the significant amount of work that has already been accomplished by scientists throughout the western Atlantic flyway. In Delaware Bay, the departure mass of Red Knots has been linked to survival rates and would serve as a key indicator of the vitality of the stopover. Weight gain achieved is primarily influenced by the availability of food resources (horseshoe crab eggs) and weight on any particular date is a function of that as well as arrival date and arrival condition. Therefore, these interrelated effects need to be monitored carefully.

A bay-wide survey of crab eggs was implemented in 2004 after 5 yr of similar surveys conducted on the New Jersey side of the bay. Moreover a bay-wide survey of spawning crabs has also been conducted since 1999 and could serve as a useful counterpart to the egg survey. Finally, a count of shorebirds on the bay has been conducted by New Jersey Fish and Wildlife since 1986. The best monitoring tool for the long term is a model based on four main parameters: shorebird numbers, egg densities, crab numbers and departure-weight profiles.

Survival rate is a critical input into long-term modeling of the population. Banding with individually identifiable flags allows for yearly assessment of the survival of birds coming through the Delaware Bay. Ultimately, banding in each of the three major wintering areas, Tierra del Fuego, Maranhão and the southeastern U.S., coupled with stable isotope studies will help distinguish survival rates related to each. A continued focus on resighting flagged birds must be a key element of monitoring, at least until recovery is assured.

With populations of shorebirds and crabs in Delaware Bay at such low levels, departure weights may also be influenced by competition for eggs from other species, particular Laughing Gulls, as well as disturbance especially in areas of high egg density. Therefore, in the short term it will be necessary to monitor disturbance and gull populations as inputs into the model based primarily on the four parameters mentioned above. Ultimately, the model could help decide the size of the horseshoe crab harvest for bait or as a source for lystate that is consistent with maintaining the shorebird population. The goals of management in Delaware Bay should be: (1) that the majority of the Red Knots (>80%) reach a departure weight of at least 185 g by the end of May, and (2) the peak stopover population of Red Knots increase to at least 100,000 as it was in the 1980s.

More comprehensive monitoring of the effect of management on the Red Knot population will come from the continuation of yearly counts in the primary wintering areas. The Patagonia counts have been carried out every year since 2000 allowing direct comparison with the population size at the time of the first comprehensive survey in the mid-1980s. A new count was carried out along the coast of Maranhão, northern Brazil, in February 2005 and if this can be repeated regularly, it too may serve as a useful measure of recovery. The wintering population in the southeastern U.S. must also be monitored with the same intensity as in Patagonia. The Florida Division of Fish and Wildlife intends to restart a coast-wide survey of shorebirds, first conducted in 1996. This survey, or at least that part that relates directly to Red Knots, should be conducted every year.

The population of Red Knots breeding in a study area of 9.2 km^2 on Southampton Island in arctic Canada was surveyed from 2000 to 2004. During this time it fell from about 1–0.3 nests/km^2. No survey was possible in 2005 due to lack of funds. These surveys are logistically challenging and costly and this means that it is difficult to expand them to an area of sufficient size to make year-to-year comparisons statistically robust. However, they would be a useful means of measuring recovery. Therefore, if at all possible they should be continued in order to monitor future change. The nest densities of Red Knots can be compared with those of other species to determine whether population change is likely to be the effect of arctic breeding conditions or factors affecting them elsewhere.

CONSERVATION GOALS AND THE SURVEYS, MONITORING, RESEARCH, AND MANAGEMENT NEEDED TO SUPPORT THEM

Brown et al. (2001) proposes a tentative target for restoration of the *C. c. rufa* population to 240,000. Though we agree that this would be desirable and would ensure *C. c. rufa*'s future, it does not now seem to be realistic. Moreover, no evidence exists that the population was ever that large. Overall the goal of conservation activities throughout the flyway should be to increase the *C. c. rufa* population to at least the figure of 25 yr ago of 100,000–150,000 by 2015. Given the uncertain genetic relationships between the three main wintering populations, there should also be a target for each. The following are suggested: (1) Tierra del Fuego wintering population increased to 70,000–80,000 birds, (2) Brazilian wintering population increased to 20,000–25,000, (3) Florida wintering population increased to 20,000–25,000, and (4) other sites increased to 15,000–20,000.

