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Presenting:

A Workshop to Assess Twenty Years of Scientific Studies And Conservation Projects In Delaware Bay And Plan Future Work

Wednesday, May 10, 2017
9:00 – 17:00
&
Thursday, May 11, 2017
9:00 – 12:00

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Agenda
May 10-11, 2017 at New Jersey Audubon Goshen Center

The aim of this meeting is to present the major scientific and conservation issues and to reach an understanding of how they can be resolved. Ultimately, we intend to develop a plan for the future management on the bay.

The workshop includes a wide range of presentations whose authors have agreed to create papers over the summer of 2017. Papers will be edited and combined into a new volume in the *International Wader Studies* series. Presentations will be brief to allow for discussion on the issues presented and targeted for a professional audience of scientists, conservation managers and policy makers.

We hope that this workshop and the accompanying volume will serve to guide landscape-wide efforts to conserve the natural resources of Delaware Bay including the National Fish and Wildlife Delaware Watershed Business Plan and the Atlantic Flyway Shorebird Business Plan.

The first day workshop contents will be divided into four sessions:

- Research and conservation of shorebirds in Delaware Bay
- Research and conservation of horseshoe crabs in Delaware Bay
- People, policy and the future
- Flyway perspectives

Each participant has been asked to develop a paper to be submitted by October 1, 2017 that will address the following questions with respect to the subject of the paper.

- What problem are they addressing?
- Why is it important to Delaware bay stopover
- What are the implication for the conservation of the bay
- What actions should be taken to promote the conservation of the stopover?

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Program

May 10, 2017: 09:00 – 17:00

Note: the program only identifies the name of each speaker. Co-authors are identified in the abstracts that follow.

09:00 **Welcome and introduction: Larry Niles**

Research and conservation of shorebirds in Delaware Bay – Chair Larry Niles

09:10 Clive Minton: Twenty years of scientific and conservation work on Delaware Bay

09:30 Humphrey Sitters: The daily rate of mass gain of Red Knots in Delaware Bay in relation to horseshoe crab egg density and from year to year

09:50 Robert A. Robinson: Mass gain in a spring-staging long distance migrant shorebird, the Red Knot C*alidris canutus*

10:10 David Mizrahi: Effects of food availability and diet on weight gain in Semipalmated Sandpipers in Delaware Bay during spring migration staging periods

10:30 Paul Smith: The estimation of population size in shorebirds using Delaware Bay – a comparison of estimated and observed numbers

10:50 Coffee/tea break

Horseshoe crabs and their eggs and other foraging options for shorebirds in Delaware Bay – Chair Charles Duncan

11:20 Philip Atkinson: Hard or soft-shelled prey? Migration strategy determines spatial distribution and resource use by an Arctic-breeding shorebird (Red Knot *Calidris canutus*) on their final spring stopover in Delaware Bay

11:40 Joanna Burger: Importance of intertidal mudflats to foraging Red Knots and other shorebirds at Delaware Bay, New Jersey

12:00 Jordan Zimmerman: Status of the population, regulations and harvest of horseshoe crabs

12:20 David Hata: Relative abundance of horseshoe crabs on the Delaware Bay

12:40 Joe Smith: The impact of restoring habitats for shorebirds and crabs on Delaware Bay

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13:00 Lunch

People, policy and the future – Chair Amanda Dey

14:00 Rick Lathrop: Implications of sea level rise on the Delaware Bay stopover

14:20 Laura Chamberlin: Utilizing community engagement for improved implementation of conservation actions on Delaware Bay

14:40 Ian Davidson: The Delaware Watershed Business Plan

15:20 Coffee/tea break

Flyway perspectives – Chair Audrey DeRose-Wilson

15:40 Philip Atkinson: Does survival vary with migration distance? A case study using Red Knot

16:00 Guy Morrison: Long-term trends of wintering Red Knot populations in Tierra del Fuego, Brazil and Florida

16:20 David Stallknecht: Influenza studies of Delaware Bay shorebirds

16:40 Ron Porter: What do geolocator data tell us about the importance of Delaware Bay in the West Atlantic Flyway?

17:00 Close

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May 11, 2017: 09:00 – 12:00
Discussion of future actions to recover the Delaware Bay stopover for shorebirds

Building on recommendations for research and conservation actions arising from the first day's talks, this three-hour discussion will focus on drawing up cost-effective strategies for research monitoring and conservation of shorebirds, horseshoe crabs and crab eggs, and their habitats

The session will start with a discussion of strategies to improve conditions for shorebirds and crabs. Included in this agenda are four Miradi Diagrams outlining strategies that can improve conditions in the next five years:

- Reducing the loss of horseshoe crabs taken for bait and bleeding for lysate
- Creating high quality horseshoe crab breeding habitats
- Reducing impacts of human disturbance
- Reducing impact of oyster aquaculture on beaches and intertidal flats

It will be followed with a discussion on what work (projects) should take place in the same five-year period.

Abstracts

Twenty years of scientific and conservation work on Delaware Bay

Clive Minton (Australasian Wader Studies Group)

The Delaware Bay 'Project' emerged from the chance meeting, in May 1997, of a scientific study of the migration of Red Knot (initiated by Alan Baker and Patricia Gonzalez) and the rapidly emerging Horseshoe Crab 'industry' on Delaware Bay and its associated environmental problems. The scientific study had been initiated in Argentina in the mid-1990's and the massive hand collection of Horseshoe Crabs for bait for conch traps had also escalated dramatically in the mid-1990's. A multi-faced bay-wide scientific program was developed with the objective of obtaining all the necessary scientific facts to illustrate that over-harvesting of Horseshoe Crabs was occurring and that this would result in major adverse effects on the shorebird populations, particularly on the Red Knot. Since then, all efforts have been focused on conservation-related science.

Major banding, colour-banding and ultimately leg-flagging programs have been carried out on both the New Jersey and Delaware sides of the Bay for 20 years. Biometric data, especially weight data, has been gathered extensively and used to show that as the Horseshoe Crab population declined as the spilt Horseshoe Crab eggs which waders feed on became less available. This resulted in significant difficulties arising for waders to achieve the desired take-off weights in the necessary timescale to complete their northward migration on time and arrive in the Arctic in a condition where they could subsequently nest successfully. Associated population studies and the weight data indicate that the nadir was probably reached in

2003/2005. In the last few years there have been the first signs of an improvement – first noticeable in the numbers of Horseshoe Crabs spawning and consequent number of eggs available to the birds, then by an increase in the weights of birds making their main stopover on Delaware Bay on Northward migration, and finally by possible small increases in the Red Knot population.

