Joint Report of the ASMFC Horseshoe Crab and USFWS Shorebird Technical Committees

March 30-31, 2009

The ASMFC Horseshoe Crab and USFWS Shorebird Technical Committees (TCs) met jointly on March 30th and 31st in Baltimore. The purpose of the meeting was to receive updates from the Adaptive Resource Management Work Group (AWG) and to make decisions or recommendations to guide the AWG's work. In addition, the TCs will receive presentations from Virginia Tech regarding its work on HSCs and red knots. The following is a summary of the meeting.

Note: Most of the work noted in this report is 'in progress'. The general structure and direction of this process will likely remain as is but details of the objectives, management alternatives, modeling, and analysis will continue to evolve. Additionally, much to the information on the AWG's progress outlined here is described in great detail in an accompanying report written by the AWG.

Attendees

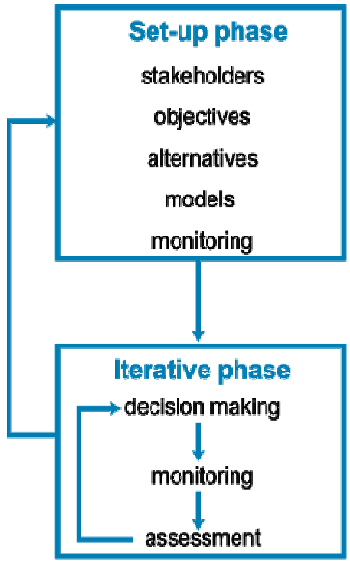
TC Members and Participants

Gregory Breese, Co-Chair (USFWS)
Mike Millard, Co-Chair (USFWS)
Dave Smith (USGS)
John Sweka (USFWS)
Jim Lyons (USFWS)
Connor McGowan (USGS)
Rick Robins (HSC AP)
Kevin Kalasz (DE)
Stew Michels (DE)
Steve Doctor (MD)
Alison Leschen (MA)
Robert Gorrell (NMFS)
Annette Scherer (USFWS)
Alicia Nelson (VA)
Amanda Dey (NJ)
Larry Niles (CWF – NJ)
David Mizrahi (NJAS)
Jeff Brust (NJ)
John Maniscalco (NY)
Rich Wong (DE)
Allen Burgenson (HSC AP)
Nellie Tsipoura (NJAS)
Carl Shuster (VIMS)
Angie Machniak (FL)
Larry DeLancey (SC)
Brad Andres (USFWS)
Penny Howell (CT)
Jim Nichols (USGS)
Brad Spear, Staff (ASMFC)

Others

Glenn Gauvry (ERDG)
Sarah Karpanty (VT)
Sheila Eyler (USFWS)
Mike Oates (Anew Inc.)
Eric Hallerman (VT)
Dave Hata (VT)
Caroline Kennedy (DoW)
Faith Zerbe (DRN)
Dan Petit (NFWF)
Pat Campfield (ASMFC)
Genny Nesslage (ASMFC)
Katie Drew (ASMFC)
Brian Hooker (NMFS)

AWG Progress Report
Adaptive Resource Management (ARM) uses the double loop process of learning and adaptation (see figure below).



Currently, the AWG is spending most of its time developing the models in the set-up phase. Discussions at this meeting focused on the entire set-up phase.

Objectives
The qualitative objective statement is to "Manage harvest of horseshoe crabs in the Delaware Bay to maximize harvest but also to maintain ecosystem integrity and provide adequate stop-over habitat for migrating shorebirds." More specifically, the objective is to "Maximize harvest of horseshoe crabs with constraints that 1) harvest of female crabs is valued only when Red Knots exceed an abundance threshold or females horseshoe crabs exceed an abundance threshold and 2) harvest of males is valued only when males are extraneous to horseshoe crab population growth (i.e., additional males in the population will not increase HSC population growth rates)."

Management Alternatives
Alternative management actions should be realistic, feasible, and different enough to represent distinct choices. The current alternative actions reflect various levels of allowable harvest:

1. Full moratorium on both sexes
2. 100,000 males and 0 females
3. 270,000 males and 0 females
4. 280,000 males and 140,000 females
5. 420,000 males and 210,000 females
6. 495,000 males and 330,000 females

Based on TC comments, the AWG is keeping open the possibility of adding one or two other management alternatives, one with a much higher male only harvest option, and one with an equal sex ratio of the harvest.

