Delaware Bay Shorebird-Horseshoe Crab Assessment

Conclusions and Recommendations to the Horseshoe Crab Management Board of the Atlantic States Marine Fisheries Commission

Shorebird Technical Committee
Peer Review Panel

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I. Purpose and Approach

The Atlantic States Marine Fisheries Commission asked the U. S. Fish and Wildlife Service to form a Shorebird Technical Committee that would provide technical guidance, regarding effects that horseshoe crab management actions could have on shorebird populations, to the Horseshoe Crab Management Board. One of the immediate tasks of the Shorebird Technical Committee was to produce a peer-reviewed report that synthesized unpublished and published information on shorebird population trends, threats to shorebird populations, shorebird habitat use, shorebird energetic requirements, and horseshoe crab egg abundance. Although several shorebird species were considered in the report, attention primarily focused on the red knot (*Calidris canutus rufa*). Available information was greatest for the red knot and was less extensive for the ruddy turnstone (*Arenaria interpres morinella*), sanderling (*Calidris alba*), semipalmated sandpiper (*Calidris pusilla*), and least sandpiper (*Calidris minutilla*). Relatively little information existed on the dunlin (*Calidris alpina hudsonia*) and short-billed dowitcher (*Limnodromus griseus griseus*). Aside from the least sandpiper, which was chosen because of its contrasting use of marsh habitats, all other species were selected because of their reliance on beach habitats and their frequency of occurrence on Delaware Bay aerial surveys (1986–2002). After reviewing the report, the Committee has generated this set of conclusions, management recommendations, and information needs. The Committee used a concordance, or preponderance, of evidence approach to evaluate the report's contents. The report, conclusions, and recommendations were evaluated by an independent Peer Review Panel, and their comments are included here as bolded text.

II. Long-distance Migration in Shorebirds

Many populations of shorebirds undertake a series of long-distance, non-stop flights to travel between their wintering and breeding grounds. Because a shorebird often crosses vast stretches of open water during migration, physiological and environmental conditions on departure can directly, and immediately, affect its survival. The red knot is an extreme example of the long-hop migration system and has one of the longest migrations of any bird. Besides adding 50% of their body weight in fat reserves, red knots at Delaware Bay, and elsewhere, exhibit major internal organ changes in response to the need to first accumulate fat and later to reduce flight mass. The long-hop migration system of red knots, and other shorebird species, is highly dependent on food availability at a limited number of stopover sites. Failure to gain sufficient body mass at stopover sites, often during a short time span, can impair the health, productivity, and survival of migrant shorebirds. Because arctic breeding grounds are generally food limited in early summer when shorebirds first arrive, food-rich stopovers in the north-temperate region are particularly important. At these sites, shorebirds are often under relatively strict time constraints to add needed fat reserves.

III. Conclusions

A. Shorebird Use of Delaware Bay

Delaware Bay has been recognized by many scientists and organizations as one of the most important and critical shorebird stopovers in the Western Hemisphere and, indeed, in the world. Depending on the species, between 12 and 80% of the Atlantic flyway population of the six beach-inhabiting shorebirds mentioned above (excluding least sandpiper) can be observed on Delaware Bay's beaches during northward migration. Far fewer numbers of shorebirds pass through Delaware Bay during southward migration. For a given species, the proportion of the population that uses Delaware Bay each spring may vary substantially among years. Compared to 1986–1996, average shorebird use of Delaware Bay beaches, as measured by seasonal maxima of aerial survey counts, has increased or remained stable during 1997–2002 for all six beach-inhabiting species. During their northward migration in the Delaware Bay region, most shorebird species use marine-influenced habitats — either salt marshes, tidal flats, or sand beaches.

The Peer Review Panel generally agrees with these conclusions, except that a more sophisticated analysis of the Delaware Bay shorebird use time-series data could have been conducted. Data on shorebird-use days could be useful in constructing a total energy budget for all northward-migrating shorebirds. The importance of accessible roosting sites to migrant shorebirds is not mentioned.