In addition, other direct and indirect conservation work has aided the improvement of the situation. Controls on the harvesting of Horseshoe Crabs proved difficult to implement but ultimately have proved sufficient to halt the decline and to facilitate a possible turn-around. Habitat improvements, especially large-scale beach-sand replenishment after the denudation by Hurricane Sandy, and protection of the key spawning/shorebird feeding beaches from human disturbance for a four-week period in May/early June each year have also contributed significantly to ameliorating the pressure on feeding shorebirds.

The key for the future restoration of the situation on a long-term sustainable basis is to maintain at least the current more favourable situation for long enough to enable a significant recovery in the Red Knot population to take place. This will take longer to achieve than people expect (or hope) because the reproduction rate of Arctic breeding shorebirds is relatively low and highly variable, being subject to various threats annually (Arctic weather conditions in June/July, predation levels on the breeding grounds, interruptions to migration along the flyaway, not to mention some potential adverse changes in the Central and South American non-breeding areas of the Red Knot). But it is a satisfying feeling that the tireless, sustained efforts of a number of people, and a huge amount of effort by scientists, conservationists, and citizens interested in the welfare of the birds has successfully managed to stop the ship sinking and to gradually turn it around onto an upwards trajectory. This workshop can, amongst other things, allow those who have been involved to fully appreciate what they have achieved so far and to try to consolidate this into the future.

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The daily rate of mass gain of Red Knots in Delaware Bay in relation to horseshoe crab egg density and from year to year

Humphrey Sitters (International Wader Study Group & University of Exeter) and all participants in the Delaware Bay Shorebird Project

The daily rate of mass gain of Red Knots in Delaware Bay, as measured by birds weighed twice in the same season, has been shown to increase with date of first capture and decline with mass at first capture (Atkinson *et al.* 2007). Thus, late arrivals can usually increase their rate of mass gain to catch up with earlier birds and leave for the Arctic on time and well provisioned.

In this analysis, we show that for 2005-2012 the rate of mass gain also increased with the global mean egg density during 14-27 May as recorded each year by the Delaware Bay Horseshoe Crab

Egg Monitoring Project. Therefore, for the range of global mean densities recorded during 2005-2012 (1,400-24,000 eggs / sq m in the top 5 cm of sand), the availability of eggs limited the ability of the birds to gain weight; that is, during those years eggs were not "super abundant", allowing the birds to make whatever mass gains they needed.

Over the 20 years, 1997-2016, recorded rates of mass gain did not change appreciably from year to year. However, in the middle years, especially 2003-2006, first capture dates were much later, and rates of mass gain failed to increase as would be expected. Therefore, controlling for the relationship with 1st date and 1st mass, rates were fairly constant during 1997-2002, dropped suddenly in 2003, remained low in 2005 and then gradually returned to their former level by 2009. Peak rates of mass gain were recorded in 2012 and 2014, but rates were significantly lower in 2015 and 2016. The period of low rate gains in the middle years coincided with a higher incidence of late arrival, as evidenced by the proportion of knots weighing <130g during 23-28 May.

In summary: the knots' ability to gain weight is constrained by the availability of horseshoe crab eggs. They especially suffered reduced rates of mass gain during the middle years of the study. Coincidentally that was a period when more birds arrived late needing to make higher mass gains which they failed to achieve. This indicates a failure of the food supply. Conservation actions should be aimed at increasing the density of eggs available to the birds to such a level that it is no longer a constraint on their ability to gain weight.

Evidence will also be presented showing that, towards the end of the Delaware Bay stopover, the weights of Red Knots caught in Mispillion Harbor tend to be lower than those of birds caught elsewhere in the bay. The most likely explanation is that more late arrivals go to Mispillion Harbor because it offers the best food supply, but other factors may also be involved.

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Mass gain in a spring-staging long distance migrant shorebird, the Red Knot C*alidris canutus*

Robert A. Robinson (British Trust for Ornithology) *et al.*

Migratory birds need to carry sufficient energy stores to fuel the next stage of their onward journey. This is a particularly important trait in shorebirds, for whom migratory 'hops' may be many thousands of kilometres, requiring substantial fat stores to be laid down. In many cases, these reserves need to be accumulated in short time-windows, especially on the northward, spring, migration, when there may be constraints imposed due to the need to arrive on the breeding grounds at a particular time. The West Atlantic population of Red Knot *Calidris rufa rufa* undertakes one of the longest migratory journeys of any bird, with some individuals travelling the length of the Americas from Tierra del Fuego to arctic Canada. Delaware Bay represents an important staging post for these birds and individuals increase their mass significantly in a short space of time before continuing their northward journey.

Mass through the season may vary for one of two reasons, either individuals may gain mass at different rates, or they arrive and/or start fattening at different times. Where groups of individuals follow the same strategy, these 'cohorts' should be identifiable from the weight data collected during banding. We assess the extent to which there is flexibility in mass gain strategies by identifying cohorts of birds with similar mass trajectories in each year. In many years, most individuals appeared to have similar patterns of mass gain, but in some years up to four 'cohorts' of birds could be identified. There was little change over time in the mean daily rate of mass gain of birds identified as starting to fatten early (before May 10th), but individuals that started to fatten later both gained mass more quickly through the season. There was little change in the rate of mass gain among early birds over the 20 years, but individuals that started to fatten later did so at greater rates in later years.

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Effects of food availability and diet on weight gain in Semipalmated Sandpipers in Delaware Bay during spring migration staging periods

David Mizrahi (Research & Monitoring, New Jersey Audubon Society)

Much attention has focused on the importance of horseshoe crab eggs for shorebirds staging in DE Bay. However, understanding the relative importance of this and other food resources is needed. We investigated the density and diversity of prey items available to Semipalmated Sandpiper (SESA) in three soft-sediment sites in DE Bay, determined diets of SESA using plasma metabolites and assessed the relative contribution of horseshoe crab eggs and soft-sediment prey to the accumulation of energy reserves using stable isotopes. Polychaetes and oligochaetes (high protein: lipid composition), made up 99% of all soft-sediment invertebrates we collected and ~92% of the biomass in 2011 and 2012, with biomass being significantly greater in 2011. The opposite was true of horseshoe crab eggs (high lipid: protein composition), whose densities were significantly greater along beaches and at the mouths of tidal creeks in 2012 compared to 2011. Inter-annual differences in relative food abundance appeared to result in plasma metabolite differences that suggest differential food consumption by SESA. Circulating uric acid, a by-product of protein catabolism, was 28% higher in 2011 than in 2012. Conversely, triglyceride levels, an indicator of lipid-rich food consumption, were 26% greater in 2012 than 2011. Importantly, rate of mass gain and mean fat mass across all captured individuals was significantly greater in 2012 compared to 2011. Together, these results suggest that SESA feeding on soft-sediment invertebrates gained less mass and at a slower rate than when feeding on horseshoe crab eggs. Conservation implications of these findings will be discussed.

