

An Overview of Horseshoe Crab Spawning Activity Along the Shores of Delaware Bay, 1990-1997

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Summary of 1997 Bay-Wide Survey

Spawning activity of the horseshoe crab, Limulus polyphemus was surveyed along the shores of Delaware Bay during the 1997 spawning season. Horseshoe crab counts along with weather observations were recorded on May 10th, May 24th, June 7th and June 21st (Tables 1A and 1B). The chosen dates were the Saturdays closest to the new and full moon phases in May and June (May 6th, May 22nd, June 5th and June 20th) during the high tides when peak spawning is expected to occur. The peak of the spawning activity occurred on the full moon survey date of May 24th with an estimate of 703,846 spawning individuals. The majority of the spawners (79%) were found on the Delaware side of the Delaware Estuary. A total of 19 beaches was surveyed on this date, seven in Delaware and twelve in New Jersey (Table 2). Approximately twice as many spawners were found during the PM tide (2308 hr predicted time of high water at the reference station, Breakwater Harbor, Delaware) than the AM tide (1050 hr predicted time) on this date (Table 3).

Horseshoe crab spawners were also abundant during the June full moon date. A spawning estimate of 453,818 individuals was found on the June 21st survey date (Table 3). Seven beaches in Delaware and nine beaches in New Jersey were surveyed on this date (Table 2). The PM spawners (2205 hr predicted time of high water at Breakwater Harbor, Delaware) were twice as many as the AM spawners (0944 hr predicted time of high water)(Table 3). The May 10th estimate was 140,121 individuals and the June 7th spawners were estimated to be 33, 599 (Table 3). The weather conditions on the June 7th survey date were not optimum for spawning with strong north winds that produced high amplitude waves. Weather conditions during the other three dates were favorable for spawning (Table 1B).

Comparison of Spawning Activities, 1990-1997

The 1997 peak estimate of 703,846 spawners is roughly halfway between the high average of 1,232,725 (1990 & 1991) and the low average of 295,244 (using the main pre-selected survey date 1992-1996) (Table 3). When the 1994 and 1995 numbers are omitted (low estimates ascribed to cold weather and missed peak spawning), the low average is then about 419,770. Although the 1997 data indicate an abrupt increase over the previous five years, it is still only 57% of the peak years of the bay-wide survey, 1990-1991. This information (1990-1997) shows that, for whatever reason, fewer spawners were counted in the years following the peaks observed in 1990 and 1991 and that years of observations are required in order to achieve an insight into what may be happening. The average ten-year juvenile life span and the eight or more years life span of the adults are obvious factors.

Relative Abundance on the Eastern and Western Shores of Delaware Bay.

The shift in the abundance of spawning crabs from the shores of New Jersey to those of Delaware continued in 1997. For the past five years, 88% in 1993, 74% in 1994, 96% in 1995, 79% in 1996 and 79% in 1997, the majority of spawners have been found on the Delaware side of the Delaware River Estuary. This occurrence has been documented in the past by commercial fisheries and historical accounts and recently by the 1993 to 1997 surveys.

The interesting part of this occurrence is the different patterns that exist for the eastern and western shorelines if the 1990-1997 estimates are examined separately. The 1990, 1991, 1993, 1996 and 1997 estimates on the Delaware side of the bay range from 327,250 to 553,229 spawning individuals (Table 4A). These year estimates were not believed to be influenced by weather and are considered to be reliable estimates of the year's spawning activity. Low counts in 1992 and 1994 of 109,851 and 76,745 respectively may be explained by cold weather. The low count in 1995 of 102,100 was attributed to a missed peak count.

The estimates on the New Jersey side throughout the years have fluctuated drastically (Table 4B). From high counts in the years 1990 and 1991 of 812,408 and 722,342 respectively to a moderate count of 322,367 in 1992 to low counts in the years following of 49,780 in 1993, 27,255 in 1994, 10,812 in 1995, 97,320 in 1996 and 150,547 in 1997. The low count in 1994 may be explained by suboptimum weather conditions for spawning and the low 1995 estimate to a missed peak count.

Weather is a factor affecting spawning activity. The June 7th 1997 count of 33,599 spawning individuals further emphasizes the direct effect that high velocity winds that create rough waters has on spawning activity. Weather conditions during the 1993, 1996 and 1997 counts, however, were optimum for spawning and are not believed to be a significant contributor to the low counts on the New Jersey side of the bay during these years.

It appears from the uneven distribution of crabs along the bay shore that other factors besides weather are affecting the crabs' distribution. Crabs do winter in Delaware Bay. However, these crabs do not fully account for the large number of spawning crabs that occur on the shores of Delaware Bay in May and June. Additional adult crabs must be entering the bay from within 50 miles of the mouth of Delaware River Estuary based on tagging (Table 5) and fisheries trawl studies. It is presently assumed that crabs situated north of the Delaware Bay entrance enter the bay close to Cape May, New Jersey because the shoals are more extensive and the flood tide first flows into the bay from the ocean on the New Jersey side. The presumption that horseshoe crabs move in the direction of water currents is based on field observations of adults and on preliminary experiments on juveniles. Horseshoe crabs south of the entrance may either enter the bay along Cape Henlopen, Delaware or travel further north and enter near Cape May, New Jersey. It would be logical, however, to assume that the majority of the crabs would take the shorter route and enter the bay along the Delaware side. Could the explanation of the uneven distribution of spawning crabs along the eastern and western shores of Delaware Bay be explained by the location of the offshore crabs in proximity to the entrance to Delaware Bay?

The majority of horseshoe crabs on the continental shelf may be at a more southern location than during previous years. Recoveries of tagged crabs suggest that the crabs mainly

moved south of the bay mouth (Table 5). The crabs may be entering the bay from a southerly route and ending up on the Delaware shores of the Delaware River Estuary. This southern location may be due to a new foraging site or a change in ocean and bay currents or perhaps the amount of freshwater drainage flow from the Delaware River.

Another explanation may be related to the fisheries harvest at different locations. The present location of the majority of horseshoe crabs may not be a result of the crabs moving south, but be a result of declining horseshoe crab numbers in the northern region. Current fisheries harvest data do indicate greater fishing activity south of the Delaware Bay entrance, the area where the horseshoe crabs are presently located. If harvesting off the New Jersey coast and the New Jersey side of Delaware Bay was great enough to deplete these areas of horseshoe crabs, less crabs would be found in these areas and seemingly more crabs would be located south of the bay. When the horseshoe crabs migrate to their spawning areas, the result would be fewer crabs along the New Jersey shoreline of Delaware Bay and equivalent numbers on the Delaware side of the bay over the years.

Spawning at the Mouths of Tidal Streams and Marsh Concentration Areas.

During the 1997 survey, tidal creeks in New Jersey were also surveyed. The survey of the tidal creeks was initiated to estimate the number of spawners at the tidal creek mouths and also to accumulate information regarding the tidal creeks themselves. Information was gathered on where the tidal creeks are located, the orientation of the stream mouth, the width of the stream, a subjective estimate of the current velocity, the existence of offshore sandbars and the shoreline vegetation (Table 1B-- Column R Notes).

The overall estimate of the number of spawners located at the tidal creek mouths was 54,181 individuals during the four survey dates of May 10th, May 24th, June 7th and June 21st (Table 2C). Information and counting was recorded for six tidal creeks along the New Jersey shore of Delaware Bay. This estimate does not appear to add a significant number to the estimate of spawners along the New Jersey shoreline. It should be noted, however, that during the 1997 spawning season, harvesting was allowed to take place in these areas on Tuesdays and Thursdays.

In contrast to the creek estimate, the estimate of horseshoe crabs located in the marsh area behind Thompsons Beach, the old Maurice River Township Salt Hay Farm, was considerable. An estimate of 334,273 individuals was calculated for this area during the AM count on the four survey dates (Table 1A and 2C). This estimate was obtained by surveying from a boat. The areas surveyed were east of Thompsons Beach Road and included the PSE&G restoration site and Riggins Ditch (a natural tidal stream). A PM estimate was not determined due to the inaccessibility of this area.

The large number of horseshoe crabs in the extensive back bay area of Thompsons Beach, compared to very few along the beachfront, is illustrative of two drastic changes that have occurred in the area. First, the quality of Thompsons Beach, as a horseshoe crab spawning habitat, has deteriorated since at least 1979, based on bay-wide observations summarized in Shuster and Botton (1985). This deterioration has been largely due to dual impacts on the beach: erosion and structures to slow down that erosion, including bulkheads and concrete rubble. Second, two centuries of events modified the area behind Thompsons Beach. Beginning

with the impoundment of a tidal marsh, about 1810, the marsh was transformed into a salt hay farm, now known as the Maurice River Township Salt Hay Farm. When the impoundment dike was breached around 1992, salty bay water poured in and flooded the hay farm grasslands. This killed the hay grasses, leaving a denuded "tableland," and carried thousands of horseshoe crabs onto the denuded farm area and washed some westward over the road leading to Thompsons Beach. But the receding waters during the ebb cycle did not furnish sufficient currents that would have enabled the crabs to get off the flat area. Horseshoe crabs are also guided back to water by slopes, as on beaches, but there were no slopes on the flatland. This situation is alarming but not disastrous, since it is a transitory phenomenon according to Dr. John Teal, a tidal marsh authority. When the tidal streams are established and the marsh is revegetated with salinity tolerant plants, grasses such as Spartina along the channel margins will act as barriers preventing many horseshoe crabs from getting onto the flat area. Thus far, except for the hand-harvested crabs, the fate of the rest of the animals on the salt-hay flats and channels has not been ascertained. In summary, the area has been under observation since 1979 and is currently being monitored because it provides an excellent opportunity to study how horseshoe crabs cope with environmental changes.