B. Shorebird Population Trends

Based on a variety of sources, all available data indicate that the *rufa* red knot population has decreased since the 1980s, but the magnitude of the decline is not precisely known. Besides the red knot, the semipalmated sandpiper is the only other Delaware Bay shorebird species that has relatively consistent patterns of population decreases among trend datasets. Because of unknown turnover and detection rates, aerial survey data from Delaware Bay are not useful for estimating population sizes of shorebirds in Delaware Bay.

The Peer Review Panel agrees that, although imperfect, patterns in the trend analyses reasonably indicate a decrease, of some magnitude, in populations of *rufa* red knots and semipalmated sandpipers. Most surveys of wintering and migrating red knots do not cover the needed range of the population and complicate interpretation of changes in populations at specific sites. Analytical methods used to summarize ISS data also lack rigor and may only reveal general patterns of population change. Current and future surveys of shorebird populations should undergo rigorous statistical review.

C. Shorebird Population Threats

The Shorebird Technical Committee evaluated information on the potential threats to shorebird populations across their annual cycle. Testing for contaminants in shorebirds and crabs indicates that metals and pesticides are not likely causing population reductions in shorebirds. Little information exists on disease and parasite occurrence in red knots, particularly in Delaware Bay, but there is no current evidence to suggest that these are major, potential problems. Although environmental conditions vary considerably from year to year, arctic breeding habitats do not appear to have changed in ways that would likely contribute to the observed reductions in red knot survival and productivity. More information is needed to assess the effects that weather and predation in the arctic have on *rufa* red knot population dynamics. Arctic environmental conditions should also be evaluated for semipalmated sandpipers. Habitat conditions in wintering areas have numerous potential threats, but these are not believed to have currently affected key wintering sites. Food availability, however, has only been measured at a few South American wintering or stopover sites. Beach nourishment is not having a negative effect on shorebird use on Delaware beaches and is likely improving habitat quality; beach nourishment is not widely practiced in New Jersey. Although no Bay-specific studies have been conducted, repeated human disturbance likely reduces shorebird feeding efficiency in Delaware Bay. Elsewhere, migrant shorebirds have been disturbed by dogs, self-propelled human recreation, and vehicles. Human disturbance to semipalmated sandpipers feeding along the coast of Massachusetts as they prepared for a long over-water flight, reduced their subsequent survival. Gulls can potentially reduce food availability to shorebirds through direct and indirect competition for crab eggs. Shorebirds, however, most often forage with other shorebirds, and preliminary data and

field observations suggest that the number of gulls using Delaware Bay beaches has not substantially increased in recent years. Lastly, reduced numbers of horseshoe crab eggs available for shorebird consumption, relative to the early 1990s, could reduce survival and reproductive success in the six shorebird species that use Delaware Bay as the last stopover prior to departing for their breeding grounds (see following sections).

The Peer Review Panel agrees that contaminants and parasites do not currently appear to provide a major threat to shorebirds stopping at Delaware Bay. Further information is needed to thoroughly evaluate whether or not changes in habitat quality on the breeding and wintering grounds are contributing to declines in shorebird populations. However, changes in breeding or wintering area conditions do not minimize the importance of maintaining high quality north-temperate stopovers. Information presented in the report is insufficient to determine if beach nourishment generally improves habitat quality for spawning horseshoe crabs and foraging shorebirds. Although numerous studies have demonstrated the immediate, disruptive effects of human disturbance to migrant shorebirds, ultimate effects of disturbance on survival of shorebirds are not well-documented and are usually inferred (including the Massachusetts semipalmated sandpiper study referenced above). Increases in gull numbers do not superficially appear to have direct or indirect influences on shorebird population changes, but more quantitative information on effects of interference and exploitative competition between gulls and shorebirds is needed. The life history of long-distance, long-hop shorebird migrants indicates that the availability of abundant food resources at north-temperate stopovers is critical for completing their annual cycle.