The means whereby such population increases might be achieved include:

1. Recovery and maintenance of Delaware Bay horseshoe crab egg densities at levels sufficient to sustain stopover populations of all shorebirds including 100,000 Red Knots.
   a. Continuation of all current yearly studies of shorebird numbers, weight distribution and rate of mass gain, horseshoe crab numbers, and egg densities.
   b. Development and testing of a predictive model for use by managers to determine the egg densities appropriate to support the existing stopover population and the gradual increase necessary as shorebird numbers recover.
2. By 2008, development of a system for the yearly determination of population demographic status based on survey results, capture data, and re-sightings of banded individuals.
   a. Create a survival and population status model using existing data and updated annually with new data.
   b. Develop annual estimates of productivity and juvenile survival as inputs for population models using the framework established for waterfowl population assessments.
   c. Distinguish the population parameters of each wintering population (Tierra del Fuego, Maranhão, and Florida) based on site-specific banding, re-sightings of marked individuals, and stable isotope analyses.
3. By 2008, determine the genetic and breeding status of the three main wintering populations (Tierra del Fuego, Maranhão, and Florida).
   a. Identify the arctic breeding area associated with each wintering subpopulation.
   b. Determine sub-specific status of each wintering population.
   c. Determine the migration routes used by each wintering population.
4. By 2011, create a hemisphere-wide system of protected areas for each significant wintering, stopover and breeding area.
5. By 2009, complete site assessment, using Western Hemisphere Shorebird Reserve Network (WHSRN) site assessment tools, for Bahia Lomas, Rio Grande, San Antonio Oeste, Lagoa do Piexe, Maranhão, the west coast of Florida, the Altamaha Region of Georgia, the Virginia Barrier Islands, Delaware Bay, Stone Harbor Point, James Bay, Southampton Island, and King William Island.
   a. Development management plans and integrate them into local and national conservation systems.
   b. Identify survey and research needs for each site.
6. By 2008, identify all important breeding locations in Canada, and recommend protection needs for the top ten sites.
   a. Use radio telemetry to determine the arctic breeding areas of each winter populations (Florida, northern Brazil, and Tierra del Fuego).
   b. Use GIS to determine suitable breeding habitat and extent of important breeding areas.
   c. Formulate recommendations to national governments on protection designations for most important breeding areas.
7. By 2009, delineate and propose protection measures for key habitats within the main wintering areas of Maranhão, Tierra del Fuego, and Florida, and develop management plans to guide protection.
   a. Conduct intensive surveys and determine areas of greatest importance within each site.
   b. Create maps of each site and determine chief threats and management needs using WHSRN site-assessment tools.
   c. In conjunction with national and local government agencies, create management plans for each wintering area that identify actions necessary to improve conditions and protect sites.
   d. Conduct site-specific research necessary to determine important-use areas as well as existing and emerging threats.
8. Carry out studies of food resources and studies of habitat use using radio telemetry.
9. Determine key southbound and northbound stopovers that account for at least 80% of stopover areas supporting at least 100 Red Knots, and develop coastwide surveillance of birds as they migrate.
   a. Set up survey, re-sighting, and banding programs to determine importance of individual stopovers relevant to associated wintering and breeding areas in places other than the Delaware Bay, including James Bay, the Mingan Islands in the Gulf of St Lawrence, at least two sites each in New Jersey, Virginia, South Carolina, Georgia, Maranhão, Brazil, and Patagonia, Argentina.
   b. Use WHSRN site-assessment tools to determine threats and management

needs at each site and develop a plan to meet them.

10. Control impact of disturbance at all stopovers and wintering areas, particularly in high-importance, high-disturbance areas like Delaware Bay and the west coast of Florida
    a. Identify, through site-assessment tools, all sites where human use is impacting birds by preventing access to key resources and/or roost sites
    b. Restrict access to all beaches using methods developed in Delaware Bay as outlined in this report.

Survey Needs

To effectively manage the Red Knot population, it is necessary to undertake regular assessment of numbers, demographic rates and conditions in wintering, and staging and breeding areas. A comprehensive and integrated monitoring program is necessary, not only to monitor the status of the populations but also for the objective assessment of the results of any management actions undertaken as a result of this review and further research.

