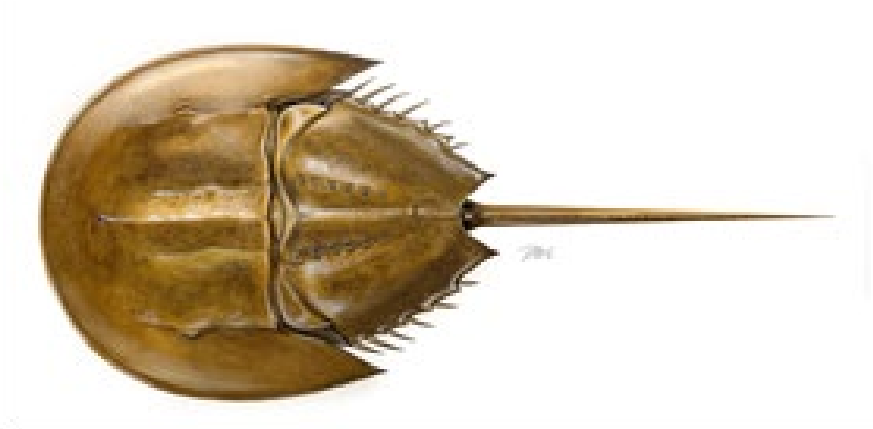
2019 Horseshoe Crab Benchmark Stock Assessment



Management Board Meeting

May 1, 2019

Stock Assessment Subcommittee

- John A. Sweka (Chair) – US FWS
- Natalie Ameral – RI DEM
- Kristen Anstead – ASMFC
- Linda Barry – NJ DFW
- Jeff Dobbs – NC DMF
- Michael Kendrick – SC DNR
- Mike Schmidtke – ASMFC
- David R. Smith – USGS
- Rachel Sysak – NYS DEC
- Rich Wong – DE DFW

- HSC Technical Committee, ARM Committee, DB Ecosystem TC, Advisory Panel, Management Board

Assessment History

Previous Assessments

- 2009 Benchmark
  - A formal set of reference points not adopted by HSC Board
  - Increased abundance in SE and DB regions
  - Declining abundance in NY and NE regions

Regional Trends in Horseshoe Crab Abundance		
Region	**Time series duration**	**Conclusion about population change**
New England	1978-2008	Declined
New York	1987-2008	Declined
Delaware Bay	1988-2008	Increased
Southeast	1993-2009	Increased

- 2013 Update
  - NE, NY declining abundance
  - Positive trends in SE, some of DB
  - Need for biomedical inclusion, regional

Current Efforts

- This Benchmark (2019)
  - Includes biomedical, discard estimates, bait landings
  - More modelling approaches
  - Regional assessment for DB using CMSA

Addenda I-VI

- **FMP established in 1998**
- **I (2000):** State-by-state quotas; recommended formation of the Shuster Reserve
- **II (2001):** Quota transfers
- **III (2004):** Reduced DE Bay harvest quotas; seasonal bait harvest closures in New Jersey, Delaware, and Maryland; revised monitoring components
- **IV (2006):** Further limited NJ & DE bait harvest restrictions (100,000 males only); delayed harvest in Maryland and Virginia
- **V (2008):** Extended Add IV
- **VI (2010):** Extended Add IV; no NJ or DE bait harvest Jan 1-June 7, males only after June 7; VA harvest east of COLREGS line must be <=40% of quota and must have >=2:1 M:F ratio

Addendum VII – ARM Framework

- Approved in 2012, first implementation in 2013
- Adaptive Resource Management model run annually using DE Bay horseshoe crab and red knot input data
- Model results recommend 1 of 5 harvest packages for management of DE Bay-origin crabs
  - Packages range from full moratorium to 630,000 crabs at 2:1 M:F ratio (420,000 males; 210,000 females)
- Since 2013 FY, recommended and implemented harvest quota has been 500,000 male-only crabs

Current Quotas

Jurisdiction	ASMFC Quota 2017	State Quota 2017	Jurisdiction	ASMFC Quota 2017	State Quota 2017
MA	330,377	165,000	PRFC	0	-
RI	26,053	8,398	VA**	172,828	172,828
CT	48,689	48,689	NC***	24,036	25,236
NY	366,272	150,000	SC	0	0
NJ*	162,136	0	GA***	29,312	28,112
DE*	162,136	162,136	FL	9,455	9,455
MD*	255,980	255,980	TOTAL	1,587,274	1,028,280

***Male-only harvest**

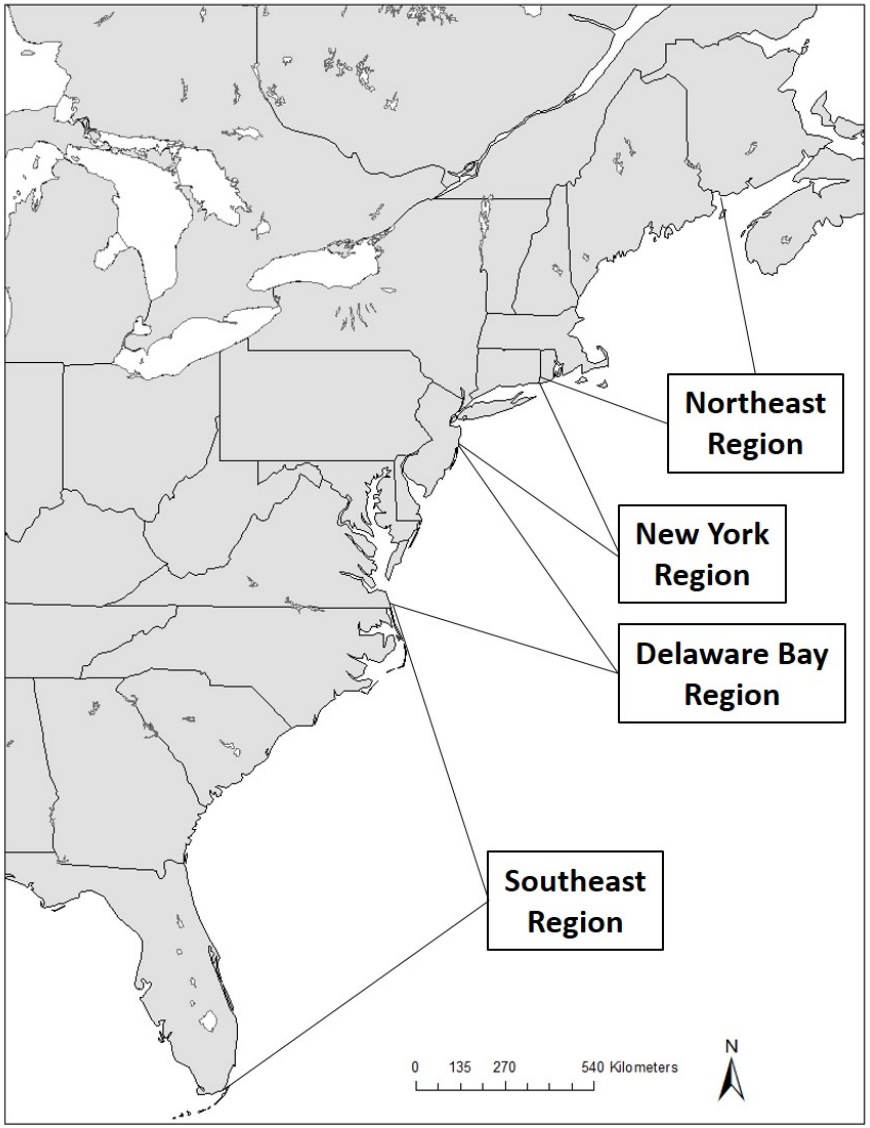
****Virginia harvest east of the COLREGS line is limited to 81,331 male-only crabs under the ARM harvest package #3.**

*****A quota transfer of 1,200 crabs from Georgia to North Carolina was approved in March 2018 to cover their quota overage of 1,125 horseshoe crabs in 2017.**

Biomedical

- No FMP limits on harvest
  - Some state-specific daily, annual, or seasonal restrictions
- Monitoring Requirements (Add III) annually reported to ASMFC in state compliance reports
  - Monthly and Annual Harvest
  - % observed mortality up to the point of release
  - Harvest method
  - Sex ratio
  - Disposition of bled crabs and condition of holding environment of bled crabs prior to release

Regional Stock Assessment



Tagging Data Analysis

Recapture % relative to total recaptures for each region of release

		Recapture Region								
Release region	**Released**	**Ches Bay**	**Coast DE-VA**	**Coast NY-NJ**	**Del Bay**	**Gulf**	**NC**	**Northeast**	**Southeast**	**Unk**
Ches Bay	840	93.75	5.36	0.89	0	0	0	0	0	0
Coast DE-VA	96,095	0.2	65.86	1.35	31.44	0	0.1	0.94	0.06	0.06
Coast NY-NJ	27,765	0	0.58	93.28	1.43	0.03	0.03	4.61	0.03	0
Del Bay	78,841	0.03	3.41	1.96	94.25	0.01	0.03	0.18	0.02	0.11
Gulf	1,853	0	1.37	0	0	97.26	0	0	1.37	0
NC	280	12.5	12.5	0	12.5	0	50	12.5	0	0
Northeast	98,274	0.01	0.08	4.78	0.15	0	0	94.92	0.01	0.03
Southeast	13,305	0	0.29	0.34	0.52	0.17	0	0.34	98.34	0
Unknown	17	0	0	47.06	0	0	0	47.06	0	5.88

Tagging Data Analysis

Cormack-Jolly-Seber estimates of annual survival

Region	$\hat{\varphi}$	SE	LCL	UCL
Coastal DE-VA	0.71	0.0118	0.6874	0.7335
Coastal NY-NJ	0.62	0.0162	0.5884	0.6516
Delaware Bay	0.76	0.0137	0.7275	0.7813
Northeast	0.67	0.0058	0.6587	0.6813
Southeast	0.63	0.0350	0.5545	0.6907

Coastwide Bait Landings

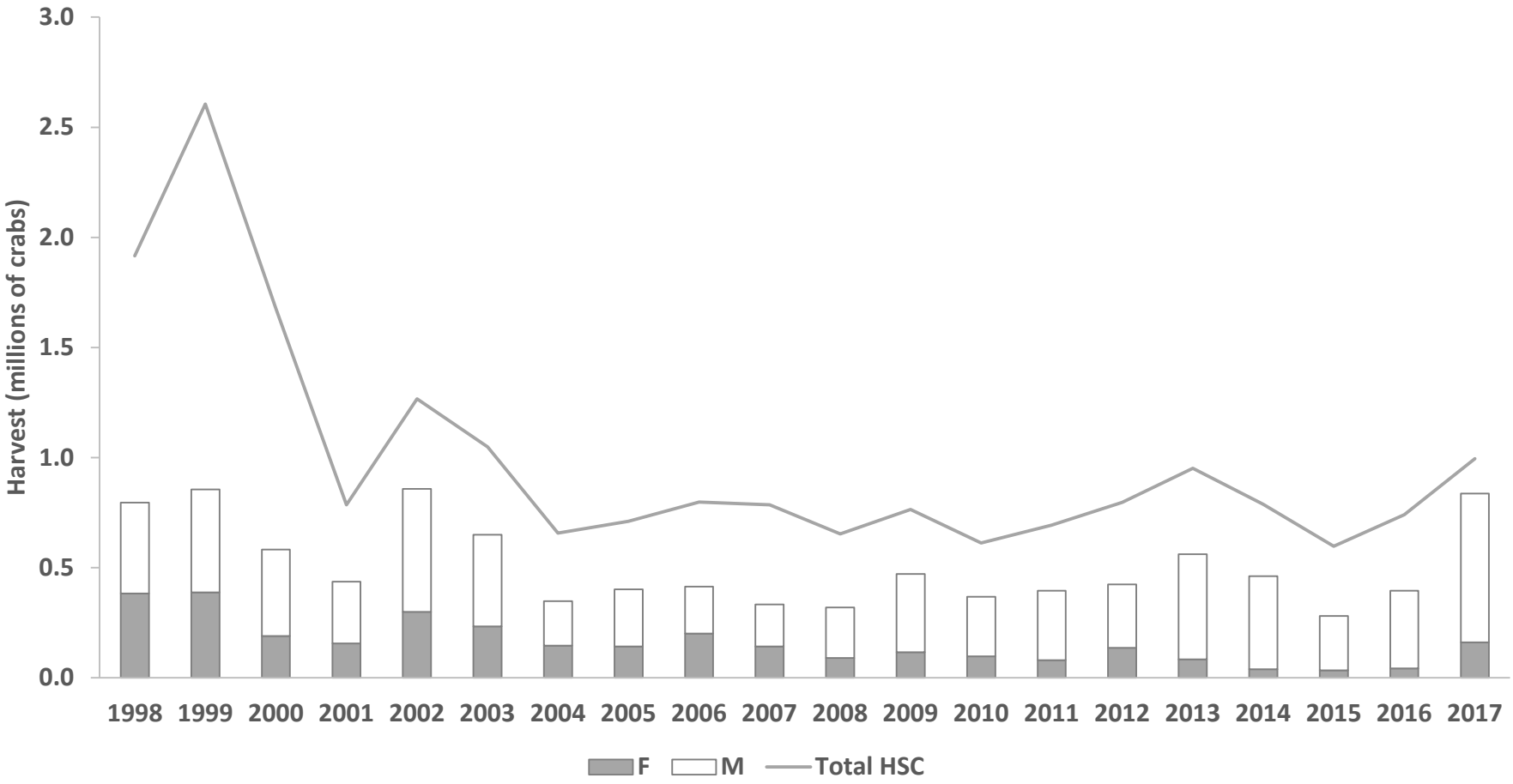


Figure 1. Coastwide horseshoe crab bait landings, 1998-2017, in numbers and by sex. Not every state along the Atlantic coast provides comprehensive sex data and therefore some are unclassified. Landings from 1998-2016 were validated by ACCSP; 2017 landings came from the 2018 FMP Review and state compliance reports.

