RED KNOT CONSERVATION PLAN
FOR THE WESTERN HEMISPHERE
(*CALIDRIS CANUTUS*)

Version 1.1
February 2010

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WHSRN
WESTERN HEMISPHERE
SHOREBIRD RESERVE NETWORK

NOTE about Version 1.1:

The only difference between Version 1.1 (February 2010) and Version 1.0 (August 2007) is the addition of a Spanish executive summary.

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Financial Contributors:

New Jersey Natural Lands Trust

Conserve Wildlife Foundation of New Jersey

National Fish and Wildlife Foundation

USGS Patuxent Wildlife Research Center

Manomet Center for Conservation Sciences

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Acknowledgments:

We wish to thank all of the authors who contributed to this document – Olivia Blank, Ruth Boettcher, Susan Cameron, Sharon DeFalco, Pamela Denmon, Jenny Dickson, Nancy Douglass, Carmen Espoz, William Haglan, Michael Haramis, Stephanie Koch, Richard G. Lathrop, Ricardo Matus, Scott Melvin, David Mizrahi, Tom Penn, Christopher Raithel, Susan Rice, Felicia Sanders, Inês L. Serrano, Becky Suomala, Glen Therres, Kim Tripp, Barry Truitt, Lindsay Tudor, Dennis Varza, Julia Victoria, Bryan Watts, Alexandra Wilkie and Brad Winn – this was a monumental task that could not have been completed without each of you. We also wish to thank Annette Scherer, U.S. Fish and Wildlife Service, New Jersey Field Office, for supporting this assessment, and we thank Annette and Joe Jehl for commenting an earlier draft of this review. Additionally, we thank the NJDFW's Endangered and Nongame Species Program technical staff: Sharon DeFalco, Bill Pitts, Kim Korth, Pete Winkler, Gretchen Fowles, Patrick Woerner, Mike Davenport and Brian Henderson.

We wish to thank the following people for their expertise, assistance, and/or use of data for preparing this assessment: David Allen, North Carolina Wildlife Resources Commission, Nongame and Endangered Wildlife Program; Joseílson de Assis Costa, CEMAVE, Brazil; John Arvin, Gulf Coast Bird Observatory, Lake Jackson, TX; Luis Bala, CenPat, Argentina; Daniel Blanco, Wetlands International; Milan Bull, Connecticut Audubon Society and Connecticut Ornithological Society; Winnie Burkett, Houston Audubon Society; Professor Roberto Carmona, Mexico; CEMAVE/IBAMA; Luis A. Espinosa G., Censo de Aves Acuticas Chile, UNORCH; Silvia Ferrari, University Patagonia Austral, John Fussell, Consulting Biologist, North Carolina; Bob Gill, U.S. Geological Survey, Alaska Science Center, Anchorage, AK; William Howe, U.S. Fish and Wildlife Service, TX; Sid Maddock, Audubon North Carolina; Brian McCaffery, U.S. Fish and Wildlife Service, Yukon Delta National Wildlife Refuge, Bethel, AK; Katy McWilliams, The Nature Conservancy, Charleston, VA; Brent Ortego, Texas Parks and Wildlife Department; Sergio Luis Pereira, Brazil; Don Reipe, American Littoral Society, NY; Dr. Wallace

Rodrigues Telino-Júnior, Brazil; Ken Ross, Canadian Wildlife Service, National Wildlife Research Center, Ottawa, Canada; Craig Watson, U.S. Fish and Wildlife Service, South Carolina.

Recommended Citation:

Niles, L., H. Sitters, A. Dey, and Red Knot Status Assessment Group. 2010. Red Knot Conservation Plan for the Western Hemisphere (*Calidris canutus*), Version 1.1. Manomet Center for Conservation Sciences, Manomet, Massachusetts, USA.

Front Cover Photo:

Red Knot with chicks at Southampton Island, Nunavut, Canada.

Photo by Larry Niles.

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EXECUTIVE SUMMARY

The population of the *rufa* subspecies of the Red Knot *Calidris canutus*, which breeds in the central Canadian arctic and mainly winters in Tierra del Fuego, has declined dramatically over the past twenty years. Previously estimated at 100,000-150,000, the population now numbers 18,000-33,000 (18,000 if just the Tierra del Fuego birds are *rufa*, more if the knots of uncertain subspecific status that winter in northern Brazil (7,500) or Florida (7,000) are also *rufa*). Counts show that the main Tierra del Fuego wintering population dropped from 67,546 in 1985 to 51,255 in 2000, 29,271 in 2002, 31,568 in 2004, but only 17,653 in 2005 and 17,211 in 2006.

Demographic studies covering 1994-2002, showed that the population decline over that period was related to a drop in annual adult survival from 85% during 1994-1998 to 56% during 1999-2001. Population models showed that if adult survival remained low, *rufa* would go extinct within about ten years. After 2002, the population held up in 2003-2004, but plunged again by nearly 50% in 2005 increasing the likelihood of extinction within the next decade.

Despite intensive studies, the reasons for the population decline and reduced adult survival are imperfectly known.

During northward migration, most *rufa* stopover in Delaware Bay where they feed mainly on the eggs of horseshoe crabs (*Limulus polyphemus*) and lay down fat and protein reserves both to fuel the 3,000 kilometer flight to the arctic breeding grounds and ensure their survival after they arrive at a time when food availability is often low.

The crucial importance of Delaware Bay is demonstrated by studies that show that lower weight knots in Delaware Bay have lower survival than heavier birds and that over 1998-2002 the proportion of birds there at the end of May that weighed more than the estimated departure mass of 180 grams declined by over 60%. This might be the result of the progressive failure of the food supply in Delaware Bay and/or a trend for birds to arrive there later and/or in poorer condition. In years when Red Knots experience both reduced food availability and there are late arrivals, the result may be an exacerbation of the effects of each of these deleterious factors.

The main identified threat to the *rufa* population is the reduced availability of horseshoe crabs eggs in Delaware Bay arising from elevated harvest of adult crabs for bait in the conch and eel fishing industries. Since 1990, there has been a substantial decline in the crab population. Although significant uncertainty regarding the extent of the decline of the horseshoe crab

population remains, there is general agreement that horseshoe crab stocks have declined to a level where increased management of the fishery is necessary and appropriate. The decline in crabs has led to a decrease in the density of eggs available to shorebirds. Because of their delayed maturity, demographic models indicate that even if further exploitation of crabs ceases immediately, it will be some years before the horseshoe crab population recovers to its former level.

Although there is clear evidence, as in 2003 and 2005, that the reduced availability of eggs is already having an impact in some years on the knots ability to gain mass in Delaware Bay, it is likely that there are other threats to *rufa* and that these are the cause of some birds arriving in the Bay late and/or in poor condition. It is not known what these are, but they could be related to Bahia Lomas, the main wintering site in Tierra del Fuego (because the largest reduction in recent years has occurred there and because northwards migration from Bahia Lomas along the Atlantic coast of Argentina has taken place 1-2 weeks later since year 2000).

If it is proved that there are factors that lead knots to arrive late in Delaware Bay and/or in poor condition, this does not diminish the importance of the Delaware Bay food resource. If anything, it is increased because it is of critical importance in enabling the birds to recover quickly and reach the breeding grounds on time and in good reproductive condition.

Actions already being taken to improve feeding conditions for Red Knots and other shorebirds in Delaware Bay include beach closures to prevent disturbance and exclosures to reduce competition from gulls. However, although these measures help, they are no substitute for a recovered horseshoe crab population. Actions to conserve horseshoe crabs have included reduced harvest quotas, more efficient use of crabs as bait, closure of the harvest in certain seasons and places and the designation of a sanctuary off the mouth of Delaware Bay. The latest information is that the crab population may have stabilized, but there is no evidence of recovery.

Another Red Knot subspecies, *roselaari*, breeds in Alaska and is presumed to include those knots that winter on the Pacific coast of the U.S. and Mexico. There are two other Red Knot wintering populations of uncertain subspecific status: one in the southeast of the United States (mainly Florida) of about 7,000 and one on the north coast of Brazil of about 7,500. These populations have not been the subject of regular systematic surveys, but it is not thought that either has suffered the same catastrophic decline as the *rufa* that winter in Tierra del Fuego. Substantial proportions of both pass through Delaware Bay during northward migration, but banding shows that these are distinct populations without interchange with the Tierra del Fuego birds. Moreover genetic studies show that there has been no exchange of genes between the SE United States and the Tierra del Fuego birds for at least 1,200 years.