South America – overall

Red Knots use South America both for locations to spend the northern winter and for stopover sites to and from the breeding areas. During northward migration, passage through Peninsula Valdés, Patagonia, Argentina, has become later since year 2000 (Bala et al. 2005). This may have led the number of Tierra del Fuego birds arriving late into Delaware Bay to have increased and some evidence shows this for 2000, 2001, and 2003 (Baker et al. 2004; K. Clark, unpubl. data). Any such late arriving birds will be at a lower weight compared with those that arrived earlier and Baker et al. (2004) has shown that low mass birds in Delaware Bay subsequently have a lower resighting rate throughout the flyway, implying lower survival. Therefore, further investigation is required to determine the reasons why northward passage has become later. This should focus particularly on the food resources used in South America, especially in Chile, Argentina, and Brazil. More specific needs are detailed below.

Very little is known about the distribution of juvenile Red Knots during their first northern winter apart from the fact that most do not go as far south as the main wintering area of the adults in Tierra del Fuego. It should be a priority to determine their distribution and monitor their survival as well as year-to-year changes in their numbers as a measure of breeding productivity.

South America – Argentina

Counts of and resighting of individually marked Red Knots at Rio Grande, Tierra del Fuego to increase the precision of annual survival and recruitment estimates specifically of the *C. c. rufa* population, and to allow the estimation of specific locality-survival-resighting parameters with multi-state models are needed. Training of more local biologists and shorebird rangers at key sites is needed.

South America – Chile

Aerial surveys of Bahia Lomas and surrounding areas have provided the best estimate of the change in the *C. c. rufa* population and these should continue. Studies on population dynamics of the wintering population (i.e., monitoring survival and recruitment through marking and subsequent resighting of individually marked birds) are needed because this area represents the largest known wintering concentration of *C. c. rufa*. Given the delayed northward migration through Patagonia and its implications, studies of any interactions of Red Knots with other migrant and non-migrant species, and use of the Bahia Lomas by all these birds as a foraging ground will determine whether this is caused by lack of food supplies on the non-breeding grounds.

South America – Brazil

How Red Knots use Brazil as a wintering and staging area is one of the largest unknowns in their life cycle. Basic count and distribution information is needed before more detailed studies can be designed:

1. Aerial surveys on the Amazon coast, especially the coast of the state of Maranhão, during migration (boreal and austral), as well as during wintering seasons.
2. Ground surveys on the Río Grande do Sul coast during the migrations.
3. Aerial survey on the Amapá and Pará coast when Red Knots are wintering in Maranhão.
4. Establish to what extent the Pantanal is used as a stopover site during northward and southward migration using aerial and/or ground surveys (April and end of September to first week of October).

Caribbean countries and northern South America

Because feather isotope studies suggest that a substantial number of birds winter in an unidentified area, clarification of the status and numbers wintering around the Caribbean and less known parts of northern South America is necessary. This unidentified area may be within Brazil but other likely areas include the Gulf of Maricaibo where high hundreds were found during an early March survey in the early 1980s.

Mexico

Confirmation of numbers and subspecific status of Red Knots wintering and staging on both the east and west coasts is needed. Birds wintering on the east coast may be *C. c. rufa,* those on the west coast, *C. c. roselaari*

United States – Delaware Bay

Cross-bay commuting for the whole 12–14 d stopover is equivalent in distance to almost half of the flight to the arctic breeding grounds. This is an energetic cost the birds can ill afford at a time when they are under pressure to reach the breeding grounds. Continued surveys of the Hereford Inlet roosting site are warranted to help evaluate roost site management and improvement. Roost sites in Delaware should be identified and surveyed to monitor management actions.

United States – Virginia

Systematic resighting survey efforts should be conducted in conjunction with daily counts of Red Knots using the barrier islands during spring migration, April through early June.

United States – North Carolina, South Carolina, Georgia, and Florida

1. The survey of wintering Red Knot numbers in southeastern U.S. needs to be expanded with an annual winter aerial survey of appropriate coasts including the west coast of Florida, and the Atlantic coasts of Georgia, South Carolina, and Florida. Early January would be best because that is when annual ground-based counts are traditionally carried out in Georgia. Determining the size of the population wintering in the southeastern U.S. is seen as a high priority. It is particularly important that surveys aimed at achieving this are coordinated, time-constricted, and wide-ranging in view of the apparent mobility of this population. Ideally aerial counts should be combined with ground counts.
2. Statewide surveys of Red Knots are needed to document important areas, habitats and timing of migration. Surveys would include color-band resightings. These states should participate in ISS surveys that have long-term data sets.