The decrease in sandy beaches in these areas of Delaware Bay may have a negative impact on the successful local reproduction of horseshoe crabs. The Delaware Bay Shore has always been a unique area, unlike any other area, in that the shoreline offers extensive sandy beaches that are essential for successful horseshoe crab spawning. In contrast, the Chesapeake Bay area lacks the great concentration of horseshoe crabs seen along the Delaware Bay Shore. The main reason for this may be the infrequent, scattered beaches that exists along the shoreline of the Chesapeake Bay (Shuster, 1985). In addition, the sandy substrate and other conditions associated with the beaches of Delaware Bay are believed to provide an optimum microenvironment for embryonic development.

Assessments of Spawning Survey Results & Methodology. The "health" of the horseshoe crab population that spawns on the shores of Delaware Bay has been the topic of much discussion and increased legal action during the past year. Mainly, the increasing harvest of the crabs for bait has heightened a concern for the impact this may have had on the migratory shorebirds which are also declining in numbers along the shores of the Delaware Bay. Research sponsored by the states of Delaware and New Jersey, particularly those evaluating the success of spawning, will be valuable additions to our understanding of the spawning activity. Consideration of management of the horseshoe crab resource, as by the Atlantic States Marine Fisheries Commission, is timely.

The spawning survey data suggests that the Delaware Bay area adult population of horseshoe crabs has been declining since 1990. In some years, in addition to this general downward trend in the population, spawning was affected by adverse weather conditions during the survey. For the past five years, the data have shown a consistent majority of spawners on the Delaware side of the Bay. This shift to the Delaware side has not been solely due to weather.

The horseshoe crab spawning survey was initially undertaken as an educational exercise in 1990, to determine if a volunteer force could survey the extensive spawning area of Delaware Bay. That survey was successful but it was recognized that the resulting data would be more accurate if the basic methodology was modified. Modifications in subsequent years have

included: additional sampling dates; a more rigorous, random sampling; and, additional reports on weather conditions.

There are no clear-cut reasons for the marked one-year (1997) increase within the general trend of declining numbers of spawners from 1990 on. Yet, anyone who has studied horseshoe crabs knows that this is not completely unexpected because annual patterns of spawning occur. The problem is that we do not fully understand what causes changes in the annual patterns. The following discussion, therefore, is intended to review some factors that are involved.

In previous reports and at the 1996 Horseshoe Crab Forum held at the University of Delaware, we have commented on the distribution of spawning beaches, spawning activity and environmental factors. Many factors affecting spawning are obvious, even when not fully understood:

- 1) Weather Conditions--storms and cold weather depress spawning activity.
- 2) Distribution and abundance of adults--foraging crabs range far out onto the continental shelf, a reflection of large numbers of animals in Delaware Bay.
- 3) The longevity an adult horseshoe crab--upwards of eight years (Botton & Ropes, 1988; Swan, 1997).
- 4) Success of a year class--evidenced by greater than average spawning numbers. This results when there have been some ten years of better than average living conditions during the juvenile stage and attendant survival to adulthood.
- 5) Loss of beaches suitable for spawning--over the years the Delaware and New Jersey shorelines of Delaware Bay have been severely eroded. The erosion of the beaches has no doubt increased due to the combined effect of the slow rise in sea level, the subsidence of the coastal level, and decreased amounts of sediment transport by the Delaware River.

The contribution of year-classes to spawning activity has not been evaluated, partly because there are no absolute criteria for the age of individual adults. These animals live in an abrasive environment and sooner-or-later their carapaces are eroded through or become brittle and crack (adult horseshoe crabs do not molt). Added to this are diseases and the epiphytes and epifauna that attach to the carapaces, sometimes so heavily as to immobilize an individual crab. Three major groups of adults can be recognized: 1) young--clear, lustrous carapace to slightly eroded (usually upon reaching an adult age of 3 years); 2) mid-age--carapace moderately to heavily eroded (from about 3 to 7 years of adult age), and 3) old age--carapaces entirely eroded and black (over 7 years as an adult). Actually, since we can easily estimate the percentage of young adults (1 to 3 years old as an adult) in a spawning population--they are the individuals with lustrous, clean carapaces with minor scratches and mating scars--we can institute an accounting of these individuals during each spawning survey. Thus, their numbers would immediately be reflected in a greater-than-average abundance in the first year that they participate in spawning. Also, young adults are more vigorous than an old adult. Except for releasing them (young and old) at the top of a beach and timing the rate it takes them to progress down the slope, we know of no other test besides handling each crab. Perhaps one could be done with a spring scale by dangling a crab from a hook (or putting it into a large pail and weighing the pail) and seeing how far the hand jerks across the dial due to the activity of the crab.

Overall Considerations

The merits of the spawning survey are numerous. The horseshoe crab survey has continued from 1990 onward, providing eight years of data. The survey has also been conducted on both sides of the Delaware Bay covering most of the accessible beaches in New Jersey and Delaware. Other horseshoe crab population studies have not been conducted in both states simultaneously. The survey counts the horseshoe crab adults that can be seen visibly on the beach. The number of crabs can be estimated through simple observation and then checked and tabulated by counting random segments. The counting of visible adults is quite different than counting subsurface eggs or horseshoe crabs in considerable depths of water. It is easier to do and less labor intensive. And, due to the educational aspect of the survey, the many participants were able to sense what was happening in terms of the numbers of spawning horseshoe crabs. Initially, this survey was the primary source of information suggesting a decline in the horseshoe crab population. This was buttressed by the fishery trawl data on horseshoe crabs from Delaware Department of Natural Resources, also tabulated beginning in 1990 and the New Jersey trawl data from the Atlantic shelf.

1998 Spawning Survey Schedule

1998 Lunar Data and Dates/Delaware Bay High Tide Times

<u>Lunar Date</u>	<u>Survey Date</u>	<u>Time and Height of High Water*</u>
Full Moon - May 11	May 9	0800/4.0 2017/4.6
New Moon - May 25	May 23	0654/4.4 1924/5.3
Full Moon - June 9	June 6	0636/3.7 1901/4.4
New Moon - June 23	June 20	0531/4.1 1810/5.0

*Predicted time/water height at the reference station, Cape Henlopen, Delaware. Time is Daylight Savings in the 24 hour system (first two digits = hour; next two digits = minutes; high water height is given in feet, to nearest 0.1 foot).

Special Instructions for 1998 (Optional)

In addition to the basic survey methodology used in 1997, whenever personnel, equipment, and time permit, two additional records could be made:

- 1) The Young Age-Classes: Estimate of the number of young spawners (see above).

2) **Amount of Light:** Barlow et al. (1986) demonstrated that the peaks of spawning activity in Buzzards Bay, Massachusetts, occurred during hours of dusk (roughly just before sunrise and just after sunset). There is no assurance that horseshoe crabs at the latitude of Delaware Bay perform exactly as those of Buzzards Bay do, but it would not be too difficult, by recording the time of observations to relate these times to the amount of sunlight (dusk, full, etc.) along with reports on the weather, including cloud cover, haze, fog, bright sunlight, etc. The more adventurous participants in the survey could use a photometer to record the ASA number, etc.--aiming it in the direction that the spawners are facing and, at a 90-degree angle, toward the most-lighted side.

References

Barlow, Robert B. Jr., Maureen K. Powers, Heidi Howard, and Leonard Kass, 1986. Migrations of *Limulus* for mating: relation to lunar phase, tide height, and sunlight. *Biological Bulletin* 171:310-329.

Botton, Mark L. and John W. Ropes. 1988. An indirect method for estimating longevity of the horseshoe crab (*Limulus polyphemus*) based on epifaunal slipper snail shells (*Crepidula fornicata*). *Journal of Shellfish research* 7 (#): 407-412.

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Swan, Benjie Lynn. 1997. Data from "Finn-Tech's Tagging Program"
1 female tagged on 23 May 1988 at Reeds Beach, NJ recovered on 31 May 1996 Highs Beach, NJ.

1996 University of Delaware Horseshoe Crab Forum (in press).

Legend 1 for Table 1A. and 1B.

Table 1A. 1997 Spawning Survey Data (Pages 1 -8)

Column A Beach - Delaware or New Jersey

Column B Date the Survey was Conducted

Column C Time the count was taken

Column D Number of 5 m segments counted or if different sampling was used, the length surveyed is listed with "m" (meters) noted.

Column E Total number of crabs counted within the segments

Column F Column E divided by Column D

$$\frac{\text{Total number of crabs counted}}{\text{Number of 5 m segments}} = \frac{\text{Average number of crabs per}}{\text{5 m segment}}$$

Column G Estimate of Spawning Length based on 7.5' USGS topographic quadrangles in kilometers. Creeks were roughly estimated to have a spawning length of 0.5 kilometers. Spawning length is divided by 5m to obtain a multiplication factor for calculations.

