Horseshoe Crab Technical Committee Report

July 10, 2008

The Technical Committee (TC) held a web-based conference call on July 10th to respond to two tasks assigned by the Management Board. The Board asked the TC to review and comment on: (1) estimates of mortality from biomedical bleeding of horseshoe crabs; and (2) the Stock Assessment Subcommittee's update on status of population in the Delaware Bay region. The committee used for the first time "Go To Meeting" web-service and software to view presentations while listening over the phone. The web-based call attracted a record number of committee members and served as a successful forum to complete the tasks. The following is a summary of the conference call.

Attendees

Technical Committee Members

Alicia Nelson (VA)
Andy Draxler (NMFS)
Stew Michels (DE)
John Maniscalco (NY)
Clare McBane (NH)
Greg Breese (USFWS)
Larry DeLancey (SC), Vice Chair
Jeff Brust (NJ)
Alison Leschen (MA)
Tina Moore (NC)
Rich Maney (NMFS)
Steve Doctor (MD)
Penny Howell (CT)
Mike Millard (USFWS), Chair
Joanna Burger (Rutgers)
Brad Winn (GA)
Linda Stehlik (NMFS)
Brad Spear (ASMFC), Staff

*Carl Shuster (VIMS) was not able to join the call but submitted written comments. Those comments have been included in this summary.

Other

Brian Hooker (NMFS), HSC PRT
Dave Smith (USGS), HSC SAS Chair
Michelle Davis (VT), HSC SAS

Biomedical Bleeding Mortality Estimates

The committee reviewed and discussed available literature on this topic. A table summarizing methods and relevant findings of the studies reviewed is at the end of this report. The TC felt the Rudloe (1983) study provided reliable estimates of mortality caused by bleeding. However, the study did not simulate typical transport or handling that commonly occurs in the biomedical industry. Thompson (1998) used a small sample size (n = 20), did not control for post-bleeding conditions, and observed crabs for only one week after bleeding. The TC found the Kurz and James-Pirri (2002) study to be uninformative because of the small sample size (n = 20). However, their study showed disorientation of bled crabs two months after release. This illustrated to the TC that bleeding might affect crab spawning and feeding.

Walls and Berkson (2003) used a small sample size but the experiment was repeated 8 times. They used only male crabs in their study. The Hurton and Berkson (2006) study highlighted the difference in mortality resulting from low and high stress conditions after bleeding.

Steve Doctor conducted informal experiments using bled crabs. He found that more blood could be extracted from a crab kept in warmer conditions. But, higher survival was seen in bled crabs kept in colder conditions. Alison Leschen reported on a pilot study of mortality from bleeding that is in progress. Preliminary results showed 20% mortality of bled and handled females; however this result did not differ significantly from the control, bled only, or handled only groups. The results of the pilot study will be used refine methodology for a study next year.

The TC concluded that there were differences and limitations with all of the studies reviewed. It agreed that regional differences should be expected and further study on the effects, particularly long-term effects, of bleeding and handling of horseshoe crabs is needed. However, the TC is comfortable with the Plan Review Team's methodology for estimating coastwide mortality of crabs from biomedical use. The PRT compiles, from biomedical harvest and use reports, mortality numbers from the time the crabs are harvested until they are bled. It estimates crab mortality numbers after bleeding by applying a 15% mortality rate to the number of crabs bled. The two numbers are added to provide a coastwide estimate of mortality from the transport, handling, and bleeding of horseshoe crabs used for biomedical purposes.

The TC also concluded that there is opportunity to develop and implement guidelines for using horseshoe crabs for biomedical purposes to reduce mortality. Temperature and time out of water appear to contribute significantly to a crab's survival during the biomedical process. Lonza, a biomedical company from Maryland, was given as an example of a company that uses 'best practices' to minimize mortality.

Status of Horseshoe Crabs in the Delaware Bay Region

TC Chair, Mike Millard, presented to the Management Board preliminary results of the SAS's analyses on the status of crabs in the Delaware Bay region. The Board asked that the TC review and comment on the analyses and report prior to the next Board meeting on August 21^{st}. A copy of the SAS's report is included below as Attachment A.