Some progress has been made towards understanding why the Tierra del Fuego population has suffered a major decline, but the northern wintering birds have apparently remained more stable. It appears that physiological constraints mean that the southern birds, which mostly make a long, non-stop flight to Delaware Bay from at least Northern Brazil, are more reliant on soft, easily-digested horseshoe crab eggs in Delaware Bay than the northern winterers, many of which feed on blue mussel (*Mytilus edulis*) spat or surf clams (*Donax variablis*) on the Atlantic coast of New Jersey. There is also evidence from Patagonia that, for a reason that remains obscure, northward migration of Tierra del Fuego birds has become 1-2 weeks later since year 2000 and this has probably led to more Red Knots arriving late in Delaware Bay. Late arriving birds have been shown to have the ability to make up lost time by increasing their mass at a higher rate than usual provided there are sufficient food resources. However, late-arriving Red Knots failed to do this in 2003 and 2005 when egg availability was low.

Although *rufa* knots are spread thinly across a large area of the Canadian arctic during the breeding season, for the rest of the year they occur mainly in large flocks at a limited number of key coastal wintering and staging sites. This review describes each of these sites and the threats the birds face ranging from oil pollution to disturbance and reclamation for development.

Overall the goal of conservation activities throughout the flyway should be to increase the *rufa* population to at least the figure of 25 years 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 to 70,000-80,000 birds
2. Brazilian wintering population to 20,000-25,000
3. Florida wintering Population to 20,000-25,000
4. Other sites 15,000-20,000

The means whereby such population increases might be achieved include:

1) By 2015, recover and maintain Delaware Bay horseshoe crab egg densities to levels sufficient to sustain stopover populations of all shorebirds including 80,000 Red Knots.
2) By 2010, 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.
3) By 2008, develop a system for the yearly determination of population demographic status based on counts, capture data, and resightings of banded individuals.
4) By 2009, determine the genetic and breeding status of the three main wintering populations (Tierra del Fuego, Maranhão, and Florida).
5) By 2009, identify all important breeding locations in Canada and recommend protection needs and designations for the most important sites.
6) By 2009, complete site assessments and management plans for all important wintering areas and stopovers in the Flyway.
7) By 2010, 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.
8) By 2009, determine key southbound and northbound stopovers that account for at least 80% of stopover areas supporting at least 100 Red Knots, and develop coast-wide surveillance of birds as they migrate.
9) By 2011, create a hemisphere-wide system of protected areas for each significant wintering, stopover, and breeding area.

Also crucial to *rufa*'s recovery is adequate funding to support the conservation actions and research needed. Despite the fact that much of the research, survey, monitoring and conservation work has been carried out by volunteers and has been supported financially by state, federal government and non-government agencies, present funding levels are inadequate to sustain the work required.

RESUMEN EJECUTIVO

La población de la subespecie *rufa* de la especie *Calidris canutus*, que se reproduce en el ártico canadiense central y pasa el invierno en Tierra del Fuego, ha disminuido drásticamente en los últimos veinte años. Anteriormente la población fue calculada en 100.000 a 150.000 individuos aproximadamente, y actualmente ha sido estimada entre 18.000 y 33.000 (18.000 si las aves en Tierra del Fuego solamente son de *rufa*, y más si los *C. canutus* de subespecies inciertas que pasan el invierno en el norte de Brasil (7.500) ó Florida (7.000) también son de *rufa*). Los conteos muestran que la población principal que pasa el invierno en Tierra del Fuego se redujo de 67.546 en el año 1985 a 51.255 en el 2000; 29.271 en el 2002; 31.568 en el 2004; a tan sólo 17.653 en el 2005 y 17.211 en el 2006.

Estudios demográficos que abarcan del año 1994 al 2002 demuestran que la disminución de la población durante este período fue relacionada con la disminución de la supervivencia anual de los adultos que correspondió al 85% durante el período de 1994 a 1998 y al 56% en el período de 1999 al 2001. Modelos de población demostraron que sí la supervivencia de adultos de los *C. c. rufa* sigue siendo baja, la subespecie puede extinguirse dentro de unos diez años. Después del 2002, la población no disminuyó entre el 2003 al 2004, pero en el año 2005 descendió de nuevo en casi un 50%, aumentando la probabilidad de extinción en la próxima década.

A pesar de los intensos estudios, los motivos de la disminución de la población y de la supervivencia de adultos no son conocidos claramente.

Durante la migración hacia el norte, la mayoría de los *C. c. rufa* hacen sus paradas en la Bahía de Delaware donde se alimentan principalmente de los huevos de *Limulus polyphemus* (cangrejos herradura) para hacer reservas de grasa y proteína como combustible para el vuelo de 3.000 kilómetros hasta las zonas de reproducción en el ártico y asegurar su supervivencia después de su llegada, cuando la disponibilidad de alimento es baja usualmente.

La importancia crucial de la Bahía de Delaware es demostrada por estudios que comprueban que los *C. c. rufa* de menor peso en la Bahía de Delaware tienen menor posibilidad de sobrevivir que las aves más pesadas. Entre 1998 y 2002, la proporción de las aves en la bahía a finales de mayo que pesaban los 180 gramos al tiempo de salida redujo por más del 60%. Esto podría ser el resultado de la falta progresiva de la oferta de alimentos en la Bahía de Delaware, y/o una tendencia de las aves llegar a la bahía más tarde y/o en peor estado. En los años cuando los *C. c. rufa* tienen la experiencia de la reducción de la disponibilidad de alimentos además las llegadas tarde por algunos individuos, el resultado puede ser un aumento considerable de los efectos de cada uno de estos factores perjudiciales.

La principal amenaza identificada de la población de *C. c. rufa*, es la menor disponibilidad de huevos de *L. polyphemus* en la Bahía de Delaware, debido a la alta colecta de los adultos como cebo en la industria pesquera de caracoles y anguilas. Desde 1990, ha habido una disminución sustancial de la población de *L. polyphemus*. Aunque se mantiene la incertidumbre sobre la magnitud de la disminución de la población de *L. polyphemus*, hay acuerdo general en que las poblaciones han disminuido al nivel donde el manejo aumentado de procesos pesqueros es necesario y apropiado. La disminución de los *L. polyphemus* ha llevado a una baja densidad de huevos para la disposición de las aves playeras. Debido al retraso en la madurez de *L. polyphemus*, los modelos demográficos indican que si la explotación de ellos debe cesar de inmediato, todavía pasarán muchos años antes que la población recupere a su nivel anterior.

Aunque hay evidencia clara, como en el 2003 y 2005, que la menor disponibilidad de los huevos de *L. polyphemus* ya está generando un impacto en varios años en la capacidad de los *C. c. rufa* ganar masa en la Bahía de Delaware, es probable que existan otras amenazas para la subespecie y que ellas son la razón que algunas aves lleguen tarde a la Bahía de Delaware y/o en malas condiciones. No se sabe cuales son las amenazas, pero las podrían estar relacionado a Bahía Lomas, el sitio principal en Tierra del Fuego donde las aves pasan el invierno (porque la reducción más larga en los últimos años ha ocurrida allí y porque la migración hacia el norte desde Bahía Lomas a lo largo de la costa Atlántica de Argentina se ha llevado a cabo entre una a dos semanas más tarde desde el año 2000).

Si se puede confirmar que hay factores que causan los *C. c. rufa* llegar tarde y/o en malas condiciones a la Bahía de Delaware, esto no disminuye la importancia del recurso de alimento de la bahía. En todo caso, su importancia continúa porque el sitio es crítica por permitir que las aves se recuperen rápidamente y que lleguen a zonas de reproducción a tiempo y en buena condición.

Las acciones que ya se llevando a cabo para mejorar la condición de alimentación en la Bahía de Delaware para los *C. c. rufa* y otras aves playeras incluyen el cierre de las playas para evitar la perturbación humana, y las exclusiones para reducir la competencia de las gaviotas. Sin embargo, aunque estas medidas ayudan, no son un sustituto para la recuperación de la población de *L. polyphemus*. Las acciones para conservar los *L. polyphemus* han incluido la reducción de su cosecha, el uso más eficiente de los cangrejos como cebo, el cierre de la cosecha en algunas estaciones y lugares, y la designación de un santuario cerca de la boca de la Bahía de Delaware. La información más reciente es que la población de *L. polyphemus* puede haberse estabilizada, pero no hay pruebas de recuperación.