Column H Estimate of total individuals spawning during AM or PM tide using random sampling method. The total number of crabs on a particular beach was determined by taking the average number of crabs per 5 m multiplied by the spawning length of the beach (km).

Column I Total number of males counted

Column J Total number of females counted

Column K Male to Female Ratio - Column I divided by Column J

Table 1B. 1997 Survey Weather Data (Pages 1 -8)

Column A Beach - Delaware or New Jersey

Column B Date the Survey was Conducted

Column C Time the count was taken

Column M Air Temperature at the Time of the Survey

Column N Wind Direction at the Time of the Survey

Column O Wind Velocity at the Time of the Survey

Column P Wave Height at the Time of the Survey

Column Q Weather at the Time of the Survey

Column R Notes at the Time of the Survey

Table 1. A. 1997 Spawning Survey Data

A	B	C	D	E	F	G	H	I	J	K
Beach	Date	Time	Seg	Total	Crabs per 5m	Length	Estimate	M	F	M/F
Delaware						3.00				
Slaughter	5/11/97	11:30AM-2:50PM	18	1,707	94.83	600.00	56,900	1254	453	2.77
Slaughter	5/11/97	11:30PM-1:45AM	18	13	0.72	600.00	433	8	5	1.60
Slaughter	5/23/97	9:00-11:30PM	18	1,731	96.17	600.00	57,700	1169	562	2.08
Slaughter	5/24/97	10:30AM-12:30PM	18	2,074	115.22	600.00	69,133	1406	668	2.10
Slaughter	6/21/97	9:30-10:30AM	18	156	8.67	600.00	5,200	93	63	1.48
Big Stone						7.60				
Big Stone	5/10/97	11:40AM-1:20PM	18	0	0.00	1520.00	0			
Big Stone	5/11/97	12:30-1:40AM	18	0	0.00	1520.00	0			
Big Stone	5/24/97	10:30AM-1:15PM	18	41	2.28	1520.00	3,462	25	16	1.56
Big Stone	5/24/97	11:30PM-12:45AM	18	2,152	119.56	1520.00	181,724	1,759	393	4.48
Big Stone	5/30/97	4:00-7:15PM	18	133	7.39	1520.00	11,231	72	61	1.18
Big Stone	5/31/97	4:30-7:00PM	18	168	9.33	1520.00	14,187	119	49	2.43
Big Stone	6/7/97	10:30AM-1:00PM	18	1	0.06	1520.00	84	0	1	0.00
Big Stone	6/7/97	11:30PM-12:15AM	18	0	0.00	1520.00	0	0	0	0.00
Big Stone	6/21/97	10:00-10:45AM	18	38	2.11	1520.00	3,209	26	12	2.17
Big Stone	6/21/97	10:30-11:15PM	18	1,717	95.39	1520.00	144,991	1472	245	6.01
South Bowers						2.30				
South Bowers	5/9/97	12:00-12:14PM	18	6	0.33	460.00	153	5	1	5.00
South Bowers	5/10/97	12:45-1:00PM	18	18	1.00	460.00	460	17	1	17.00
South Bowers	5/10/97	11:55PM-1:05AM	18	15	0.83	460.00	383	11	4	2.75
South Bowers	5/11/97	1:45-1:55PM	18	4	0.22	460.00	102	3	1	3.00
South Bowers	5/23/97	11:25-11:50PM	18	984	54.67	460.00	25,147	783	201	3.90
South Bowers	5/24/97	11:48PM-12:28AM	18	1,287	71.50	460.00	32,890	984	303	3.25
South Bowers	5/25/97	12:18-1:05PM	18	1,517	84.28	460.00	38,768	1,304	213	6.12
South Bowers	6/6/97	10:50AM	18	67	3.72	460.00	1,712	53	14	3.79
South Bowers	6/7/97	11:40AM	18	23	1.28	460.00	588	14	9	1.56
South Bowers	6/8/97	12:00-12:30PM	18	409	22.72	460.00	10,452	312	97	3.22
South Bowers	6/20/97	9:36AM	18	83	4.61	460.00	2,121	69	14	4.93
South Bowers	6/22/97	11:44AM-1:00PM	18	1,574	87.44	460.00	40,224	1,164	410	2.84

Table 1. A. 1997 Spawning Survey Data

A	B	C	D	E	F	G	H	I	J	K
Beach	Date	Time	Seg	Total	Crabs per 5m	Length	Estimate	M	F	M/F
Delaware						1.30				
North Bowers	5/9/97	12:13-12:22PM	18	154	8.56	260.00	2,224	116	38	3.05
North Bowers	5/10/97	12:48-1:20PM	18	177	9.83	260.00	2,557	123	54	2.28
North Bowers	5/10/97	12:05-12:25AM	18	138	7.67	260.00	1,993	97	41	2.37
North Bowers	5/11/97	1:40-1:50PM	18	118	6.56	260.00	1,704	92	26	3.54
North Bowers	5/11/97	1:00-1:45AM	18	100	5.56	260.00	1,444	76	28	2.71
North Bowers	5/23/97	10:45-11:33AM	18	269	14.94	260.00	3,886	211	58	3.64
North Bowers	5/23/97	11:04PM-12:13AM	18	2,961	164.50	260.00	42,770	2,257	704	3.21
North Bowers	5/24/97	11:30AM	18	1,107	61.50	260.00	15,990	910	197	4.62
North Bowers	5/24/97	12:10AM	18	2,064	114.67	260.00	29,813	1,487	577	2.58
North Bowers	5/25/97	12:00-1:08PM	18	1,632	90.67	260.00	23,573	1,354	278	4.87
North Bowers	6/6/97	11:05-11:53AM	18	458	25.44	260.00	6,616	342	116	2.95
North Bowers	6/7/97	11:40AM-12:15PM	18	197	10.94	260.00	2,846	135	62	2.18
North Bowers	6/8/97	12:22-12:50PM	18	1,656	92.00	260.00	23,920	1,313	343	3.83
North Bowers	6/20/97	9:45-10:45AM	18	362	20.11	260.00	5,229	299	63	4.75
North Bowers	6/20/97	9:55-11:43PM	18	2,640	146.67	260.00	38,133	2,163	477	4.53
North Bowers	6/21/97	10:24-10:40AM	18	594	33.00	260.00	8,580	516	78	6.62
North Bowers	6/21/97	10:30PM	18	1,465	81.39	260.00	21,161	1,291	174	7.42
North Bowers	6/22/97	11:15AM	18	680	37.78	260.00	9,822	598	82	7.29
St. Jones Neck						1.00				
St. Jones Neck	5/9/97	12:10-12:50PM	18	93	5.17	200.00	1,033	73	20	3.65
St. Jones Neck	5/10/97	12:35-1:00AM	18	357	19.83	200.00	3,967	258	99	2.61
St. Jones Neck	5/11/97	1:00-1:45AM	18	48	2.67	200.00	533	27	21	1.29
St. Jones Neck	5/11/97	1:30PM	18	27	1.50	200.00	300	20	7	2.86
St. Jones Neck	5/23/97	11:04AM-12:08PM	18	174	9.67	200.00	1,933	145	29	5.00
St. Jones Neck	5/23/97	11:11-11:43PM	18	1,103	61.28	200.00	12,256	899	204	4.41
St. Jones Neck	5/24/97	11:55PM-1:45AM	18	3,137	174.28	200.00	34,856	2,297	840	2.73
St. Jones Neck	5/25/97	12:30-1:33PM	18	909	50.50	200.00	10,100	714	195	3.66
St. Jones Neck	6/8/97	12:34-2:30PM	18	117	6.50	200.00	1,300	90	27	3.33
St. Jones Neck	6/20/97	9:49-10:25AM	18	115	6.39	200.00	1,278	91	24	3.79
St. Jones Neck	6/21/97	11:15-11:40AM	18	58	3.22	200.00	644	43	15	2.87
St. Jones Neck	6/21/97	11:16PM	18	1,257	69.83	200.00	13,967	1,069	188	5.69