Bait Landings by Region

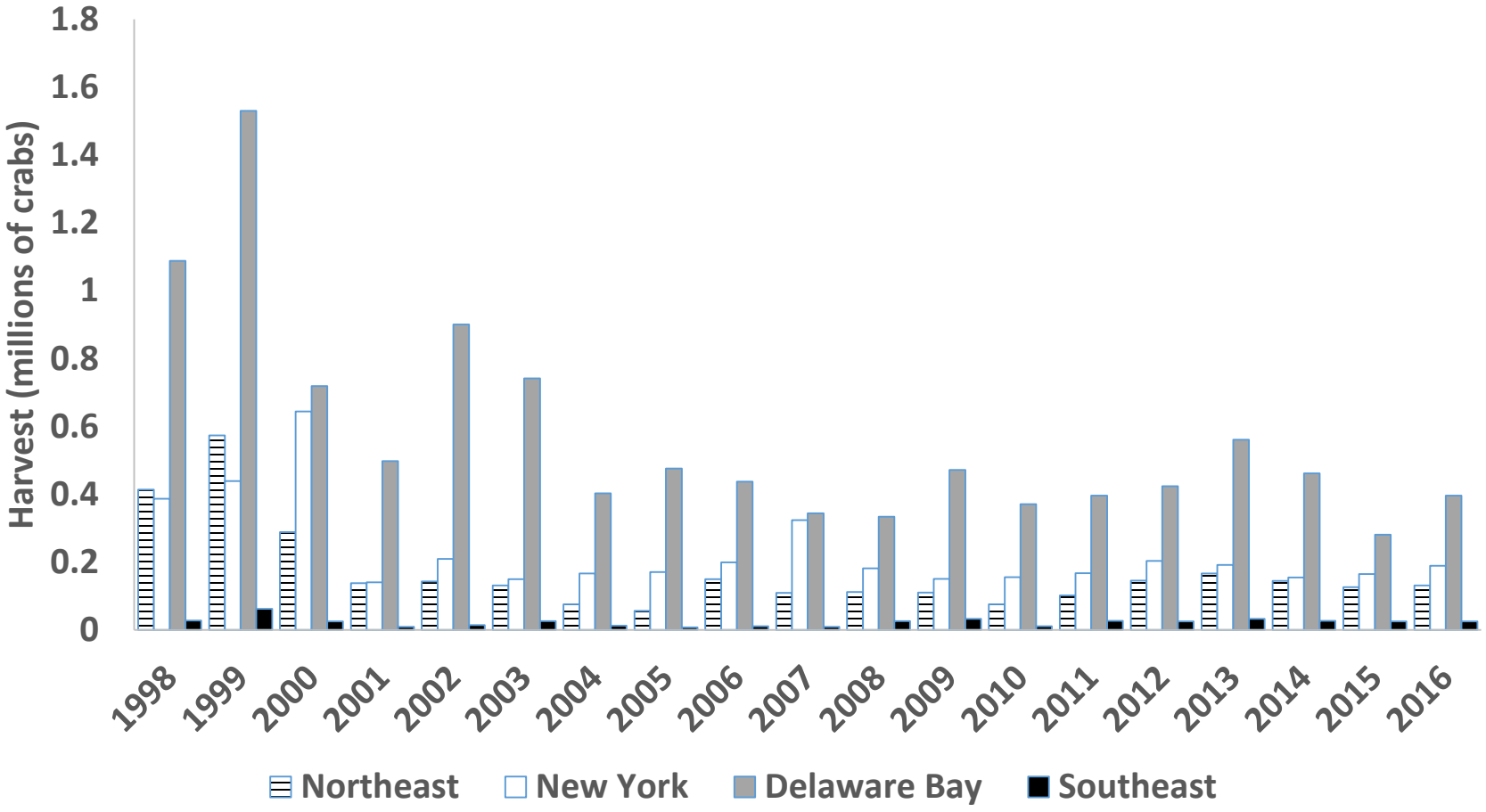


Figure 3. Horseshoe crab bait harvest by region, 1998-2016. The four regions are the Northeast (Maine, Massachusetts, Rhode Island), New York (Connecticut, New York), Delaware Bay (New Jersey, Delaware, Maryland, Virginia), and Southeast (North Carolina, South Carolina, Georgia, Florida).

Delaware Bay Bait Landings

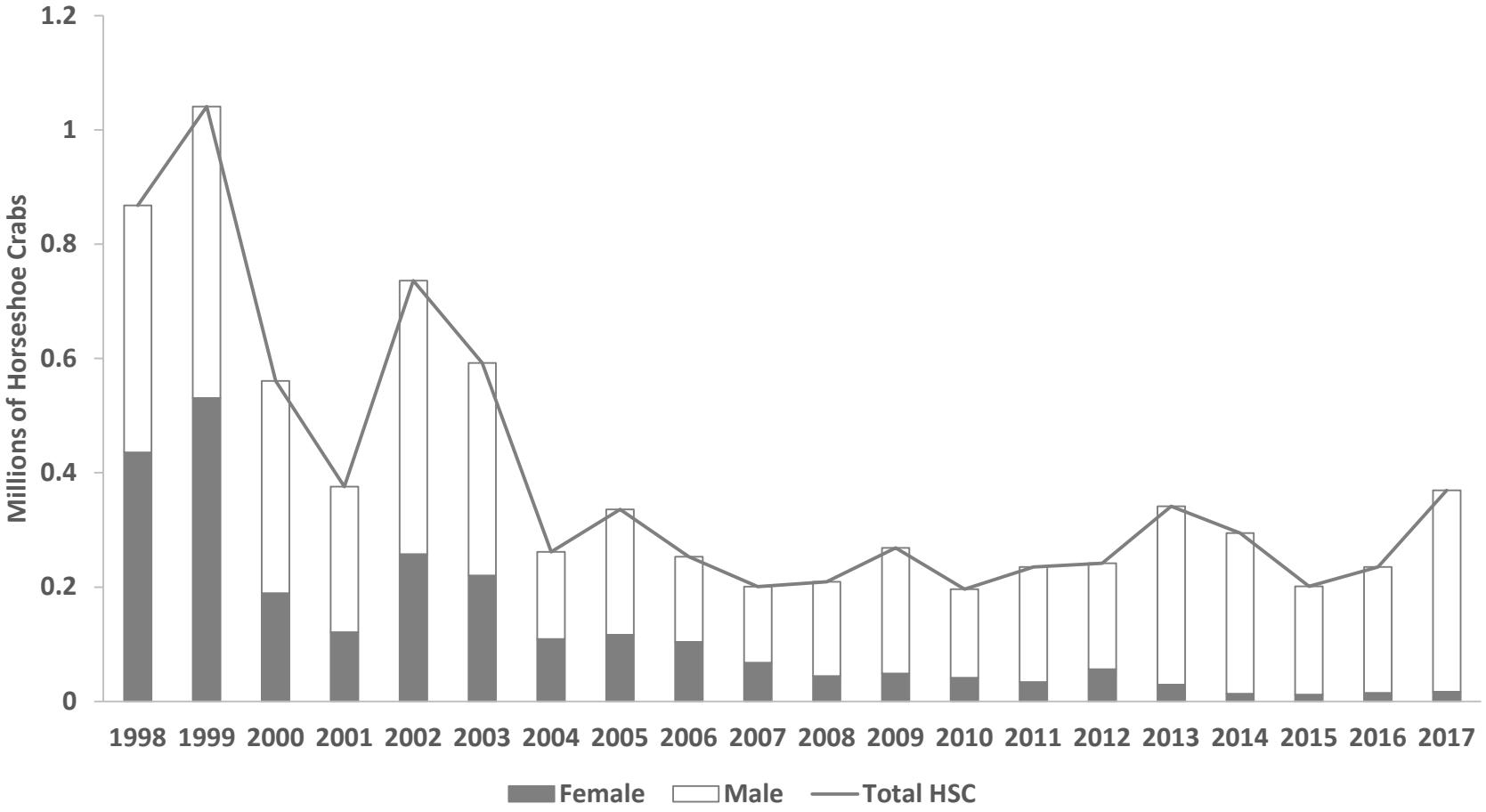


Figure 4. Horseshoe crab bait landings of Delaware Bay origin, 1998-2017, by sex to support the catch multiple survey model. All landings were validated through ACCSP.
Note: NJ & DE are considered to be 100% DB origin (i.e., has spawned at least once in Delaware Bay) whereas 51% of MD harvest and 35% of VA's are believed to be DB origin based on genetic data and analysis (ASMFC 2012)

Biomedical Mortality

Author(s)	Year	Mortality Rate	Sample Size
Rudloe	1983	0.10	4822
		0.03	40
Thompson	1998	0.15	20
		0.00	594
SCDNR	1999	0.07	132
Wenner and Thompson	2000	0.08	75
Kurz and James-Pirrri	2002	0.20	10
Walls and Berkson	2003	0.00	10
		0.30	10
		0.00	30
		0.00	30
		0.20	30
		0.00	30
		0.07	30
		0.17	30
Hurton and Berkson	2005	0.00	40
		0.00	40
		0.00	40
		0.00	40
		0.03	39
		0.05	39
		0.10	39
		0.15	39

Author(s)	Year	Mortality Rate	Sample Size
Leschen and Correia	2010	0.15	15
		0.23	19
		0.40	13
		0.07	14
		0.31	14
		0.20	14
		0.20	17
		0.29	21
		0.49	14
		0.10	9
		0.40	15
		0.27	18
DeLancey and Floyd	2012	0.20	50
Anderson et al.	2013	0.00	7
		0.14	7
		0.14	7
		0.43	7
Linesh	2017	0.11	48
Owings	2017	0.00	8
		0.06	17
		0.14	8
		0.13	8
		0.44	9
		0.75	8

Bootstrap simulations

Mean: 15%
95% CL: 4 – 30%

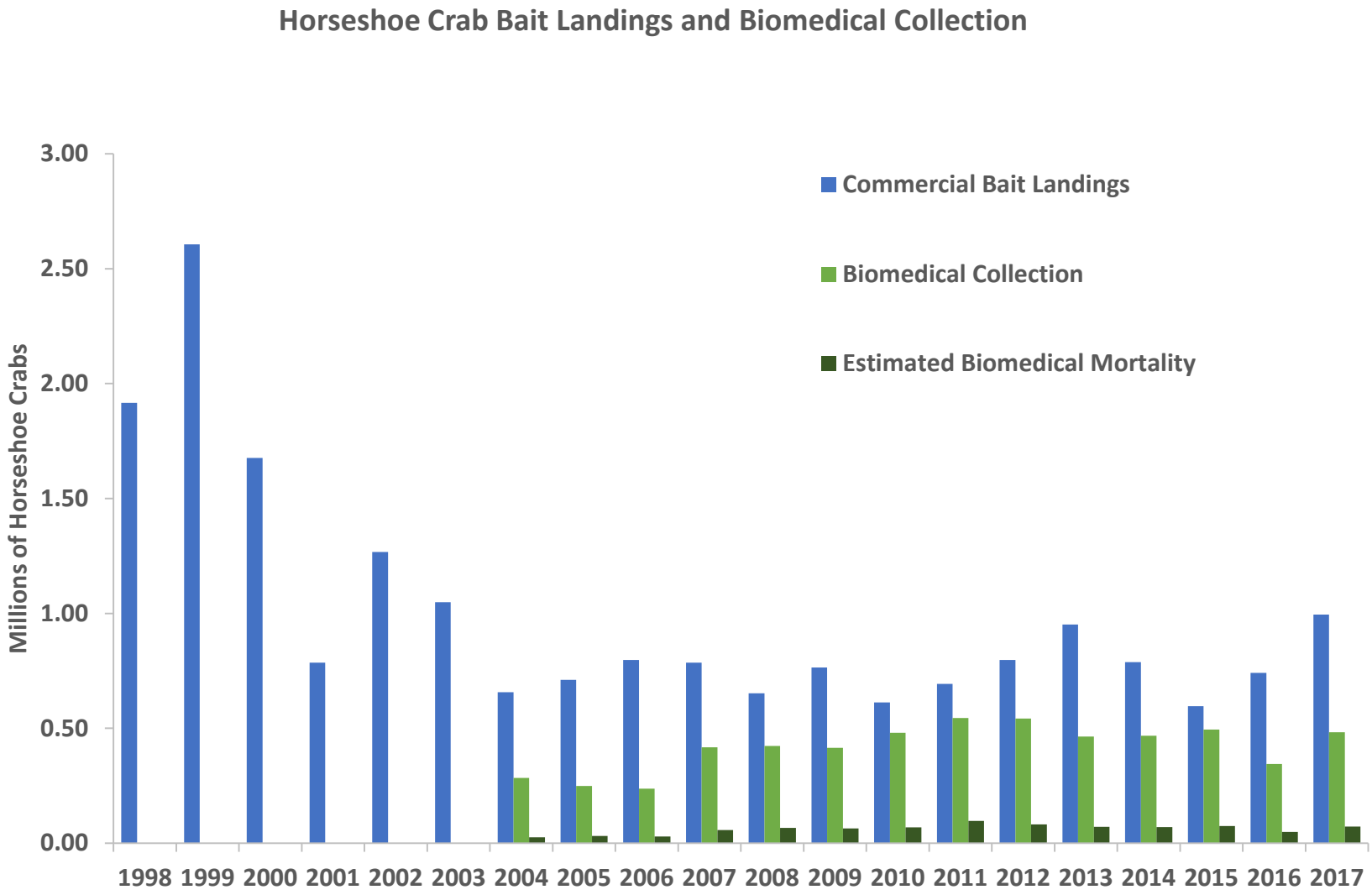
Biomedical Mortality

CJS tagging model to determine effect of bleeding on long-term survival

		Not bled				Bled			
Sex	**Years**	$\hat{\varphi}$	**SE**	**LCL**	**UCL**	$\hat{\varphi}$	**SE**	**LCL**	**UCL**
F	1999-2001	0.5576	0.1386	0.2953	0.7914	0.7747	0.0667	0.6191	0.8791
F	2002-2004	0.6263	0.1078	0.4046	0.8051	0.8212	0.0527	0.6945	0.9027
F	2005-2007	1.000*	0.0001	0.0000	1.0000	0.5068	0.0227	0.4623	0.5512
F	2008-2010	0.6483	0.0488	0.5480	0.7371	0.7472	0.0313	0.6811	0.8036
F	2011-2013	0.7036	0.0770	0.5352	0.8303	0.8434	0.0547	0.7050	0.9238
F	2014-2017	0.7022	0.3896	0.0577	0.9891	0.8126	0.1769	0.3079	0.9769
M	1999-2001	0.7068	0.0729	0.5474	0.8276	0.9161	0.0408	0.7940	0.9687
M	2002-2004	0.7243	0.0870	0.5278	0.8606	0.7215	0.0280	0.6636	0.7729
M	2005-2007	0.9010	0.0752	0.6357	0.9793	0.7472	0.0210	0.7039	0.7860
M	2008-2010	0.6365	0.0268	0.5825	0.6873	0.6731	0.0208	0.6311	0.7125
M	2011-2013	0.6804	0.0438	0.5892	0.7596	0.8624	0.0358	0.7762	0.9189
M	2014-2017	0.7813	0.1789	0.3145	0.9653	0.6660	0.0790	0.4986	0.7999

*Survival for unbled females during 2005-2007 was not estimable.