Otra subespecie *C. c. roselaari* reproduce en Alaska y se presume que incluye las aves que pasan el invierno en la costa Pacífica de los Estados Unidos y México. Existen otras dos populaciones invernadas de *C. canutus* pero sus subespecies están inciertas: una población está en el sureste de los Estados Unidos (principalmente en Florida) cerca de 7.000 individuos y la segunda está en la costa norte de Brasil cerca de 7.500 individuos. Estas poblaciones no han sido el objeto de censos sistemáticos, pero no se piensa que las han sufrido un declive catastrófico similar a lo que sucede a los *C. c. rufa* que pasan el invierno en la Tierra del Fuego. Proporciones considerables de ambas poblaciones pasan a través de la Bahía de Delaware durante la migración hacia el norte, pero estudios de anillamiento muestran que son distintas, sino el intercambio con las aves desde Tierra del Fuego. Por otra parte, estudios genéticos demuestran que no ha habido intercambio de genes entre las aves del sureste de los Estados Unidos y las de Tierra del Fuego durante los 1.200 años pasados, por lo menos.

Alguno progreso ha sido logrado hacia la comprensión de por qué la población de la Tierra del Fuego ha sufrido una disminución mayor, pero las aves que pasan el invierno en el norte aparentemente han permanecido más estables. Parece que las limitaciones fisiológicas tienen una significa, en que las aves en el sur que hacen vuelos largos sin paradas desde el norte de Brasil hasta la Bahía de Delaware dependen más de la fácil digestión de los huevos de *L. polyphemus* en relación a las aves en el norte. Los individuos que pasan el invierno más al norte se alimentan de mejillones azules (*Mytilus edulis*) o de almejas blancas (*Donax variabilis*) en la Costa Atlántica de Nueva Jersey. También hay evidencia de la Patagonia que, por alguna razón que se desconoce, la migración de las aves hacia al norte desde la Tierra del Fuego se hace de 1 a 2 semanas más tarde desde el año 2000, y esto ha conducido probablemente a los *C. c. rufa* que lleguen tarde a la Bahía de Delaware. Cuando las aves llegan tarde, se ha demostrado que ellas tienen la capacidad de recuperar el tiempo perdido por incrementando sus niveles de masa al ritmo mayor que lo normal, si haya suficientes recursos alimenticios. Sin embargo, los *C. c. rufa* que llegaron tarde entre los años 2003 y 2005 no pudieron hacerlo porque la disponibilidad de huevos fue baja.

Aunque los *C. c. rufa* son muy dispersos a través una gran superficie de zona ártica de Canadá en la temporada de reproducción, los forman grandes bandadas para el resto del año en un número limitado de zonas costeras y sitios clave de reposo. Este plan describe cada uno de los sitios y las amenazas a las aves, desde la polución petróleo hasta la perturbación y reclamación para el desarrollo.

En general, la meta de las actividades de conservación a lo largo de su ruta de migración debe ser aumentar la población de la subespecie *C. c. rufa* a, por lo menos, la cantidad de 25 años atrás de 100.000 a 150.000 individuos, para el año 2015. Dada la incertidumbre de las relaciones genéticas entre las tres principales poblaciones invernadas, se proponen objetivos para cada una de ellas. Se sugiere lo siguiente aumentos:

1. Población invernada en Tierra del Fuego a 70.000 a 80.000 individuos.
2. Población invernada en Brasil a 20.000 a 25.000 individuos.
3. Población invernada en Florida a 20.000 a 25.0000 individuos.

4. Otros sitios a 15.000 a 20.000 individuos.

El medio por el cual la población aumentaría, se podría lograr:

1. Para el 2015, recuperar y mantener la densidad de huevos de *L. polyphemus* en la Bahía de Delaware a los niveles suficientes para mantener las poblaciones de todas aves playeras durante la migración, incluyendo los 80.000 de *C. canutus*.
2. Para el 2010, controlar el impacto de las perturbaciones en todos los sitios de parada y donde las aves pasan el invierno, especialmente en los sitios de alta importancia y de gran perturbación como la Bahía de Delaware y la costa oeste de Florida.
3. Para el 2008, desarrollar un sistema para determinar anualmente del estatus demográfico de la población, basada en resultados de censos, datos de su captura, y reavistamientos de individuos anillados.
4. Para el 2009, determinar el estatus genético y de reproducción de los tres principales poblaciones que pasan el invierno en la Tierra del Fuego, Maranhao, y Florida.
5. Para 2009, identificar todos los lugares importantes de reproducción en Canadá, y recomendar medidas de conservación y designación para los sitios de mayor importancia.
6. Para el 2009, completar una evaluación del sitio y desarrollar planes de manejo para todos los sitios importantes donde las aves pasan el invierno y áreas de paradas en la ruta de vuelo.
7. Para el 2010, delinear y promover medidas de protección en hábitats claves dentro de las principales áreas en el invierno en Maranhao, Tierra del Fuego, y Florida, y desarrollar planes de manejo que guiarán su protección.
8. Para el 2009, determinar las paradas claves de los recorridos hacia el sur y hacia al norte que representen al menos el 80% de los áreas de paradas que apoyan por lo menos 100 *C. canutus,* y desarrollar un monitoreo de las aves durante su migración a lo largo de la costa.
9. Para el 2011, crear un sistema hemisférico de áreas protegidas de cada uno de los sitios de invernada, de parada, y de reproducción.

Para la recuperación de *C. c. rufa* es crucial adquirir suficientes fondos para apoyar acciones necesarias de conservación y de investigación. A pesar de que gran parte de la investigación, el estudio, el monitoreo, y conservación se ha llevado a cabo por voluntarios y ha sido apoyado financieramente por el estado, el gobierno federal, y otras agencias no gubernamentales, los niveles actuales de financiación son insuficientes para mantener el trabajo requerido.

PURPOSE

The Red Knot, *Calidris canutus*, is a worldwide species with a total population of approximately 1.15 million (Wetlands International 2005, Minton pers. comm. 2005, this review). Breeding in the Arctic and wintering as far south as New Zealand, Australia, South Africa and Tierra del Fuego, the Red Knot is one of nature's most prodigious travelers, exciting the interest of scientists and conservationists around the world. The Red Knot is also one of the most extensively studied of the world's 221 species of shorebirds. Central to this research effort is a team led by Professor Theunis Piersma on Texel in the Netherlands where the Royal Netherlands Institute for Sea Research has a purpose-built laboratory, the size of an aircraft hangar, for studying Red Knots under precisely controlled conditions.

There are six subspecies of the Red Knot which, together, have a circumpolar Arctic breeding distribution, though each breeds in a distinct area and winter separately. Except as otherwise noted, this status assessment focuses on the New World Red Knot subspecies *Calidris canutus rufa*, hereafter simply "*rufa*."

Building on earlier work led by the Manomet Center for Conservation Science, *rufa* has been the subject of intensive studies throughout the West Atlantic shorebird flyway since 1997. These studies were instigated and have been sustained by concern that the Patagonian population has fallen from 100,000-150,000 in the early 1980s to around 17,500 in 2005. The work has involved a diverse selection of people and organizations, government and non-government, from Argentina, Chile, Brazil, and Canada as well as all east coast states of the U.S. from Florida to Massachusetts and the U.S. Fish and Wildlife Service. From the beginning, shorebird ecologists from outside the Americas have also been involved, especially from the UK, The Netherlands and Australia. Several of these scientists have contributed to this review.

Studies of *rufa* have focused on determining the cause of the population decline and whether anything can be done to reverse the situation. With limited resources, they have sought to cover the whole of *rufa*'s latitudinal range of over 120° from Tierra del Fuego (54°S) to King William Island (68°N) and the whole of its annual cycle from one Arctic breeding season to the next. More specifically, a large proportion of the effort has been directed at measuring demographic rates and identifying where in the annual cycle the problems lie.

Worldwide, the main organization concerned with research and conservation science in relation to the world's 221 species of shorebird is the International Wader Study Group[1], which organized a workshop attended by 132 specialists from 20 countries in 2003 to address the question "Are shorebird populations worldwide in decline?" The conclusions show that of those shorebirds whose population trend is known, 48% are declining and only 16% increasing (International Wader Study Group 2003). Many of the declining populations were found to be those of long-distance migrants and *rufa* was cited as a prime example. Problems identified as common to several long-distance migrants were their high dependency on a very limited number of key stopover sites making them particularly vulnerable to habitat loss (as in the Yellow Sea where huge areas of intertidal habitat have been lost to reclamation) and declining food resources at stopover sites arising from the unsustainable exploitation of natural resources. In the latter case, the prime examples worldwide were considered to be unsustainable shell-fish harvesting in the Dutch Wadden Sea and the exploitation of horseshoe crabs, *Limulus polyphemus*, in Delaware Bay, U.S.A.

As a result of *rufa*'s decline, it is currently being considered for listing as endangered by the Canadian government's Committee on the Status of Endangered Wildlife in Canada which has recently commissioned a status review similar to the present document. In South America, Argentina has proposed that the *rufa* be designated as endangered and as such added to Appendix 1 of the Bonn Convention. In Brazil it is being proposed for listing as endangered.