Table 1. A. 1997 Spawning Survey Data

A	B	C	D	E	F	G	H	I	J	K
Beach	Date	Time	Seg	Total	Crabs per 5m	Length	Estimate	M	F	M/F
Delaware										
Pickering	5/9/97	11:55PM-12:40AM	18	257	14.28	1.00	2,856	181	76	2.38
Pickering	5/10/97	1:00-1:35PM	18	372	20.67	200.00	4,133	281	91	3.09
Pickering	5/23/97	11:30PM-12:45AM	18	1,921	106.72	200.00	21,344	1,449	472	3.07
Pickering	5/24/97	11:30AM	18	2,411	133.94	200.00	26,789	1,811	600	3.02
Pickering	6/6/97	11:00PM-12:30AM				200.00	0			
Pickering	6/7/97	11:30AM-1:00PM	18	0	0.00	200.00	0			
Pickering	6/20/97	10:00-11:30PM	18	3,080	171.11	200.00	34,222	2,449	631	3.88
Pickering	6/21/97	10:30AM-12:00PM	18	2,073	115.17	200.00	23,033	1,711	362	4.73
Kitts Hummock						1.00				
Kitts Hummock	5/24/97	11:30AM-12:15PM	3	409	136.33	200.00	27,267	245	164	1.49
Kitts Hummock	5/25/97	12:30-12:45AM	3	546	182.00	200.00	36,400	273	273	1.00
Kitts Hummock	5/24/97	12:30PM	6	311	51.83	200.00	10,367	257	54	4.76
Kitts Hummock	5/24/97	12:45-2:00PM	9	151	16.78	200.00	3,356	111	40	2.78
Kitts Hummock	5/24/97	12:40-2:00AM	9	875	97.22	200.00	19,444	614	261	2.35
Kitts Hummock	6/7/97	1:00-1:15PM		0		200.00	0			
Kitts Hummock	6/7/97	1:20-1:30AM		0		200.00	0			
Kitts Hummock	6/21/97	10:00-10:35AM	6	206	34.33	200.00	6,867	168	38	4.42
Kitts Hummock	6/21/97	10:20-11:00PM	6	334	55.67	200.00	11,133	252	82	3.07
Kitts Hummock	6/21/97	11:03AM	9	974	108.22	200.00	21,644	673	201	3.35
Kitts Hummock	6/21/97	11:40PM-12:20AM	9	997	110.78	200.00	22,156	685	312	2.20
Kitts Hummock	6/21/97	11:30AM-12:30PM	1	10 to 20		200.00	0			
Kitts Hummock	6/21/97	10:00-10:30PM	3	368	122.67	200.00	24,533			
Port Mahon						0.80				
Port Mahon	5/29/97	5:35-5:50PM	4	212	53.00	160.00	8,480	138	74	1.86
Port Mahon	6/1/97	8:30-9:45AM	15	2,057	137.13	160.00	21,941	1,553	504	3.08
Totals				57,639			1,351,651	44,079	13,096	3.37

Table 1. A. 1997 Spawning Survey Data

A	B	C	D	E	F	G	H	I	J	K
Beach	Date	Time	Seg	Total	Crabs per 5m	Length	Estimate	M	F	M/F
New Jersey										
Higbees	5/10/97	12:30PM	18	0	0.00	0.98	0	0	0	
Higbees	5/11/97	12:30AM	18	0	0.00	196.00	0	0	0	
Higbees	5/24/97	10:30AM-12:00PM	18	0	0.00	196.00	0	0	0	
Higbees	5/24/97	11:15-11:37PM	18	2	0.11	196.00	22	1	1	1.00
Higbees	6/7/97	10:00AM	18	1	0.06	196.00	11	1	0	
Higbees	6/7/97	10:20-10:37PM	18	1	0.06	196.00	11	1	0	
Higbees	6/21/97	9:30-10:40AM	18	5	0.28	196.00	54	3	2	1.50
Higbees	6/21/97	9:55-10:50PM	18	39	2.17	196.00	425	31	8	3.88
Higbees	5/22/97	9:45-10:10AM	18	20	1.11	196.00	218	14	6	2.33
Higbees	6/5/97	9:20-10:12AM	18	0	0.00	196.00	0	0	0	
Higbees	6/5/97	8:45-9:45PM	18	0	0.00	196.00	0	0	1	0.00
Higbees	6/19/97	7:30AM	18	1	0.06	196.00	11	1	0	
Higbees	6/19/97	8:00-8:55PM	18	25	1.39	196.00	272	19	6	3.17
Norbury's										
Norbury's	5/10/97	1:00-2:00PM	18	17	0.94	2.43	459	12	5	2.40
Norbury's	5/11/97	1:00-1:45AM	15	5	0.33	486.00	162	5	0	
Norbury's	5/24/97	10:45AM-12:45PM	18	275	15.28	486.00	7,425	201	74	2.72
Norbury's	5/24/97	10:45PM-1:20AM	18	849	47.17	486.00	22,923	643	206	3.12
Norbury's	6/7/97	9:45-11:30AM	18	7	0.39	486.00	189	7	0	
Norbury's	6/7/97	10:20-11:05PM	18	20	1.11	486.00	540	16	4	4.00
Norbury's	6/21/97	10:15-10:35AM	18	33	1.83	486.00	891	17	16	1.06
Norbury's	6/21/97	10:20-11:15PM	18	471	26.17	486.00	12,717	369	102	3.62
Norbury's	6/5/97	10:30AM	18	4	0.22	486.00	108	3	1	3.00
Norbury's	6/5/97	9:45-10:42PM	18	96	5.33	486.00	2,592	67	29	2.31
Norbury's	6/19/97	7:00AM	18	31	1.72	486.00	837	25	6	4.17
Norbury's	6/19/97	7:40-8:05PM	18	491	27.28	486.00	13,257	361	130	2.78
Rutgers South										
Rutgers South	5/24/97	10:30-11:30AM	100m	248	12.40	2.20	5,456	208	40	5.20
Rutgers South	5/24/97	10:30-11:30AM	18	406	22.56	440.00	9,924	352	54	6.52
Rutgers South	5/24/97	10:40PM-12:10AM	100m	1,252	62.60	440.00	27,544	1,085	167	6.50
Rutgers South	5/24/97	10:40PM-12:10AM	18	1,012	56.22	440.00	24,738	882	130	6.78

Table 1. A. 1997 Spawning Survey Data

A	B	C	D	E	F	G	H	I	J	K
Beach	Date	Time	Seg	Total	Crabs per 5m	Length	Estimate	M	F	M/F
New Jersey										
Highs						0.80				
Highs	5/10/97			0		160.00	0			
Highs	5/24/97	11:00AM	45m	69	7.67	160.00	1,227	60	9	6.67
Highs	5/24/97		45m	475	52.78	160.00	8,445	419	56	7.48
Highs	5/24/97		50m	555	55.50	160.00	8,880	485	70	6.93
Highs	6/7/97	11:20AM		0		160.00	0			
Highs	6/21/97	PM	45m	35	3.89	160.00	622	30	5	6.00
Kimbles						1.00				
Kimbles	5/10/97	AM		0		200.00	0			
Kimbles	5/10/97	PM		0		200.00	0			
Kimbles	5/24/97	10:30AM-12:00PM	18	61	3.39	200.00	678	42	19	2.21
Kimbles	5/24/97	11:30PM-1:30AM	18	1044	58.00	200.00	11,600	879	165	5.33
Kimbles	6/7/97	12:00-1:00PM	18	11	0.61	200.00	122	11	0	
Kimbles	6/7/97	12:00-1:20AM	18	542	30.11	200.00	6,022	424	118	3.59
Kimbles	6/21/97	10:10-11:30AM	18	10	0.56	200.00	111	7	3	2.33
Kimbles	6/21/97	10:35PM-12:20AM	18	287	15.94	200.00	3,189	219	68	3.22
Kimbles/Cooks Ck						0.50				
Kimbles/Cooks Ck	5/24/97	10:30AM-12:00PM	3	97	32.33	100.00	3,233	73	24	3.04
Kimbles/Cooks Ck	5/24/97	11:30PM-1:30AM	3	too high		100.00				
Kimbles/Cooks Ck	6/7/97	12:00-1:00PM	3	38	12.67	100.00	1,267	30	8	3.75
Kimbles/Cooks Ck	6/7/97	12:00-1:20AM	3	too high		100.00	0			
Kimbles/Cooks Ck	6/21/97	10:10-11:30AM	3	32	10.67	100.00	1,067	28	4	7.00
Kimbles/Cooks Ck	6/21/97	10:35PM-12:20AM	3	65	21.67	100.00	2,167	49	16	3.06
Kimbles/Pierces Ck	5/24/97	10:30AM-12:00PM	3	69	23.00	100.00	2,300	64	5	12.80
Kimbles/Pierces Ck	5/24/97	11:30PM-1:30AM	3	162	54.00	100.00	5,400	133	29	4.59
Kimbles/Pierces Ck	6/7/97	12:00-1:00PM	3	1	0.33	100.00	33	1	0	
Kimbles/Pierces Ck	6/7/97	12:00-1:20AM	3	too high		100.00				
Kimbles/Pierces Ck	6/21/97	10:10-11:30AM	3	6	2.00	100.00	200	4	2	2.00
Kimbles/Pierces Ck	6/21/97	10:35PM-12:20AM	3	34	11.33	100.00	1,133	27	7	3.86