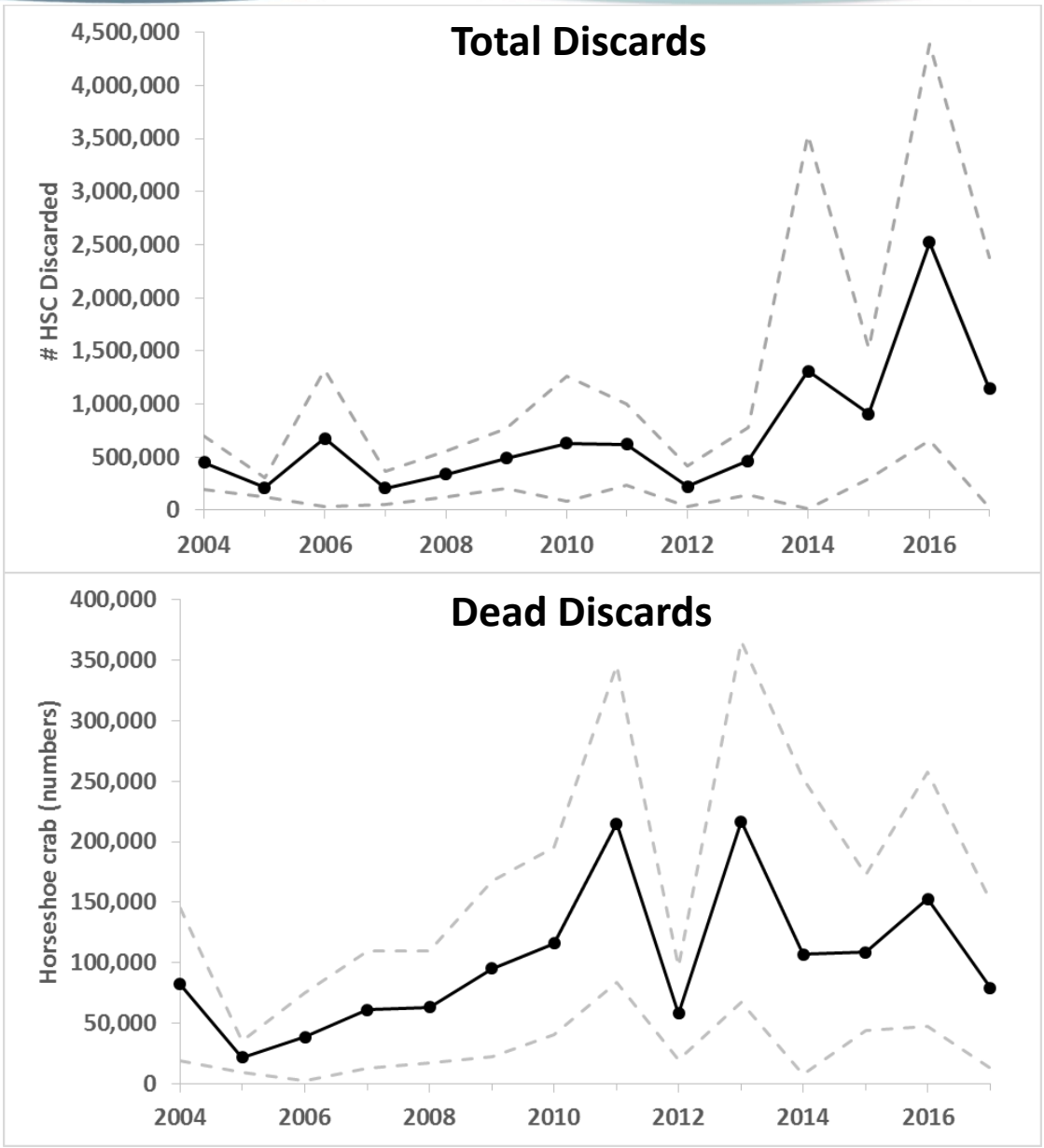
Biomedical Mortality



Discards

- Horseshoe crabs are taken as bycatch in a number of fisheries, but commercial discards have not been quantified.
- Northeast Fisheries Observer Program run by NEFSC collects data on harvested & discarded catch, gear, effort, species L&W
- Maine to North Carolina
- Began in 1989, HSC data beginning in 2004
- HSC landings minimal from several states, focused on DB for CMSA modeling

Discards


Total Discards
HSC Discarded
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
2004
2006
2008
2010
2012
2014
2016
Dead Discards
Horseshoe crab (numbers)
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
2004
2006
2008
2010
2012
2014
2016

Fisheries-Independent Data

SAS Inclusion Criteria

1. Time series: Ideally, the time series should be 20 years long to account for the lifespan of horseshoe crab. Recognizing that would eliminate many surveys, the SAS recommended at least 10 years of data be available in a survey.
2. Survey design: Surveys with statistical designs are preferred, such as surveys with random stratified sampling.
3. Gear: Surveys should operate with gear that is capable of catching horseshoe crabs and to which horseshoe crabs are available.
4. Temporal and spatial coverage: Only surveys that operate during a time and place where horseshoe crab are available for capture should be considered. Examining the precision or proportion of zero catches of horseshoe crabs in a survey can be tools for evaluating this.
5. Methodology: Survey methodology should be consistent throughout the time series or changes should be able to be accounted for in the standardization process.

Fisheries-Independent Data

Data Source	Survey	Accepted	Rejected	Reason(s) Rejected			
				Time series too short or broken	Rare occurance of HSC	Inconsistent methods, gear changes	Better survey available with similar coverage
ME DMR	ME-NH Trawl		X		X		
NH F&G	Habitat Monitoring Survey		X	X			
NH F&G	Spawning Survey	X					
MA DMF	Resource Assessment Trawl	X					
MA DMF	Spawning Beach Survey		X	X		X	
RI DEM	Coastal Trawl Survey (seasonal segment)		X				X
RI DEM	Coastal Trawl Survey (monthly segment)	X					
Sacred Heart Univ	Project limulus		X			X	
CT DEEP	Long Island Trawl Survey	X					
NYS DEC	Peconic Bay Small Mesh Trawl Survey	X					
NYS DEC	Western Long Island Beach Seine Survey	X					
NYS DEC	Horseshoe Crab Spawning and Tagging Survey		X			X	
NJ DFW	Ocean Trawl	X					
NJ DFW	Delaware Bay Trawl Survey		X				X
NJ DFW	Surf Clam Survey	X					
DE DFW	Adult Trawl Survey (30')	X					
DE DFW	Juvenile Trawl Survey (16')		X				X
MD DNR	Coastal Bays	X					
Virginia Tech	Virginia Tech Mid-Atl HSC Benthic Trawl	X					
NC DMF	North Carolina fisheries independent gillnet survey	X					
SC DNR	Crustacean Research and Monitoring large trawl survey	X					
SC DNR	SEAMAP- South Atlantic Coastal Trawl Survey	X					
SC DNR	Trammel Net Survey	X					
GA DNR	Ecological Monitoring Trawl Survey	X					
FL FWC	Fisheries- Independent Monitoring Program (FIM)		X	X	X		
NMFS	NEFSC Trawl		X		X		X
NEAMAP	NEAMAP	X					

Fisheries-Independent Data

- Pursued several approaches:
  - nominal, geometric mean, GLM standardization
  - By sex, stage (for CSA), season
- High proportion of zero tows in most surveys
- Decided to use delta distribution for the mean and variance for each year (Pennington 1983)
  - Also used in VT Trawl Survey Report
  - Use of the delta-distribution can lead to more efficient estimators of the mean and variance because zeros are treated separately
  - positive observations are drawn from a lognormal distribution
  - final estimates of abundance are obtained from the product of the proportion and mean for nonzero observations.

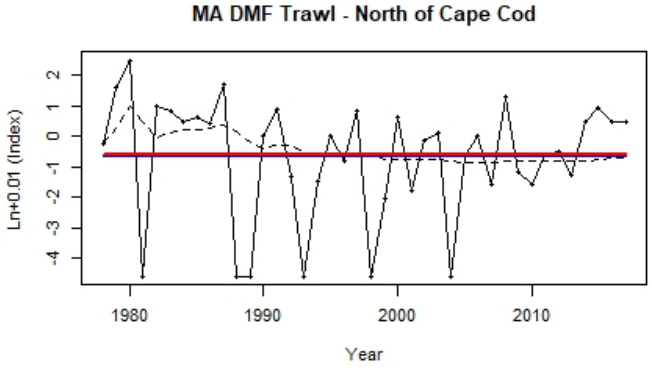
Analysis of Trends

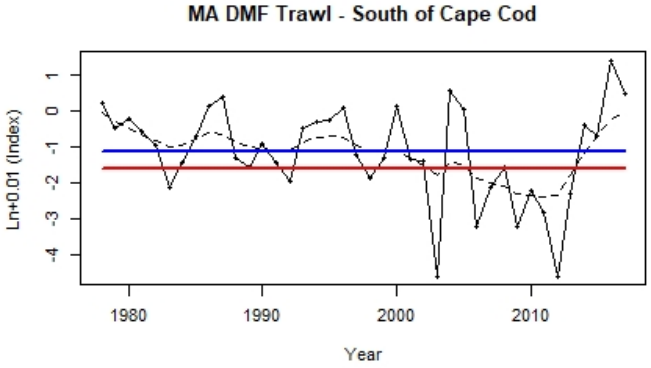
Two approaches:

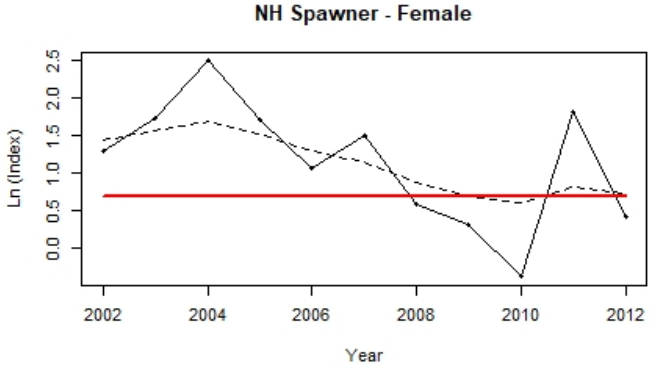
- **Conn (2010)**
  - Several abundance indices are combined into a composite index using hierarchical modeling
  - Assumes each index samples relative abundance but is subject to observation and process errors

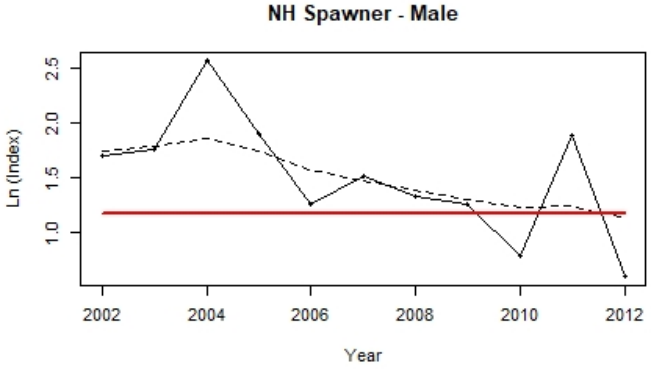
- **Auto Regressive Integrated Moving Average (ARIMA) models**
  - Derives fitted estimates of abundance over the entire time series
  - Minimizes measurement error
  - Estimates the probability of being less than some index-based reference point
    - Q_{25} of fitted index values
    - 1998 fitted index value

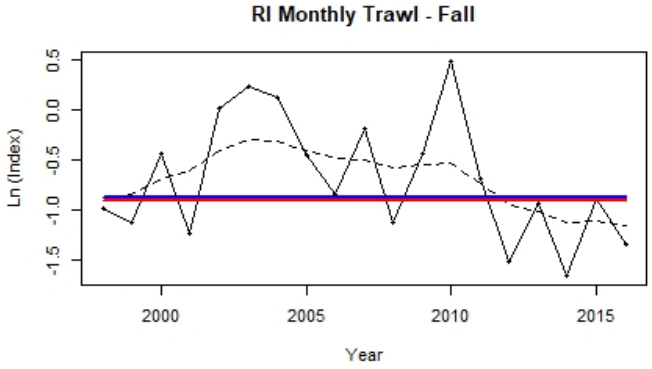
Northeast ARIMA





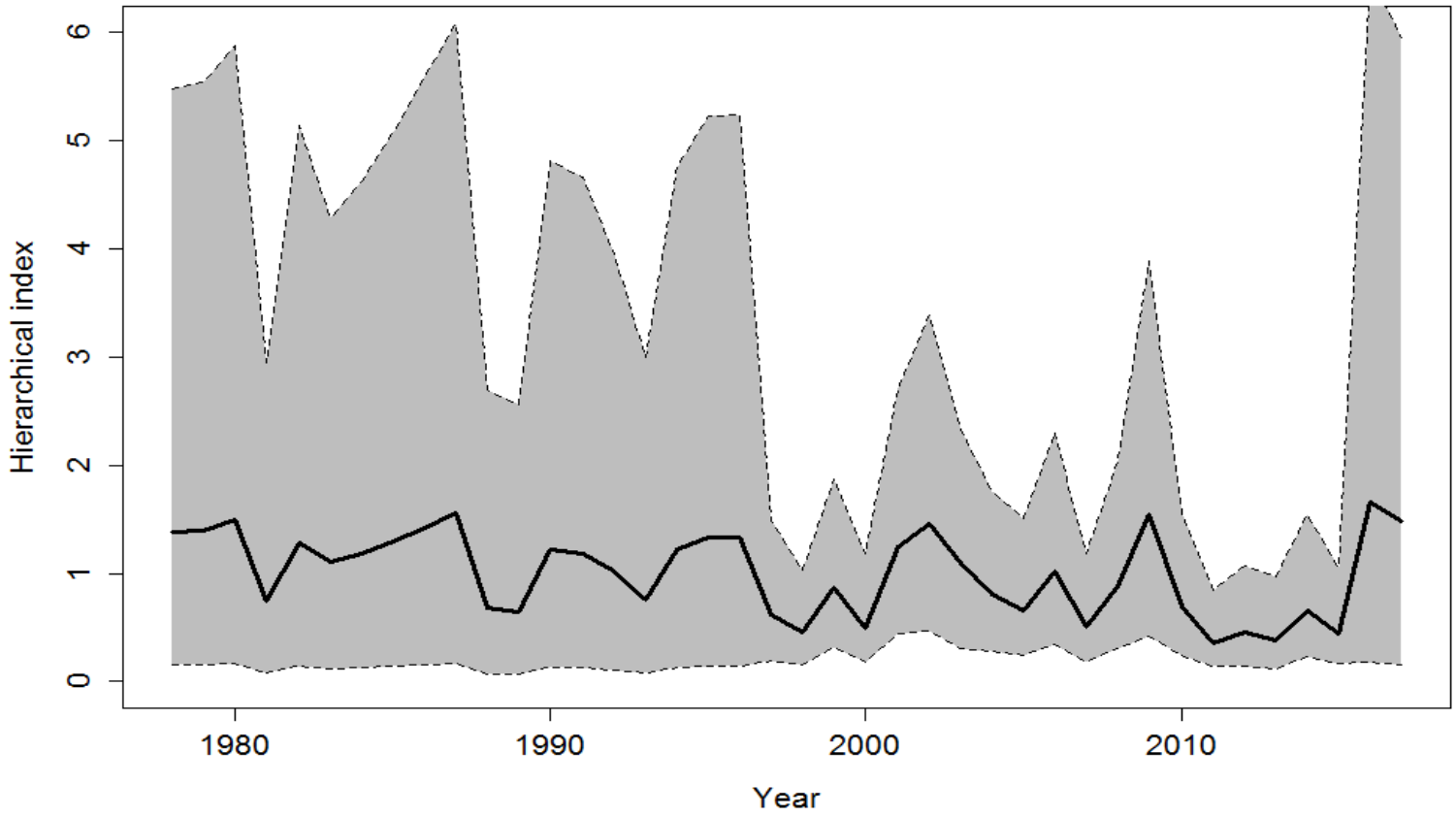




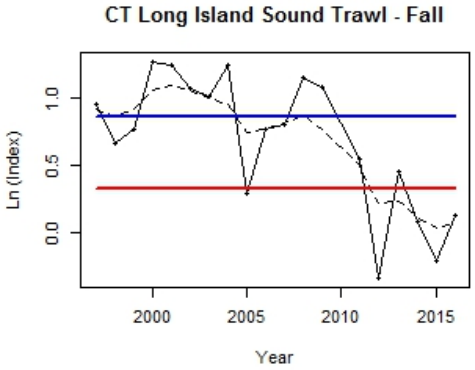


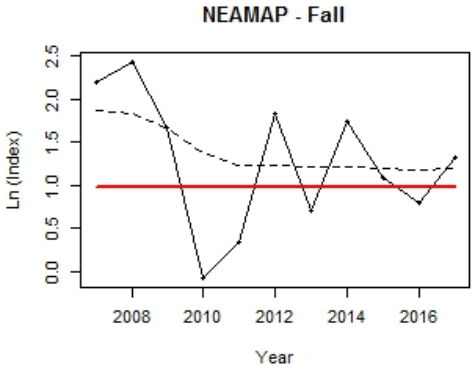
Northeast Conn Index

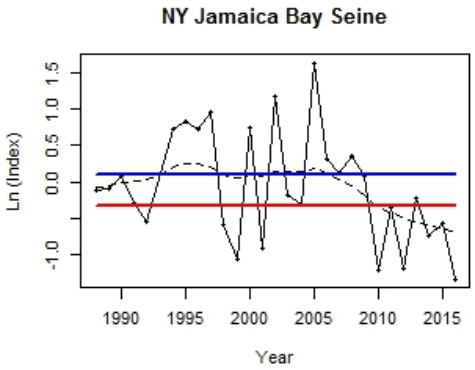
- Includes MA and RI Trawls (fall months)