United States – Alaska

Spring aerial or ground surveys are needed in the major spring staging areas to compare with previous counts which may no longer reflect the current situation. Ground-based searching for color-marked birds to determine which wintering populations these birds come from is a major objective. This could be particularly productive in view of the large numbers of Red Knots that are currently marked in the western Atlantic and east Asian–Australasian flyways.

United States – California

Statewide surveys need to be carried out to update counts of wintering and staging Red Knots in California.

United States – Washington

Regular monitoring of the Red Knot is needed on spring passage through areas such as Westport and Gray's Harbor.

MONITORING — NEEDS

Overall

1. Monitoring is essential to objectively determine trends in numbers, survival and recruitment to the Red Knot population on an annual basis. Because several separate, apparently isolated populations exist, it is important to focus attention on wintering areas (i.e., the discrete wintering populations) as well as staging sites such as Delaware Bay.
2. It is important to continue to individually color-mark samples from all populations (Florida, Georgia, Carolinas, Northern Brazil, and Tierra del Fuego). Comparison of the proportions of birds from each wintering and migration site will facilitate a clear understanding of the migration routes and breeding areas of each population. Without this information it will be impossible to monitor the success

of conservation actions throughout the flyway.
3. Considerable effort is needed in all major sites to locate individually marked birds to determine which populations use which sites.
4. Other wintering sites need to be investigated to locate the wintering location of the group identified by their isotope signatures as being from an unknown wintering area.
5. To ensure that conservation action is focused on reversing the declines observed, it is vital that we identify all migration stopover sites that are used by the species on a regular basis. Identification of individually marked birds will enable conservation effort to be focused on those sites that hold the highest proportion of birds from groups that are known to be in greatest decline. Catching samples at these sites and individually marking (and taking a feather for isotope analyses) may also help in identifying the location of the unknown group.
6. Autumn monitoring of return rates and juvenile abundance should be developed further to increase our understanding of breeding success and how it feeds through into recruitment into the breeding population monitored in spring in Delaware Bay.

South America – Argentina

1. Continue the long-term monitoring programs and management plan development already in place.
2. Continue to catch and mark Red Knots as individuals. Collect blood samples from a sample of birds to monitor parasite levels, collect a feather from a sample of birds to maintain a current up-to-date isotopic signature for wintering areas.
3. Resight individually marked Red Knots to increase the precision of annual survival and recruitment estimates, and to allow the estimation of specific locality-survival-resighting parameters.
4. Monitor food sources at Argentinian wintering and staging areas to investigate the cause behind the delayed northward migration reported by Bala et al. (2005).

South America – Chile

1. Constantly monitor abundance, both aerial and terrestrial, during every season of the year, especially during the key arrival and departure periods.
2. Continue to catch and mark Red Knots as individuals. Collect blood samples from a sample of birds to monitor parasite levels, collect a feather from a sample of birds to maintain a current up-to-date isotopic signature for wintering areas.
3. Resight individually marked Red Knots to increase the precision of annual survival and recruitment estimates, and to allow the estimation of specific locality-survival-resighting parameters.
4. Continue with, and develop, the benthic invertebrate sampling program at Bahia Lomas to investigate the cause behind the delayed northward migration reported by Bala et al. (2005).

South America – Brazil

1. Monitor Red Knots on the coast of Maranhão during passage and winter (September to May).
   a. Capture Red Knots using cannon and mist nets and individually mark them.
   b. Attach radio transmitters in May to determine date of arrival in Delaware Bay.
   c. Gather biometric data (molt, age, sex, ectoparasites load, feathers for stable isotope analysis, blood samples for studies of genetic variability, and disease data such as West Nile virus, avian influenza, etc.).
   d. Search for individually marked birds to increase the precision of annual survival and recruitment estimates, and to allow the estimation of specific locality-survival-resighting parameters.
   e. Initiate a benthic invertebrate sampling program to determine whether the later northward passage is due to poor food supplies farther south.
2. Create a field station in the municipality of Cururupu for supporting field work in Maranhão.
3. Monitor Red Knots and their food supplies in Lagoa do Peixe National Park during September, October, April, and May using the same methods as described above.
4. Publish literature and give talks about the conservation importance of the Red Knot and the activities mentioned above for local communities and the authorities responsible for land management (IBAMA, Government of the States of Maranhão and Río Grande do Sul).
5. Monitor shorebird species in the Pantanal (Río Negro) during northward and southward migration.