Table 1. A. 1997 Spawning Survey Data

A	B	C	D	E	F	G	H	I	J	K
Beach	Date	Time	Seg	Total	Crabs per 5m	Length	Estimate	M	F	M/F
New Jersey										
Reeds						1.53				
Reeds-SouthBC	5/10/97	1:15-1:45PM	18	0	0.00	306.00	0	0	0	
Reeds-SouthBC	5/10/97	1:15-1:45AM	18	0	0.00	306.00	0	0	0	
Reeds-SouthBC	5/24/97	11:15-11:40AM	18	940	52.22	306.00	15,980	746	194	3.85
Reeds-SouthBC	5/23/97	10:20-11:05 PM	18	707	39.28	306.00	12,019	534	173	3.09
Reeds	6/7/97	11:25-11:45PM	18	131	7.28	306.00	2,227	106	25	4.24
Reeds	6/10/97	10:39-11:00AM	18	2	0.11	306.00	34	2	0	
Reeds	6/20/97	10:00-10:50PM	18	480	26.67	306.00	8,160	356	124	2.87
Reeds	6/21/97	10:30-11:00AM	18	105	5.83	306.00	1,785	76	29	2.62
Moores										
Moores	5/10/97	12:00-12:55PM	18	15	0.83	600.00	500	9	6	1.50
Moores	5/10/97	12:20-12:50AM	18	0	0.00	600.00	0	0	0	
Moores	5/23/97	12:00AM	18	285	15.83	600.00	9,500	184	101	1.82
Moores	5/24/97	12:25-1:15PM	18	171	9.50	600.00	5,700	131	40	3.28
Moores	6/7/97	11:35AM-12:00PM	12	25	2.08	600.00	1,250	15	10	1.50
Moores	6/7/97	10:33-10:45PM	11	26	2.36	600.00	1,418	19	7	2.71
Moores	6/20/97	8:00-9:40PM	10	384	38.40	600.00	23,040	279	105	2.66
Moores	6/21/97	8:50-9:30AM	17	47	2.76	600.00	1,659	27	20	1.35
Moores-Creek										
Moores-Creek	5/10/97	12:40-12:50PM	6	4	0.67	100.00	67	4	0	
Moores-Creek	5/10/97	12:45-12:55AM	6	4	0.67	100.00	67	3	1	3.00
Moores-Creek	5/23/97	12:40-12:50AM	6	100	16.67	100.00	1,667	72	28	2.57
Moores-Creek	5/24/97	12:55-1:07PM	6	246	41.00	100.00	4,100	178	68	2.62
Moores-Creek	6/7/97	12:00-12:25PM	8	135	16.88	100.00	1,688	110	25	4.40
Moores-Creek	6/7/97	10:17-10:30PM	8	291	36.38	100.00	3,638	230	61	3.77
Moores-Creek	6/21/97	9:20-9:30AM	6	147	24.50	100.00	2,450	96	51	1.88
Moores-Creek	6/21/97	8:00-8:50PM	6	936	156.00	100.00	15,600	755	181	4.17
Thompsons-Marsh										
Thompsons-Marsh	5/10/97	11:00AM-2:30PM	18	1,198	66.56	780.00	51,913	1,008	190	5.31
Thompsons-Marsh	5/24/97	10:30AM-2:00PM	12	1,665	138.75	780.00	108,225	1,317	348	3.78
Thompsons-Marsh	6/7/97	11:15AM-3:00PM	12	1,511	125.92	780.00	98,215	1,154	357	3.23
Thompsons-Marsh	6/21/97	9:30AM-1:00PM	12	1,168	97.33	780.00	75,920	869	299	2.91

Table 1. A. 1997 Spawning Survey Data

A Beach	B Date	C Time	D Seg	E Total	F Crabs per 5m	G Length	H Estimate	I M	J F	K M/F
New Jersey										
Thompsons-Beach	5/10/97	11:00AM-1:00PM	18	24	1.33	1.00	267	21	3	7.00
Thompsons-Beach	5/10/97	11:00AM-1:00PM	18	29	1.61	200.00	322	24	5	4.80
Thompsons-Beach	5/24/97	10:0AM-12:30PM	18	167	9.28	200.00	1,856	101	66	1.53
Thompsons-Beach	5/24/97	10:0AM-12:30PM	18	302	16.78	200.00	3,356	175	127	1.38
East Point						0.95				
East Point	5/10/97	11:20PM	18	28	1.56	190.00	296	20	8	2.50
East Point	5/11/97	11:35PM	6	0	0.00	190.00	0	0	0	
East Point	5/24/97		18	414	23.00	190.00	4,370	319	95	3.36
East Point	5/24/97	11:00PM	18	490	27.22	190.00	5,172	245	57	4.30
East Point	6/7/97	10:40AM	18	302	16.78	190.00	3,188	7	4	1.75
East Point	6/7/97	10:40PM	9	11	1.22	190.00	232	94	39	2.41
East Point	6/21/97	11:10AM	18	133	7.39	190.00	1,404	383	116	3.30
East Point	6/21/97	12:00AM midnight	6	499	83.17	190.00	15,802			
Fortescue						2.60				
Fortescue	6/7/97	12:45-1:40PM	9	220	24.44	520.00	12,711	182	38	4.79
Fortescue	6/7/97	11:35PM-12:05AM	3	0	0.00	520.00	0	0	0	
Fortescue	6/21/97	10:30AM-12:30PM	9	529	58.78	520.00	30,564	456	73	6.25
Fortescue-Creek						0.50				
Fortescue-Creek	5/24/97	11:10AM-1:45PM	9	196	21.78	100.00	2,178	130	66	1.97
Fortescue-Creek	6/7/97	12:45-1:15PM	3	34	11.33	100.00	1,133	29	5	5.80
Fortescue-Creek	6/7/97	11:15-11:35PM	3	15	5.00	100.00	500	11	4	2.75
Fortescue-Creek	6/21/97	12:30-1:00PM	5	120	24.00	100.00	2,400	108	12	9.00
Gandys						1.20				
Gandys	5/5/97	9:50-10:30PM	300m	0	0.00	240.00	0			
Gandys	5/6/97	10:45-11:30AM	600m	0	0.00	240.00	0			
Gandys	5/24/97	11:00AM-1:25PM	18	255	14.17	240.00	3,400	192	63	3.05
Gandys	5/24/97	11:40PM-12:30AM	18	62	3.44	240.00	827	36	26	1.38
Gandys	6/5/97	9:35AM-1:05PM	18	37	2.06	240.00	493	27	10	2.70
Gandys	6/5/97	10:30-11:10PM	18	11	0.61	240.00	147	4	7	0.57
Gandys	6/20/97	9:15-11:35PM	18	1060	58.89	240.00	14,133	876	184	4.76

Table 1. B. 1997 Survey Weather Data

A	B	C	M	N	O	P	Q	R
Beach	Date	Time	Air Temp	Wind Dir	Wind Vel	Wave Hgt	Weather	Notes
Delaware								
Slaughter								
Slaughter	5/11/97	11:30AM-2:50PM	upper 60's	NNW	light	4-6",calm	clear	
Slaughter	5/11/97	11:30PM-1:45AM	45	N	moderate	8"	part clouds	occasional gust, cold
Slaughter	5/23/97	9:00-11:30PM	low 60's		light	4"	clear	nice day
Slaughter	5/24/97	10:30AM-12:30PM	65					
Slaughter	6/21/97	9:30-10:30AM	75-80	N	7mph	3-4"	clear	
Big Stone								
Big Stone	5/10/97	11:40AM-1:20PM	55	NW	20	1'	cloudy	
Big Stone	5/11/97	12:30-1:40AM	50	NW	5mph	<1'	clear	
Big Stone	5/24/97	10:30AM-1:15PM	68	SE	5mph	<1'	clear	
Big Stone	5/24/97	11:30PM-12:45AM	65	SE	5mph	<1'	cloudy	
Big Stone	5/30/97	4:00-7:15PM					cloud/clear	foggy set up, then clear, breezy+warm
Big Stone	5/31/97	4:30-7:00PM					cloudy	cool, overcast
Big Stone	6/7/97	10:30AM-1:00PM	59	NE	15-20	2'	cloudy	very high tide
Big Stone	6/7/97	11:30PM-12:15AM	54	E	10	1-1.5'	clear	
Big Stone	6/21/97	10:00-10:45AM	80	W	10	<1'	clear	
Big Stone	6/21/97	10:30-11:15PM	80	W	10	1'	clear	
South Bowers								
South Bowers	5/9/97	12:00-12:14	70	W	calm	0	part cloudy	delightful,migrating birds
South Bowers	5/10/97	12:45PM-1:00AM	61	SW			part cloudy	tire marks along shore-harvest
South Bowers	5/11/97	11:55PM-1:05AM					part cloudy	cool
South Bowers	5/11/97	1:45-1:55PM		NW	strong			Gusty wind,crabbers 2nd truck that tide
South Bowers	5/23/97	11:25-11:50PM	cool	none			calm,mild	
South Bowers	5/24/97	11:48PM-12:28AM						
South Bowers	5/25/97	12:18-1:05PM		SW	strong		windy	
South Bowers	6/6/97	10:50AM	60		20mph	mild	clear	breezy
South Bowers	6/7/97	11:40AM	80			1'	clear	sunny
South Bowers	6/8/97	12:00AM-12:30PM	65	SE				
South Bowers	6/20/97	9:36AM						
South Bowers	6/22/97	11:44PM-1:00PM	75	SE		calm		sunny,crabbers had already been there