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Mark-recapture based estimates versus aerial surveys of Red Knot abundance in Delaware Bay: comparing apples to orchards?

Paul A. Smith (Environment and Climate Change Canada), James E. Lyons & Conor P. McGowan

For Red Knots in Delaware Bay, the size of the passage population is used to inform management of the fishery for Horseshoe Crabs. As specified in the fishery's adaptive management plan, a mark-recapture based "superpopulation estimate" recently replaced an "aerial survey peak count" as the primary metric of annual abundance of Red Knots in Delaware Bay. The superpopulation approach offers significant advantages over the aerial survey approach in that it accounts for length of stay and probability of detection, so that the estimate reflects the full passage population size. However, discrepancies between some components of the estimate and the aerial- and ground-based survey results have raised concerns among some about the model assumptions. We discuss model assumptions, field methods, and potential refinements to data collection, or the model, that may increase correspondence between the various surveys. Results indicate that despite some temporal and spatial data collection inconsistencies, the model was robust to violating assumptions. Further, some of the disagreement may arise from inaccuracy in the aerial and ground-based surveys, due to counting error and unknown probability of detection. We carried out simulations using experienced shorebird aerial surveyors, and documented a negative bias from counting errors of 12-32% for the flock sizes typical in Red Knot surveys. Double observer methods in real surveys of Red Knots suggested a mean difference of 17% between the observers' estimates. Other studies report similar counting error in ground based surveys of waterbirds. When counting error and probability of detection during aerial and ground surveys are acknowledged, the discrepancy between methods may be small. A distinct advantage of the aerial- and ground-based surveys over the mark-recapture based approach, however, is the ability to describe the spatial distribution of Red Knots throughout the Bay; critical for understanding the locations requiring management and how these locations may vary over time. Consequently, we feel that the most efficient vision is for a monitoring program that emphasizes the unique strengths of the two methods, while addressing the important biases where possible through methodological refinements.

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Hard or soft-shelled prey? Migration strategy determines spatial distribution and resource use by an Arctic-breeding shorebird (Red Knot *Calidris canutus*) on their final spring stopover in Delaware Bay.

Philip W. Atkinson (British Trust for Ornithology), Allan J. Baker, Karen A Bennett, Nigel. A. Clark, Jacquie A. Clark, Kimberly B. Cole, Anne Dekinga, Amanda Dey, Simon Gillings, Patricia M. Gonzalez, Brian A. Harrington, Kevin Kalasz, Clive D.T. Minton, Jason Newton, Lawrence J. Niles, Theunis Piersma, Robert A. Robinson, Ines de Lima Serrano & Humphrey P. Sitters

Migrant shorebirds, such as Red Knot *Calidris canutus*, travel vast distances between their wintering and breeding grounds. In spring birds are under a severe time constraint to arrive in the breeding grounds in time and need to make optimal and strategic use of resources on staging areas en route. Between the second and fourth weeks of May, Red Knot arrive in Delaware Bay from wintering areas in Patagonia/Tierra del Fuego (TDF), north-western Brazil and the south-eastern USA (Florida and Georgia), and thus have to travel 12,000, 5,200 and 1,400 km respectively to the bay. Birds can either forage on soft-shelled crab eggs or hard-shelled mussel spat in the Atlantic marshes. Birds from different wintering areas exhibited spatial and temporal differentiation in their usage of food resources in Delaware Bay. By assigning birds to wintering areas using $\delta^{13}C$ and $\delta^{14}N$ values in feathers, we showed that birds caught feeding on mussel spat in the Atlantic marshes early in the migration period had a much higher proportion of short-distance migrants, whereas the lightest, latest arriving, birds were predominantly birds from Patagonia/TDF, which travelled the longest distance. Using birds collected under licence, we demonstrate that gizzard size (the muscular crushing organ) was reduced for migration for long-distance migrants but not for short-distance migrants. This allows short-distance migrants a choice of foods to feed on, whereas long-distance migrants, especially later arriving individuals, will have no choice but to feed on Horseshoe Crab eggs. Therefore, late in May, feeding solely on crab eggs is therefore the only viable strategy available to new arrivals.

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Importance of intertidal mudflats to foraging Red Knots and other shorebirds at Delaware Bay, New Jersey

Joanna Burger (Rutgers University) & Larry Niles

Shorebirds normally forage on mudflats that are exposed during low tide in many places in the World. However, the focus of most studies of shorebirds, especially Red Knots, during spring migration on Delaware Bay, New Jersey has centered around high tide because of the abundance of eggs from spawning Horseshoe Crabs (*Limulus polyphemus*). The eggs are concentrated at the high tide line. Most shorebirds were thought to roost during low tide on salt marshes or sand bars. However, given the short stopover time (less than 3 weeks), and the need to nearly doubletheir weight to reach northern breeding grounds, the importance of the intertidal to foraging has emerged as a central issue for Red Knots.

Three issues surround the importance of intertidal mudflats or salt flats to Red Knots during spring migration on Delaware Bay: 1) Do Red Knots use the intertidal? 2) When do they use the intertidal? and 3) What impediments are there for Red Knot use of the intertidal?

We examined shorebird use of exposed intertidal areas as a function of distance from the mid-high tide line (up to 300 m) at 14 Delaware Bay beaches in New Jersey in 2015, and at 5 key beaches in 2016. Understanding how Red Knots use the intertidal mudflat is important because there are permit requests to deploy oyster culture wracks within this space. Regardless of the tide stage, shorebirds were present on at least 35 % of the censuses in 2015, and 82 % of the censuses in 2016. In the two hours before and after low tide, shorebirds were present on over 86 % (2015) and 100 % (2016) of the censuses. As expected, shorebirds moved out on the mudflats as they became uncovered.