United States – Delaware Bay

1. Monitor survival and recruitment of different sub-populations of Red Knots. In order to fill in the gaps in knowledge that have been identified in this status review, regular samples of Red Knots need to be caught throughout the spring season at a range of locations. Each bird should be individually color-marked, a primary covert taken (for isotope analysis to identify wintering area) along with full biometrics including weight. The level of the catching should be minimized, consistent with keeping enough individually color-marked birds in the population to assess survival rates of the different populations coming through the bay and sufficient to allow Pradel modeling of recruitment rates.
2. Undertake a program of daily counts and resightings each spring in Delaware Bay to estimate the total number of birds of each wintering population passing through the bay.
3. Continue the aerial survey during May and early June using consistent methods to ensure the long-term data set is maintained.
4. Continue the various horseshoe crab monitoring programs, specifically the Delaware Bay spawner survey and Delaware Bay egg abundance survey, both of which need support and provide critical data.
5. Continue fall ground-based shorebird counts, especially in the Atlantic coast of New Jersey.
6. Monitor site use through aerial and ground surveys. Bay-wide radio tracking should be further evaluated for its application to monitor and track changes in site use patterns. These data in combination with other site-specific data should be used to determine site-specific management actions.

United States – Virginia

1. Regularly count and resight banded birds to investigate arrival date, departure date, and residence time of Red Knots using the barrier islands during spring migration.
2. Assess the body condition of Red Knots upon arrival and also at the time of departure in order to determine whether they are able to fly direct to the Arctic or may need to stop over further north, such as in Delaware Bay.
3. Determine food supplies available at the main staging sites.

United States – North Carolina and South Carolina

Cannon net flocks and mark individuals during winter and passage periods to determine how these birds use the Florida and Georgia wintering areas and Delaware Bay in spring.

United States – Florida and Georgia

1. Catch birds using cannon and/or mist nets and mark as individuals using coded flags in winter.
2. Collect biometric data and details of molt, age, sex, and ectoparasites; collect feathers for stable isotopic analysis and blood samples for studies of genetic variability.
3. Resight individually marked Red Knots to increase the precision of annual survival and recruitment estimates, and to allow the estimation of specific locality-survival-resighting parameters.

United States – other sites on the United States East Coast

Search for and monitor other potentially important stopover sites for Red Knots along the U.S. East Coast, such as Jamaica Bay, New York.

Arctic – Canada and Alaska

Marking Red Knots in the Arctic will be incredibly valuable for understanding the migration routes. Feather samples need to be taken to obtain isotope signatures of their wintering areas. This is extremely difficult as the birds are highly dispersed but even small samples of individually marked birds can be extremely valuable as resighting rates are >50%.

If sites are located where adults congregate even in small numbers on arrival in the Arctic or before departure, effort should be put into increasing the samples of birds from the Arctic. It would be of particular value to mark samples of birds in Alaska in order to identify their wintering areas, as resighting effort in some known wintering areas is quite high.

Research Needs

Several key gaps exist in our knowledge of the Red Knot's life cycle in the Americas. Some relate to specific sites or countries while others can only be addressed by broad-scale coordinated research throughout one or more of the major flyways.