A problem arising from the continuous nature of the *rufa* studies over the past nine years has been a lack of time and resources to write up and publish results. All too often, data have been analyzed and partly written up, only to be overtaken by the accumulation of more data. We therefore greatly welcome the opportunity that this status review affords to take stock and set out a full account of our current knowledge. We will describe *rufa* in the context of worldwide Red Knot populations; we will assess its status, its general natural history, its habitat, its breeding system, its migrations and its feeding ecology. We will especially address the threats it faces and the conservation actions that may lead to its recovery.

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[1] Outside North America, most English-speaking people call shorebirds "waders". Both terms refer to the world's 221 species of *Charadrii*. As some are never found on the shore and some never wade in water, neither term can be regarded as better than the other.

MANAGEMENT STATUS AND NATURAL HISTORY

TAXONOMY

Available evidence from long term banding programs indicates that distinct flyways exist (Piersma and Davidson 1992) and six separate breeding areas are known to host different populations, all of which are now formally recognized as subspecies based on body size and plumage characteristics (Tomkovich 1992, Piersma and Baker 2000, Tomkovich 2001; Table 1, Fig. 1).

C. c. roselaari is thought to breed in northwest Alaska and Wrangel Island. Its wintering areas are unknown, but museum skins studied by Tomkovich (1992) indicate that this subspecies may migrate down the Pacific coast of North America and winter in the Gulf of Mexico. Because knots wintering in Florida, Georgia and South Carolina have a different molt schedule, and they do not migrate to southern South America, they have been referred to *C. c. roselaari*. However, the breeding grounds of the southeast U.S. wintering knots have not been confirmed. *C. c. rufa* breeds in the central Canadian Arctic and winters in southern Patagonia and Tierra del Fuego. Another group wintering in northern Brazil and possibly Venezuela is presumed to belong to this subspecies. *C. c. rogersi* breeds on the Chukotski Peninsula in eastern Russia and winters in southeast Australia and New Zealand. *C. c. piersmai* breeds on the New Siberian Islands in north central Russia and winters in northwest Australia, and *C. c. islandica* breeds in northern Greenland and northeast Canada and winters in north west Europe. The nominate subspecies, *C. c. canutus*, breeds on the Taymyr Peninsula in western Siberia and winters in west and south west Africa. Earlier work failed to distinguish geographically isolated groups indicating apparent panmixia caused by a late Pleistocene bottleneck (Baker *et al.* 1994, Piersma 1994). This analysis, however, was limited by an extreme lack of genetic variability making it difficult to distinguish between genetic variation inherited from a common ancestral stock following a recent bottleneck and current gene flow between current populations.

Table 1. Population estimates of the six subspecies of the Red Knot *Calidris canutus*.

Subspecies	Estimated population size	Source
Canutus	400,000	Wetlands International (2006)
Islandica	450,000	Wetlands International (2006)
Rogersi	90,000	Minton unpublished data
Piersmai	50,000	Minton unpublished data
Roselaari	35,000-50,000*	Wetlands International (2006)
Rufa	18,000-35,000	This review

* As discussed elsewhere in this review, *roselaari* almost certainly has a much smaller population than that suggested by Wetlands International (2006)

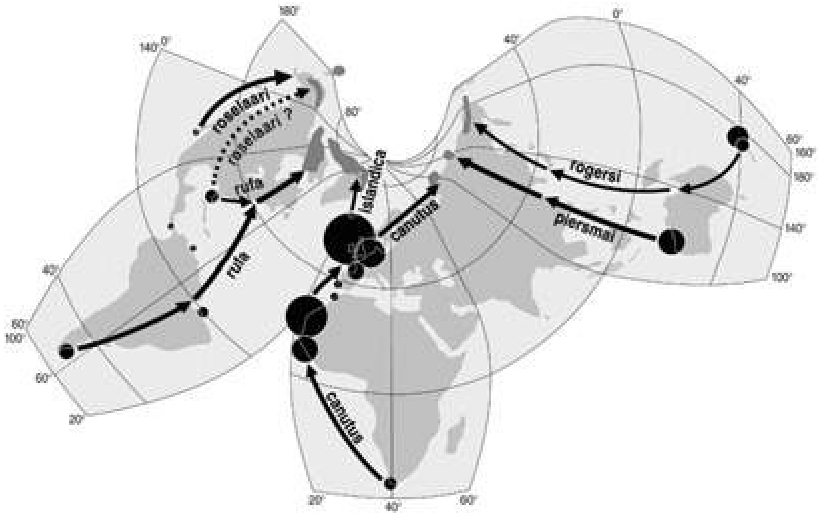


Figure 1. Worldwide distribution of the six recognized subspecies of the Red Knot. All breeding areas (dark gray shading) are on high-Arctic tundra, where the adults spend June-July. After their long-distance migrations (arrows) they spend the non-breeding season (August-May) mainly in intertidal soft-sediment habitats (dots, which are scaled according to population size). This map was prepared in 2003 and revised according to recent studies described in this review. Note that it is uncertain whether the knots that winter in N Brazil and/or Florida are *roselaari*, but some birds presumed to be *roselaari* winter on the coast of California and Baja California. Map drawn by Dick Visser, provided by Jan van Gils and reproduced with their permission.

POPULATION ESTIMATE AND TREND

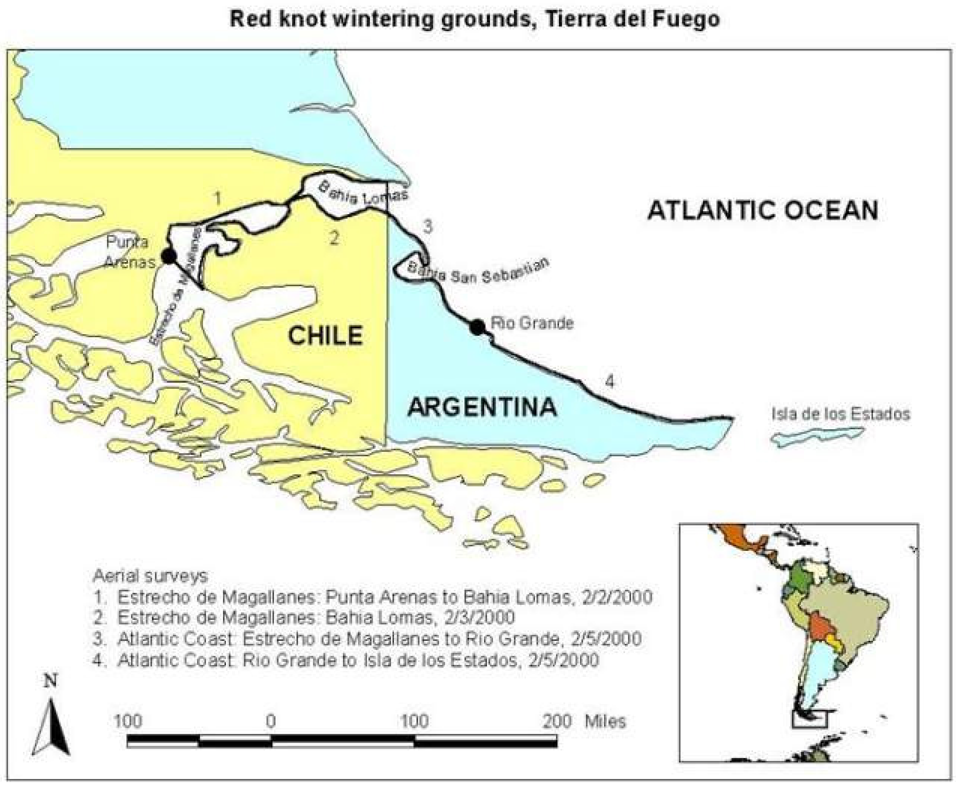
Usually, species status reviews set out a state-by-state or region-by-region assessment of breeding populations. The Red Knot, however, breeds in the Arctic, for which there is little to no comprehensive understanding of breeding density and productivity. It is thus necessary to rely on surveys and band-resighting analyses done in primary wintering and stopover areas as the basis for demonstrating population changes. Fortunately, the Red Knot is one of the best studied long-distance shorebird migrants, with surveys taking place in nearly all important habitats along its 15,000 km flyway (Fig. 1). This work has given us a reasonably complete picture of its critical habitat throughout the flyway. It has also identified a number of problems in population structure that influence the assessment of population change.