Table 1. B. 1997 Survey Weather Data

A	B	C	M	N	O	P	Q	R
Beach	Date	Time	Air Temp	Wind Dir	Wind Vel	Wave Hgt	Weather	Notes
Delaware								
North Bowers	5/9/97	12:13-12:22PM	68	SW	4-6mph	<1'	clear	
North Bowers	5/10/97	12:48-1:20PM	55	NE	10-15mph	1.5'	part cloudy	partly sunny, very windy
North Bowers	5/10/97	12:05-12:25AM	55	S		6"	part cloudy	overcast, missed pickup truck with crabs
North Bowers	5/11/97	1:40-1:50PM	65	W	15-25mph		clear	sunny
North Bowers	5/11/97	1:00-1:45AM	50			1'	clear	cold, windy
North Bowers	5/23/97	10:45-11:33AM	60	NE	10-15mph	1.5'	clear	sunny
North Bowers	5/23/97	11:04PM-12:13AM	50		2mph	0	clear	clear
North Bowers	5/24/97	11:30AM	65	W	15mph	1'	clear	
North Bowers	5/24/97	12:10AM						
North Bowers	5/25/97	12:00-1:08PM	82	W	20mph		cloudy	sprinkling
North Bowers	6/6/97	11:05-11:53AM	15C	E	10-15mph	1'	part cloudy	sunny
North Bowers	6/7/97	11:40AM-12:15PM	55	SE	25mph	2'	cloudy	very windy, rough
North Bowers	6/8/97	12:22-12:50PM	70	SW	8-10mph	1.5'	part cloudy	light breeze
North Bowers	6/20/97	9:45-10:45AM	78	SW	<5mph	4"	clear	sunny
North Bowers	6/20/97	9:55-11:43PM	80	SE	10mph	6-8"	clear	hot, humid
North Bowers	6/21/97	10:24-10:40AM	85			3"	clear	hot, humid
North Bowers	6/21/97	10:30PM	80				clear	hot, humid
North Bowers	6/22/97	11:15AM	91				clear	hot, humid
St. Jones Neck								
St. Jones Neck	5/9/97	12:10-12:50PM	68	NE		0	part cloudy	S Overcast
St. Jones Neck	5/10/97	12:35-1:00PM	55			0	part cloudy	overcast
St. Jones Neck	5/11/97	1:00-1:45AM	47	NW	3mph		clear	
St. Jones Neck	5/11/97	1:30PM	65	NE	15-25mph		clear	clear, windy
St. Jones Neck	5/23/97	11:04AM-12:08PM	60	NW	10-15mph	6"	clear	sunny
St. Jones Neck	5/23/97	11:11-11:43PM	56				clear	calm, cool
St. Jones Neck	5/24/97	12:00AM-1:45PM	68	S	9mph		part cloudy	warm, no wind, crabs everywhere
St. Jones Neck	5/25/97	12:30-1:33PM	77					
St. Jones Neck	6/8/97	12:34-2:30PM	75				part cloudy	Windy
St. Jones Neck	6/20/97	9:49-10:25AM	24C	S	0-5K		clear	sunny, warm
St. Jones Neck	6/21/97	11:15-11:40AM	85				clear	hot, humid

Table 1. B. 1997 Survey Weather Data

A	B	C	M	N	O	P	Q	R
Beach	Date	Time	Air Temp	Wind Dir	Wind Vel	Wave Hgt	Weather	Notes
New Jersey								
Higbees	5/10/97	12:30PM					windy	
Higbees	5/11/97	12:30AM					windy	
Higbees	5/24/97	10:30AM-12:00PM	70	SW	light	<1'	clear	clear, sunny
Higbees	5/24/97	11:15-11:37PM	60's	SSW	light	0.5'	clear	
Higbees	6/7/97	10:00AM	60	NE	10 knots	1'	cloudy	cloudy, cool
Higbees	6/7/97	10:20-10:37PM	55	none	none	1'	clear	fair
Higbees	6/21/97	9:30-10:40AM	warm	S	light	<1'	clear	
Higbees	6/21/97	9:55-10:50PM	60-65	S	light	1-1.5'	clear	
Higbees	5/22/97	9:45-10:10AM						
Higbees	6/5/97	9:20-10:12AM	60	N		1'	clear	
Higbees	6/5/97	8:45-9:45PM	mid 50's		light	1'	clear	clear, pleasant
Higbees	6/19/97	7:30AM	70	none		0.5'	part cloudy	
Higbees	6/19/97	8:00-8:55PM	65	N	1-2 knots	<1'	clear	
Norbury's								
Norbury's	5/10/97	1:00-2:00PM			windy	1.5-2'		mostly sunny, very windy
Norbury's	5/11/97	1:00-1:45AM		NW	20-25			
Norbury's	5/24/97	10:45AM-12:45PM	72	SW	0-5	2-3"	clear	calm
Norbury's	5/24/97	10:45PM-1:20AM	60	SSW	0-5	3-5"	part cloudy	calm
Norbury's	6/7/97	9:45-11:30AM	upper 50's	N	light	1'	cloudy	cool
Norbury's	6/7/97	10:20-11:05PM	50		little	1'	clear	cool
Norbury's	6/21/97	10:15-10:35AM	80	S to N	light	0.5'	clear	fair
Norbury's	6/21/97	10:20-11:15PM	65	S	light	none	part cloudy	fair, lots of mosquitoes
Norbury's	6/5/97	10:30AM	63	N	light	6"	clear	
Norbury's	6/5/97	9:45-10:42PM	60	None	none	<1'	clear	fair
Norbury's	6/19/97	7:00AM	70	W	light	none	clear	pleasant
Norbury's	6/19/97	7:40-8:05PM	75	None	none	0	clear	pleasant
Rutgers South								
Rutgers South	5/24/97	10:30-11:30AM	65	W	0-5mph	3"	clear	calm, sunny
Rutgers South	5/24/97	10:30-11:30AM	65	W	0-5mph	3"	clear	calm, sunny
Rutgers South	5/24/97	10:40PM-12:10AM	65	S	5-7mph	6"	Hazy	More crabs offshore, water brown
Rutgers South	5/24/97	10:40PM-12:10AM	65	S	5-7mph	6"	Hazy	More crabs offshore, water brown

Table 1. B. 1997 Survey Weather Data

A	B	C	M	N	O	P	Q	R
Beach	Date	Time	Air Temp	Wind Dir	Wind Vel	Wave Hgt	Weather	Notes
New Jersey								
Highs								
Highs	5/10/97			NW	windy			very windy
Highs	5/24/97	11:00AM						
Highs	5/24/97		75	S				Almost carpet, one layer and 1 m in
Highs	5/24/97		75	S				
Highs	6/7/97	11:20AM	52	NE				Sunday finally warmed up
Highs	6/21/97							
Kimbles								
Kimbles	5/10/97	AM			windy			
Kimbles	5/10/97	PM			windy			
Kimbles	5/24/97	10:30AM-12:00PM	warm		windy			
Kimbles	5/24/97	11:30PM-1:30AM	warm			clear		
Kimbles	6/7/97	12:00-1:00PM	warm			clear		
Kimbles	6/7/97	12:00-1:20AM	warm			clear		
Kimbles	6/21/97	10:10-11:30AM	warm			clear		
Kimbles	6/21/97	10:35PM-12:20AM	warm			clear		
Kimbles/Cooks Ck								
Kimbles/Cooks Ck	5/24/97	10:30AM-12:00PM	warm		windy			Right angle to shoreline
Kimbles/Cooks Ck	5/24/97	11:30PM-1:30AM	warm			clear		Width 20-25 ft.
Kimbles/Cooks Ck	6/7/97	12:00-1:00PM	warm			clear		sand bar with spawning occurring
Kimbles/Cooks Ck	6/7/97	12:00-1:20AM	warm			clear		
Kimbles/Cooks Ck	6/21/97	10:10-11:30AM	warm			clear		
Kimbles/Cooks Ck	6/21/97	10:35PM-12:20AM	warm			clear		
Kimbles/Pierces Ck	5/24/97	10:30AM-12:00PM	warm		windy			
Kimbles/Pierces Ck	5/24/97	11:30PM-1:30AM	warm			clear		Right angle to shoreline
Kimbles/Pierces Ck	6/7/97	12:00-1:00PM	warm			clear		Width 20-25 ft.
Kimbles/Pierces Ck	6/7/97	12:00-1:20AM	warm			clear		sand bar with spawning occurring
Kimbles/Pierces Ck	6/21/97	10:10-11:30AM	warm			clear		
Kimbles/Pierces Ck	6/21/97	10:35PM-12:20AM	warm			clear		

Table 1. B. 1997 Survey Weather Data

A	B	C	M	N	O	P	Q	R
Beach	Date	Time	Air Temp	Wind Dir	Wind Vel	Wave Hgt	Weather	Notes
New Jersey Reeds								
Reeds-SouthBC	5/10/97	1:15-1:45PM	50	W	15-20mph	1-2ft.	cloudy	Stranded F 8 M 7
Reeds-SouthBC	5/10/97	1:15-1:45AM	45	W	15-20mph	2-3ft.	clear	very windy, very rough water
Reeds-SouthBC	5/24/97	11:15-11:40AM	72	SW	0-5mph	1ft.	clear	Lots of birdwatchers
Reeds-SouthBC	5/23/97	10:20-11:05	50	S	5mph	1ft.	clear	Crabs in surf+ deep water, water brown
Reeds	6/7/97	11:25-11:45PM	46	N	5-10mph	1-2ft.	clear	
Reeds	6/10/97	10:39-11:00AM	55	N	10-15mph	3-4ft.	cloudy	
Reeds	6/20/97	10:00-10:50PM	75	SE	15mph			
Reeds	6/21/97	10:30-11:00AM	75	SW	10mph	2ft.	clear	
Moores								
Moores	5/10/97	12:00-12:55PM	50	WNW	15-20mph	1-2ft.	cloudy	less beach than last year
Moores	5/10/97	12:20-12:50AM	45	W	10-15mph	1-2ft.	clear	no activity at high line, but in surf
Moores	5/23/97	12:00AM	50	S	5-10mph	1ft.	clear	stranded on beach, none in inlet
Moores	5/24/97	12:25-1:15PM	72	S	0-5mph	<1ft.	clear	Crabs at East end, most segs. 0
Moores	6/7/97	11:35AM-12:00PM	55	N	10-15mph	3-4ft.	cloudy	No exposed beach at high tide
Moores	6/7/97	10:33-10:45PM	46	N	5-10mph	1-2ft.	clear	No exposed beach at high tide
Moores	6/20/97	8:00-9:40PM	78	SE	15mph	2-3ft.	clear	Surf rough, difficult to count
Moores	6/21/97	8:50-9:30AM	75	SW	5-10mph	1-2ft.	cloudy	
Moores-Creek								
Moores-Creek	5/10/97	12:40-12:50PM	50	WNW	15-20mph	1-2ft.	cloudy	Mouth S-SW, 150' width, strong, sandy+marsh
Moores-Creek	5/10/97	12:45-12:55AM						
Moores-Creek	5/23/97	12:40-12:50AM						
Moores-Creek	5/24/97	12:55-1:07PM						
Moores-Creek	6/7/97	12:00-12:25PM						
Moores-Creek	6/7/97	10:17-10:30PM						
Moores-Creek	6/21/97	9:20-9:30AM						
Moores-Creek	6/21/97	8:00-8:50PM						
Thompsons-Marsh								
Thompsons-Marsh	5/10/97	11:00AM-2:30PM	70	W	20 knots	NA		
Thompsons-Marsh	5/24/97	10:30AM-2:00PM	70	S	15 knots	NA	Clear	
Thompsons-Marsh	6/7/97	11:15AM-3:00PM	80	SW	5 knots	NA	part cloudy	
Thompsons-Marsh	6/21/97	9:30AM-1:00PM	85	W	10 knots	NA	part cloudy	

