Horseshoe Crab Spawning Activity in Delaware Bay:
1999 – 2004

Report to the ASMFC Horseshoe Crab Management Board

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Summary

- Over the past six years the Delaware Bay Horseshoe Crab Spawning Survey has been implemented in a standardized manner throughout Delaware Bay during May and June. Numerous volunteers and coordinators have worked very hard to implement this survey in a rigorous manner.
- Estimates of spawning activity from this survey have been precise. Coefficient of variation has been below 14% over the past six years and 10% or less over the past four years.
- In 2004, spawning activity peaked markedly during mid-May and dropped sharply during June. Spawning has tended to peak in late-May, although there has been considerable year-to-year variation in the timing of spawning activity. In some years spawning activity has been more uniformly distributed (2000 and 2001), and in other years spawning activity has been more sharply peaked (1999, 2002, and 2004).
- Overall conclusions are similar to last year's report. We conclude that spawning activity in Delaware Bay over the past 6 years has been either stable or declining at a rate less than 4% per year (regression slope was -0.006; 90% CI -0.038, 0.027). Patterns in spawning activity between the New Jersey and Delaware shores appear to be somewhat off-setting, possibly due to shifts in spatial distribution. State-specific trend was positive in New Jersey (slope = 0.04, SE = 0.042, P = 0.41), but negative in Delaware (slope = -0.04, SE = 0.017, P = 0.06). However, spawning in Delaware is now showing a significant decline (regression slope was -0.04; 90% CI -0.069, -0.011).
- The spawning survey database has been converted to MS ACCESS, and a visual basic program has been developed to calculate estimates of spawning activity and present results in tables and graphs. In the process of converting the data from MS Excel format, a number of errors were detected and corrected. The corrections resulted in some changes in past ISA estimates, more so in NJ than in DE. The overall patterns in spawning activity were largely unaffected. All corrections are listed in the Appendix of this report. The full database and software are available for downloading from an internet site
http://www.lsc.usgs.gov/aeb/2065/SPAWNAR/index.asp

Background

The Atlantic State Marine Fisheries Commission (ASMFC) sponsored a workshop on horseshoe crab surveys in January 1999. The workshop resulted in recommendations for the design and implementation of a statistically valid survey of spawning horseshoe crabs in the mid-Atlantic region. In Delaware Bay, the recommendations were used to redesign the volunteer-based spawning survey that began in 1990. Funds were awarded from the USGS State Partnership Program in 1999, the U.S. Fish and Wildlife Service in 2000, and the Delaware Division of Fish and Wildlife in 2001—2004 to implement the Delaware Bay Horseshoe Crab Spawning Survey. During those years, Ms. Benjie Swan (Limuli Labs) and Dr. Bill Hall (Univ. of Delaware) have been contracted to coordinate the survey.

The Delaware Bay Horseshoe Crab Spawning Survey was designed to accomplish several important objectives: (1) provide a reliable index of spawning activity to monitor the temporal and spatial distribution of horseshoe crab spawning activity for comparing baywide spawning among years, beach-level spawning within Delaware Bay, and distributions of spawning horseshoe crabs and shorebirds; (2) increase our understanding of the relationship between environmental factors (tidal height and wave height) and spawning activity; and (3) promote public awareness of the central role of horseshoe crabs in shorebird population dynamics, Atlantic coast fisheries, and human health through production of *Limulus* amoebocyte lysate (LAL).

With this report, we continue an annual series of statistical reports on the survey. A detailed description and evaluation of the spawning survey design were previously reported.

This and previous reports are intended to complement the ongoing series of reports that have been issued by the survey coordinators, Ms. Swan and Dr. Hall in cooperation with Dr. Carl Shuster.

Data availability

This past year, with funding provided by the Delaware Estuary Program, spawning survey database has been converted to MS ACCESS, and a visual basic program has been developed to calculate estimates of spawning activity and present results in tables and graphs.

In the process of converting the data from MS Excel format, a number of errors were detected and corrected. The corrections resulted in some changes in past ISA estimates, more so in NJ than in DE. The overall patterns in spawning activity were largely unaffected from past reports. All corrections are listed in the Appendix of this report. Most corrections had minimal affect on past estimates. However, in 2002 and 2003 the amount of beach surveyed at Sea Breese dropped from 190 m to 100 m, but was not accounted for and spawning density was previously underestimated by nearly half at that beach and resulted in an increase in the spawning density estimate for NJ.

Data presented in this report (both the estimates and the raw data) and the software used to calculate estimates, are available on internet at
http://www.lsc.usgs.gov/aeb/2065/SPAWNAR/index.asp

Summary results

In 2004, 24 beaches were surveyed on as many as 12 tides from May 2nd through June 19th. Thirteen of the beaches were in Delaware and 11 were in New Jersey. The number of tides per beach sampled ranged from 8 to 12 (median = 11), and the total number of tides sampled for all beaches was 252.