1. Red Knot Populations of the Americas

The primary wintering area of the *rufa* subspecies of the Red Knot is now restricted to three sites on the main island of Tierra del Fuego (Morrison and Ross 1989, Morrison *et al.* 2004). In recent years, about 70% of the population has been found in just one bay, Bahía Lomas in Chilean part of the island, with most of the remainder at Río Grande in the Argentinian part with smaller numbers at Bahía San Sebastián (Fig. 2). In the mid 1980s, this population numbered 67,000 and the wintering area extended northwards along the Argentinian coast from Tierra del Fuego to Río Negro province. Now, the population is not only confined to Tierra del Fuego but has decreased to only 17,211 in 2006.

During migration to its Arctic breeding grounds, *rufa* stop over in Delaware Bay in late May and numbers counted there have fallen in broad correlation with those in Tierra del Fuego. However, recent studies have shown that knots from two other wintering areas also migrate through Delaware Bay. These are the populations that winter in the southeast of the United States (mainly Florida) and Maranhão, northern Brazil (Atkinson *et al.* 2005), the subspecific status of which is uncertain (see Taxonomy section).

The knot population that winters mainly on the west coast of Florida was counted by aerial surveys in the 1980s, and was variously estimated at between 6,500 and 10,000 (Morrison and Harrington 1992) and 4,500 (Sprandel *et al.* 1997). The most recent estimate is 7,500 birds based on a count of 7,000 knots in South Carolina (April 2003) and 4,000 to 5,000 in one area in western Florida (November 2004) (Harrington unpublished data). There is also recent evidence that this population may move with available resources as far north as the coast of Georgia and the winter population there can vary from hundreds in some years to a maximum of 5,000 in others (Winn pers. comm. 2005). There is no reliable evidence of trend for the Florida wintering population. The count data are very erratic from year to year, probably because of the difficulty of finding knots along Florida’s greatly fragmented coastline. All that can be said is that there is no evidence of a major change in the size of the population and that it is probably still of the same order of magnitude as it was in the 1980s. Counts in Cape Romain National Wildlife Refuge, South Carolina, indicate declines in the number of knots on passage in both spring and late summer-fall (Fig. 3). It is not known to which wintering population or populations these birds belong. Possibly they are from the Tierra del Fuego population that has shown a clear decline, as described above.



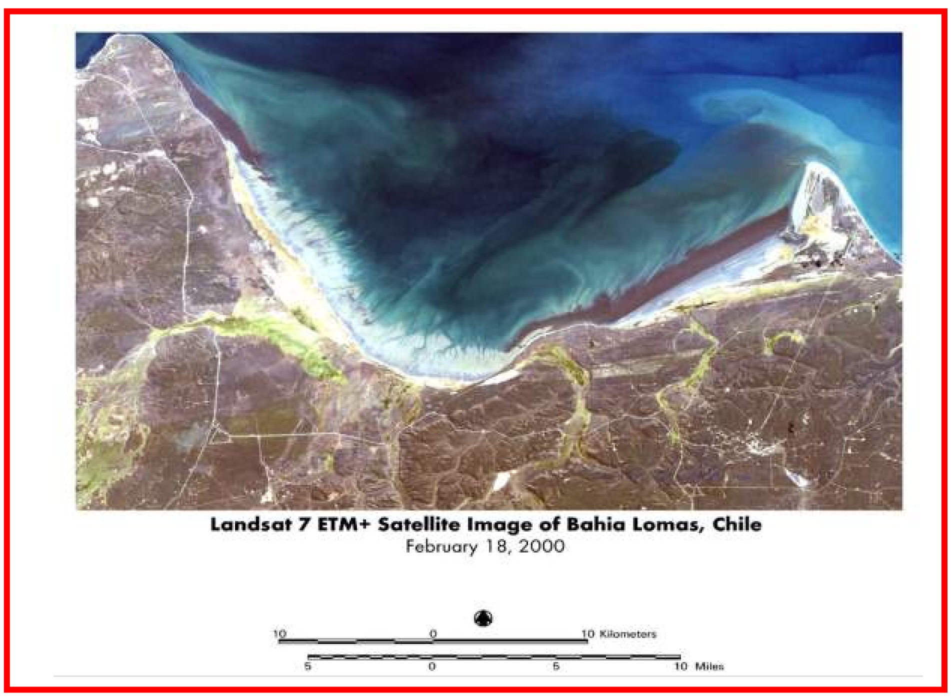


Figure 2. Tierra del Fuego (top), the primary wintering grounds of *C. c. rufa*, and Bahía Lomas, Chile (bottom) where approximately 70% of the population is currently found.

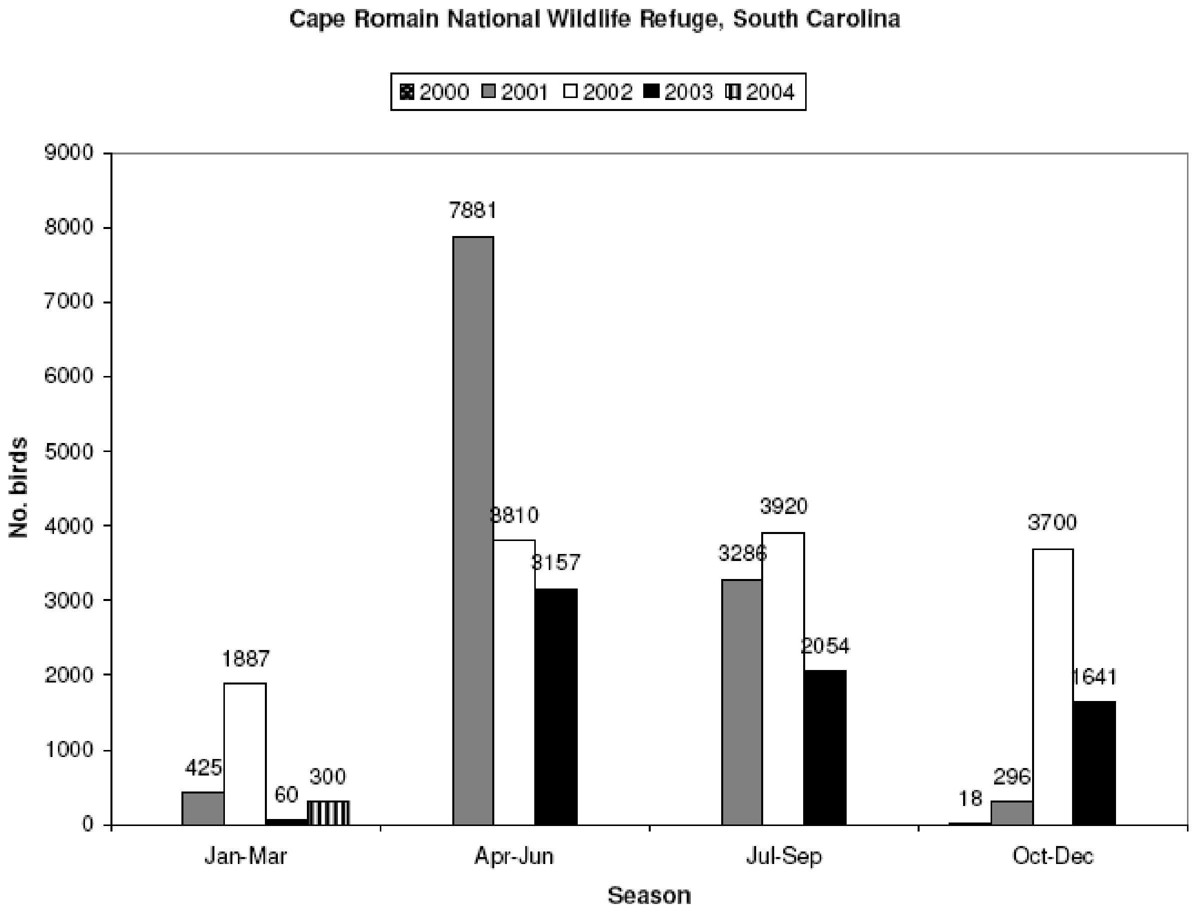


Figure 3. The number of Red Knots counted at Cape Romain National Wildlife Refuge, South Carolina, 2000-2004 (Cape Romain NWR & South Carolina DNR pers. comm., 2005).

The population wintering in the Maranhão region of Brazil was surveyed in February 2005 with a count of 7,575 (Baker *et al.* 2005a), which is only slightly below the 8,150 recorded by Morrison and Ross (1989) in the mid 1980s. However, the 20-year gap between surveys means that there could have been trends that have not been detected.