D. Shorebird Use of Horseshoe Crab Eggs

The importance of Delaware Bay as a spring shorebird stopover is likely due to the unique and important food resource — horseshoe crab eggs. A variety of methods (stomach analyses, captive feeding studies, and field observations) indicate that horseshoe crab eggs are a variable component in the diet of numerous invertebrates and vertebrates (shorebirds, other birds, fish, and turtles). Birds, and particularly shorebirds, are important predators of crab eggs. Stable isotope analysis indicates that red knots are highly dependent on horseshoe crab eggs. Isotope analysis of other shorebird species is currently underway. Red knots feed by pecking at surface eggs and making shallow probes into beach sediments. Captive knots fed exclusively eggs gained weight at rates that were similar to those observed in wild birds. Egg consumption was estimated at 18,000 eggs per day and rates of knot weight gain ranged from 2.6 to 8.0 grams per day while they were in Delaware Bay. Daily weight gains of *rufa* red knots in Delaware Bay are the highest reported for any stopover site or knot population. At other stopovers throughout the world, knots generally feed on molluscs or bivalves. Although Bay beaches were reported to have low invertebrate prey densities, detailed evidence does not exist to thoroughly evaluate whether or not alternative shorebird foods exist in high

enough abundances to meet the energetic needs of red knots and other migrant shorebirds while in the Delaware Bay region.

The Peer Review Panel believes that the importance of Delaware Bay to shorebirds is due to a number of factors such as an abundant primary food resource (crab eggs), the availability of secondary food resources, and availability of safe roost sites. Stable isotope analysis indicates that red knots feed almost exclusively on horseshoe crabs while at Delaware Bay. Although this result does not necessarily indicate a "dependency" on this food, crabs should be assumed to be critically important unless a viable alternative prey base is shown to exist. A comprehensive review of migrant shorebird foraging behavior and diet is needed to thoroughly evaluate the importance of Delaware Bay, and its food resources, to shorebirds; caloric value of alternative foods should be determined. No information was presented on the specific egg or larval life stage was being consumed by shorebirds. Foraging behavior of knots, in particular, at sites other than Delaware Bay could provide insights into the importance of the Bay's horseshoe crabs to shorebirds. The habitat section of the report should have included more information, if available, on the correlation between beach use by shorebirds and the distribution of horseshoe crab spawning females and eggs.

E. Availability of Horseshoe Crab Eggs

Although a sampling plan has been devised, no Bay-wide, systematic survey of egg availability has yet been conducted. Geographically limited surveys conducted in May, variably over the last four years, do not provide conclusive evidence of a trend in the abundance of surface eggs available to shorebirds. Likewise, there are not ample data to assess whether or not surface horseshoe crab eggs occur in abundances that will support Delaware Bay populations of migrant shorebirds. Although counts of spawning crabs have not changed between 1999 and 2002, trawl survey indices of all age-classes of crabs are now lower than they were in the early 1990s. Further analysis of egg data collected on New Jersey beaches and additional information on the temporal and spatial distribution of surface and sub-surface eggs is needed to thoroughly evaluate if there has been a significant trend in horseshoe crab egg abundance. Further refinement of the total shorebird energy budget is needed to determine how many eggs are required across the entire spring season.

The Peer Review Panel believes that knowledge about the spatial and temporal patterns of horseshoe crab egg densities is critical to understanding how crab management affects migrant shorebird populations. Specifically, a clearer understanding of how eggs become available to shorebirds is needed. Energetic considerations indicate that horseshoe crab eggs are only profitable to shorebirds if they occur in high surface densities. The excavation and transport of eggs to the beach surface might only occur when spawning females occur in very high densities, and there may be a threshold female crab density at which sufficient numbers of

eggs become available on the surface. Little appears to be known about the depletion of surface eggs attributable to shorebird, and other bird, predation. Depletion of surface eggs would be consistent with the hypothesis that crab eggs are a limiting resource for shorebirds. The Panel agrees that information from trawl surveys, given gear limitations for adequately sampling large numbers of crabs, indicates that horseshoe crabs in Delaware Bay are currently at lower levels than they were in the early 1990s. Uncertainty in recent estimates of sizes of horseshoe crab age classes precludes reasonable comparison of recruitment rates and harvest levels. The report would have benefitted from thorough analyses of datasets already collected on changes in egg densities on New Jersey beaches. An unified bioenergetics model for Delaware Bay shorebirds will be needed to integrate the information about available food with the requirements of shorebirds.