Red Knots (*Calidris canutus rufa*) were recently placed on the U.S. threatened list, making it important for management to understand how they use intertidal space. Red Knots were present on 24 % or more (2015), and 41 % (2016) of the censuses overall, and on 45-64 % (2015) and 41-74 % (2016) of the censuses in the 2 hours before and 2 hours after low tide. Knots moved farther out on the mudflats as they became exposed, although numbers of foraging knots decreased with distance from the mean high tide line. For example, in the three hours before low tide in 2015 knot numbers averaged 50 to 120 in the 101-200 m offshore segment, but there was great variation, indicating differences in overall flock size. These and other previous data indicate that the tidal flats along Delaware Bay serve an important function for the knots and other shorebirds.

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Horseshoe Crab Management in the Delaware Bay Region

Jordan Zimmerman (Delaware Division of Fish & Wildlife), Amanda Dey, Audrey DeRose-Wilson & Wendy Walsh

The Delaware Bay Region (NJ, DE, MD & VA) has a long history of Horseshoe Crab harvest, dating back centuries. Despite this lengthy history, formal coast-wide management of the species did not begin until 1998. Since 1998, management efforts have varied by state and have included emergency moratoria, license rescissions, harvest limits, and seasonal and area closures. Horseshoe Crab harvest in the Delaware Bay Region is managed through Addendum VII of the Atlantic States Marine Fishery Commissions Horseshoe Crab Fishery Management Plan. Addendum VII established the adaptive resource management (ARM) framework which uses

HSC and Shorebird data to select appropriate harvest levels from a suite of options. Since the adoption of the framework in 2012, a harvest quota for HSCs of Delaware Bay origin has been set annually at 500,000 male crabs. State-by-state allocation varies, and is based on the estimated proportion of Delaware Bay crabs in the harvest. The harvest of Delaware Bay origin

Horseshoe Crabs is limited to June 8 through December 31 (unless the quota is harvested). Despite the male-only harvest, there were no detectable impacts in the operational sex ratio on Delaware Bay spawning beaches. The Delaware Bay Horseshoe Crab Spawning Survey indicated stability in the spawning activity since 1999. Periods of peak spawning activity varied over the course of the 18-year time series, with peaks occurring after the departure of migratory shorebirds in one third of the years.

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Relative abundance of horseshoe crabs on the Delaware Bay: A factor affecting shorebird populations

David Hata & Eric Hallerman (Department of Fish and Wildlife Conservation, Virginia Polytechnic Institute and State University)

The spawning of horseshoe crabs (*Limulus polyphemus*) provides an abundance of high-energy food for Delaware Bay shorebirds. Hence, Delaware Bay horseshoe crabs are managed not only to sustain two fisheries, but also to sustain the threatened red knot (*Calidrus canutus rufa*). To properly manage the horseshoe crab stock, a time-series of data on relative abundance of all demographic groups is needed. We have conducted a trawl survey in the coastal Delaware Bay area since 2002 and the lower Delaware Bay since 2010, quantifying mean catch per 15-minute tow and tracking the dynamics of key demographic groups. Mean catch-per-tow of mature males were higher in 2016 than in previous years, although the confidence interval was large; mean catches of mature females were higher than in most previous years, but still lower than in 2008. Mean catch-per-tow of immature horseshoe crabs in the coastal Delaware Bay area has been variable since 2002 with no trend, and remained below the peak of 2009. Our findings are used by the Atlantic States Marine Fisheries Commission to parameterize the Adaptive Resource

Management model used to set harvest levels for horseshoe crabs, which are constrained in order to maintain a large spawning stock to support the foraging of red knots on their northward spring migration.

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The impact of restoring habitats for shorebirds and crabs on Delaware Bay

Joe Smith, Alek Modjeski & Larry Niles

Superstorm Sandy caused widespread degradation to NJ's Delaware Bay beaches as storm surge pushed sand from the beach face into adjacent marshes. This exposed underlying peat and rubble that reduced habitat suitability for spawning crabs. A post-storm survey revealed a 70% loss of optimal spawning habitat. This sudden degradation of beaches triggered a multi-partner effort led by American Littoral Society and Conserve Wildlife Foundation of NJ to restore high quality spawning habitat to benefit red knot and other shorebirds. Over the course of the four years since Sandy, the project has placed 200,000 cubic yards of sand on 8 beaches comprising 2.75 miles of shoreline and has removed more 2,000 tons of concrete rubble. The project team has tracked changes in beach morphology and the effect of restoration on shorebirds and horseshoe crabs. Using before-after, control-impact study design, we documented a two-fold increase in horseshoe crab egg cluster abundance between restored and adjacent unrestored beach sections. We found that increasing sand depth through restoration increases egg cluster abundance on beaches and that sand grain size has important effects on horseshoe crab spawning and egg development. Over the four-year restoration period, red knot weights have reached their highest level in 15 years and the stopover population has disproportionately used the NJ side of the bay. Ongoing studies of beach morphology and sand movement are documenting areas that are sources and sinks for sand. This and other monitoring data is informing an adaptive management process intended achieve more cost effective and lasting restoration outcomes with each iteration of restoration.

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Implications of sea level rise on the Delaware Bay stopover

Rick Lathrop & Joe Smith

Delaware Bay is fringed by extensive coastal marshes and mudflats that are typically fronted by a sandy barrier beach and backed by low dunes. The sandy barrier beaches overlay marsh sediments (generally a fibrous peat formed by the root mat of the marsh plants) and vary in thickness from a thin veneer to about 2 m thick. The Delaware Bay shoreline is very dynamic with active erosion and overwash. The intertidal portions of these sandy barrier beaches are of special significance as these are the locus of the horseshoe crab spawning activity and the shorebirds' foraging activities. In this paper we will review the role of both human land use and sea level rise on shorebird and horseshoe crab habitat quality and the implications of continued, if not accelerated, sea level rise. Using a combination of field surveys, remotely sensed mapping,

and geospatial modelling, we examine past and project future rates of change of the bay/marsh shoreline, interior marsh platform and the marsh/upland edge. The role of human land uses such as shoreline hardening, hydrological alteration, and salt hay farming are also examined. The long-term sustainability of the Delaware Bay stopover must be understood in light of the fact that this coupled beach and marsh system is not spatially fixed but rather continually shifting in response to rising sea levels, changing sediment supply and other coastal processes. In the short run, attempting to maintain existing bay side spawning beaches and coastal marshes in place makes sense but only while recognizing that in the long run we need to promote flexibility to allow their movement. Addressing the legacy of past human impacts through targeted intervention will help to facilitate this adaptation process.