Table 1. B. 1997 Survey Weather Data

A	B	C	M	N	O	P	Q	R
Beach	Date	Time	Air Temp	Wind Dir	Wind Vel	Wave Hgt	Weather	Notes
New Jersey								
Thompsons-Beach								
Thompsons-Beach	5/10/97	11:00AM-1:00PM	70	W	20 knots	1.5ft.	cloudy	windy
Thompsons-Beach	5/10/97	11:00AM-1:00PM	70	W	20 knots	1.5ft.	cloudy	windy
Thompsons-Beach	5/24/97	10:0AM-12:30PM	70	S	10 knots	1 ft.	clear	sunny, Western part
Thompsons-Beach	5/24/97	10:0AM-12:30PM	70	S	10 knots	1 ft.	clear	sunny, Eastern part
East Point								
East Point	5/10/97	11:20PM	52	onshore	20-30mph	2-3'	cloudy	miserable
East Point	5/11/97	11:35PM	49	onshore	10-15mph	3-4'	clear	Not accessible 7-18 seg
East Point	5/24/97		68			1-2'	clear	large amounts of eggs
East Point	5/24/97	11:00PM	60	SSE	8-10knots	1-2'	clear	Not accessible 7-18seg, lots of crabs
East Point	6/7/97	10:40AM	68	NE	0		cloudy	many eggs, much subsurface activity
East Point	6/7/97	10:40PM						Not accessible 10-18 seg
East Point	6/21/97	11:10AM						large quantity of eggs
East Point	6/21/97	12:00AM mignight						Not accessible 7-18 seg
Fortescue								
Fortescue	6/7/97	12:45-1:40PM	60	W	10-15 knots	minimal	part cloudy	
Fortescue	6/7/97	11:35PM-12:05AM						
Fortescue	6/21/97	10:30AM-12:30PM	80	SW	5-10 knots	6-12"	clear	sunny
Fortescue-Creek								
Fortescue-Creek	5/24/97	11:10AM-1:45PM	60	W		calm	clear	sunny, no clouds, humid
Fortescue-Creek	6/7/97	12:45-1:15PM						
Fortescue-Creek	6/7/97	11:15-11:35PM						
Fortescue-Creek	6/21/97	12:30-1:00PM	80	SW	5-10 knots	6-12"	clear	Mouth E-W, 60'width, moderate, sandy+marsh
Gandys								
Gandys	5/5/97	9:50-10:30PM						
Gandys	5/6/97	10:45-11:30AM	50-60	SW	brisk	choppy	clear	
Gandys	5/24/97	11:00AM-1:25PM	65	W	1-2mph	6"		
Gandys	5/24/97	11:40PM-12:30AM	55	S	5mph	1ft.		
Gandys	6/5/97	9:35AM-1:05PM	65	NNW	3mph	6"	clear	
Gandys	6/5/97	10:30-11:10PM	55	SE	8-9mph	2ft.	clear	
Gandys	6/20/97	9:15-11:35PM	65	SE	3mph	1ft.	clear	

Table 2. Summary of 1997 Survey Data
B. New Jersey Beaches

	Estimate 5/10/97		Estimate 5/24/97		Estimate 5/24/97		Estimate 6/7/97		Estimate 6/7/97		Estimate 6/21/97		Estimate 6/21/97		Beach Totals
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	
Higbees	0	0	0	22	11	11	54	425	523						523
Norbury's	459	162	7,425	22,923	189	540	891	12,717	45,306						45,306
Rutgers South			9,924	27,544					37,468						37,468
Higs	0	0	1,227	8,880	0	0	0	622	10,729						10,729
Kimbles	0	0	678	11,600	122	6,022	111	3,189	21,722						21,722
Reeds	0	0	15,980	12,019		2,227	1,785	8,160	40,171						40,171
Moores	500	0	5,700	9,500	1,250	1,418	1,659	23,040	43,067						43,067
Thompsons-Beach	322		3,356	5,172				3,678							3,678
East Point		296	4,370	5,172	3,188	232	1,404	15,802	30,464						30,464
Fortescue					12,711	0	30,564		43,275						43,275
Gandys	0	0	3,400	827	493	147	1,200	10,787	16,854						16,854
Sea Breeze	5/6/97	5/5/97			6/5/97	6/5/97			220						220
AM and PM Totals	1,281	458	52,060	98,487	18,184	10,597	37,668	74,742	293,477						293,477
Daily Totals		1,739		150,547		28,781		112,410	293,477						293,477

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Table 2. Summary of 1997 Survey Data
C. Tidal Creek and Marsh Areas

	Estimate 5/10/97 AM	Estimate 5/10/97 PM	Estimate 5/24/97 AM	Estimate 5/24/97 PM	Estimate 6/7/97 AM	Estimate 6/7/97 PM	Estimate 6/21/97 AM	Estimate 6/21/97 PM	Beach Totals
New Jersey									
Kimbles/Cooks Ck			3,233		1,267		1,067	2,167	7,734
Kimbles/Pierces Ck			2,300	5,400	33		200	1,133	9,066
Moores-Creek	67	67	4,100	1,667	1,688	3,638	2,450	15,600	29,277
Thompsons-Marsh	51,913		108,225		5/23/97 98,215		75,920		334,273
Fortescue-Creek				2,178	1,133	500	2,400		6,211
Gandys-Creek					100		60		160
Sea Breeze-Creek			0		6/5/97 1,733				1,733
AM and PM Totals	51,980	67	117,858	9,245	104,169	4,138	82,097	18,900	388,454
Daily Totals		52,047		127,103		108,307		100,997	388,454

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Table 3. Comparison of Data on Horseshoe Crabs Spawning on Delaware Bay Shores on Pre-Selected Dates*.

	10-May-97	24-May-97	7-Jun-97	21-Jun-97
Estimation of Spawning Individuals	140,121	703,846	33,599	453,818
Percentage of DE Spawning Individuals	99	79	14	75
Percentage of NJ Spawning Individuals	1	21	86	25
Individuals During AM High Tide	93,631	228,036	23,002	140,202
Individuals During PM High Tide	46,490	475,810	10,597	313,616
Ratio of Individuals PM vs. AM Tide	0.5	2.09	0.46	2.24
Beaches Surveyed in Delaware	7	7	6	7
Beaches Surveyed in New Jersey	9	12	10	9
Ratio of Male Individuals to Female		3.48		
Ratio Male to Female Delaware		3.37		
Ratio Male to Female New Jersey		3.78		
Main Spawning Beaches in Delaware		Slaughter Big Stone		
Main Spawning Beaches in New Jersey		Norburys Rutgers South		

* Each Year, at least two months prior to the expected spawning season, a "census" date is selected.

Table 3. Comparison of Data on Horseshoe Crabs Spawning on Delaware Bay Shores on Pre-Selected Dates*.

	4-May-96	18-May-96	1-Jun-96	15-Jun-96
Estimation of Spawning Individuals	163,239	209,976	466,124	182,193
Percentage of DE Spawning Individuals	95	88	79	88
Percentage of NJ Spawning Individuals	5	12	21	12
Individuals During AM High Tide	59,003	27,953	67,834	25,229
Individuals During PM High Tide	104,236	182,023	398,290	156,964
Ratio of Individuals PM vs. AM Tide	1.77	6.51	5.87	6.22
Beaches Surveyed in Delaware	6	6	7	5
Beaches Surveyed in New Jersey	4	8	10	8
Ratio of Male Individuals to Female			avg. 2.45	
Ratio Male to Female Delaware			avg. 2.82	
Ratio Male to Female New Jersey			avg. 2.52	
Main Spawning Beaches in Delaware			Slaughter Big Stone South Bowers	
Main Spawning Beaches in New Jersey			Norburys Rutgers South Highs East Point	

* Each Year, at least two months prior to the expected spawning season, a "census" date is selected.