In view of current uncertainties about the subspecific status of the northern wintering knots, they are here treated as distinct biogeographic populations and considered separately so far as is possible. *C. c. rufa* breeds in the central and eastern Canadian Arctic, and birds wintering in southern South America are referable to this race. However, it is unclear where the Florida and Maranhão birds breed or whether they are referable to *rufa* or *roselaari* or even a hitherto undescribed subspecies. Color banding and the isotope signature of flight feathers show that substantial numbers (though probably not all) of the birds that winter in both Maranhão and the southeast U.S. pass through Delaware Bay during spring migration along with the birds from Tierra del Fuego (Atkinson *et al.* 2005). Isotope signatures from Southampton Island (Atkinson, unpublished) suggest that some of the knots nesting there are from the northern-wintering roup, but birds with the orange flags of the Argentinian (Tierra del Fuego) population have also been seen on the same island at East Bay (P.A. Smith pers. comm. 2006).

If the southeast U.S. and Maranhão birds are *roselaari*, the implication is that at least some of them migrate from their wintering areas to Delaware Bay and then to Alaska. Isotope signatures of Alaskan birds (N. Clark unpublished data & Atkinson unpublished data) do not support this view. Furthermore, this would seem to be an unlikely scenario because the distance between Florida and Alaska is almost the same as the distance between Delaware Bay and Alaska (but both are well within the capability of Red Knots for a non-stop flight (Weber and Houston 1997) and Delaware Bay is on an approximate great circle route between Maranhão and Alaska). Therefore the flight from Florida to Delaware Bay would seem unnecessary. However, the possibility that Alaska-bound birds take such a circuitous migration route should not be discounted because it could have arisen in view of what is known about Red Knot evolution (see Taxonomy section). Another factor that might have led to or maintained such a migration route is the existence of an abundant food resource in Delaware Bay in the form of horseshoe crabs' eggs. Therefore the 5,000-6,000 km cross-continent flight might have been possible from Delaware Bay but not from Florida.

C. c. roselaari certainly use the Pacific coast flyway and at least some winter in California and Baja California (Tomkovich 1992, Page *et al.* 1997, Page *et al.* 1999, Paton *et al.* 2003). However, it has also been suggested that knots wintering in Florida conceivably may include *C. c. roselaari* and that they use a mid-continent route to reach breeding areas in Alaska (Harrington 2001). However, there is no good evidence to support or refute this idea.

Color-banding shows that there is little or no interchange between the knots that winter in Maranhão and Tierra del Fuego or between Florida and Tierra del Fuego. There is no evidence of interchange between Florida and Maranhão, but there have been insufficient observations (few knots marked in Maranhão) to accept this as verified.

Isotope analysis of primaries from 16 knots caught in Alaska in spring shows that almost certainly they did not molt in Florida (N. Clark unpublished data, Atkinson unpublished data).

However, although this is inconsistent with *roselaari* molting and wintering in Florida, it is not proof that they do not because at 35,000-50,000 (Wetlands International 2006) the Alaska population is much greater than the 7,500 wintering in Florida. Therefore, as most of the Alaskan birds must winter elsewhere, a much greater sample than 16 will be necessary before there can be any confidence that none go to Florida.

Isotope analysis of primary coverts taken from Red Knots nesting in the main *rufa* breeding area on Southampton Island, Hudson Bay, showed a southeast U.S. (or possibly northern Brazil) signature. This confirms that at least some birds wintering in that area are *rufa* (Atkinson unpublished data, Peck unpublished data).

Until the taxonomic uncertainties are resolved, the possibility remains that the Maranhão and Florida wintering populations include unknown numbers of *roselaari* as well as an unknown proportion of *rufa*. This complicates the assessment because the trend and population size of *roselaari* are uncertain. The estimate for *roselaari* in the U.S. Shorebird Conservation Plan (Brown *et al.* 2001) of 150,000 is based on counts in the 1970s and 1980s is probably a gross overestimate of the population at the time it was published. Current estimates at 35,000-50,000 are much lower (Wetlands International 2006). However, without systematic surveys it is uncertain whether there has been a decline in the *roselaari* population. It is likely that all knots using the Pacific flyway are *C. c. roselaari*. However, counts on the U.S. Pacific coast from California to Washington reported by Page *et al.* (1999) of 9,035 in spring, 7,981 in fall and 4,813 in winter during 1988-1995 suggest that that flyway comprises no more than about 10,000 birds. It is therefore very difficult to account for even the current *roselaari* estimate of 35,000-50,000 birds in winter, if it is true that they all winter in the Americas. This is especially so if it were shown that the Florida and Maranhão wintering populations are all *rufa* as some of the evidence would seem to suggest.

In summary, there are five known major wintering sites used by >1,000 Red Knots in the New World. These support a combined total of about 45,000 individuals (Table 2). To this figure a few small populations elsewhere can be added (e.g. 100 in the Upper Bay of Panama in Feb 2002 (Buehler 2002)) and possibly some in western Venezuela where there were 520 in the mid-1980s (Morrison and Ross 1989). Allowing for some error in counts and estimates, and the fact that some counts are not recent, it would seem unlikely that the total is less than 40,000 or more than 50,000.

Table 2. Recent population estimates of Red Knots wintering in the New World

Location	Population	Recent trend	Date	Subspecies	Data source
Tierra del Fuego	17,653	Major decline	Jan 2005	*rufa*	Morrison unpublished data, Ross pers. comm. 2005
Maranhão, northern Brazil	7,575	Slight decline	Feb 2005	uncertain	Baker *et al.* (2005a)
Florida	7,500	Not known	2004/05 winter	uncertain	Harrington unpublished data
California, Mexico and possibly farther south	9,035[1]	Not known	spring 1988-95[1]	*roselaari*	Page *at al.* 1999
Texas coast	3,000 (300)[2]	Probable decline	1985-1996 (Jan 2003)[2]	uncertain	Skagen *et al.* 1999
Total	44,763				

[1] The figure of 9,035 represents the maximum spring count along the main U.S. Pacific coast during 1988-1995 and probably includes both migrants and wintering birds. Winter counts alone produced 4,813 in the United States 1988-95 (Page *et al.* 1999) and 1,082 in Baja California (Page *et al.* 1997). Presumably the remaining 3,000 winter elsewhere in Mexico or further south.

[2] Inquiries suggest that the Texas coast wintering population may now be as little as 300, but there has been no recent census.

Assuming that the figures in Table 2 are accurate and discounting small numbers elsewhere, then, depending on whether the populations of uncertain subspecies are all *rufa* or all *roselaari*, the population of these two subspecies can range from a *rufa* population of 17,653 to 35,728 birds and a *roselaari* population of 9,035 to 27,110 birds. This does not take account of the fact that the Alaskan population, assumed to be *roselaari*, has been estimated at 35,000-50,000 (Wetlands International 2006). However, as discussed below, there is the possibility that many of the Alaskan birds are not *roselaari* but *rogersi*.

2. Population Size and Trends in *Calidris canutus rufa*

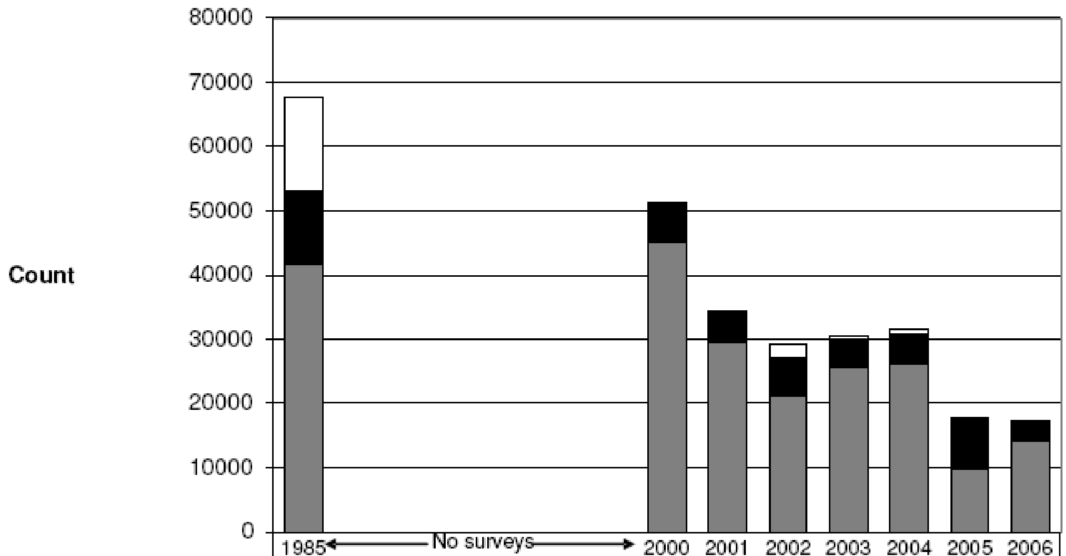
a. Wintering Population Trends

The uncertainty about the numbers of *roselaari* and the areas in which it winters is in strong contrast to what is known about the *rufa* population of Tierra del Fuego. That population has been counted there several times since the mid 1980s and (mixed with birds from Florida and Maranhão) every year from 1986 to 2005 as it passes through Delaware Bay as well as at several sites in between. It is the decline in this distinct biogeographic population that is of primary concern.

