Hummock	Slaughter	Pickering	Big Stone	Big Stone	Big Stone	Big Stone
	Slaughter	Big Stone	South Bowers	Slaughte	Pickering	Pickering	Ted Harvey	Slaughter	Slaughter	Slaughter	Slaughter
	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	South CSL	Norburys	Norburys	Norburys	Norburys	Fortescue	Fortescue	South CSL	South CSL	South CSL	South CSL
	Fortescue	South CSL	South CSL	South CSL	Reeds	Norburys	South CSL	Norburys	Norburys	Norburys	Norburys
	Norburys	Fortescue		Fortescue	Fortescue		Gandys	Fortescue	Gandys	Reeds	

**Table 2. Comparison of Date on Horseshoe Crabs Spawning on Delaware Bay Shores
Years 1999-2018 (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 1999-2018

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

Table 4. Seasonal Estimates of Horseshoe Crabs 1999-2018

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

Table 5. Sex Ratios and Estimates of Male and Female Horseshoe Crabs 1999-2018

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

Table 6. Sex Ratios by Beach (15 dates)

Beach	2016	2017	2018
	Average Sex Ratio Male to Female	Average Sex Ratio Male to Female	Average Sex Ratio Male to Female
Cape Henlopen, DE	5.06	5.96	6.94
Broadkill, DE	3.85	3.76	6.71
Prime Hook, DE	2.76	3.29	5.46
Fowlers, DE	3.20	3.03	3.75
Slaughter, DE	3.63	4.14	4.30
Big Stone, DE	4.53	5.66	6.07
Bennetts, DE	2.24	2.08	5.70
South Bowers, DE	5.44	6.57	7.21
North Bowers, DE	5.62	6.73	6.60
Ted Harvey WMA, DE	5.10	5.90	6.27
Kitts Hummock, DE	4.72	6.14	6.02
Pickering, DE	4.82	6.95	6.28
Woodland, DE	2.88	2.81	-
Average Sex Ratio		4.85	5.88
Higbees, NJ	2.76	3.35	2.50
North Cape May, NJ	3.34	2.43	3.71
Townbank, NJ	3.09	3.85	3.31
Villas, NJ	3.12	3.57	3.51
Norburys Landing, NJ	3.64	4.74	5.46
South Cape Lab, NJ	4.79	4.58	5.11
Highs Beach, NJ	5.08	5.72	6.51
Pierces Point, NJ	6.14	4.03	5.26
Kimbles, NJ	4.30	5.58	6.19
Reeds, NJ	4.71	4.68	5.58
Fortescue, NJ	4.61	7.03	8.85
Gandys, NJ	3.50	4.10	4.11
Average Sex Ratio			5.17
North Pierces, NJ	5.61	6.50	8.29
Cooks, NJ	3.67	4.57	4.69
Moores, NJ	4.62	4.73	5.72
Thompsons, NJ	5.35	5.35	6.94
Dyers Cove, NJ	4.48	6.05	4.48
Average Sex Ratio			6.38

Table 6. A. Sex Ratios During the Survey Season , 15 nights, 12 nights and 3 nights (April)

	Delaware (13 beaches)	New Jersey (12 beaches)	New/Restored New Jersey (5 beaches)
3 April Dates	5.53	7.01	3.59
12 Dates	5.90	5.16	6.37
15 Dates	5.88	5.17	6.38

Table 7. Percentages of Sex Ratios During 2018 Survey (12 nights) compared to 2015-2017

Sex Ratio	DE	DE	DE	DE	NJ	NJ	NJ	NJ	Added	Added	Added	Added
	% 2015	% 2016	% 2017	% 2018	% 2015	% 2016	% 2017	% 2018	NJ % 2015	NJ % 2016	NJ % 2017	NJ % 2018
No Sex Ratio	24	21	24	8	20	11	22	4	13	15	30	6
Less Than 1	6	1	3	3	1	2	1	0	0	0	0	0
1 to less than 3	33	28	20	24	23	29	22	27	10	22	17	20
3 to less than 5	26	28	19	15	26	38	35	27	19	35	33	25
5 to less than 7	8	17	21	26	23	15	15	29	27	22	13	22
Greater than 7	2	5	13	24	6	6	5	13	31	7	7	27

Table 8. Tagged Horseshoe Crabs Observed During Surveys 2007-2018

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
Totals	2154	765	1389	493	1661	2020	134	50

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