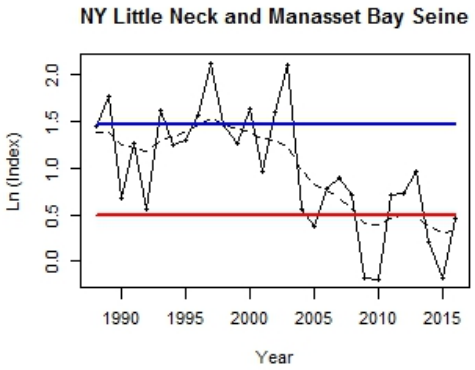


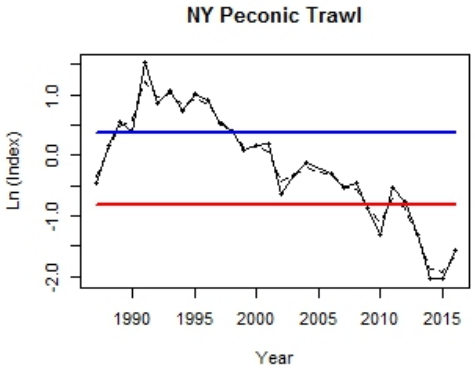
New York ARIMA





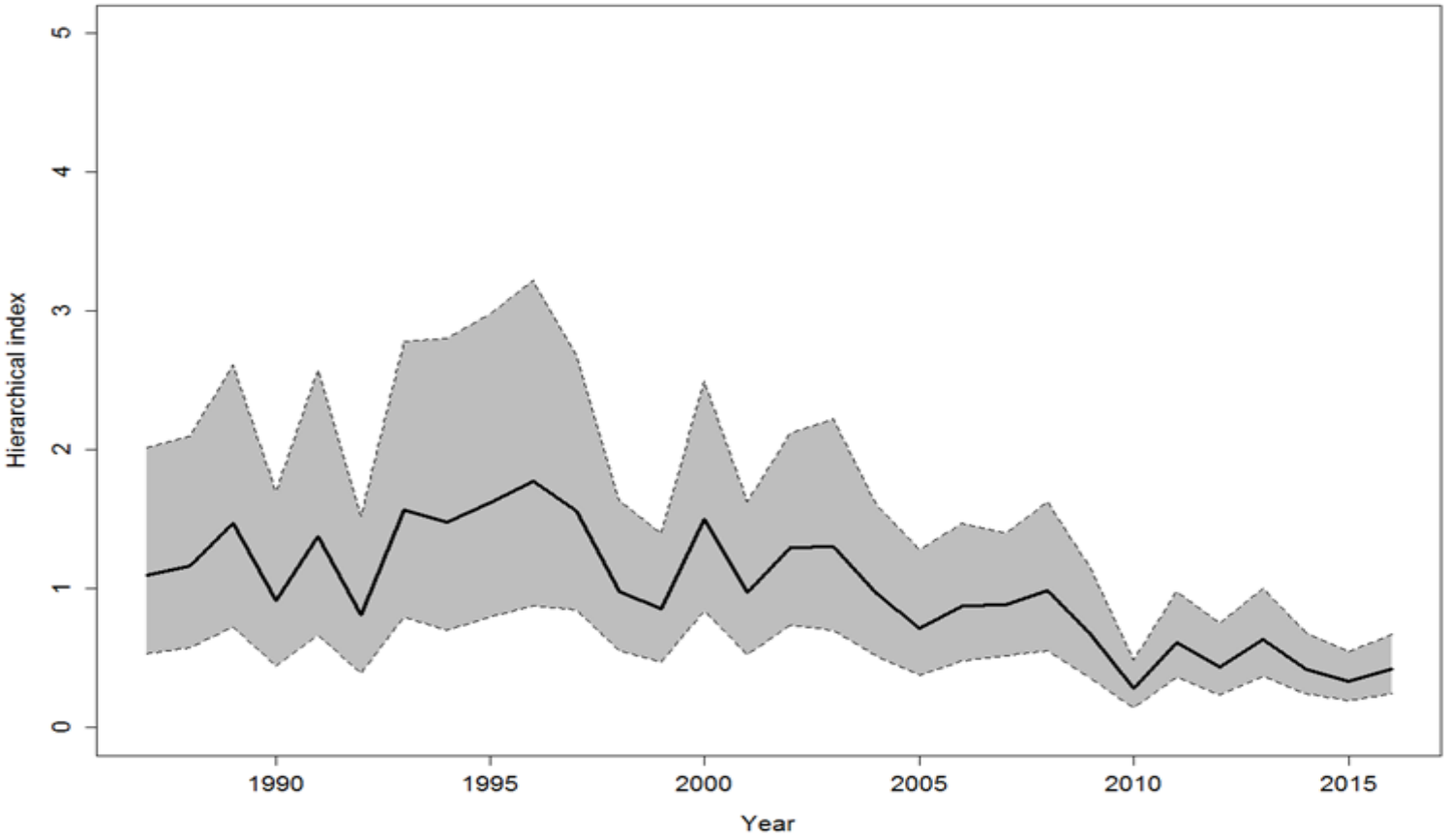




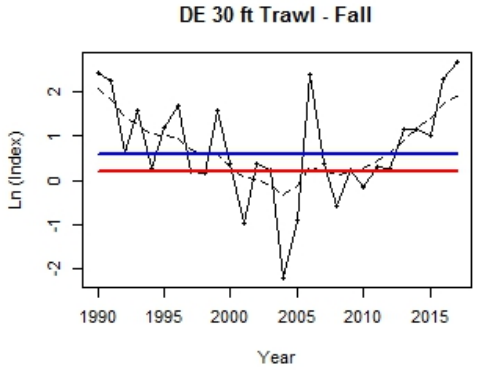


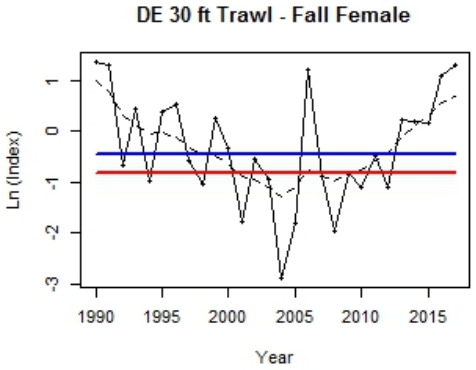
New York Conn Index

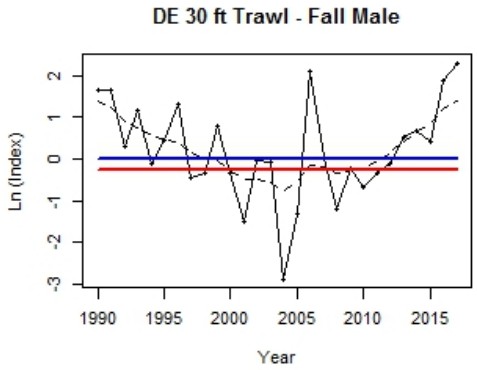
- Includes CT LISTS, NY Peconic Bays, NY Seine – Jamaica Bay, NY Seine – Manhasset & Little Neck, NEAMAP – NY

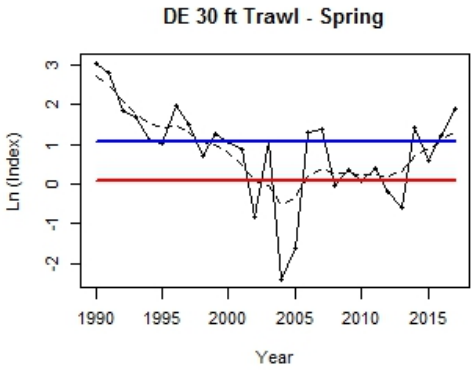


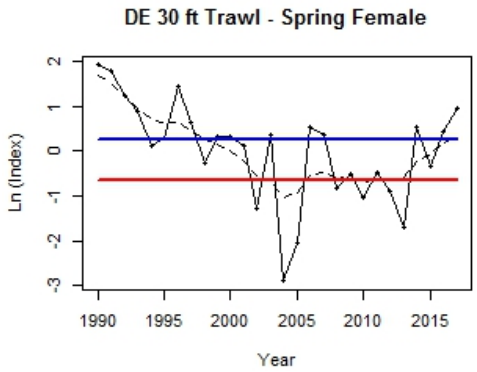
DE Bay ARIMA

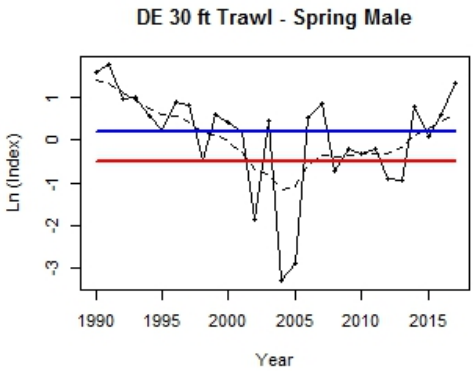

DE 30 ft Trawl - Fall
Ln (Index)
Year


DE 30 ft Trawl - Fall Female
Ln (Index)
Year

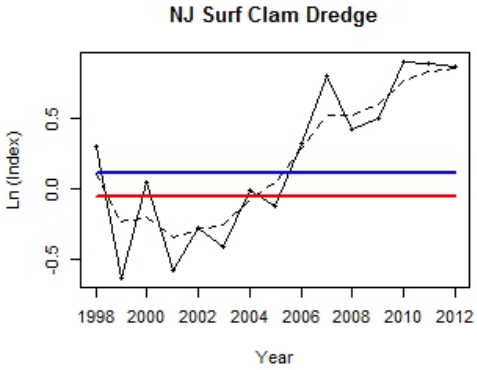

DE 30 ft Trawl - Fall Male
Ln (Index)
Year

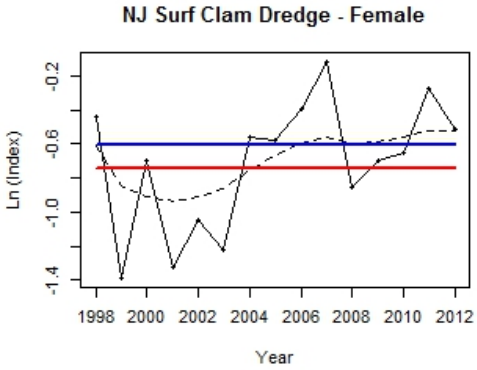

DE 30 ft Trawl - Spring
Ln (Index)
Year


DE 30 ft Trawl - Spring Female
Ln (Index)
Year


DE 30 ft Trawl - Spring Male
Ln (Index)
Year

DE Bay ARIMA


NJ Surf Clam Dredge
Ln (Index)
-0.5
0.0
0.5
1998 2000 2002 2004 2006 2008 2010 2012
Year


NJ Surf Clam Dredge - Female
Ln (Index)
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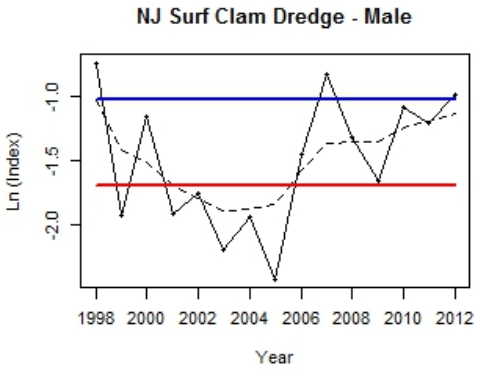
-1.0
-0.6
-0.2
1998 2000 2002 2004 2006 2008 2010 2012
Year


NJ Surf Clam Dredge - Male
Ln (Index)
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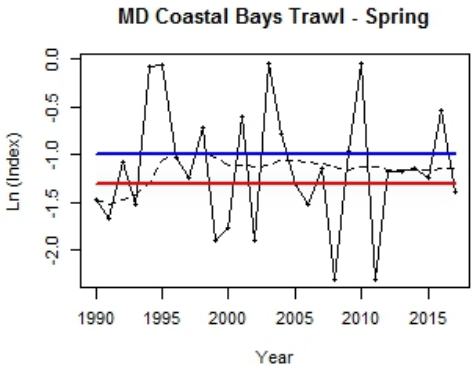
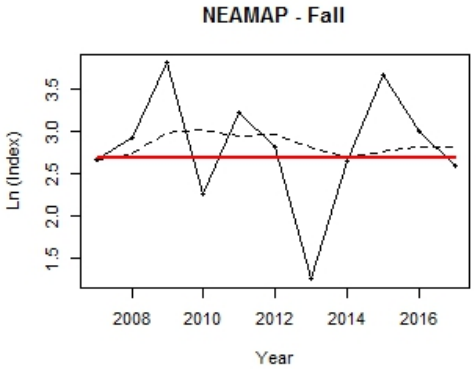
-1.5
-1.0
1998 2000 2002 2004 2006 2008 2010 2012
Year


MD Coastal Bays Trawl - Spring
Ln (Index)
-2.0
-1.5
-1.0
-0.5
0.0
1990 1995 2000 2005 2010 2015
Year