Aerial counts during December to early February within the main *rufa* wintering area in southern South America have shown catastrophic decline over the 20 years, 1985-2005. The birds are thought to be relatively sedentary at this time of the year so there should be little possibility of double counting or missing those that have not yet arrived or have already departed. Moreover the same observers and survey techniques were used for all the aerial counts in South America. Surveys in the main non-breeding areas are the main method of population estimation for Red Knots recommended by the *U.S. Shorebird Conservation Plan* (Brown *et al.* 2001).

In the mid 1980s, the southern wintering *rufa* population numbered 67,546 and was found along 1,600 km of the Atlantic coast from Tierra del Fuego to Río Colorado in northern Patagonia (Morrison and Ross 1989). By 2006, numbers had fallen to 17,211 and almost the entire population was confined to Tierra del Fuego (Fig. 4). Within Tierra del Fuego, the largest numbers (at least 70% of the population) have always occurred at Bahía Lomas. There the count fell by about 50% (from over 45,000 to just over 20,000) between 2000 and 2002, remained stable in 2003 and 2004, but then fell again by a further 50% to less than 10,000 in 2005 (Fig. 5). In Tierra del Fuego as a whole, numbers fell from over 51,000 in 2000 (compared with 53,000 in the 1980s) to the 27,000-31,000 range between 2002 and 2004, and only 17,211 in 2006 (Fig. 4). By 2003, Bahía Lomas held 84% and the combined core areas 98% of all knots counted over the entire wintering range in southern South America. The most recent decreases have occurred mainly in the numbers at Bahía Lomas. At Río Grande in the Argentinian part of Tierra del Fuego, aerial counts show that the population has remained relatively stable at 3,500-5,000 (Fig. 4) though ground counts in November have shown a drop from 6,000 in 2000 to 4,000 in 2004 (Baker *et al.* 2005a). Knots have almost disappeared from wintering sites outside of Tierra del Fuego on the Patagonian coast of Argentina, falling from over 14,300 in the 1980s to 790 in 2004 (Morrison *et al.* 2004, Morrison unpublished data) (Fig..4). This is reflected in surveys at all other sites in Patagonia where knots have occurred during the past 20 years, with 14 out of the 18 sites occupied in 1985 having none in 2004-2005. In the same period, the population of Hudsonian godwits (*Limosa haemastica*) which also spends the northern winter in Tierra del Fuego but takes the mid-continent flyway to breeding sites in Arctic Canada, remained stable (Morrison unpublished data, Ross pers. comm. 2005).

Banding studies in Tierra del Fuego invariably show a low proportion of juveniles and it is thought that most winter further north (Baker *et al.* 2005b). Therefore the aerial counts of the Tierra del Fuego wintering population will underestimate its true size to the (probably marginal) extent that not all of the juveniles are included.



	1985	2000	2001	2002	2003	2004	2005	2006
□ Other Argentina	14314	-	-	2029	560	790	-	-
■ Other Tierra del Fuego & S Chilean Patagonia	11532	6105	5000	6086	4415	4608	7826	3081
■ Bahia Lomas	41700	45150	29355	21156	25500	26170	9827	14130

Year

Figure 4. The number of Red Knots spending the austral summer in southern South America according to aerial counts made during the *Atlas of Shorebirds* project in 1985 (Morrison and Ross 1989) and during 2000-2006. Grey sections are numbers at Bahía Lomas, black other sites in Tierra del Fuego (mainly Río Grande) and Southern Chilean Patagonia and white other sites further north along the coast of Argentina. No counts were made north of Tierra del Fuego in 2000, 2001 or 2005 because reports by ground observers (e.g. Ferrari *et al.* (2002) & Escudero *et al.* (2003)) showed that very few knots wintered at any of the sites at which they had previously been reported.

b. Passage Population Trends

The decline observed in wintering populations is also reflected in surveys of knots at all major stopover sites along the coast of South America. At Bahía San Antonio, where surveys of passage birds are made during March and April, numbers have fallen from 15,000-20,000 in

1990-1997, to 7,000-12,000 in 1998-2002, to 5,000-6,500 in 2003-2005 (Fig. 5). Similar declines have been recorded at Península Valdés (Bala *et al.* 2001, Bala *et al.* 2002, Hernández *et al.* 2004). In Brazil, yearly counts at Lagoa do Peixe fell from a high of 10,000 in 1996 to 5,500-7,000 in 1996-1999, and 900-1,500 in 2001-2003 . Taken together, these results support the conclusion that the Tierra del Fuego wintering population has declined significantly.

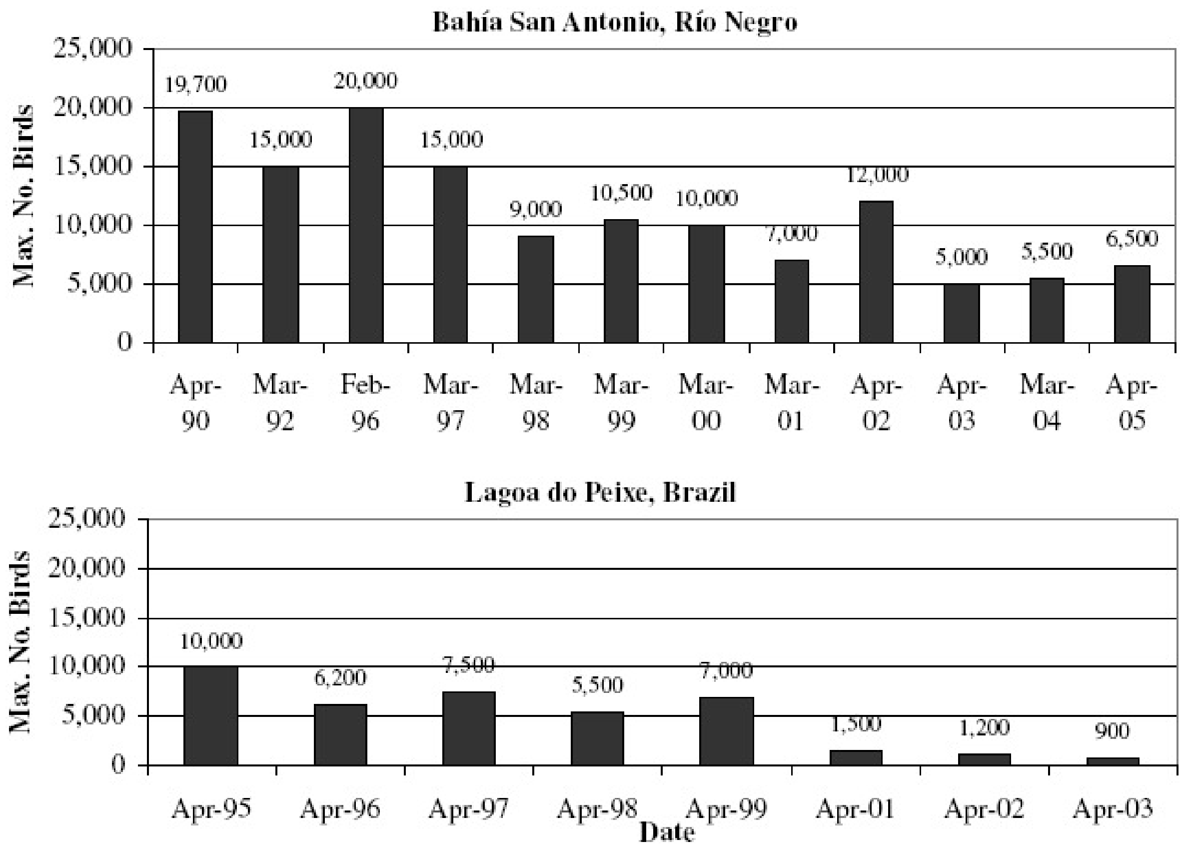


Figure 5. Peak numbers of Red Knots during northward passage at Bahía San Antonio, Argentina 1990-2005 (González unpublished data) and Lagoa do Peixe, Brazil 1995-2003 (Serrano unpublished data). Counts at Bahía San Antonio were mostly carried out on a weekly basis throughout February to April. Counts at Lagoa do Peixe were obtained during expeditions that covered the peak spring passage in April.