Broad-scale research topics

1. Good evidence from feather isotope studies shows that birds from different wintering areas use the foraging resources of Delaware Bay in different ways. New Jersey-banded Red Knots (based on resightings and isotope signatures) are being found in the southeastern U.S. more frequently than Delaware-banded Red Knots, particularly those feeding on mussel spat on the Atlantic coast of New Jersey adjacent to Delaware Bay. Collection of these data should be amplified by expansion of individual marking efforts in Tierra del Fuego and in the northern Brazil and southeastern U.S. migration and wintering areas and intensified searches for them on Delaware Bay. In addition, a well designed radio-tracking program could be used to establish whether Red Knots from the various wintering areas use Delaware Bay in the same way with respect to foraging activities. The focus for radio tracking of Red Knots from the U.S. wintering areas should be on migrants during April in South Carolina. In view of this apparent difference in usage, efforts should be made to improve conditions across the Delaware Bay, rather than just in a few hotspots.
2. About 20% of the Red Knots passing through Delaware Bay have isotope signatures not compatible with known molting areas—where do these birds molt? Currently, the non-breeding distribution of northern wintering Red Knots is not well known. The group of Red Knots that winters in the Northern Hemisphere may now comprise as much as half of the Red Knots passing through Delaware Bay during northward migration. This is a dramatically higher proportion than was estimated to have been the case in the middle 1980s. One possible cause of this change is that the Patagonian-wintering Red Knots have shown a major decline since the 1980s, whereas the northern-wintering group has not declined. If so, the health of the Red Knot population passing through Delaware Bay may substantially depend on the continued well-being of the northern wintering group.
3. Although it is clear that some of this group winters in the southeastern U.S. (coasts of South Carolina, Georgia, and the gulf coast of Florida), it is possible that substantial numbers also use other major wintering areas. The individual marking and scanning of Red Knots from this group will be valuable at key migration staging sites during southward migration, especially at Cape Cod, Massachusetts, and the Altamaha River Estuary, Georgia, as well as during winter and in March and April on the coasts of South Carolina, Georgia, and the gulf coast of Florida. In combination with counts, such a banding-scanning effort should yield a much better idea of the size of the northern-wintering group, an improved understanding of its migration strategies as well as a clearer understanding of the relationships between the U.S.-wintering Red Knots and those that spend winter on the coast of northern Brazil.
4. There is a need for a better understanding of Patagonian-wintering Red Knots and their food supplies. Numbers at Bahía Lomas have declined dramatically since 2000, whereas those at Río Grande have not. This suggests that the cause of the recent decline may originate at Bahía Lomas. Birds from both wintering sites pass through Delaware Bay, so both populations should have decreased if the environment of Delaware Bay is the root cause of the overall decline in the Red Knot population. Evidence also shows that the northerly wintering populations (southeastern U.S. and northen Brazil), of which some birds pass through Delaware Bay, have not undergone the catastrophic decline observed in Tierra del Fuego. Individual color marking and resighting can be used to determine whether there is any difference between the survival of birds from Bahía Lomas and Río Grande. Consistent monitoring of Red Knots and their food resources at Bahía Lomas and other wintering areas is also required. This should include regular (e.g., monthly) counts to determine whether Red Knot numbers change during the season, monitoring body condition (e.g., plumage oiling, ectoparasites and general health, molt, and mass), and regular sampling of food resources. This work might be promoted through the formation and funding of a Chile–Argentina working group.
5. Feather isotope studies indicated that in 2003–2005, a third to a half of the Red Knots passing through Delaware Bay were from northerly wintering areas. As far as it is possible to ascertain, a dramatic decline amongst these birds has not occurred since 2000. In spring

2004, turnover and isotope studies indicated that 24,000 birds passed through Delaware Bay, 12,000 from each population (Gillings et al. 2007).

6. Although 31,568 birds were counted in southern South America in January 2004 (Fig. 31), it is apparent that many did not pass through Delaware Bay on northward migration that year. In January 2005, the southern wintering count dropped to 17,653, indicating a major decline. If this dramatic population change was due to mortality solely caused by changes in conditions in Delaware Bay then most if not all of the 12,000 southern South American Red Knots passing through Delaware Bay in May 2004 must have died. Annual survival rates of the Tierra del Fuego population averaged only 56% during 1999–2001 (Baker et al. 2004), and little different at around 60% in 2004 and 2005. This indicates that major problems may be occurring for Red Knots in the wintering or staging grounds, and this may be a reason for some of the later arriving birds into Delaware Bay. Studies aimed at understanding why numbers have dropped at Bahía Lomas and at other traditional wintering sites in southern South America are urgently needed. Although the decline in Bahía Lomas suggests problems in the wintering areas, an alternative explanation is that birds are facing problems at staging areas farther north in South America. One possibility is that they are affected by ectoparasite infestation as found in the Maranhão, Brazil, wintering area in February 2005 (Baker et al. 2005a) and among birds from each of the three wintering areas passing through Delaware Bay in the springs of 2004 and 2005. Because very little is known about conditions at several staging sites in South America, exploration of this part of the life cycle is a priority.
7. As discussed in the taxonomy section of this review, a great deal of uncertainty exists about the subspecific status of Red Knots wintering in southern South America, in comparison with those in Maranhão, in the southeastern U.S., on the Northern Hemisphere Pacific coast (San Francisco Bay, Mexico (Baja California, and Sonora-Sinaloa), and on the Pacific coast of Chile. Genetic and isotopic studies need to be continued and expanded. In view of numbers claimed for Alaska, it is possible that populations wintering in Mexico and on the west coast of South America are higher than currently thought. Surveys of Mexican Red Knot populations should be expanded. This might be achieved as part of the annual January winter waterfowl surveys conducted jointly by the U.S. and Mexico.
8. Breeding productivity is a major unknown—monitoring it might help with understanding the impact of depleted food resources in Delaware Bay as well as allowing full demographic modeling. It is argued that Red Knots unable to secure adequate resources on Delaware Bay have lower survival. It should follow that they also have lower breeding productivity. Given the difficulty of measuring breeding success in sufficient representative areas of the nesting grounds, the most practical option would seem to be counting juveniles during southward migration and possibly also in the wintering areas. This might be achieved using volunteer surveys. Participation in the collection of juvenile/adult ratios during the ISS has been low, but appropriate training could change this and increase participation in age-monitoring.