Overall, the Delaware Bay region population of horseshoe crabs appears to be increasing and healthy. The TC notes that these analyses do not give any indication of population status or trends for other areas.

One TC member commented that the Spawning Survey index should be reported in two different groups. Recognizing that crabs are managed for shorebirds, the index should be broken into a time period when migratory shorebirds are in the Bay area and the time when there is no overlap.

The TC points out that the graphs in Figure 2 of the report do not show values for the y-axes. The SAS is comfortable with reporting relative biomass and fishing morality this way (i.e., qualitatively) to show trends rather than absolute estimates (i.e., quantitatively). It is unsure how the surplus production model, the one used to produce the graphs, works for long-lived species.

Further, there is much variation in past years when more years of data are added. The SAS would only quantify relative biomass and fishing mortality if confidence intervals were also included.

Maximum sustainable yield (MSY) is a component of the surplus production model that provides a comparative benchmark for assessing trends. However, MSY is not used as a benchmark to manage horseshoe crabs. The FMP makes it clear that the horseshoe crab population is also managed for shorebirds.

Table. Summary of published Horseshoe Crab Bleeding studies reviewed by TC.

Authors	**Method and number of crabs**	**Study time post bleeding**	**Study Location**	**Percent mortality observed**
Rudloe (1983)	Tagged, bled, released into estuary; n = 2101 male, 2728 female bled; 2494 male, 2936 female control	1 and 2 years	Florida west coast	10% Year 1 11% Year 2
Thompson (1998)	Held in outdoor tank post bleeding; n = 20	1 week	South Carolina	15%
Kurz and James- Pirri (2002)	Bled and sonically tagged, released; n = 20 females	Intensive for 2 months; dead crab found 68 days after, active tags detected up to 10 days	Mass., Nauset estuary (Cape Cod)	20%; in addition 3 crabs not detected
Walls and Berkson (2003)	Biomedical crabs bled, held in tanks; between 10-30 male crabs repeated 8 times	2 weeks in tanks	MD – VA	7.5%
Hurton and Berkson (2006)	*Test 1*-10-40% estimated blood volume removed; exposed to low stress levels; n = 100 male, 100 female	2 weeks in tanks	MD - VA	0%
	Test 2-Held in high stress conditions prior to and after bleeding, then bled as in Test 1; n = 100 male, 95 fem.	2 weeks in tanks	Same	5.7% overall Max. of 40 % blood volume removed- 29.4% females

Attachment A

Update on Horseshoe Crab Assessment in Delaware Bay Region

Recent data and analyses have indicated that the population of horseshoe crabs in the Delaware Bay region is experiencing positive population growth. Because of current interest in horseshoe crab status, we are reporting these data to the HSC TC for their review.

There are 3 sections to the report:

I. updated meta-analysis of trends in fishery independent surveys (ASMFC 2004)
II. updated surplus production modeling (Davis et al. 2006)
III. comparison of female size distribution from 1980s to early 2000s

I. Meta-analysis of trends in fishery independent surveys

Fishery-independent surveys that consistently catch horseshoe crabs were listed and described in the 2004 stock assessment (ASMFC 2004). These surveys have been updated with recent data and the analyses presented in ASMFC (2004) were repeated with the updated data (Manly 2001). We begin by reviewing recent results from the offshore trawl survey (Hata 2008) and the spawning survey (Michels et al. 2008), which were designed specifically for monitoring horseshoe crabs. The offshore trawl and spawning surveys have been highly correlated ($r = 0.77$ for females, $r = 0.94$ for males) for the years 2002 through 2007 when both surveys have been implemented. We also consider the data collected on juveniles during the baywide tagging study from 2003-2005 (Smith et al. in review).