HSC Modeling
The AWG has identified various sources of uncertainty that exist in natural resource management:

- Ecological (structural): nature of system dynamics is not completely known, or there are competing ideas about the system response to management actions
- Environmental variation
- Partial controllability: management decision is applied to the system indirectly, or immediate effects of management actions are characterized by uncertainty
- Partial observability: the state of nature is rarely seen perfectly and, therefore, must be estimated

Where possible, these sources of uncertainty will be dealt with explicitly in the model.

Partial controllability will not be included in our current modeling effort due to software limitations. The ARM group has decided to direct our limited computing capacity towards ecological and environmental uncertainty. Uncertainty due to partial observability, though important, cannot be incorporated at this time because no publically available optimization software packages allow for this uncertainty.

The AWG presented two possible HSC models, advising the TCs due to limitations of software and processing capabilities, only one HSC model will be used to link into the three competing models of the Delaware Bay system: 1) there is no effect of HSCs on Red Knots; 2) HSCs affect Red Knot fecundity only; and 3) HSCs affect fecundity and survival of Red Knots. The two models are based on Sweka et al.'s age/stage-structured model and Davis et al.'s surplus production model. The AWG is using an optimization program (ASDP) that can't handle both models at the same time and gives different results for each model. The advantages of the stage-structured model are it is more precautionary and it allows sensitivity analyses on early life history characteristics. The advantages of the logistic model are it is a simpler model (i.e., uses less computing power) and it is more easily updated. Accepting the AWG's recommendation, the TCs decided to move forward with the stage-structured model at this point. However, both models will be retained, and their ability to predict will be compared over time. Eventually, the best model will be identified and used, or both models will be incorporated into the decision analysis.

When using a two-sex model to make decisions for male and female harvest levels, the reproductive capacity must be linked to sex ratio, which could be in terms of the population or operational sex ratio. [Population sex ratio is the number of males to females among the entire population. Operational sex ratio is the number of males to females spawning on the beach.] The TCs agreed that male and female models are linked by a fertility factor that limits reproduction as a function of sex ratio, where a certain minimum proportion of males would result in maximum females spawning and maximum eggs fertilized.

The TCs also agreed that the AWG should use operational sex ratio (OSR) as opposed to population because it more closely reflects the most important features of spawning, pairing of available females and fertilization of eggs. Based on research conducted on unharvested populations of HSCs in Florida and Maine, observed OSR is around 2:1 male to female. Observed OSR in the Delaware Bay spawning survey has averaged 3.8:1 males to females. This is likely due to past harvest of HSCs targeting females and the fact that males are quicker to mature and spawn on beaches. This ratio is expected to drop in future years as harvest of females has dropped significantly and as the population rebuilds. While there was debate about what OSR should be used, the TCs agreed to use as a starting point a 2:1 male to female ratio is the minimum that is needed for 100% fertilization of eggs. The OSR observed in the spawning survey will be monitored to determine if this ratio is appropriate.

Red Knot Modeling

The red knot population models used by the AWG are based on the stage-structured model from Baker et al. (2004). The three models represent different interactions with HSCs: 1) no effect model; 2) fecundity only model; and 3) survival and fecundity only model. Parameters used were obtained from the literature on red knots, surrogate species, or best professional judgment. The AWG used a fecundity of 0.7 female chicks per breeding female. The TCs felt this value was high and advised the AWG to verify it.

Calculating the proportion of red knots that make weight before leaving for the Arctic (P180) remains a key component of the models. It is calculated by combining arrival condition probabilities with weight gain (state transition probabilities) to get the probability of departure above and below the threshold of 180 grams. P180 is the term that links red knots to female horseshoe crabs by relating knot weight gain to the number of female HSCs that spawn during the knot migration period.

Utility Function and Optimization

The ASDP optimization process will identify the optimal harvest package (i.e., one of the six scenarios listed in the *Management Alternatives* section above) based on red knot and HSC abundance conditions. The optimization will seek to maximize cumulative reward (i.e., abundance of red knots and harvest of HSCs) over an infinite horizon.

The AWG has developed the following reward functions to use in optimizing management decisions:

$$\text{Reward} = \sum_{t}^{\infty} \left(\alpha_1 2\text{H}_{\text{F,t}} + \alpha_2 2\text{H}_{\text{M,t}} \right)$$

where α_1 and α_2 are utility values, which are a function of horseshoe crab and shorebird abundance, $H_{F,t}$ and $H_{M,t}$ are female and male harvest, and the summation is over a long time period. The harvest of females is multiplied by 2 to reflect the differential market value between female and male horseshoe crabs. The utility values (α_1 and α_2) are determined by the follow conditional statements:

- If # of observed red knots is greater than the knot threshold, then harvest of female HSCs has value and α_1=1. Otherwise, harvest of female HSCs has no value and α_1=0.
- If # of observed female HSCs is greater than the low HSC threshold, then harvest of female HSCs has partial value. If # of observed female HSCs is greater than the high HSC threshold, then harvest of female HSCs has a value of α_1=1. Otherwise, harvest of female HSCs has no value and α_1=0.
- If the proportion of male to female HSCs is above 2:1, then harvest of male HSCs has a value and α_2=1. Otherwise, harvest of male HSCs has no value and α_2=0.