NEAMAP - Fall
Ln (Index)
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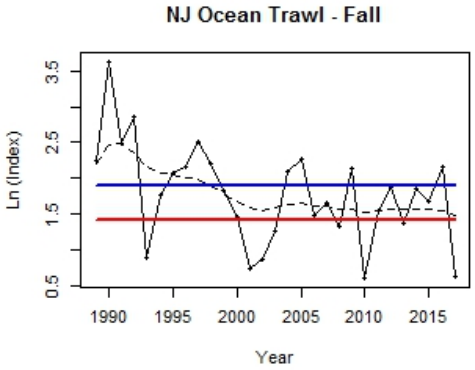
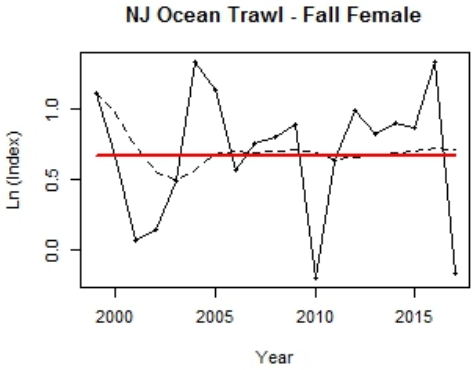
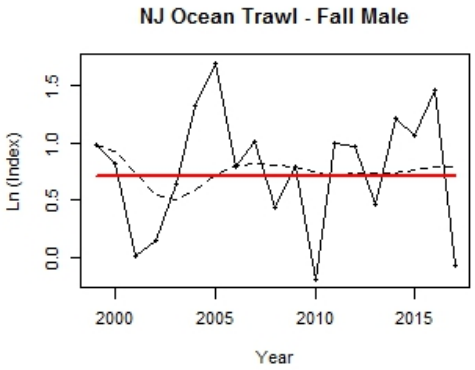
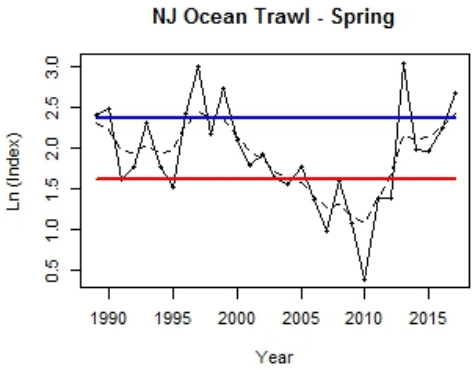
2.0
2.5
3.0
3.5
2008 2010 2012 2014 2016
Year

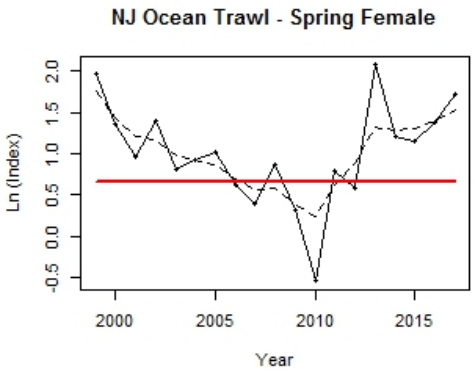
DE Bay ARIMA

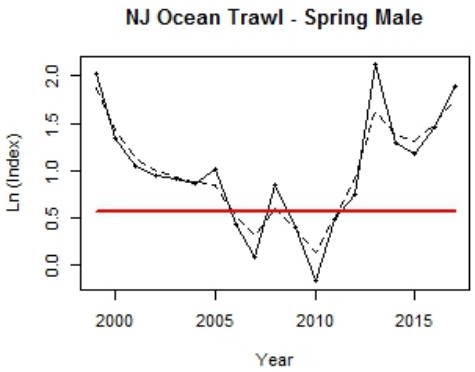

NJ Ocean Trawl - Fall
Ln (Index)
Year


NJ Ocean Trawl - Fall Female
Ln (Index)
Year

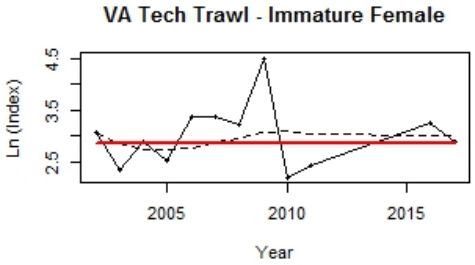

NJ Ocean Trawl - Fall Male
Ln (Index)
Year

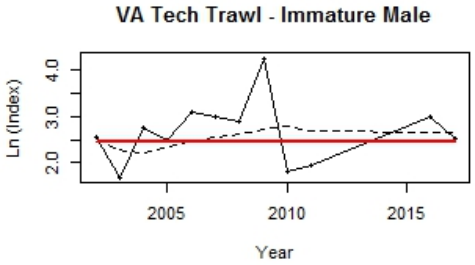

NJ Ocean Trawl - Spring
Ln (Index)
Year

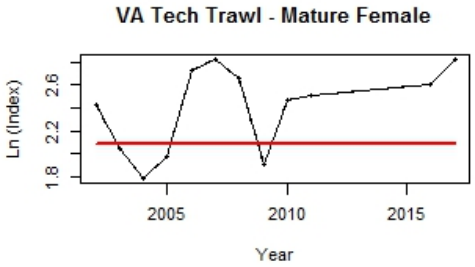

NJ Ocean Trawl - Spring Female
Ln (Index)
Year

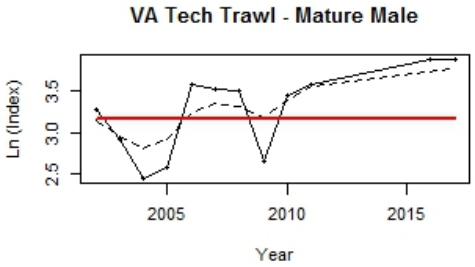

NJ Ocean Trawl - Spring Male
Ln (Index)
Year

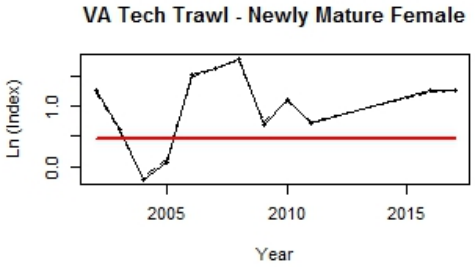
DE Bay ARIMA

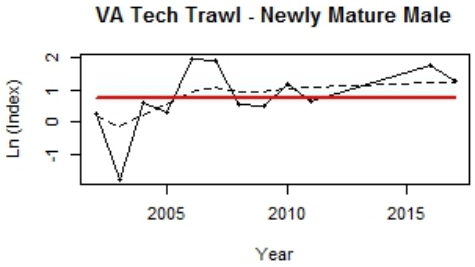

VA Tech Trawl - Immature Female
Ln (Index)
2.5
3.5
4.5
2005
2010
2015
Year

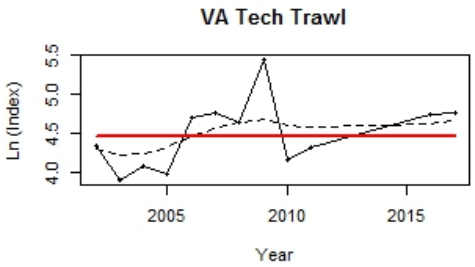

VA Tech Trawl - Immature Male
Ln (Index)
2.0
3.0
4.0
2005
2010
2015
Year


VA Tech Trawl - Mature Female
Ln (Index)
1.8
2.2
2.6
2005
2010
2015
Year


VA Tech Trawl - Mature Male
Ln (Index)
2.5
3.0
3.5
2005
2010
2015
Year

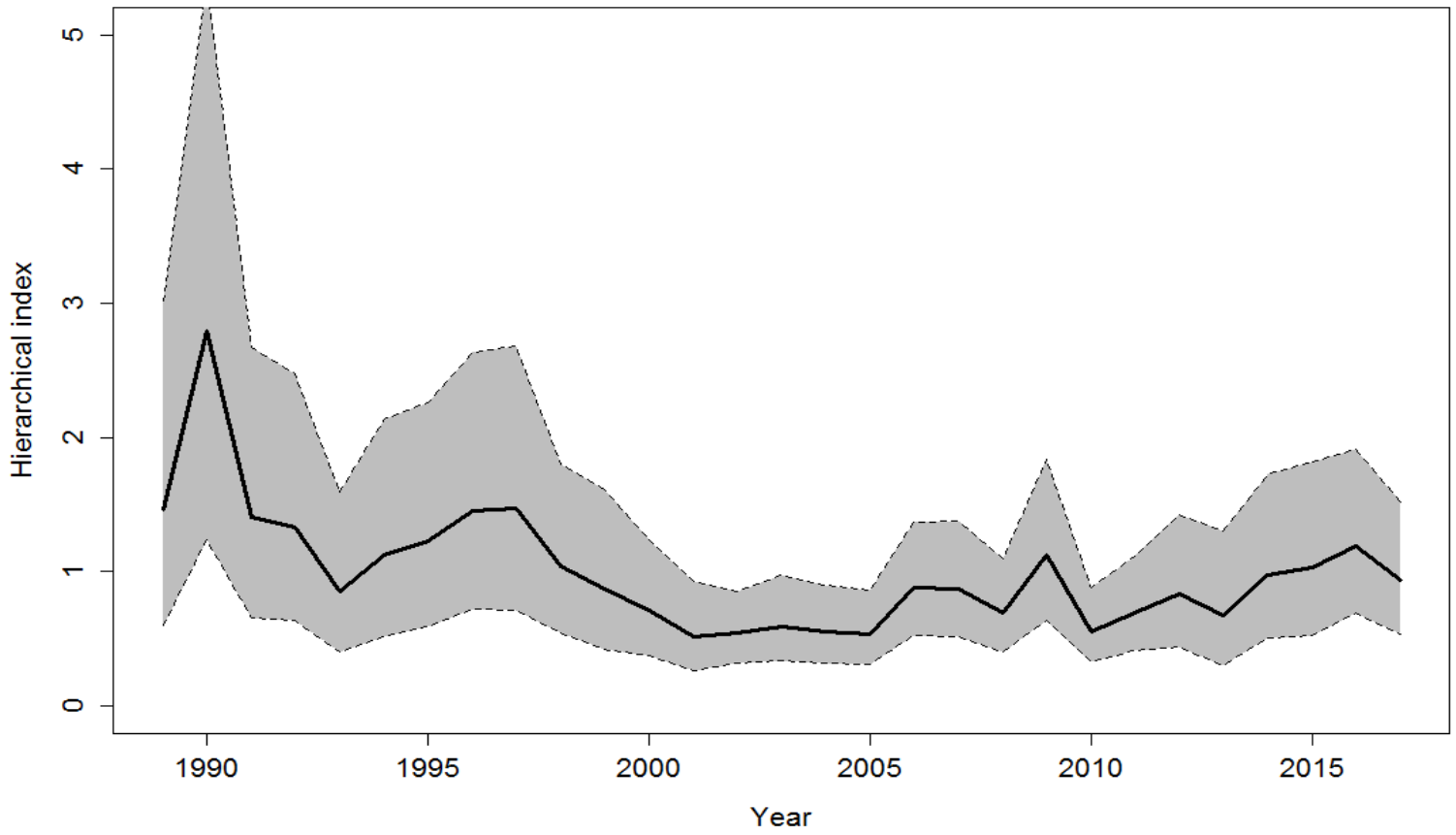

VA Tech Trawl - Newly Mature Female
Ln (Index)
0.0
1.0
2005
2010
2015
Year


VA Tech Trawl - Newly Mature Male
Ln (Index)
-1
0
1
2
2005
2010
2015
Year

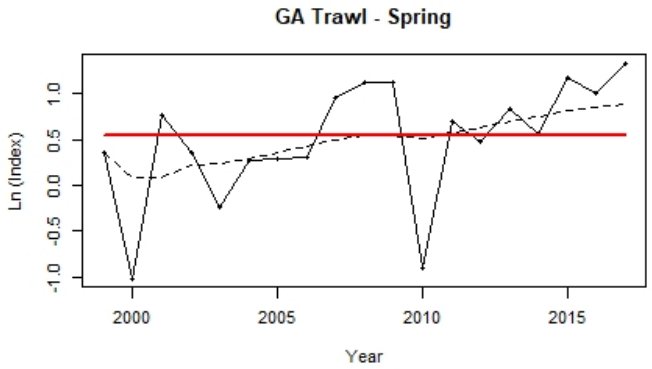

VA Tech Trawl
Ln (Index)
4.0
4.5
5.0
5.5
2005
2010
2015
Year

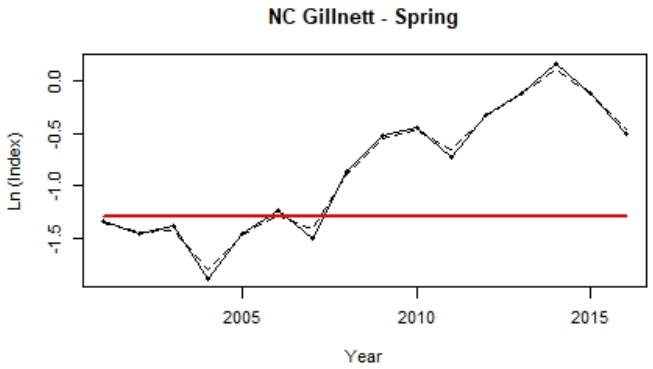
Delaware Bay Index

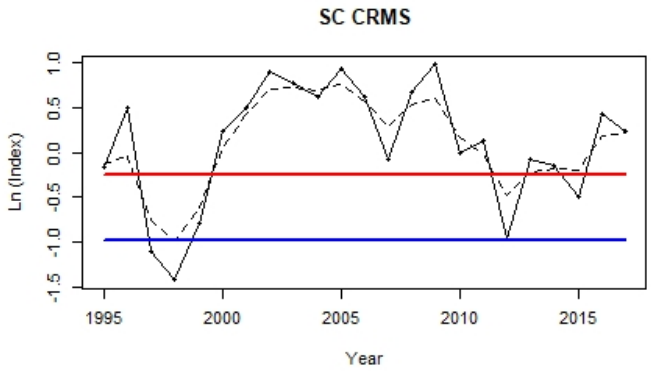
- Includes New Jersey OT, Delaware Adult Trawl, the NJ Surf Clam, NEAMAP (Delaware Bay strata only), VT Tech Trawl, and Maryland Coastal Bays surveys
- Also developed a male and female Conn index