Country-specific research needs – Argentina

1. Conduct trophic ecology studies at San Antonio Oeste, the key site hosting highest numbers of Red Knots in Argentina, to determine whether food supplies at this site limit the pace or timing of migration.
2. Monitor food supplies at Río Grande and movements between nearby Bahía Lomas.
3. Continue individually marking birds with coded flags and resighting individually marked birds to allow analyses of site and population specific survival and recruitment rates.
4. Collect a sample of primary covert feathers each year to maintain a current isotopic signature for each major wintering site.

Country-specific research needs – Chile

1. Study geomorphology of the intertidal ecosystem, floristic analysis of the palustrine and steppe communities, and ecosystem ecology.
2. Study population dynamics of the wintering Red Knot population and interaction with local species and other Nearctic visitors, and use of the bay by all these birds as a foraging ground including regular surveys of benthic invertebrates.

3. Continue individually marking birds with coded flags and resighting individually marked birds to allow analyses of site and population specific survival and recruitment rates.
4. Collect a sample of primary covert feathers each year to maintain a current isotopic signature for each major wintering site.

Country-specific research needs – Brazil

1. Study how birds use staging sites in Brazil—one of the greatest unknowns in the life cycle of the Red Knot wintering in Chile and Argentina. Research into this aspect is urgently needed to determine whether problems affecting sites in Brazil are the cause of birds arriving late into Delaware Bay. This will require the development of studies on foraging ecology and food availability in Maranhão and Lagoa do Peixe National Park.
2. Study potential impact of disease (West Nile virus, avian influenza, Newcastle virus, etc.).
3. Study ectoparasite infection during winter and also during different stages of migration, especially in Maranhão.

Country-specific research needs Mexico

1. Clarify the status and number of Red Knots wintering in Baja California, and Sonora-Sinaloa.
2. Collect a sample of primary covert feathers to obtain a current isotopic signature for comparison with passage birds in Delaware and also other wintering sites.
3. Initiate marking programs in conjunction with other Red Knot biologists.
4. Collect genetic material to determine affinity of these populations with others.

Country-specific research needs – United States

New Jersey and Delaware:

1. Horseshoe crab egg data and shorebird behavior need to be integrated into a model that can predict the numbers of eggs needed by shorebirds. From this, an estimate of the density of eggs required to support present and future numbers of shorebirds can be calculated. This can be used as one benchmark against which to determine whether Delaware Bay is in a satisfactory condition for shorebirds and provides an easily collected metric against which to assess the impacts of management actions. The changes in food supply are thought to be the main reason for the decline in birds in Delaware Bay, but it is also important to determine the importance of changes in gull numbers and human disturbance (including at roost sites) on the stopover birds. The behavior-based individuals models (Stillman et al. 2003) are suitable for this situation, and steps need to be taken to integrate the existing egg density and bird-behavioral data into a comprehensive model. Much of the data required for the models exist, but they still need to be integrated.
2. Modeling food availability to Red Knots in Delaware Bay will need bay-wide egg data and an understanding of the conditions under which the egg supply in the top 5 cm of sand (and therefore potentially available to Red Knots) increases and decreases. These data can then be used for determining the minimum level of the crab population necessary to produce a sustainable food resource for the birds. These data are also needed to fully parameterize the CEH individual based population model and use it to predict the quantity of eggs that need to be on the beaches for current shorebird populations and for future populations if they recover from the declines of the last two decades.
3. Studies that determine the level of harvest that will ensure enough eggs for migratory shorebirds are essential. Horseshoe crabs do not breed until they are about 8 yr old and the demographic structure of the population, especially immature survival, is only partly understood.