The TCs discussed the red knot and female HSC thresholds mentioned above. These thresholds are value-based. The TCs decided to set the red knot threshold at 45,000 birds, which is 50% of the maximum number of knots counted in Delaware Bay (90,000 birds) in the early 1990s. The TCs agreed that the AWG should incorporate a phased in male and female harvest based on how much greater observed numbers are above the threshold. This led the TCs to select a low threshold of 50% of Delaware Bay's carry capacity (K) for female HSCs (~7 million) and a high threshold of 80% of K (~11.2 million). K will be recalculated as new data are analyzed and the models of the horseshoe crab population are updated. Again, if estimates of female horseshoe crabs are above 7 million, the model will assign partial value to harvest. Once the number of female crabs exceeds 11.2 million, the model will assign full value to female harvest. The AWG envision a two to three year cycle of monitoring and model revision as part of the double loop in the adaptive management framework.

Monitoring

The purpose of monitoring is threefold (in the context of the double loop figure above):

- Annually estimate state variables (i.e., abundance numbers) to determine best management action (iterative phase).
- Assess model predictions and re-evaluate model weights (iterative phase and double loop)
- Update model parameters (i.e., survival rates) and variance structure to improve model performance (double loop)

Monitoring needs will become apparent as the objectives, models, and utility functions are set. The AWG expects to recommend a monitoring protocol in July.

Update on Virginia Tech Research Projects

Dave Hata presented the most recent results of the benthic trawl survey. Changes from 2007 to 2008 for mean catches in the Delaware Bay region include: immature crabs (decrease), multiparaous crabs (slight decrease), primiparous females (slight increase), and primiparous males (decrease). Within the survey area outside the Delaware Bay region, mean catches have been variable with no clear trends. Size frequency distributions throughout the survey indicate continued recruitment of small crabs. The 2009 survey will include the Delaware Bay region and the New York apex. Funding for the 2010 survey is expected, but beyond that is unclear.

Hata also presented information on a pilot juvenile HSC study. The purpose of the study was to examine whether the 6-inch stretched mesh net was under-catching smaller HSCs. Sampling was conducted in state waters only along the DelMarVa peninsula. Hata found that the 6-inch mesh net caught crabs within the same size range as the 4-inch mesh net, but may have under-caught the smallest cohort encountered. He also concluded a juvenile monitoring survey can achieve relatively precise abundance estimates with 20 or less tows within the sample area.

Eric Hallerman presented interim results of a HSC tag recovery study in Tom's Cove on Chincoteague Island, Virginia. The study has multiple objectives including estimating the number of spawners in the population, characterizing the fishery, and assessing whether the assemblage of crabs is part of the Delaware Bay population. The study re-sighted 6 crabs that were tagged in the Delaware Bay in 2003, supporting the hypothesis that the Tom's Cove is included in the Delaware Bay region spawning stock. However, data to evaluate this hypothesis will become stronger with future re-sightings.

Sarah Karpanty presented information on red knot numbers and ecology during a migratory stopover in Virginia. Her research shows:

- Historical use of VA as a stopover for red knots
- Knots from all wintering sites (North and South America) stop in VA
- The number of red knots observed in one season is around 7-10K birds
- Red knots stopover in VA for an average of 14 days
- Flock size and presence is related to food (coquina clams) availability

Other findings that could help frame the DE Bay ARM modeling work include:

- ~30% of the western Atlantic Ocean red knot population stops in VA
- There is little interchange with DE Bay within years and more interchange across years
- Red knot numbers in VA during the stopover appear to be increasing

Unfinished Business

The TCs were not able to address a few agenda items at the meeting. Two discussions regarding the external peer review of the ARM modeling work will take place through email. The TCs will be asked to accept draft Terms of Reference to guide the model work and peer review. In addition, they will be asked to submit nominations for peer reviewers.

The TCs received a copy of the 2009 report of the DE Bay Spawning Survey prior to the meeting. However, time was not available for a presentation and discussion of the results.