Based on the offshore benthic trawl survey, Hata (2008) concluded that all demographic groups (i.e., juveniles, adult males, and adult females) of the Delaware Bay horseshoe crab population have been increasing since 2003 (Table 3). For example, catch per tow from the offshore benthic trawl survey has increased by 1.4 on average (SD = 0.16) each year since 2003. Density of spawning males in the spawning survey has increased significantly (slope = 0.196; SE = 0.0438; $P = 0.003$). Density of spawning females has not changed significantly during that period (slope = 0.011; SE = 0.0103; $P = 0.31$). Because males mature earlier than females (Shuster and Sekiguchi 2003; Smith et al. in review), the increasing density of spawning males could be a leading indicator of significant increases in female spawning density. Hata (2008) also observed an increase in the smallest size classes caught by the trawl gear (i.e., >100 mm or >7 year old), indicating increased recruitment to the population. Smith et al. (in review) observed expanding size distributions among juveniles (n = 9,075) during 2003-2005 (K-S GOF $P < 0.001$).

We updated the meta-analysis of ASMFC (2004) using data from surveys conducted within the Delaware Bay region from 1999 to 2007. These years correspond to the time since harvest regulation began. Surveys were: NMFS spring and fall trawl survey, which combines the catches of adults and juveniles (B Kramer, NMFS, unpubl. data), state-specific Delaware Bay trawl surveys in Delaware and New Jersey, which record the catches of adult females, adult males, and juveniles separately (SF Michels, Delaware Division of Fish and Wildlife, J Brust, New Jersey Division of Fish and Wildlife unpubl. data), Delaware Bay spawning survey, which counts adult females and adult males separately (Michels et al. 2008), and offshore benthic trawl survey, which records the catches of adult females, adult males, and juveniles separately (Hata

2008). These surveys are described in Appendix C of ASMFC (2004). Among the 13 surveys, 7 (54%) had a significantly positive slope (P £ 0.10; Table 1). Three surveys caught juveniles (New Jersey and Delaware trawls and offshore benthic trawl), and all showed significantly increasing catches. Four surveys recorded sex-specific catches of adults (New Jersey and Delaware trawls, offshore benthic trawl, and spawning survey), and 3 out of 4 showed significant increases in catches of males and 1 out of 4 showed significant increases in catches of females. There was no evidence of declines (Fisher's method: S = 6.61, df = 26, P = 0.99). Also, the weighted slope among all surveys was significantly positive (RMSE-weighted slope = 0.22, SE = 0.045, 90% CL = 0.14 to 0.30).

Evidence for increases was strongest among juvenile catches, evident among adult males, and tentative among adult females (Table 2). This pattern reflects the horseshoe crab maturity schedule, which determines that an expanding population would appear first among juveniles, then among adult males, and finally among adult females. Males mature 1 to 2 years earlier than females.

The long-term trends from the late 1980s to the present in fishery-independent catches of horseshoe crabs indicate a population that declined during the 1990s and began a recovery in the early 2000s (Fig. 1). These long-term data sets were used in surplus production modeling presented in section II.

Table 1. Linear regression for Del Bay or mid-Atlantic Indices over 1999 to 2007. Surveys are described in ASMFC (2004: Appendix).