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Utilizing community engagement for improved implementation of conservation actions on Delaware Bay

Laura Chamberlin (Delaware Bay Program Coordinator for the Shorebird Recovery Project, Manomet), Stephanie Feigin, Lisa Ferguson & Jane Morton Galetto

The Delaware Bay beaches in New Jersey present a model for conservation programs aimed at balancing the needs of arctic-bound migrating shorebirds with the communities of people that that use the beach. Disturbance from recreational and aquaculture related activities is a threat for foraging shorebirds. Mortality of horseshoe crabs from overharvesting, biomedical industry, and strandings and loss of spawning habitat due to climate change, sea level rise, and extreme storms also result in fewer foraging resources and opportunities for shorebirds. Community engagement is a necessary component of resolving these threats, ensuring effective implementation and building a constituency to support the regulation, municipal ordinances, and large scale restoration that are needed for conservation. Three key volunteer strategies will be reviewed- beach stewardship, reTURN the Favor, and hosting of Delaware Bay Shorebird Project team.

In order to reduce disturbance of feeding shorebirds, key foraging beaches were closed during peak migration season with municipal ordinances and state regulations. In 2003, in order to ensure effective implementation, an annual beach stewardship program was created to provide education and create social norms with a non-enforcement presence on the beaches.

Recognizing that one key reason people wanted access to beaches was to rescue stranded horseshoe crabs, reTURN the Favor was created as a sanctioned multi-partner, volunteer-based program working to rescue overturned or impinged horseshoe crabs on New Jersey's Delaware Bay beaches. Stewardship and citizen science projects, like reTURN the Favor, build a base of supporters through hands-on engagement and personal interaction. In addition, reTURN the Favor has secondary impacts on other key conservation actions that benefit shorebirds – reducing horseshoe crab mortality and restoration of spawning habitat.

Each year since 2006, Citizens United for the Maurice River volunteers have hosted the Delaware Bay Shorebird Project team, providing the visiting biologists and volunteers with food,

local culture, and additional support during their visit. The immediate impact is an alleviation of pressure on the team's budget, time, and stress; ensuring that they are able to focus on their research and have positive visit to the Delaware Bay which increases the retention rate for volunteers. For the local volunteers, they have a hands-on and personal experience while contributing their own expertise which builds a stronger connection to conservation here on the Delaware Bay and beyond that they can bring back to their own communities.

Each of these strategies focuses on making those personal, hands-on connections, which builds a local constituency that will be supportive of current and future conservation actions on the Delaware Bay. Lessons learned on the Delaware Bay can be utilized by other sites to assess the role that community engagement can have in reducing threats with measureable change.

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The Delaware Watershed Business Plan

Ian J. Davidson (Director, Birds and Wildlife Conservation, National Fish and Wildlife Foundation ian.davidson@nfwf.org)

The Delaware Bay's nearshore habitat serves as a critical stopover for migratory shorebirds including the threatened Red Knot (*Calidris canutus rufa*). Horseshoe crab (*Limulus polyphemus)* eggs spawned on beaches in May provide an essential energy source for survival and completion of the annual migration for Red Knots and dozens of additional shorebirds. These long distant migratory shorebirds occupy habitat that is important to other coastal migrants including Semipalmated Sandpiper (*Calidris pusilla*) and Ruddy Turnstone (*Arenaria interpres*). The harvest of horseshoe crabs for bait, the loss of habitat for spawning crabs, and the extraction of lysate from living horseshoe crabs for pharmaceuticals affect the availability of horseshoe crab eggs for Red Knots and other migratory species. An emerging threat to the spawning success of horseshoe crabs, and by extension, the habitat and energetic needs of Red Knots, is the expansion of oyster aquaculture. Recognizing the importance of the bay to global populations of migratory shorebird species and the ongoing threats to their survival, the National Fish and Wildlife Foundation convened local stakeholders to design a conservation investment strategy that addresses the needs of shorebirds within the context of the bay and the greater Delaware River watershed. Successfully implemented, the resulting outcome's focused strategy offers a unique landscape approach to the conservation of critical shorebird sites along the Atlantic Flyway.

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Does survival vary with migration distance? A case study using Red Knot

Philip W. Atkinson (British Trust for Ornithology), Nigel. A. Clark, Jacquie A. Clark, Kimberly B. Cole, Amanda Dey, Kevin Kalasz, Clive D.T. Minton, Jason Newton, Lawrence J. Niles & Humphrey P. Sitters

Long distance migration has often been associated with increased risk of mortality compared with migrants that undertake shorter migrations. Long-distance migrants may be more vulnerable to environmental change at stopover sites as well as stochastic events such as unsuitable weather conditions along the way. Red Knot arrive in Delaware Bay from wintering areas in Patagonia/Tierra del Fuego (TDF), north-western Brazil and the south-eastern USA (Florida and Georgia), and thus have to travel 12,000, 5,200 and 1,400 km respectively to the bay. Using stable isotope signatures in feathers, we can distinguish between the birds wintering in Patagonia/ TDF and the shorter distance migrants from SE USA and Brazil. During the migration studies in Delaware Bay, each Red Knot is individually marked with an encoded flag and a feather sample to identify wintering areas has been taken. By identifying each individual to a wintering area we can specifically test the impact of migration distance on annual survival.

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Long-term trends of wintering Red Knot populations in Tierra del Fuego, Brazil and Florida

R.I. Guy Morrison (Environment Canada)

Red Knots (*Calidris canutus rufa*) moving northwards through Delaware Bay during spring migration are considered to come from three distinctive and widely separated wintering areas: a southernmost group occurring principally in Tierra del Fuego, a group centred in northern Brazil in the Maranhao region, and a northernmost group occupying the southeastern USA. Since the groups are difficult to distinguish on migration in Delaware Bay, counts from the wintering grounds themselves provide important information on population size and trends of each group.