<u>Temporal distribution of spawning</u>

The timing of spawning is important because it affects the forage available to migratory shorebirds. Timing could also affect survival of egg, larvae, and juvenile stages.

In 2004, peak spawning occurred during mid-May and the temporal pattern was very similar in Delaware and New Jersey (Figure 1). Spawning dropped off sharply in June, and a high percentage of spawning occurred during May (Table 1). In 2003, peak spawning occurred after May 29th, which was later than in previous years. In 1999 and 2002, peak spawning occurred after May 28th in Delaware, but in those years there had been considerable spawning in New Jersey by mid-May. In 2001 and 2003, less than 50% of the spawning in Delaware occurred in May. Percent of spawning that occurs in May has been consistently higher in New Jersey than in Delaware (Table 1).
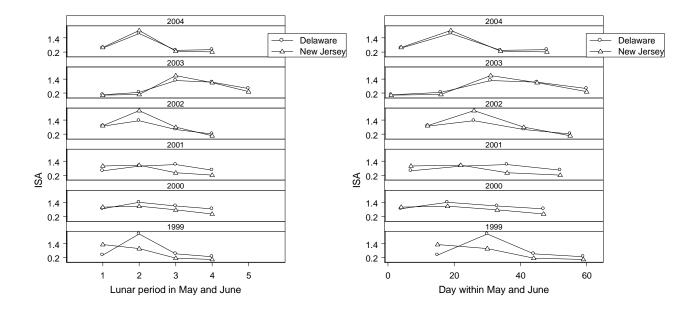

Figure 1. Index of spawning activity for Delaware Bay in May and June for 1999 to 2004. The left graph shows spawning by lunar period: lunar periods 1 and 2 are in May, and lunar periods 3 and 4 are in June. The right graph shows spawning by day within May and June. The index is the number of spawning females within 1 m of high tide line on beach index sites. Surveys were conducted within 3 days of the new or full moons, and these periods were termed 'lunar periods'. The index is shown separately for beaches in Delaware (circles) and New Jersey (triangles).

Table 1. Summary statistics reflecting the timing of horseshoe crab spawning in Delaware and New Jersey. Percentages are based on estimates of month-specific ISA.

	Delaware		New Jersey	
	Dates of peak spawning	% of spawning in May	Dates of peak spawning	% of spawning in May
1999	May 28—June 1	81	May 13—17	93
2000	May 16—18	53	May 16—18	68
2001	June 3—7	47	May 5—9	76
2002	May 24—28	73	May 24—28	78
2003	May 29—June 2	47	May 29—June 2	55
2004	May 17 – 21	75	May 17 – 21	84

State-specific spawning activity – Trends in spawning activity over 1999—2004 at the state-level show differences among states (Figure 2 and Table 2). Change in spawning activity in New Jersey is positive, although not significantly so (slope = 0.04, SE = 0.042, P = 0.41), and in Delaware the change is negative and significantly so (slope = -0.04, SE = 0.017, P = 0.06).
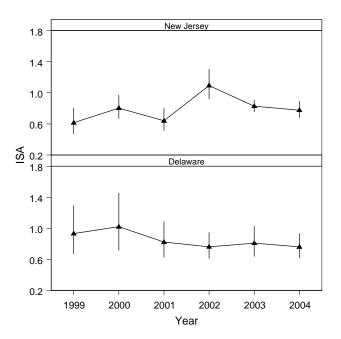

Figure 2. State-specific index of spawning activity (ISA) for New Jersey and Delaware from 1999 to 2004. Vertical bars show 90% confidence intervals.

Table 2. Index of spawning activity (ISA) calculated separately for Delaware and New Jersey from 1999 to 2004.

	Delaware			New Jersey		
Year	ISA	90% CI	Beaches surveyed	ISA	90% CI	Beaches surveyed
1999	0.93	0.67, 1.29	8	0.61	0.47, 0.80	9
2000	1.02	0.72, 1.45	11	0.80	0.67, 0.96	11
2001	0.82	0.63, 1.08	12	0.64	0.51, 0.80	10
2002	0.76	0.61, 0.94	13	1.09	0.92, 1.30	10
2003	0.81	0.64, 1.03	13	0.83	0.76, 0.91	10
2004	0.76	0.62, 0.93	13	0.78	0.68, 0.89	12

Baywide spawning activity – The data do not indicate a change in spawning activity at the baywide scale (Figure 3 and Table 3). The regression slope is close to zero (slope = –0.006, SE = 0.019, 90% confidence interval = -0.038 to 0.027).
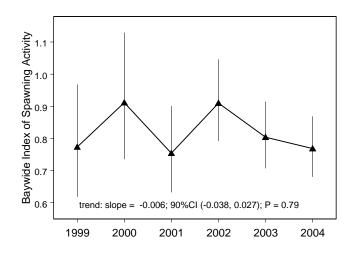

Figure 3. Baywide index of spawning activity (ISA) from 1999 to 2004. Vertical bars show 90% confidence intervals. Estimated slope from a linear regression is shown.