Dataset	time series duration	standardized RMSE	weight	standardized slope	SE_slope	t	df	p
Combined Sex/Age								
NMFS spring[1]	1999-2007	1.0689	0.935541	0.0061	0.138	0.04	7	0.9661
NMFS fall[1]	1999-2007	1.0675	0.936768	-0.0195	0.1378	-0.14	7	0.8916
Juveniles								
NJ DelBay juv[2]	1999-2007	0.8612	1.16117	0.2163	0.1112	1.95	7	0.0927
DE 16ft lt160mm[3]	1999-2007	0.763	1.310616	0.2557	0.0985	2.6	7	0.0356
VT trawl juv[4]	2002-2007	0.6412	1.559576	0.4379	0.1533	2.86	4	0.0461
Males								
NJ DelBay males[2]	1999-2007	0.8055	1.241465	0.2401	0.104	2.31	7	0.0543
DE 30ft males[5]	1999-2007	1.0573	0.945805	0.054	0.1365	0.4	7	0.7043
DelBay SS male[6]	1999-2007	0.742	1.347709	0.3145	0.0701	4.49	7	0.0028
VT trawl admale[4]	2002-2007	0.7066	1.415228	0.4142	0.1689	2.45	4	0.0703
Females								
NJ DelBay fem[2]	1999-2007	0.9987	1.001302	0.1303	0.1289	1.01	7	0.3459
DE 30ft females[5]	1999-2007	1.0663	0.937822	-0.026	0.1377	-0.19	7	0.8556
DelBay SS fem[6]	1999-2007	0.9805	1.019888	0.1455	0.1266	1.15	7	0.2882
VT trawl adfem[4]	2002-2007	0.7731	1.293494	0.3862	0.1848	2.09	4	0.1049

[1] Bottom trawl survey conducted spring and fall by Northeast Fisheries Science Center of NMFS
[2] NJ trawl survey conducted in Delaware Bay
[3] DE trawl survey conducted in Delaware Bay using 16ft trawl.
[4] Offshore benthic trawl survey conducted in fall on continental shelf by Virginia Tech.
[5] DE trawl survey conducted in Delaware Bay using 30ft trawl.
[6] Delaware Bay spawning survey.

Table 2. Summary of recent trend assessment by demographic group for horseshoe crabs in the Delaware Bay region. Data come from surveys designed specifically to monitor horseshoe crabs: Delaware Bay spawning survey[1] from 1999 to 2007 (Michels et al. 2008), offshore benthic trawl survey[2] from 2002 to 2007 (Hata 2008), and baywide tagging study[3] from 2003 to 2005 (Smith et al. in review).

Demographic group	Assessment
Adult females	Stable[1] or Increase[2]
Adult males	Increase[1,2]
Juveniles	Increase[2,3]

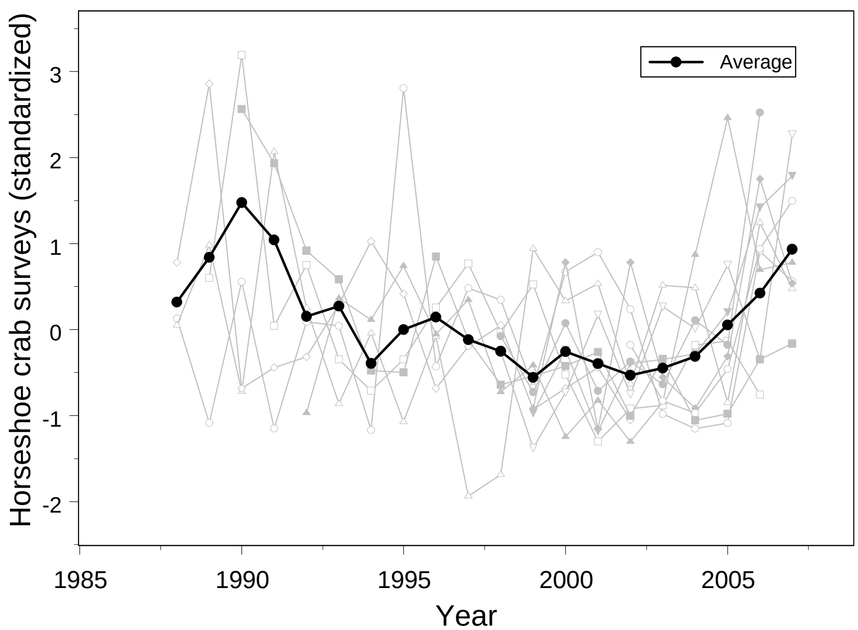


Figure 1. Standardized catches from fishery-independent surveys, which consistently catch horseshoe crabs in the Delaware Bay region. Surveys were listed and described in ASMFC (2004). Standardization was by subtracting the mean and dividing by the SD. The dark line is the average of the standardized catches.