For the southernmost group, an estimated 96-98% occur in Tierra del Fuego. Estimates since 2000 have shown that the population has crashed, falling from over 50,000 individuals (steady since 1980s) to around 15,000-17,000 by 2010. In January 2011 there was another steep decline to around 10,000 birds, an overall decline of over 80% in 11 years. Since then, totals have varied between about 10,000 and 14,000 (13,130 in 2017). Thus, while there has not been a further disastrous decline, there has not as yet been any indication of a sustained recovery.

Less extensive information is available from the other wintering areas. Aerial surveys in northern Brazil produced totals of 8,191 in the 1980s, and 7,575 in the 2000s. The most recent estimate was made in 2013, when 15,485 were counted, the higher total resulting from better survey coverage. Published numbers in the southeastern USA have generally been less than 10,000.

Totals from the three wintering areas are broadly compatible with numbers thought to pass through Delaware Bay and the east coast of the USA in spring.

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Influenza studies of Delaware Bay shorebirds

David Stallknecht (University of Georgia)

Influenza research at Delaware Bay conducted by St. Jude Children's Research Hospital and the University of Georgia spans over 30 and 15 years, respectively. There is no indication that influenza viruses affect the health of shorebirds utilizing this ecosystem, but the value of information gained related to the epidemiology of these viruses at Delaware Bay has been immeasurable. Further, it provides a clear example of how science and scientists, through collaborative efforts and shared resources, can maximize and expand research productivity beyond individual disciplines or goals. In this case, research output not only includes the central objective of shorebird conservation but also contributes to basic and applied science relevant to both public and domestic animal health. The influenza research at Delaware Bay is too broad to summarize in an abstract but includes diverse topics such as understanding influenza/host interactions, understanding influenza virus transmission, providing unique viruses that support viral phylogenetic and pathogenesis studies worldwide, documenting viral movements during migration (and understanding this potential), and exploring subtype diversity patterns related to population immunity. Delaware Bay and the shorebirds using this site represent a priceless gem related to understanding the field epidemiology of influenza viruses in wild birds, and there is every desire to continue this work into the future.

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What do geolocator data tell us about the importance of Delaware Bay in the West Atlantic Flyway?

Ron Porter, Joanna Burger, Larry Niles & Stephanie Feigin

The most important two questions surrounding Delaware Bay and shorebirds are: 'How many birds stop in the bay each year?' and 'Is Delaware Bay the most effective place to aid them?' Geolocators have provided a scientific basis for answering these questions.

How many birds are there?

The passage population can be estimated using census data, but the calculation requires data on duration of stay. This can be measured directly by geolocation and used to confirm statistical models based on direct observation of individually marked birds. Geolocators show the number of days a bird is present before it is first resighted, and the number of days after it is last seen. Peak counts are useful to estimate if the passage population is declining or growing, but are sensitive to the unknown proportion of birds that may skip the bay one year, and return the next.

How much does this proportion vary from year to year? Geolocators have the potential to illuminate this parameter.

The fact that birds from different wintering areas may behave differently adds to the complexity of calculating population size. Geolocators have shown that it is not uncommon for Florida-wintering Red Knots to fly direct to Hudson Bay, or otherwise bypass Delaware Bay. But South American winterers seldom miss the Delaware Bay stopover.

Where do the birds go?

The relative importance of Delaware Bay to shorebirds depends on the importance of other sites. There are three main questions: Are problems at other sites responsible for declines? Are there other sites available on which the birds might rely to replace stopping over in Delaware Bay? Are there other sites where our efforts might be more effective?

To answer whether there are problems at other sites, we must first know where they are. The prime function of geolocation provides this knowledge, and then fieldwork, either by visiting or by contacting local sources, provides the answer. Geolocators identified the wintering areas, breeding areas, and stopovers from the Canadian North to Tierra del Fuego, and the dates of presence needed to plan expeditions.

Expeditions have been mounted to Argentina, Brazil, Canada, Florida and the Carolinas, and elsewhere. After so many years of investigation, no greater threat to shorebirds has been found than the loss of horseshoe crab eggs in Delaware Bay. In addition, geolocator data showing the number of days birds incubated eggs indicated predation in the arctic was not particularly high.

The question whether the birds use alternative stopover sites can also be investigated using geolocator data. Geolocators not only provide us with knowledge of where to look, but by the length of stay suggest the relative importance of each site. Furthermore, because geolocators provide a record of the salinity of a bird's environment, we may also learn which habitat at each location is frequented, and, if more than one habitat, how much time is spent in each.

The answer to the last question – Are there other sites where our efforts might be more effective? – depends on the nature of the problem encountered. We cannot hope to change bad breeding weather in the arctic, but agricultural poisoning in South America, and subsistence hunting in Surinam are problems that can be addressed. Despite two decades of research and the added insight provided by geolocators, the conservation of the Delaware Bay spring stopover is still seen as one of the most important objectives in the West Atlantic Flyway. It is not beyond our reach, but it requires sustained long-term effort.

Promoting conservation

How can we get the public's attention? Nothing is better, or more visual, than a geolocator map showing the migration schedule of a Red Knot that winters in Tierra del Fuego and breeds in the Canadian Arctic.