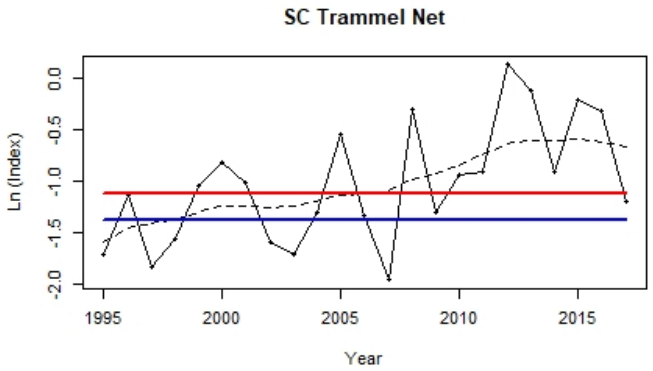


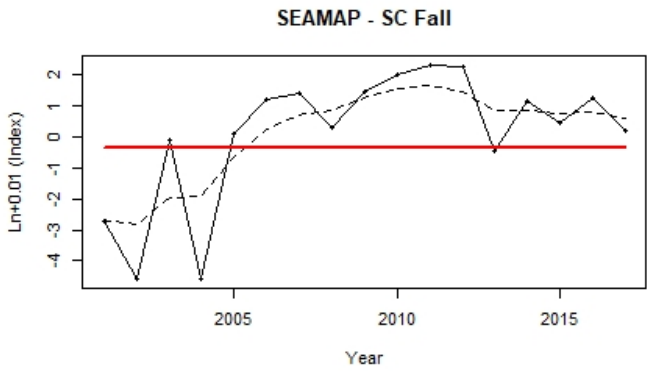
Southeast ARIMA

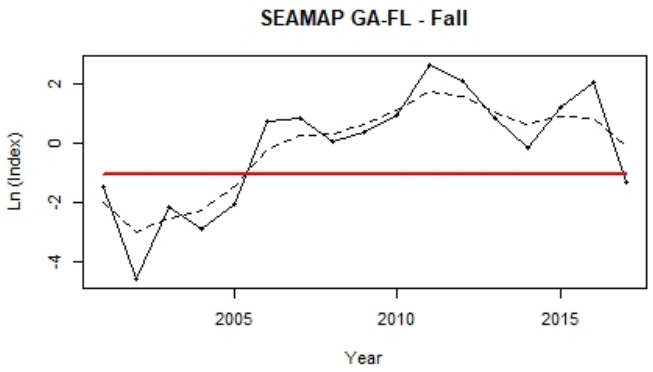






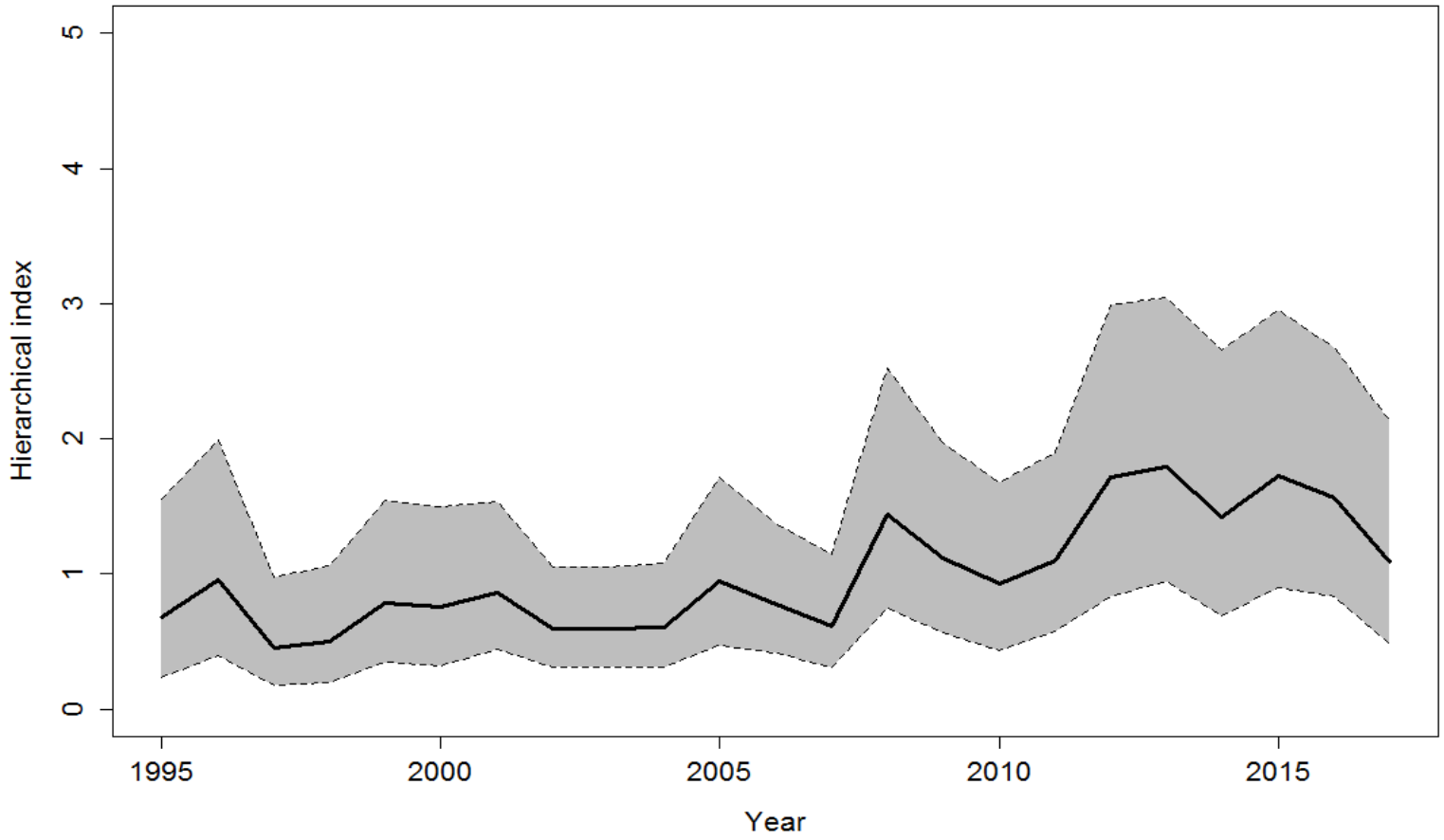






Southeast Conn Index

- Includes the North Carolina Gill Net, South Carolina Trammel, CRMS, and SEAMAP (South Carolina strata only), Georgia Trawl, and SEAMAP (Georgia-Florida strata only).



ARIMA Models

ARIMA Summary

Region	$P(i_f<i_{1998})>0.50$	$P(i_f<Q_{25})>0.50$
New England	1 out of 2	1 out of 2
New York	4 out of 4	4 out of 5
Mid-Atlantic	2 out of 5	0 out of 7
Southeast	0 out of 2	0 out of 5
Coastwide	7 out of 13	5 out of 19

*Terminal year was 2016 or 2017

*Residuals were normally distributed

*Combined sex surveys

Other Assessment Methods

- Surplus production model (ASPIC) – abandoned
- An Index Method (AIM) – abandoned
- Catch Multiple Survey Analysis (CMSA) – DE Bay females only

Catch Multiple Survey Analysis

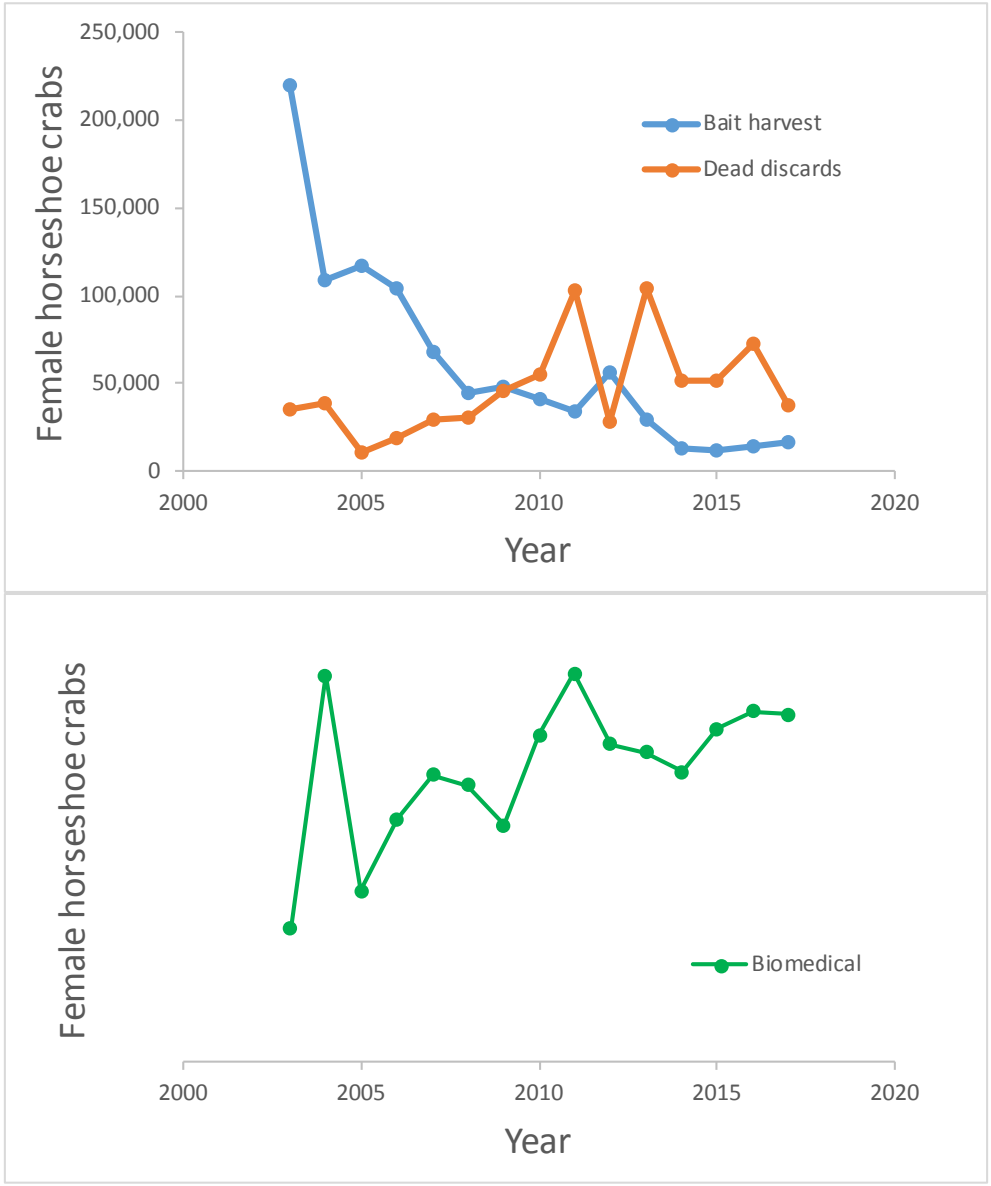
$$N_{y+1} = \left(\left(N_y + R_y \right) e^{-Mt} - C_y \right) e^{-M(1-t)}$$

Newly mature female (R_y)

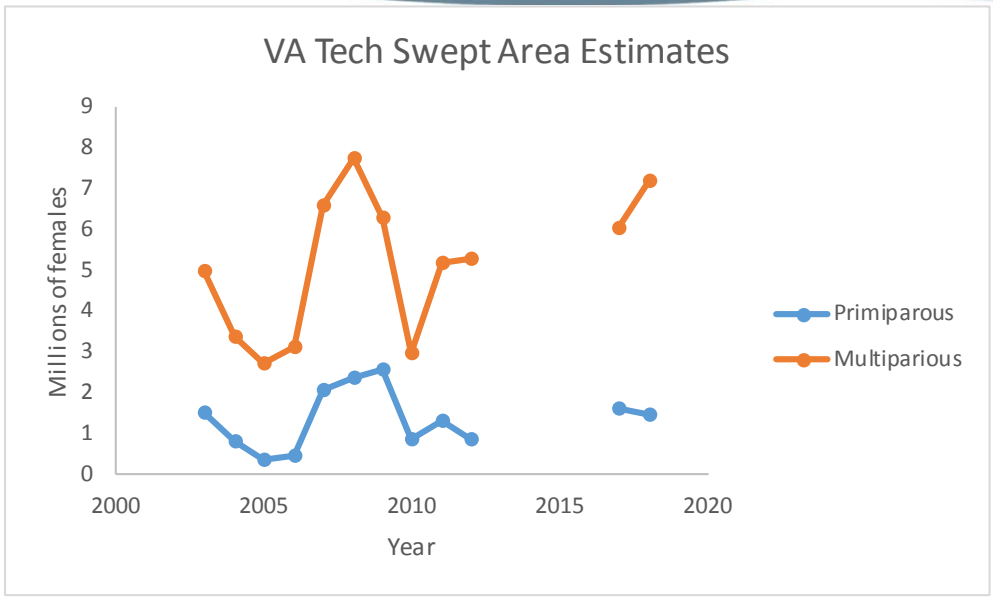
Multiparous female (N_y)

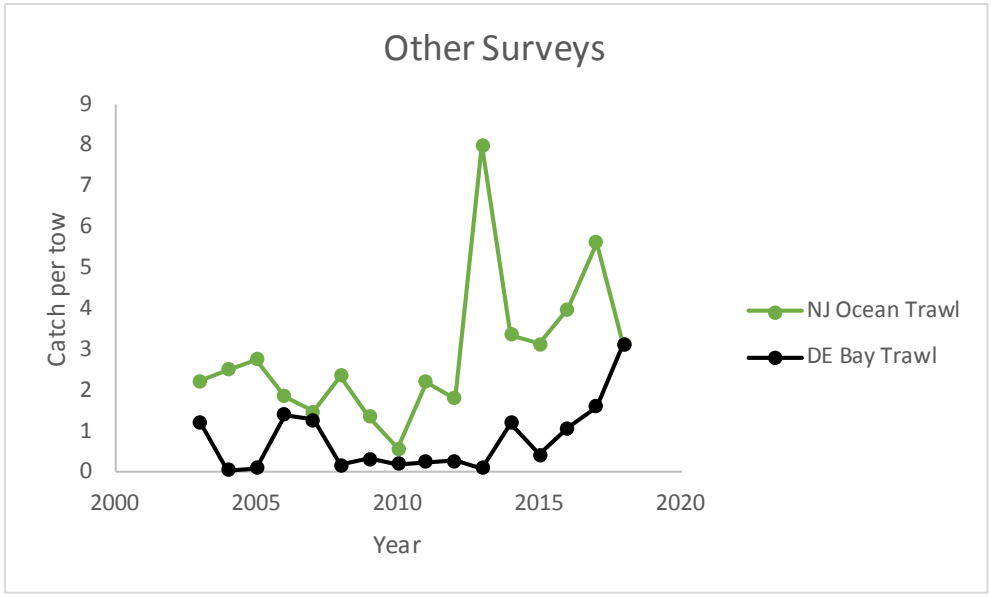
During amplexus, the contact of the male on top of the female rubs the opisthoma - the rear body section - of the female. This rubbing results in worn, often dark patches. Females with these marks are classified as multiparous, indicating they have previously spawned.