Table 3. Index of spawning activity (ISA) for the Delaware Bay from 1999 to 2004. Standard error (SE) and 90% confidence intervals are also presented.

Year	ISA	SE	CV (%)	90% CI
1999	0.77	0.10	13	0.62, 0.97
2000	0.91	0.12	13	0.74, 1.13
2001	0.75	0.08	10	0.63, 0.90
2002	0.91	0.07	8	0.79, 1.04
2003	0.80	0.06	8	0.71, 0.91
2004	0.77	0.06	7	0.68, 0.87

APPENDIX. Differences in ISA estimates or beach lengths between previous values based on a spreadsheet database and current values based on ACCESS database. Estimates that differed by less than 0.01 are not listed.

Year	Beach	*Date or beach length*	*Previous value*	*Corrected value*	*Cause & Resolution*
1999	Fowlers	6/1	2.04	1.64	Dashes in spreadsheet, which should have been zeros
	Sea Breeze	Beach length (km)	0.2	0.19	190 m was surveyed, previously assumed 200 m
2000	Bennetts	6/16	0.25	0.17	NA's in spreadsheet, which should have been zeros
		6/19	0.39	0.30	NA's in spreadsheet, which should have been zeros
	Slaughter	5/2	0.55 & 0.51	0.51	Two datasheets for 5/2, one selected for inclusion in database
	Sea Breeze	Beach length (km)	0.2	0.19	190 m was surveyed, previously assumed 200 m
2001	Sea Breeze	5/24	0.78	0.82	190 m was surveyed, previously assumed 200 m
	Sea Breeze	Beach length (km)	0.2	0.19	190 m was surveyed, previously assumed 200 m
	Kimbles	Beach length (km)	0.6	0.8	800 m was surveyed, previously assumed 600 m
2002	Kitts Hummock	5/12	1.56	1.61	<100 quadrats completed; spreadsheet calculations based on 100 quadrats
		6/10	1.19	2.38	<100 quadrats completed; spreadsheet calculations based on 100 quadrats
		6/22	0.46	0.52	<100 quadrats completed; spreadsheet calculations based on 100 quadrats
		6/24	0.74	0.76	<100 quadrats completed; spreadsheet calculations based on 100 quadrats
	North Bowers	5/26	1.34	1.25	Typo in spreadsheet
	Prime Hook	5/12	Missing	2.0	Data missing from spreadsheet
	Gandys	5/14	Missing	0.51	Data missing from spreadsheet
	Kimbles	5/28	1.69	1.74	Undetermined error
	Sea Breeze	5/10	0.02	0.04	100 m was surveyed, previously assumed 200 m
		5/24	0.865	1.73	100 m was surveyed, previously assumed 200 m
		5/28	2.005	4.01	100 m was surveyed, previously assumed 200 m
		6/10	1.235	2.47	100 m was surveyed, previously assumed 200 m
		6/12	0.76	1.52	100 m was surveyed, previously assumed 200 m

	Norburys	Beach length (km)	1.0	0.5	500 m was surveyed, previously assumed 1km
	Sea Breeze	Beach length (km)	0.2	0.1	100 m was surveyed, previously assumed 200 m
2003	Kitts Hummock	6/12	0.0	No data	Survey was cancelled at a time when spawning was observed on other nearby beaches
	Sea Breeze	5/14	0.05	0.1	100 m was surveyed, previously assumed 200 m
		5/29	0.02	0.04	100 m was surveyed, previously assumed 200 m
		6/2	0.005	0.01	100 m was surveyed, previously assumed 200 m
		6/12	0.0	No data	Survey was cancelled at a time when spawning was observed on other nearby beaches
		6/14	0.58	1.1	100 m was surveyed, previously assumed 200 m
		6/16	0.56	1.1	100 m was surveyed, previously assumed 200 m
		6/27	0.1	0.2	100 m was surveyed, previously assumed 200 m
		6/29	0.36	0.68	100 m was surveyed, previously assumed 200 m
		7/1	0.32	0.68	100 m was surveyed, previously assumed 200 m
	Pierces Point	5/31	No data	2.34	Undetermined error
	Prime Hook	7/1	1.10	1.11	Undetermined error
	Norburys	Beach length (km)	1.0	0.5	500 m was surveyed, previously assumed 1 km
	SCSL	Beach length (km)	1.0	0.8	800 m was surveyed, previously assumed 1 km
	Sea Breeze	Beach length (km)	0.2	0.1	100 m was surveyed, previously assumed 200 m