F. Shorebird Weight Gain in Delaware Bay

There is agreement that a smaller percentage of *rufa* red knots are making threshold departure weights by the end of May in recent years. These results are not dependent on inclusion of 1997, a year when shorebird-banding did not begin until 22 May. The different analytical approaches used to determine weight gains of Delaware Bay red knots (average weights of time-dependent catches, cohort analysis, and individual recaptures) have generated two hypotheses regarding decreases in rates of weight gain between 1997 and 2002 — either a greater proportion of red knots are arriving later in Delaware Bay in recent years, or red knots are increasingly unable to find sufficient food. In the first analytical approach, rates of weight gain in knots decreased through time, but in the latter two approaches they did not. Evidence suggests that rates of weight gain by semipalmated sandpipers have decreased in recent years, while rates of weight gain in least sandpipers, a more marsh-foraging species, remained stable. Patterns of decreasing (average) rates of weight gain were less consistent for ruddy turnstones and were not apparent in sanderlings. Ruddy turnstones can excavate eggs to feed on, and sanderlings are thought to commute regularly between Atlantic Ocean and Delaware Bay feeding sites. No hypotheses, as an alternative to decreased horseshoe crab egg availability, have been formulated to explain changes found in weight gains of semipalmated sandpipers. Semipalmated sandpipers do not winter in the same regions of South America as red knots. More information on the condition of South American stopovers and observations of individually marked birds are needed to fully discriminate between these two alternatives. Late arrival of knots could be caused by changes in spring weather patterns or by their inability to build fat stores at South American stopovers. Red knots can physiologically compensate for late arrival by increasing their rates of fat deposition while in Delaware Bay.

The Peer Review Panel believes that the two hypotheses forwarded to explain changes in weight gain in Delaware Bay red knots are not mutually exclusive, but instead represent two factors which operate in tandem to affect departure weights from Delaware Bay. Both factors operate within the same year, although their

relative importance may vary among years. The existing data, however, are not adequate to evaluate their relative importance for any year of record. But in any case, Delaware Bay must provide the food resources shorebirds need to adequately gain fat mass to make the flight to the arctic. That a lesser proportion of red knots are making minimal departure weights suggests that food resources in Delaware Bay may not be adequate. Similar feeding rates observed among species of different size supports the finding that the larger red knots should be most sensitive to decreases in food availability. The shorebird banding program in Delaware Bay would greatly benefit by a more cooperative approach to design and analysis. Procedures used in both analyses of weight gain were not documented adequately enough in supporting reports to allow independent evaluation. Patterns of weight gain were more clearly presented for semipalmated and least sandpipers. Unfortunately, attempts to estimate growth rate based on independent samples of body mass are inherently flawed, as assumptions must be made to accommodate the uncertainty in arrival times of birds. These assumptions lead to the possibility of conflicting results and additional controversy. Adjusting field methods to emphasize the collection of multiple measurements on individual birds would increase the sample of individually-marked birds and would ultimately strengthen conclusions about annual changes in rates of weight gain.

G. Shorebird Survival

Shorebird return rates (on southward migration) relative to stopover departure weights indicate that the inability to gain sufficient weight at stopover sites can reduce survivorship for red knots (*Calidris canutus*) and semipalmated sandpipers (*Calidris pusilla*), which supports the link between stopover conditions and population trends. Recent estimates of adult survival and productivity of *rufa* red knots are substantially lower than estimates for knot populations wintering in Europe and Australia; these knot populations also breed in arctic regions and undertake long-distance, long-hop migrations. Sustained low levels of vital rates could cause a drastic decline in the knot population. Evidence generated through population modeling, however, was insufficient to evaluate the probabilities of extinction under the current range of demographic values.