Catch Multiple Survey Analysis



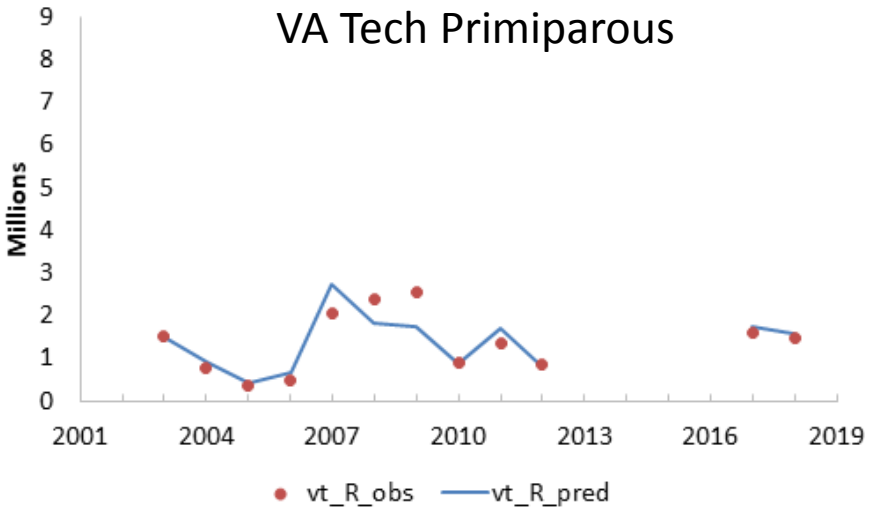
Catch Multiple Survey Analysis

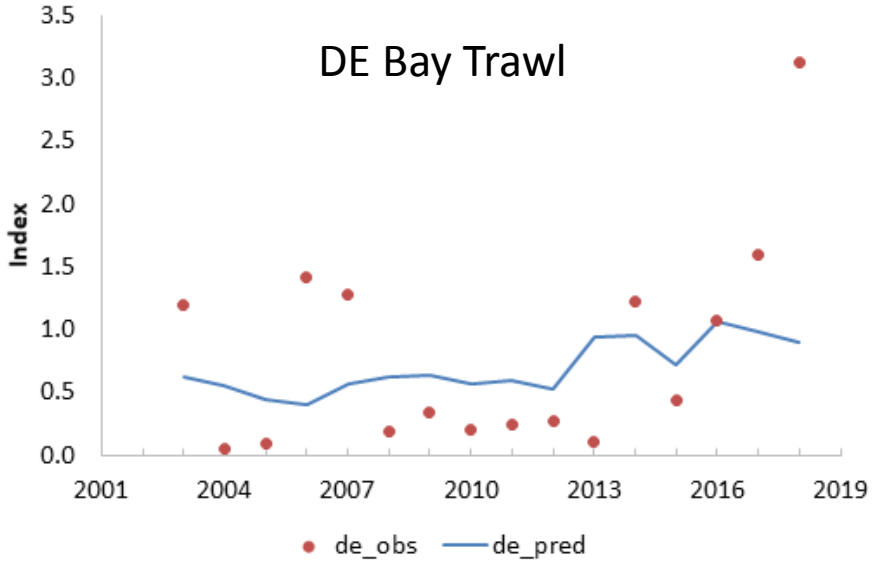


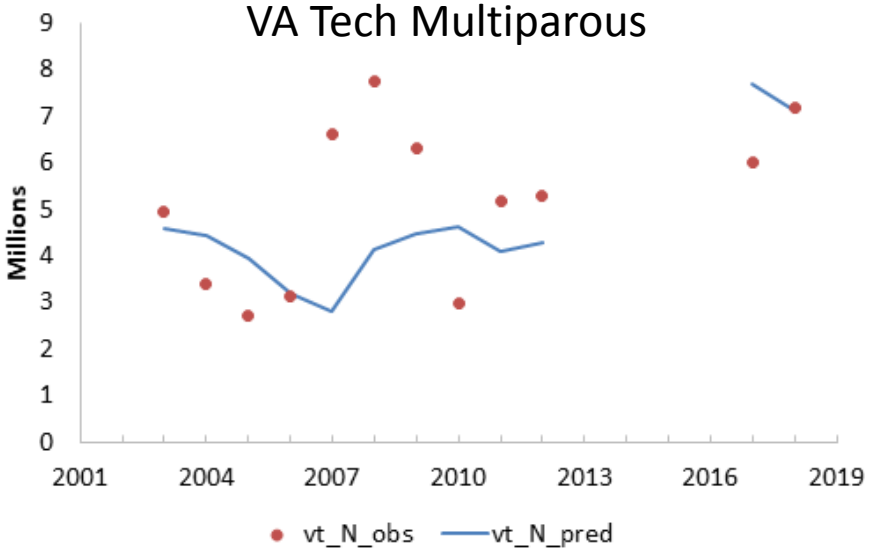


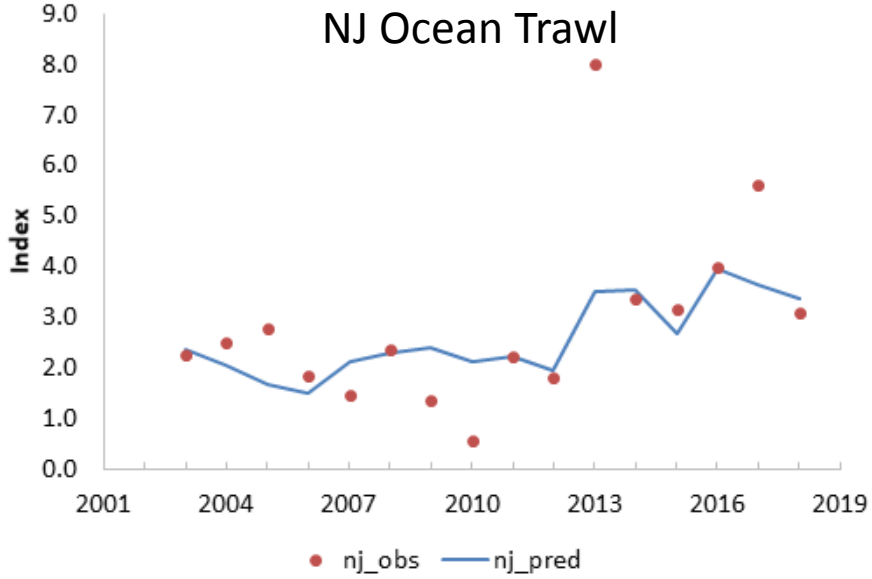
Base Model Parameters	
M	0.274
Model weights	VA Tech = 0.59
	DE Trawl = 0.16
	NJ Trawl = 0.25
Starting Values	R = 2 million
	N = 3.6 million
	q_DE = 2.3E-07
	q_NJ = 5.0E-7
	S = 1.0
Biomedical mort	15%

Catch Multiple Survey Analysis

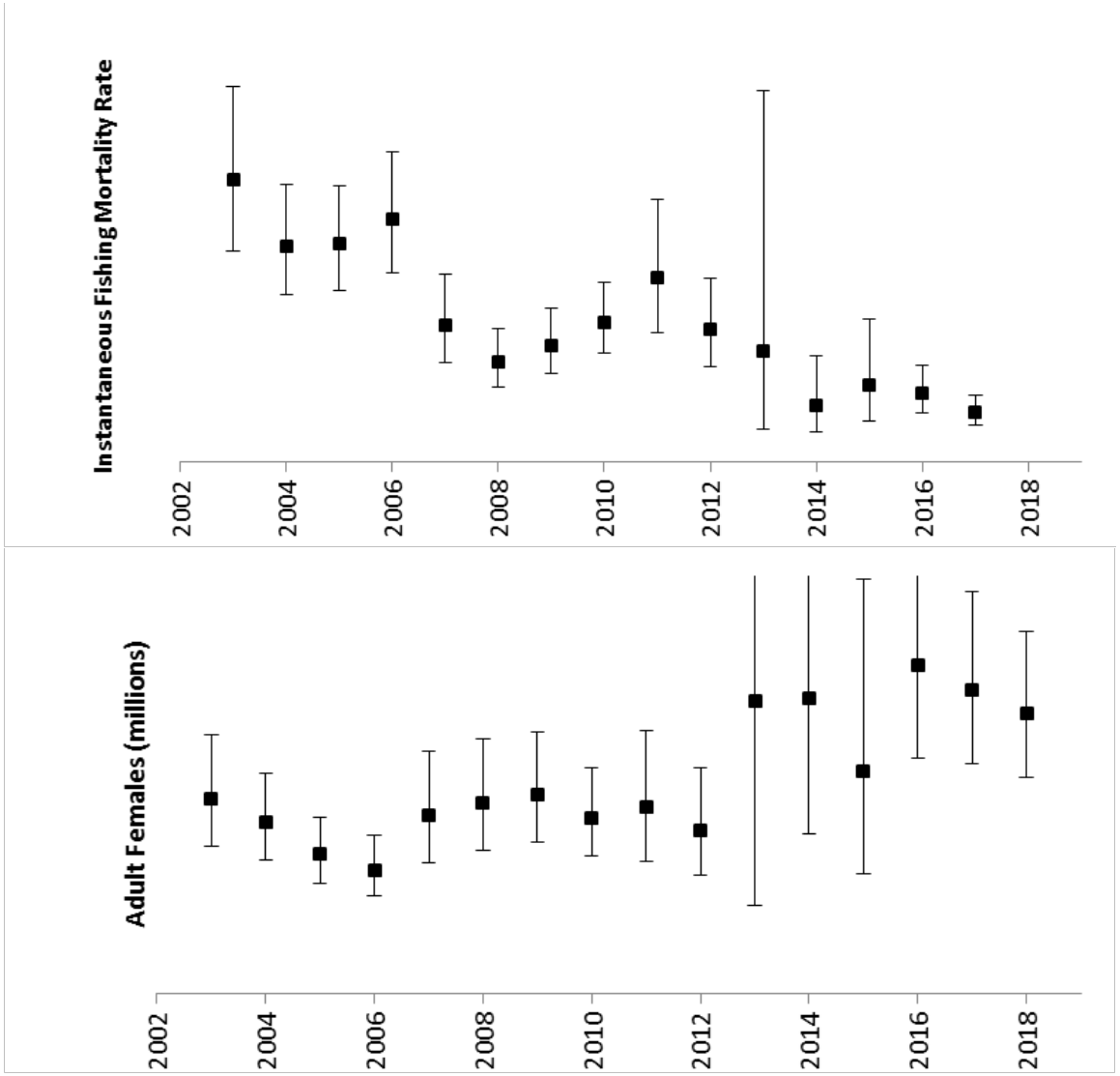








Catch Multiple Survey Analysis



**VA Tech minimum swept area estimate = 8.67 million in 2018

Catch Multiple Survey Analysis

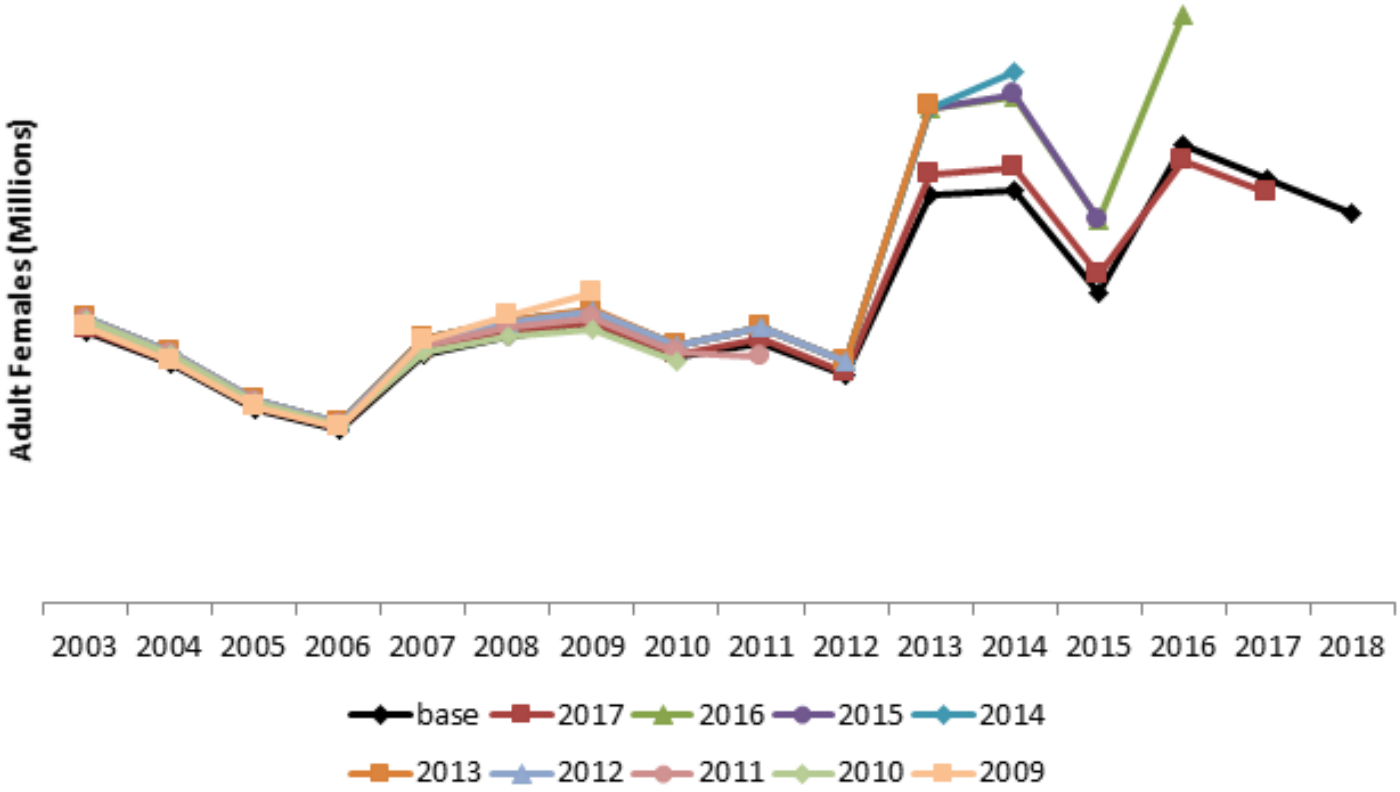
Sensitivity Runs

- Starting values of R, N, q
- Natural mortality
- Survey weights
- Survey CVs
- Primiparious:Multiparous selectivity
- % Biomedical mortality (0 – 30%)
- Exclusion of dead discards
- Inclusion/exclusion of years when VA Tech trawl did not operate

In general, model outputs were robust

- Biomedical mortality rate had very little effect
- Greatest sensitivity to freely estimating VA Tech survey q and survey weights

Catch Multiple Survey Analysis



Reference Points

Two methods for DE Bay

- Theoretical population projection model (N_{msy}, F_{msy})
- Yield- and Egg-per-Recruit models

Both methods were ultimately considered not suitable for management

- Yield- and Egg-per-Recruit reference points didn't adequately capture horseshoe crab life history and did not make biological sense
- Population projection model reference points could be biased because they were developed outside of the assessment model

<u>Management Recommendation:</u>

Use 1998 index based reference point from the ARIMA models to determine stock status

Stock Status

1998 index-based reference point from ARIMA models

Surveys included:

- Time series extending back to at least 1998
- Combined-sex indices
- Residuals of ARIMA fits were normally distributed
- Terminal year was 2016 or 2017

Status based on the % of surveys in a region having a >50% probability of their terminal year fitted value being less than the 1998 index based reference point

"Poor": >66% of surveys

"Neutral": 34 – 65% of surveys

"Good": <33% of surveys

Stock Status

Region	2009 Benchmark	2013 Update	2019 Benchmark	2019 Stock Status
Northeast	2 out of 3	5 out of 6	1 out of 2	Neutral
New York	1 out of 5	3 out of 5	4 out of 4	Poor
Delaware Bay	5 out of 11	4 out of 11	2 out of 5	Neutral
Southeast	0 out of 5	0 out of 2	0 out of 2	Good
Coastwide	7 out of 24	12 out of 24	7 out of 13	Neutral

NOTE: The suite of surveys used in each assessment as well as the index values differed between assessments.