Virginia:

1. Investigation of which prey Red Knots are targeting on the Virginia barrier islands is needed with specific attention paid to identifying the availability of prey on peat banks versus high energy beaches and the relative importance of each to migrating Red Knots.

North Carolina:

1. Conduct research on impacts of beach stabilization and impacts of human disturbance.

South Carolina:

1. Develop a South Carolina Department of Natural Resources web site with information on the status, management, and natural history of Red Knots in South Carolina. Work with public and private land managers to protect areas identified as important Red Knot roost sites. Obtain

travel money to participate in Red Knot working groups.

Massachusetts:

1. Conduct research and monitoring of human disturbance in shorebird habitats, particularly those disturbances associated with commercial and recreational fishing and public access to beaches.
2. Monitor recruitment through observations of juveniles during fall migration.

Management Needs

The management needs presented in this section are preliminary and largely based on work described in more detail in previous sections. As nearly all management work focused on Red Knot occurs in the area of the Delaware Bay, management needs in other locations will only be determined after preliminary survey and research is complete. However, the experiences of conserving the Delaware Bay stopover, as well as work in Patagonian wintering areas, provide general management needs:

1. On the Delaware Bay, recover and maintain horseshoe crab egg densities at levels sufficient to maintain a stopover population of Red Knots of >100,000 birds.
2. Control impacts of disturbance at all stopovers and wintering areas where appropriate. This is especially important at key stopovers like Delaware Bay, but applies to the many Atlantic coast stopovers that occur in both spring and fall. This would include use restrictions and outreach programs.
3. Create an oil-spill response plan for key stopovers and wintering areas.
4. Maintain precise GIS maps of important use areas in each stopover and on wintering areas.
5. Ensure that all major stopover and wintering areas are recognized in protection initiatives such as WHSRN, International Association of Fish and Wildlife Agency's expanded flyway system, and Ramsar.
6. Avoid impacts of beach replenishment through timing restrictions, and specifications on beach fill to ensure quick recovery of beach invertebrates and horseshoe crab spawning in the Delaware Bay.
7. Clean up and restore all beaches on the Delaware Bay that include any structures impeding crab spawning such as bulkheads, homes, or rip rap. Avoid the placement of any new structures. The cross-bay commuting of Red Knots from feeding sites in Delaware to roosting sites on the Atlantic coast of New Jersey for the whole 14-d stopover is equivalent in distance to almost half the flight to the arctic breeding grounds. In energetic terms, the daily flight involves expenditure of about 83 kJ, which would require the ingestion of about 6,000 horseshoe crab eggs (H. P. Sitters, unpubl. data). Conservation management prescriptions should therefore include ensuring the existence of suitable roosting sites for Red Knots at various locations throughout the bay, especially in Delaware where steps should be taken to conserve the known inland roosting site near Mispillion Harbor. Coastal impoundments should be managed to maximize their potential use as Red Knot roosting sites, or sites created by building isolated sandbars or islands along the shore (such as beside the jetty protecting Mispillion Harbor where suitable high water roosting islands once existed but have since eroded away).

UPDATE TO THE STATUS OF THE RED KNOT (*CALIDRIS CANUTUS*) IN THE WESTERN HEMISPHERE, FEBRUARY 2008

Previous sections of this volume (referred to below as the original review) were based on data available as of June 2006. Since then important new information has become available and is presented in this section based on data and analyses available in February 2008.

Recent information suggests that the population of *Calidris canutus roselaari*, which breeds in Alaska and on Wrangel Island and migrates along the American Pacific coast, may be even more threatened than *C. c. rufa*. Therefore, in this update we give equal emphasis to both subspecies.

Taxonomic Status

According to the original review, Red Knots wintering in Tierra del Fuego are *C. c. rufa*, but the subspecific status of those wintering in Florida and in Maranhão (Brazil) is uncertain and either or both could be partly or wholly *C. c. rufa* or *C. c. roselaari*.

The original review includes the following statement which has been misinterpreted as meaning that the wintering populations of Florida and Tierra del Fuego are genetically distinct: "Despite the lack of fixed genetic differences among subspecies, the population divergence time of the Red Knots that winter in the southeast of the U.S. (presumed to be *C. c. roselaari*) and those that winter in Tierra del Fuego (*C. c. rufa*) is estimated to be about 1,200 yr