The Peer Review Panel supports the conclusion that low-weight red knots had a lower return rate, but found the estimates of adult survival to be highly variable among periods. Further details of the analytical procedures used for estimating survival rates are needed to thoroughly evaluate these results for application to management decisions. To fully evaluate the biological significance of survival rates and juvenile ratios, better information on non-breeding distribution and movements of juveniles is needed. Because estimates among years were from different sites, the variability of these estimates among sites should be evaluated. Overall, the Panel believes that design and analysis of future mark-resight/ recapture studies could be improved to remove ambiguities in interpretation of results and to take better

advantage of the large number of banded birds. Use of field-readable, individually-numbered color flags should be thoroughly evaluated.

IV. Recommendations

Horseshoe crab management actions already taken (for example, bait bags, harvest reductions, alternative bait development, designation of the Carl N. Shuster, Jr. Horseshoe Crab Reserve) have likely improved conservation of crabs and shorebirds. Despite these actions, and the stability of spawning horseshoe crab numbers over the last four years, the population of red knots, and perhaps other species, has declined. As a general management action, the U. S. Shorebird Conservation Plan suggests that any declining shorebird population should be stabilized and then restored to population levels of the late 1970s and early 1980s. Accordingly, shorebirds in Delaware Bay should be managed to maintain current population sizes, and decreasing populations should be stabilized and then increased.

Based on the shorebird and crab information currently available, the Shorebird Technical Committee therefore recommends that the Horseshoe Crab Management Board pursue a management strategy that is more risk-averse to shorebirds. Using an adaptive approach, continued or improved monitoring programs for shorebirds, horseshoe crabs, and horseshoe crab eggs are needed to evaluate results of management actions and to provide guidance for future selection of management alternatives. The Shorebird Technical Committee supports the cooperative effort of the Horseshoe Crab Technical Committee and the Horseshoe Crab Stock Assessment Committee to develop and implement various crab surveys. Specific recommendations of the Shorebird Technical Committee follow, which were generally supported by all Committee members. Peer Review Panel comments are also included, as bolded text, below.

A. Direct Management

1. Until further information is available on whether or not current egg abundances are sufficient for shorebirds to reach threshold departure weights, the Committee recommends further reductions in bait landings for New Jersey, Delaware, and Maryland. Although the Committee realizes there currently are no biological reference points on which to base reduction amounts, total reductions in the range of 50 to 75% below the Reference Period Landings might be considered. Committee members could not reach consensus on the amount of reduction, if any, that would be considered risk-averse. Because crabs caught in Federal waters from New York and to Virginia ca be landed in any of the mid-Atlantic states, in New York and Virginia might also be considered. Mandatory use of bait bags and development of alternative baits could contribute to reduced bait use of horseshoe crabs.

The Peer Review Panel supports a reduction in harvest but suggests that this action be viewed as an interim solution until integrated and comprehensive models are constructed to set reasonable biological objectives for shorebirds. Although the Panel is unsure about the amount of the reduction that is immediately needed, the numerous indications of shorebird population declines suggests that harvest rates should be at or below the current levels. Based on very limited data, a 75% reduction would ensure recruitment of female crabs into the breeding population at the low bound of the population estimate of primiparus female crab; a 66% reduction would allow no population growth at this level. Development of conservation methods to use bait crabs most efficiently is worthwhile. Landings in states other than New Jersey, Delaware, and Maryland should be carefully tracked.

2. To increase abundance and availability of horseshoe crab eggs for feeding shorebirds, restrict hand harvest of horseshoe crabs, vehicles, humans, and dogs on State- and Federally-owned beaches important to shorebirds from 1 May to 7 June, the period of highest shorebird use, along the Delaware Bay shoreline of Delaware and New Jersey. Evaluate the effectiveness of restrictions.

The Peer Review Panel believes that this is a reasonable short-term action to increase the number of horseshoe crab eggs available to migrant shorebirds. Evaluation of these restrictive measures should be undertaken.