Stock Status

Region	Survey	5 year trend	10 year trend	$P(i_f<i_{1998})$	Avg. Prob
Northeast	MA DMF Trawl - South of Cape Cod	↗	↗	0.08	
	RI Monthly Trawl - Fall	↘	↘	0.62	0.35
New York	CT Long Island Sound Trawl - Fall	↘	↘	1.00	
	NY Jamaica Bay Seine	↘	↘	0.96	
	NY Little Neck and Manhasset Bay Seine	↘	↘	1.00	
	NY Peconic Trawl	↔	↘	1.00	0.99
DE Bay	DE 30 ft Trawl - Fall	↗	↗	0.02	
	DE 30 ft Trawl - Spring	↗	↗	0.33	
	MD Coastal Bays Trawl - Spring	↗	↔	0.36	
	NJ Ocean Trawl - Fall	↔	↔	0.82	
	NJ Ocean Trawl - Spring	↗	↗	0.51	0.41
Southeast	SC CRMS	↗	↔	0.00	
	SC Trammel Net	↔	↗	0.00	0.00

Comparison to ARM in DE Bay

	Coastwide Stock Assessment	Adaptive Resource Management (ARM)
Management objective	Maximum sustainable yield; > 1998 index-based reference point	Maximum yield while maintaining ecological function (shorebird constraints)
Model types	Single species models	Multi-species models
Management triggers	Reference points based on HSC biology and life history (F_{msy}, B_{msy}, index-based ref. pt.)	Threshold values based on Red Knot abundance (81,900) OR female HSC abundance (80% of K, 11.2 million)
Status conclusions	Not overfished; overfishing not occurring; Neutral Status	Thresholds for each species not met – female harvest not valued
Management recommendations	Female harvest could increase (?)	Continued male only harvest (as of 2018)

Research Recommendations

Future Research:

- Life history, movement, habitat associations
- Climate change
- Spawning survey evaluations

Data Collection:

- Standardized stage-based methods for biosampling
- Gear efficiency study of VT Trawl
- Expand surveys
- Continued evaluation of biomedical mortality

Assessment Methodology:

- Further development of CSMA, tagging analyses, delay difference model
- ARM use of CMSA population estimates

Assessment Conclusions

- CMSA estimates provide the most accurate estimates of abundance to use as input to the ARM for DE Bay
- Maintain VA Tech trawl survey – Drives the CMSA model
- Consider management action in NY given “Poor” status and continued declining trends
- Continue to monitor Northeast
- Population impacts of biomedical bleeding are minimal
- Discard mortality may be a significant factor – greater than bait in recent years

Next Assessment

SAS recommended an update in 5 years and a benchmark in 10 years given the life history of horseshoe crabs and the need for more years of data.

Peer Review panel recommended a benchmark in 5 years due to the potential for improved discard estimation and model updates to significantly affect the stock assessment.

Questions?

Horseshoe Crab Stock Assessment Review Report

Horseshoe Crab Fishery Management Board

May 1, 2019

Stock Assessment Peer Review Process

- Horseshoe Crab Technical Committee and Stock Assessment Subcommittee developed new regional stock assessment

- Horseshoe Crab Stock Assessment Review Workshop
  March 26-28, 2019, Arlington, Virginia

- Scientific review focused on data inputs, model results and sensitivity, and overall assessment quality

Products

- Stock Assessment Report
- Review Panel Report
  www.asmfc.org/species/horseshoe-crab

Stock Assessment Review Process

Scientific Peer Review Panel

- Chair + 2 additional Technical Reviewers, with expertise in
  - Horseshoe Crab / Marine Invertebrate Ecology
  - Population Dynamics and Statistics
  - Stock Assessment Modeling

Dr. Larry Jacobson (Chair), Retired (ex-NMFS-Northeast Fisheries Science Center, Woods Hole)

Dr. Ruth H. Carmichael, Dauphin Island Sea Lab, University of South Alabama

Dr. Matthew Cieri, Maine Department of Marine Resources, West Boothbay Harbor

Review Panel Overall Findings

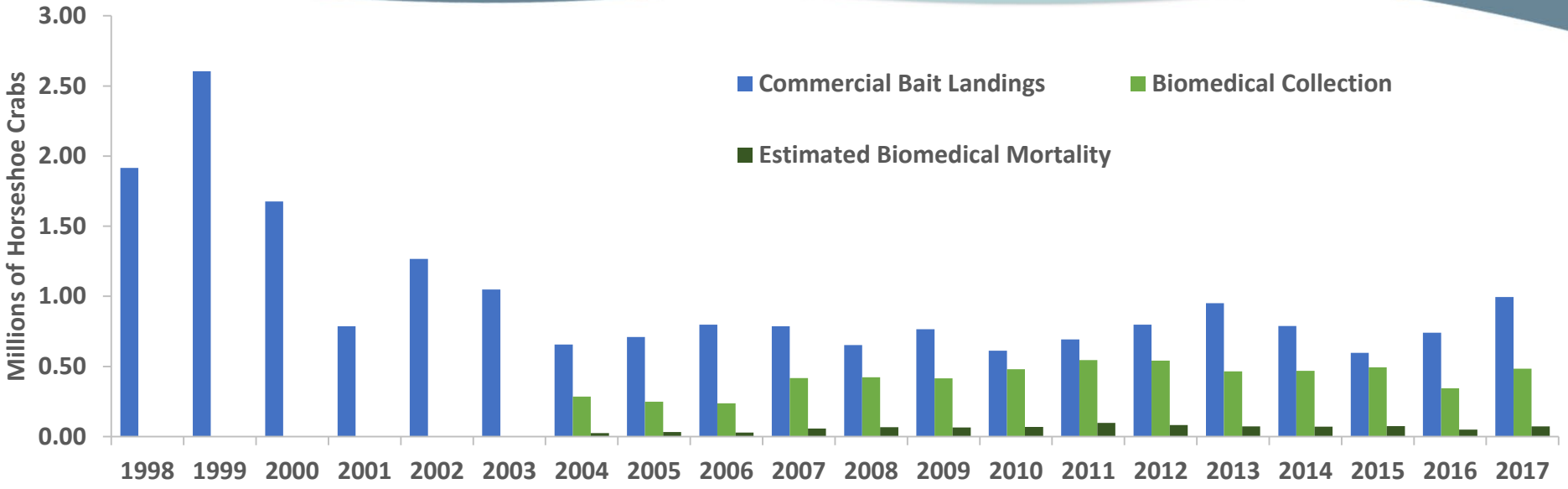
- Assessment sound, best available information, suitable for management use
- Assessment team and ASMFC staff capable, cooperative and worked diligently to improve assessment before and during the review
- Assessment work well documented in stock assessment report

Review Findings

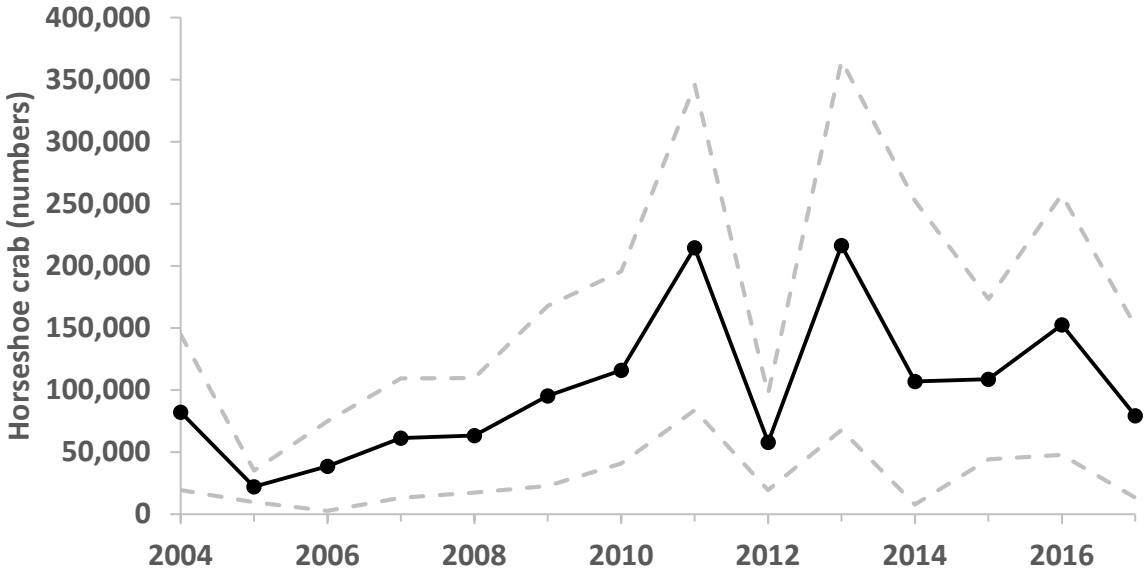
✓ ***ToR 1:*** *All potential data sources considered, evaluated, and selected correctly*

- Process for including or omitting surveys was clear and satisfactory
- Biological sampling in bait fishery/biomedical collections adequate given limited use; future assessments may require more sex, length, maturity data
- Analysis supports 15% bleeding mortality rate
  - Resulting biomedical losses <13% of bait harvest
  - Bleeding mortality no longer a major uncertainty given relatively small biomedical take and mortality relative to bait landings and discards
- Horseshoe crab discards estimated, relatively high but uncertain
  - Discard mortality rate also uncertain
  - Preliminary estimates indicate discard mortality comparable to combined bait harvest and biomedical losses

Review Findings



Dead discards Delaware Bay region only



Review Findings

- ***Recommendation 1:*** Estimate discards and discard mortality on a regional and whole stock basis

- ***Recommendation 2:*** Add discard estimation experience to assessment/management teams; allow ASMFC staff direct access to discard databases and provide training

Review Findings

✓ **ToR 2***: Evaluate methods and models used to estimate population parameters and reference points*

Panel Conclusions

- ARIMA models used here/previously good for horseshoe crabs (sound statistically, use best available data, robust to uncertainties about catch, natural mortality, stock structure, etc.)
- Catch Multiple Survey Analysis (CMSA) abundance/F estimates for Delaware Bay females; comparable reference points not available for status determination (apples to oranges) but results useful elsewhere (ARM model)
- Theoretical projection model indicates Fmsy is low (< 0.1)
  - Projections show slow increases over decades; results not comparable to ARIMA or CMSA (apples to oranges)
- ***Recommendation 3: Calculate reference points and projections within CMSA or other assessment model for comparability***
- ***Recommendation 4: Continue to improve the CMSA, particularly for use in other regions and males***

Review Findings

✓ **ToR 3***: Evaluate the diagnostic analyses performed, including sensitivity and retrospective analyses*

Panel Conclusions

- Residual analyses identified poor ARIMA model fits; historical analysis shows ARIMA stable between assessments
- Historical retrospective with new recommended 33%-66% status method showed reasonable changes in historical stock status over time
- Extensive sensitivity analyses show CMSA results robust -- no retrospective patterns
- ***Recommendation 5:*** *CMSA stability partially due to 100% catchability in the Virginia Tech HSC Trawl Survey*
  - *evaluate assumption experimentally (field work)*

Review Findings

ToR 4*: Evaluate methods used to characterize uncertainty in model estimates.*

Panel Conclusions

- Uncertainty in ARIMA model fits displayed graphically using confidence intervals based on standard statistical methods
- ARIMA stock status considers uncertainty in stock size and reference point; criterion to identify poor condition stocks requires strong evidence of poor condition but same as in other studies
- Standard variance calculations used for CMSA results; sensitivity analysis showed results were robust

Review Findings

✓ **ToR 6:** *Recommend best estimates of stock biomass, abundance, and exploitation from the assessment for use in management*

Panel Conclusions

- Use relative abundance from ARIMA models and survey data and 33%-66% method to determine stock status
- Exploitation based on ARIMA not available due to uncertainty about discards
- CMSA should not be used for status determination (apples to oranges, poor precedent and not necessary)
- CMSA estimates are suitable for other purposes (e.g., ARM model inputs)

Review Findings

✓ **ToR 7:** *Evaluate the choice of reference points and methods used to estimate them. Recommend stock status determination.*

Panel Conclusions

- Use relative abundance in 1998 from ARIMA models as abundance reference points
- Use 33%-66% status method and traffic lights to combine results from multiple surveys at regional and whole stock levels

33%-66% status table

Region	2009 Benchmark	2013 Update	2019 Benchmark	2019 Stock Status
Northeast	2 out of 3	5 out of 6	1 out of 2	Neutral
New York	1 out of 5	3 out of 5	4 out of 4	Poor
Delaware Bay	5 out of 11	4 out of 11	2 out of 5	Neutral
Southeast	0 out of 5	0 out of 2	0 out of 2	Good
Coastwide	7 out of 24	12 out of 24	7 out of 13	Neutral

Review Findings

✓ **ToR 8***: Review and prioritize research recommendations.*

<u>Panel Conclusions</u>

- Estimate discards and discard mortality rates by gear; make discard data and expertise more available to plan and assessment teams
- Increase utility of horseshoe crab survey data by recording size, sex, and reproductive status
- Coordinate data collection across survey programs
- Continue the Virginia Tech Horseshoe Crab Trawl Survey
- Continue work on stock assessment models for males and females in Delaware Bay and other regions

Review Findings

✓ **ToR 9***: Recommend timing of next assessment and updates*

Panel Conclusions

- Conduct benchmark stock assessment in five years because discard estimates and new methods might indicate need for management action
- Start work on discards soon in case observer protocols need refinement and in case substantial but avoidable discards occur - *need time to estimate and ponder discards, management, etc. prior to next assessment*

Questions?

Potential Management Responses to 2019 Horseshoe Crab Benchmark Stock Assessment

Management Board Meeting

May 1, 2019

From Assessment Conclusions

- CMSA estimates provide the most accurate estimates of abundance to use as input to the ARM for DE Bay – **Board Guidance**

- Consider management action in NY region given “Poor” status and continued declining trends – **Depends on Response**

From Previous Action/Discussion

- Draft Addendum VIII (Postponed in Oct 2016): initiated to address incorporation of biomedical mortality in the ARM model and bait harvest packages (HP) that would allow female harvest in the DE Bay – **Addendum**
  - Will need to be taken up (not necessarily this meeting)
  - Biomed mortality incorporation options
    - Subtract multi-year average biomed mortality from current HPs
    - Add biomed mortality as additional mortality source within ARM model; same HPs **(Could be done w/o addendum)**
    - Neither significantly alters HP recommendations
  - Additional/altered HPs that would allow levels of female harvest in DE Bay
    - Unless female population exceeds 80% carrying capacity (or 11.2 million females), no female harvest, regardless of HPs

From Previous Action/Discussion

- Addendum VIII (Postponed in Oct 2016): initiated to address incorporation of biomedical mortality in the ARM model and bait harvest packages (HP) that would incorporate female harvest – **Addendum**
  - Will need to be taken up

- ARM Review - **$$$, Time, & Maybe Addendum**
  - Part of "double loop" process of Addendum VII; revisit "set-up" of ARM
  - Migrate ARM model to more widely used software

From Previous Action/Discussion

- ARM Review - **$$$, Time, & Maybe Addendum**
  - Part of "double loop" process of Addendum VII
  - Migrate software platform
  - Long Term (18-24 months):
    - Model set assessment (reviewing the model setup, hypotheses, parameters)
    - Optimization algorithm update (changing model software platform)
  - Short Term (6-8 months, last conducted in 2016):
    - Monitoring program (update and improve monitoring protocols)
    - Harvest rates and specifications (evaluate the harvest of the states relative to the quotas as well as the harvest packages)
    - Revisit objective function (assess structure, revise as needed)

Questions/Discussion