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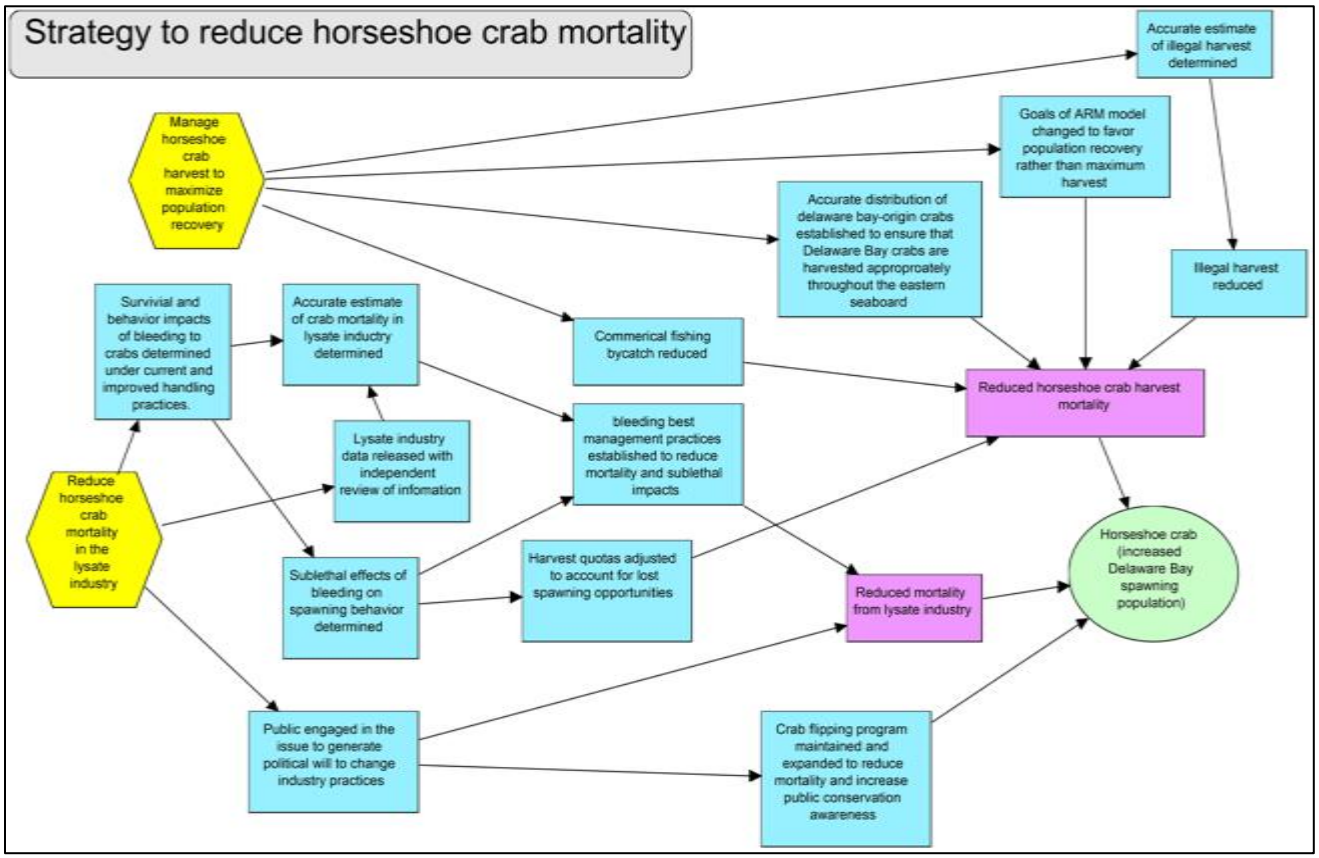
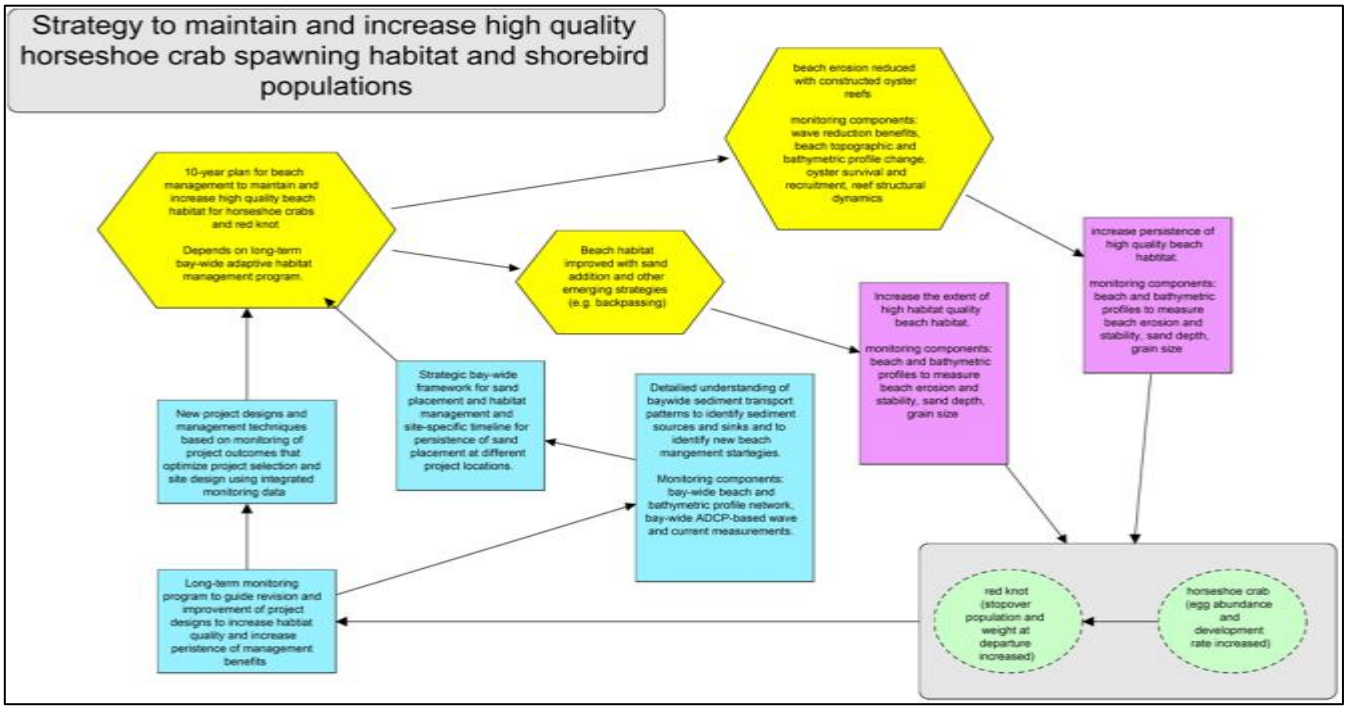
Example of Strategy Diagrams:





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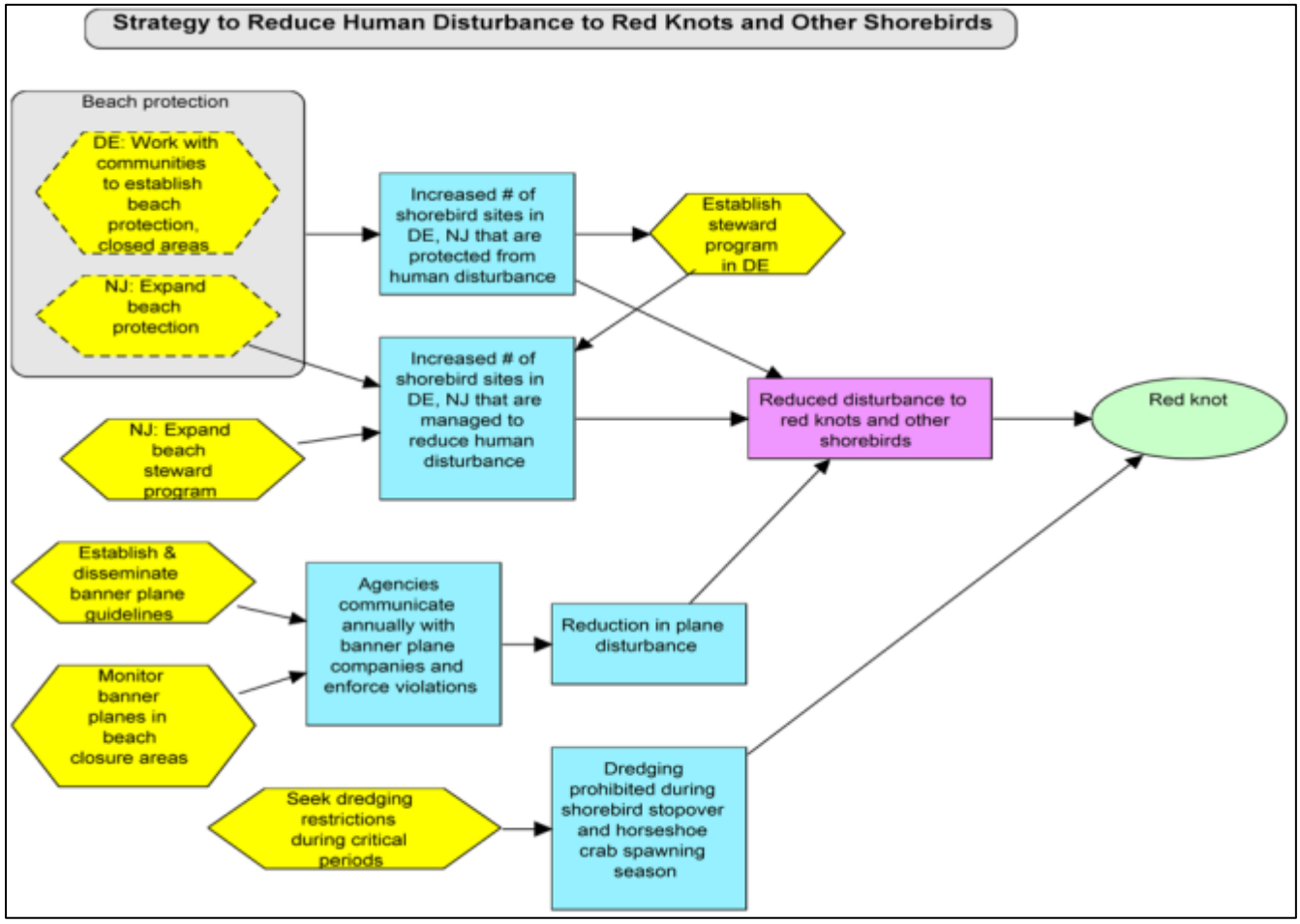

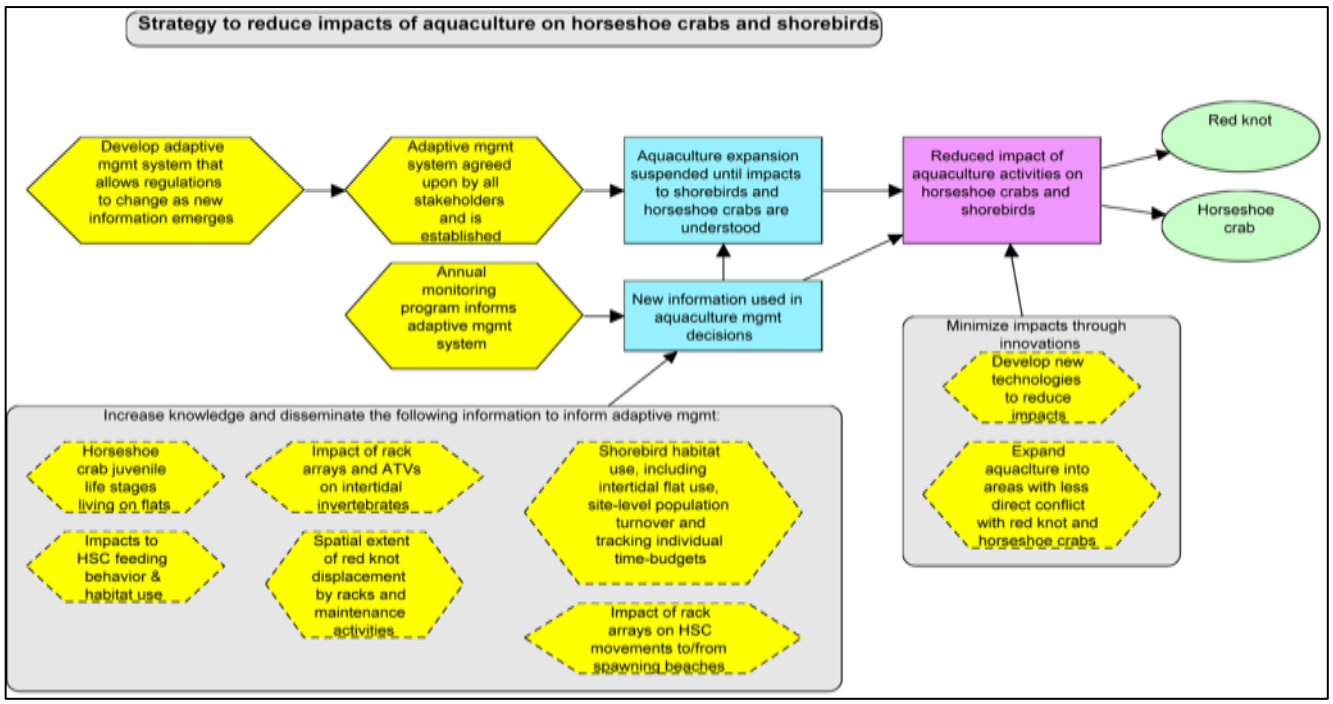

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Thank you to our workshop partners

And a special thank you to all of our presenters and volunteers for supporting twenty years of research on the Delaware Bay.