3. Encourage Delaware and New Jersey to continue environmentally responsible beach nourishment and other enhancement projects that increase high quality habitat for spawning crabs and feeding shorebirds. Consider long-term protection measures, including easements and acquisition, for beaches that are important for crab spawning and shorebird foraging. Evaluate the effectiveness of beach enhancement activities.

The Peer Review Panel believes further evaluation of the effects of beach nourishment on horseshoe crab spawning and invertebrate infauna are warranted before broad-scale activities are undertaken. If results of these evaluations, preferably using a before-and-after experimental design, are favorable, specific prescriptions of "environmentally responsible" practices should be developed. Evaluations and prescriptions should be sensitive to the geographic scale of application. Long-term protection of beaches would likely be a beneficial conservation measure.

B. Needed Analyses

1. Complete analyses of horseshoe crab egg abundance data that have already been collected on New Jersey beaches to further evaluate evidence of a change in egg abundance.

2. Compile information on annual weather conditions and predation pressure on breeding grounds to assess short- and long-term effects on red knot survival and reproduction and on semipalmated sandpiper population change. Report information on density, hatching success, and habitat use on breeding grounds.

3. Complete stable isotope analysis for remaining Delaware Bay shorebird species to quantify their dependence on horseshoe crab eggs. Develop the best possible estimate of the total energy needed and horseshoe crab eggs required by all migrant Delaware Bay shorebirds. Complete analysis of information on alternative foods available to Delaware Bay shorebirds to determine if other energy sources exist that could supplement horseshoe crab eggs. Report on role of nocturnal foraging.

The Peer Review Panel encourages efforts to expedite the reporting and analysis of all previously-collected data pertinent to topics addressed in the report. The Panel also encourages the involvement of biometricians in these analyses.

C. Improved Monitoring and Research

1. Support implementation of the Bay-wide egg survey to determine abundance of, and ultimately trend in, horseshoe crab eggs on Delaware Bay beaches. Information is needed on egg deposition and movements to understand what makes eggs available to shorebirds on Delaware Bay beaches.

2. Continue, and expand, the aerial survey of South American wintering grounds of red knots to identify additional concentration areas and track population changes. Include areas with winter aggregations of semipalmated sandpipers. Develop and evaluate other counting and demographic methods to track populations of shorebirds.

3. Increase marking and scan-sampling of red knots on wintering grounds and in Delaware Bay to track changes in population size, annual survival, and reproductive success. Expand efforts to include semipalmated sandpipers. Use individually color-flagged and radio-tagged shorebirds to determine movements into and within Delaware Bay to evaluate the late-arrival hypothesis.

4. Continue to monitor shorebird weights in Delaware Bay, while minimizing disturbance to foraging shorebirds. Agree on standard data collection techniques, for both sides of Delaware Bay, and record wing length and time after capture that weighing takes place. Develop a common, Bay-wide database and agree on analytical approaches.

5. Assess habitat quality of stopovers south of Delaware Bay to determine if South American sites are providing enough food resources for migrant red knots and other shorebird species to gain the weight needed to undertake trans-ocean flights.

The Peer Review Panel believes that virtually all management, research, and monitoring programs would benefit from being placed within a more holistic and comprehensive framework in which models are used to provide coherent structure for both combining existing information and predicting consequences of management activities. Currently, many of the research and monitoring efforts are fragmented and isolated, and it is unclear whether appropriate information is presently collected to best aid management decisions. The Panel encourages the Shorebird Technical Committee to work with all partners and stakeholders to develop a more comprehensive and integrated research and monitoring program. Theoretical models should be developed for core components of this program that would include: 1) integrated shorebird energetics and horseshoe crab egg availability, 2) shorebird demographics, and 3) monitoring design and analysis. Even in the absence of detailed quantitative information, explicit, well-developed models can illustrate the most likely explanatory hypotheses, identify speculative and real data linkages, highlight key gaps in current knowledge, and clarify specific goals and objectives. For many of the research and monitoring components, more emphasis should be placed on the use of information collected on individually-marked shorebirds, including radio-tagged birds. A premium should be placed on the development of robust survey and experimental designs.

V. Shorebird Technical Committee

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