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Table 3. Comparison of Data on Horseshoe Crabs Spawning on Delaware Bay Shores on Pre-Selected Dates*.

	27-May-95	10-Jun-95	21-May-94	11-Jun-94
Estimation of Spawning Individuals	91,864	112,912	104,000	342,884
Percentage of DE Spawning Individuals	97	96	74	91
Percentage of NJ Spawning Individuals	3	4	26	9
Individuals During AM High Tide	2,609	38,080	52,694	44,651
Individuals During PM High Tide	89,255	74,832	51,306	298,233
Ratio of Individuals PM vs. AM Tide	34.21	1.96	0.97	6.68
Beaches Surveyed in Delaware	7	5	8	4
Beaches Surveyed in New Jersey	3	9	15	3
Ratio of Male Individuals to Female		2.74	2.46	3.74
Ratio Male to Female Delaware		3.39	2.16	3.52
Ratio Male to Female New Jersey		2.74	3.14	3.62
Main Spawning Beaches in Delaware	Slaughter Pickering	Slaughter Pickering	Kitts Hummock Pickering	Big Stone Bowers Pickering
Main Spawning Beaches in New Jersey	Highs East Point	Highs East Point	Highs Moores East Point	Moores

* Each Year, at least two months prior to the expected spawning season, a "census" date is selected.

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Table 3. Comparison of Data on Horseshoe Crabs Spawning on Delaware Bay Shores on Pre-Selected Dates*.

	5-Jun-93	16-May-92	25-May-91	8-Jun-90
Estimation of Spawning Individuals	394,039	399,147	1,224,771	1,240,679
Percentage of DE Spawning Individuals	88	28	43	19
Percentage of NJ Spawning Individuals	12	72	57	81
Individuals During AM High Tide	16,846	133,952	318,153	317,399
Individuals During PM High Tide	377,193	265,195	906,618	923,280
Ratio of Individuals PM vs. AM Tide	22.39	2.04	2.85	2.91
Beaches Surveyed in Delaware	9	13	13	21
Beaches Surveyed in New Jersey	9	11	8	13
Ratio of Male Individuals to Female	2.49	3.13	2.64	2.19
Ratio Male to Female Delaware	2.77	2.12	2.78	1.76
Ratio Male to Female New Jersey	2.29	4.14	2.51	2.62
Main Spawning Beaches in Delaware	Big Stone South Bowers Kitts Hummock Pickering Port Mahon	Pickering	North Bowers Kitts Hummock Pickering Port Mahon Kelly Island	Cedar Beach South Bowers Kitts Hummock Pickering
Main Spawning Beaches in New Jersey	Kimbles Highs	Kimbles Highs	Fortescue Moores Beach East Point	Cooks Beach Highs Beach Moores Beach Thompsons East Point

* Each Year, at least two months prior to the expected spawning season, a "census" date is selected.

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Table 4. Spawning Estimates Survey Dates 1990-1997
A. Delaware Beaches

Beach	1990	1991	1992	1993	1994	1995	1996	1997
Cape Henlopen	2,375	6,250						
Roosevelt Inlet	18,400	61,120						
Broadkill	450			2,782				
Primehook		9,399	0	975	0		0	
Fowler Beach		0	0		0	120		
Slaughter Beach	72,165	14,583	28,398		120	38,298	122,628	126,833
Big Stone Beach	33,000		3,773	243,792	0	2,888	152,760	185,186
South Bowers	72,163	32,085	10,102	27,264	338	12,498	37,182	71,658
North Bowers	7,280	56,420	13,000	11,677		11,362	28,510	53,733
St. Jones Neck							3,534	44,956
Kitts Hummock	19,300	18,266*	10,212	29,874	67,000	0		22,800
Pickering Beach	21,075*	34,677	27,022	13,318	9,240	36,934	24,190	48,133
Port Mahon	8,406*	30,957*	8,298	10,617	47			
Kelly Island	70,266*	165,130*	9,046	6,095				
Kent Island	820*							
Bombay Hook Is	1,550*							
Woodland Beach	0	775	0					
Augustine Beach	0							
Collins Beach	no beach							
Totals	327,250	429,662	109,851	346,394	76,745	102,100	368,804	553,299

* Changed from Original Data

Table 4. Spawning Estimates Survey Dates 1990-1997
 B. New Jersey Beaches

Beach	1990	1991	1992	1993	1994	1995	1996	1997
Sunset Beach	0				0			
Higbees						941	305	22
North Cape May				53	0	0		
Cox Hall Creek	38,849							
Villas	4,270	4,791	28,000		425			
Norbury's Landing	7,946	8,644		13,556	535		14,687	30,348
South CSL	200		32,240	7,588	320	4,740	19,517	37,468
Highs Beach	82,991	3,179	19,880	7,718	896	2,425	8,968	10,107
Pierces Pt.					1,854	183		
Kimbles			160,980	11,732	270	224	3,256	12,278
Cooks Beach	358,020		33,348*	2,412*	360	105	4,932	
Reeds Beach		16,818	18,868*	4,667*	2,601	459	3,552	27,999
Moores Beach	198,505	481,754			3,636		7,368	15,200
Thompsons Beach	65,626							3,356
East Point	25,802	58,541*			13,146	1,705	15,420	9,542
Raybins					20			
Fortescue	13,564	145,195	14,872	390	2,808		8,840	
Gandy's Beach	7,875	3,420	14,179		384		10,475	4,227
Sea Breeze	8,760			1,664		30		
Totals	812,408	722,342	322,367	49,780	27,255	10,812	97,320	150,547

*Changed from original data

Legend 2 for Table 5. Tagged Adult Horseshoe Crabs Released Delaware Bay Shore and Recovered on Continental Shelf

- Column A Tag Number - The number of the tag that was attached to the horseshoe crab.
- Column B Release Date - Date the tagged horseshoe crab was released.
- Column C Release Site - Site where the tagged horseshoe crab was released.
- Column D Recovery Date - Date the tagged horseshoe crab was recovered.
- Column E Recovery Site - Site where the tagged horseshoe crab was recovered, alive unless otherwise noted.
- Column F C - Approximate age of the horseshoe crab, y, m or o.
y - young adult (1 to 3 year adult).
m - mid-age adult (3 to 7 year adult).
o - old age adult (over 7 years as an adult).
- Column G Sex - Sex of the horseshoe crab, M for male or F for female.
- Column H I/O - Intraocular Distance - the distance between the two, large compound eyes, measured in millimeters.
- Column I PW - Prosoma Width - the greatest width of the prosoma, usually at the level of the two, large compound eyes, measured in millimeters.
- Column J WT - Weight of the horseshoe crab, measured in kilograms.

Table 5. Tagged Adult Horseshoe Crabs Released Delaware Bay Shore and Recovered on Continental Shelf

A	B	C	D	E	F	G	H	I	J
<u>Tag Number</u>	<u>Release Date</u>	<u>Release Site</u>	<u>Recovery Date</u>	<u>Recovery Site</u>	<u>C</u>	<u>Sex</u>	<u>I/O</u>	<u>PW</u>	<u>WT</u>
1772	5/19/87	Cooks Beach, NJ	6/6/87	Boat, East of White Creek, Indian River Bay mouth, DE		F	186		3.4
2262	6/5/87	Green Creek, NJ	7/8/87	Boat, east of Ocean City, MD		F	177		2.92
5737	5/21/88	Green Creek, NJ	8/30/88	Boat, 5 miles east of Cape May, NJ 8 fathoms of water		M	116		
9154	6/23/89	Cape Henlopen, DE	7/31/89	Boat, east of Indian River, DE		F	150		
16018	5/16/92	Hights Beach, NJ	10/27/92	Boat, 2.25 miles off Hereford Inlet, NJ		F			
16198	6/5/96	Hights Beach, NJ	8/30/97	Boat, 2 miles east of Sea Isle City, NJ Bled for production of lysate and released		F			
19092	6/10/93	Pickering, DE	9/4/93	Boat, 10 miles south of Ocean City Inlet, MD	m	M	125	205	1
19120	6/10/93	Pickering, DE	9/4/93	Boat, 10 miles south of Ocean City Inlet, MD	m	F	155	234	1.6
22582	6/10/94	East Point, NJ	1/4/95	Gill Net boat, 10 miles east of Ocean City, MD	y	F	190		
28567	6/9/90	Cape Henlopen, DE	8/10/90	Boat, 5 miles east of Ocean City, MD		F	160		
29203	5/27/95	Big Stone, DE	8/?/95	Boat, east of Indian River mouth, DE Loran 27080 / 42570	o	F	143		2
32935	6/7/97	East Point, NJ	12/16/97	Scallop boat, 30 miles east of Delaware/Maryland Line Lat. 74 degrees 22' N & Long. 38 degrees 16' W		F	180		
35137	5/24/97	Slaughter, DE	9/18/97	Boat, 5 miles east of Rehoboth Beach, DE	m	M	120	225	1
23272	5/21/94	Port Mahon, DE	2/1/98	Virginia Beach, VA, washed on beach after storm	m/o	M	90	186	1
32853	6/9/97	East Point, NJ	3/2/98	Gill Net Gear, Ocean City, MD Beach		M			