II. Updated Surplus production modeling (methods follow Davis et al. (2006) and ASMFC (2006))

Data used in the models:

Fishery-independent surveys:

- Delaware 30-ft trawl, 1991-2007 (mid-year index)
- Delaware 16-ft trawl, crabs > 160-mm, April-July 1992-2007 (mid-year index)
- Delaware Bay Spawning Survey, 1999-2007 (mid-year index)
- New Jersey Delaware Bay trawl, 1998-2007 (mid-year index)
- NMFS Fall trawl, 1991-2007 (beginning of year index, advanced 1 calendar year to coincide with subsequent spring)
- Virginia Tech Offshore Trawl, 2002-2007 (end-of-year index)
    - o Note: Simulations conducted without the VT trawl data yielded similar results

Landings:

- Regional landings (PA, DE, NJ, MD, and VA) in numbers of crabs from 1991-2007
- For 1991-1997, regional landings were assumed to equal 3.2 times Delaware landings
- For 1991-1997, we assumed a 1:1 sex ratio in the landings
- For 1998-2007, we assumed a sex ratio for unsexed crabs equal to the observed sex ratio of sexed crabs

Some assumptions of the models:

- Graham-Shaefer (logistic) model form, where BMSY = K/2
- All survey indices were weighted equally

Model 1 – Both Sexes Combined

Data: Both sexes combined for DE 30-ft trawl, DE 16-ft 160mm, NJ trawl, NMFS Fall trawl, and VT trawl. Females only for DB spawning survey.

Negative correlations observed: DE 30-ft vs. DE 16-ft 160mm; DB spawning survey vs. DE 16-ft 160mm

Model 2 – Females Only

Data: Females only for DE 30-ft trawl, DB spawning survey, NJ trawl, and VT trawl. Both sexes combined for DE 16-ft 160mm and NMFS Fall trawl.

Negative correlations observed: DE 30-ft vs. NJ trawl; DE 30-ft vs. DE 16-ft 160mm; DB spawning survey vs. DE 16-ft 160mm

Model 3 – Males Only

Data: Males only for DE 30-ft trawl, DB spawning survey, NJ trawl, and VT trawl. Both sexes combined for DE 16-ft 160mm and NMFS Fall trawl.

Negative correlations observed: DE 30-ft vs. DE 16-ft 160mm

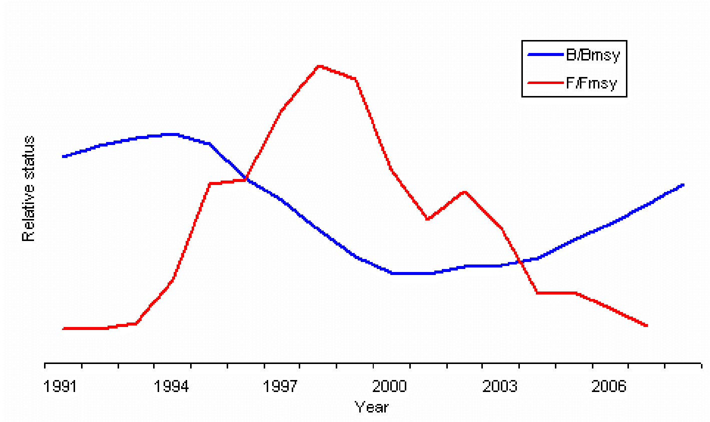
Results:

All three models showed the general trend of relative fishing mortality (F/FMSY) increasing through the 1990's to a peak in 1998-1999 (Figure 2). From that peak, fishing mortality declined steadily. Current (2007) relative fishing mortality is at approximately the same level as relative fishing mortality in 1991-1993.

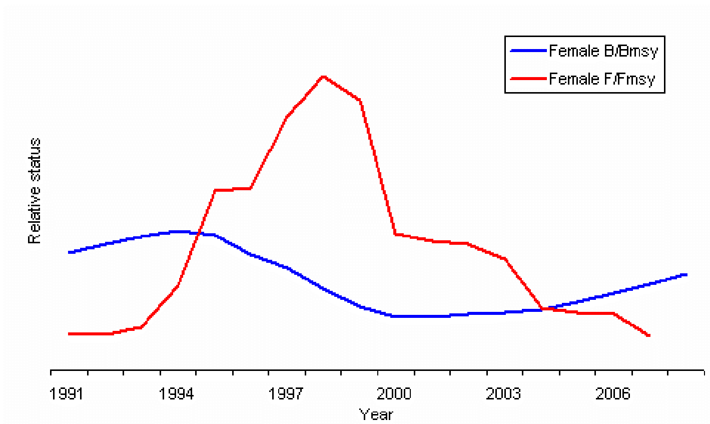
According to production model runs, relative biomass (B/BMSY) began declining in 1994-1995 and continued declining until 2000-2001 (Figure 2). Since 2001, biomass has been increasing steadily, and current (2008) relative biomass is at approximately the same level as relative biomass in 1996-1997.

Figure 2. Relative biomass (B/BMSY) and relative fishing mortality (F/FMSY) for Delaware Bay horseshoe crabs from 1991-2008, as estimated by surplus production models for (a) both sexes combined, (b) adult females only, and (c) adult males only.

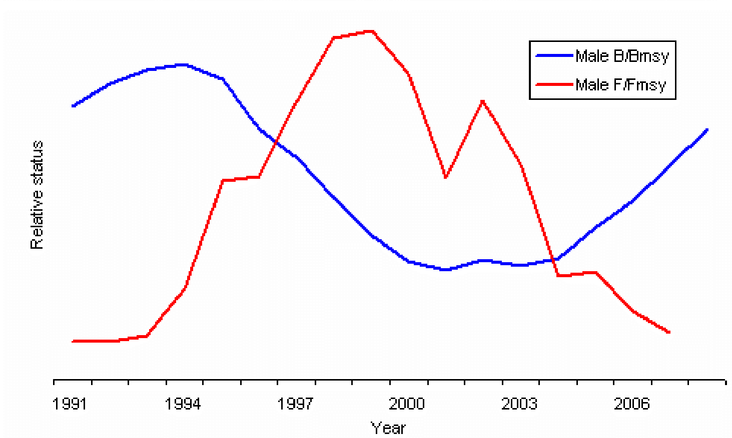
a.)



b.)



c.)



III. Comparison of female size distribution from 1980s to early 2000s

A prediction based on the hypothesis that horseshoe crab populations has been dramatically over-fished during the past 10 to 20 years is that the size distribution of females will shift to smaller sized individuals and that large females will be removed from the populations. To evaluate this prediction, we compared size (prosomal width) distributions from data collected in 1980s (Botton and Loveland 1992) to data collected in 2003-2005 (Smith et al. in review). These data are presented in Table 3.

Table 3. Sizes (prosomal width) of female and male horseshoe crabs collected from Delaware Bay in mid 1980s (Botton and Loveland 1992) and early 2000s (Smith et al. in review).

	1986-1987				2003-2005			
	Mean (mm)	SD	Min/Max	n	Mean (mm)	SD	Min/Max	n
Females	258	14	208/316	216	266	19	125/385	9749
Males	201	14	154/256	447	208	16	90/340	26525

Size distributions of horseshoe crabs in Delaware Bay have not changed from the mid 1980s to the present. Of particular note, the largest females in the mid 1980s are not larger than the largest females in the current population.

Acknowledgements: Members of the HSC SAS are Jeff Brust, Michelle Davis, Scott Olszewski, Dave Smith (chair), John Sweka, and Rich Wong. Updated fishery-independent survey data were provided by Stew Michels (DE DNREC), Dave Hata (VT), John Sweka (USFWS), Bill Kramer (NMFS), and Jeff Brust (NJ DFW). Mark Botton provided size data from the 1980s. Michelle Davis conducted the surplus production modeling. Dave Smith conducted the meta-analyses on trends.

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