There have been no regular systematic surveys of knots at any site further north in South America, either on passage or during the northern winter. Baker *et al.* (2005a) found no evidence of decline in knots wintering in Maranhão, though this was based on just two counts 20 years apart (in 1985 and 2005). In South Carolina, the USFWS carried out annual surveys in Cape

Romain National Wildlife Refuge during 2000-2004 (Sanders pers. comm. 2005) (Fig. 5). These show a decline in passage birds similar to that seen in South America with numbers dropping from a March-April high of over 7,000 in 2000 to a low of 3,157 in 2004. Southbound knots also declined from over 3,000 in 2001 and 2002 to 1,641 in 2003.

The longest running survey is the Delaware Bay Aerial Shorebird Survey that was started in 1982-1983 by the New Jersey Audubon Society and has been carried out from 1986 to the present by the NJDFW-ENSP (Fig. 6, Clark *et al.* 1993). The survey covers both shores of the bay and takes place under similar tidal conditions each week for the six weeks of the stopover period. Every effort has been made to ensure even and consistent coverage. This has been achieved partly by keeping to the same methodology and partly by minimizing turnover of personnel. In fact the key role of counter has been fulfilled by the same person (K. Clark, NJDFW-ENSP) since 1986. It is not a total census, as it does not cover the adjacent Atlantic Coast of New Jersey or the intertidal marshes of Delaware Bay (Fig. 7). Moreover the peak count does not represent the total flyway population because of turnover (some birds may not have arrived, others may have departed). In 2004, for example, Gillings *et al.* in prep.) estimated that, due to turnover, approximately 24,000 Red Knots passed through the Delaware Bay, despite the peak count being only 13,315 (Fig. 6). It is also likely that turnover rates have varied as the birds have responded to changes in the quantity of food. Overall, turnover rates were probably higher during 1986-1996 when horseshoe crab eggs were abundant than subsequently because of decreased egg availability. Higher turnover in the early years may be the reason for the greater volatility in peak numbers when compared with more recent years (Fig. 6).

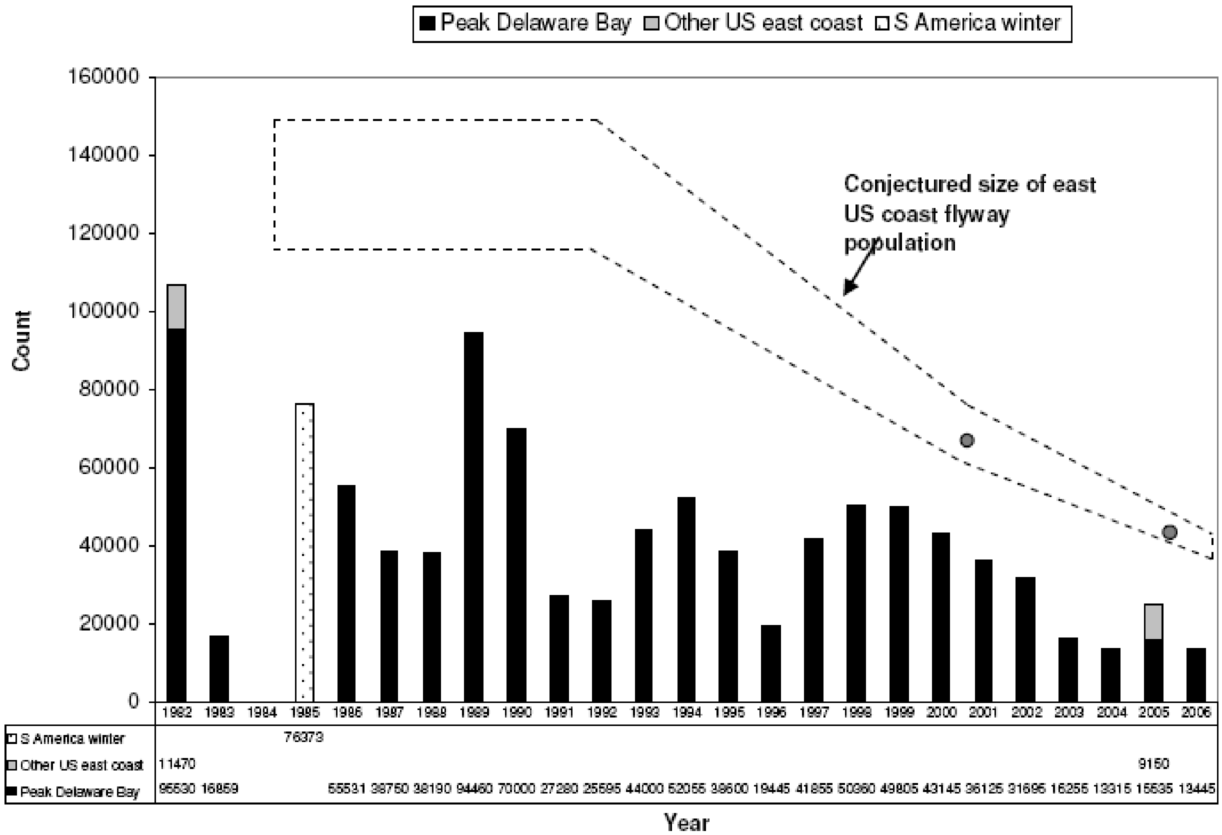


Figure 6. Peak counts of Red Knots in Delaware Bay May 1982-2006 as shown by weekly aerial counts (New Jersey Audubon Society (1982-1983), New Jersey Division of Fish and Wildlife, Endangered and Nongame Species Program (1986-2005). Also shown are simultaneous counts from other U.S. East Coast sites (mainly Virginia), the 1985 S. America winter count (Morrison and Ross 1989), our conjectured estimate of the size of the total U.S. east coast flyway population (range enclosed by dashed lines) and the estimates of the flyway population in 1999 of 60,000 (Baker *et al.* 1999a) and in 2005 of 32,728 (shown by gray dots (also see text).

In 1982 and 1989, the number of knots in Delaware Bay reached peaks of 95,530 and 94,460 respectively. Although peak counts in the intervening years were lower and in some years surprisingly few, there is no reason to suppose that the population declined. In 1985 when there was no aerial survey in Delaware Bay, for example, the South America count (mainly the far south and Maranhão) was 76,373 to which can be added whatever population was then wintering in Florida. Since the early 1990s, however, the aerial survey has documented a steady decline with only 13,445 in 2006 (Fig. 6).

Figure 7. Flight path of aerial surveys along the Delaware Bay conducted by the New Jersey Division of Fish and Wildlife.

Included in Fig. 6 are counts made simultaneously with the Delaware Bay peak elsewhere on the east coast of the U.S. (mainly in Virginia). The dashed lines represent our conjectured estimate of the flyway population and indicates the range over which we considered the population fluctuated as well as the broad trend. Included is the estimate of 60,000 for 1999 by Baker *et al.* (1999a) and the aggregate counts for the three main wintering populations (Tierra del Fuego, Maranhão and Florida) of 32,728 set out in Table 2.

Until the late 1990s, the peak aerial counts in Delaware Bay were quite erratic from year to year (Fig. 6). Many of these changes are so big that they cannot have reflected changes in the total population because they are demographically impossible. Moreover they are also far too large to be due to counting error. At this stage we can only speculate about the reasons. Possibly high availability of horseshoe crab eggs led to rapid turnover, leading to a reduction in the count; conversely bad weather may have prevented birds from departing leading to a build-up. It is also possible that in some years many birds exploited food resources, such as *Donax* or mussel spat, elsewhere along the Atlantic coast and did not visit Delaware Bay.

Our conjectured estimate of the east U.S. coast flyway population is based on the peak aerial counts in Delaware Bay, counts elsewhere along the U.S. east coast, the 1985 and 2000-2005 aerial counts in Tierra del Fuego, and the counts in Florida and Maranhão referred to above. It also takes into account the fact that peak counts will almost invariably underestimate total stopover population because of turnover (Gillings *et al.* in prep.).

In the past, it has been assumed that all the knots stopping over in Delaware Bay in May are *rufa*. This is no longer certain, but the fact that a large proportion of the birds that pass through Delaware Bay are *rufa* from southern South America is suggested by the fact that the stopover population and the southern South America wintering populations have shown similar declines (Fig. 6). However, recent studies using carbon and nitrogen isotope ratios of feathers (Atkinson *et al.* 2005), and resightings of birds marked from other wintering areas, have shown that approximately half the birds caught in Delaware Bay in 2004 and 2005 were from the Tierra del Fuego wintering population (Fig. 8). The remainder were from the more northerly wintering areas in Florida and Maranhão, Brazil.

The literature includes various estimates for the *rufa* population in the 1980s and early 1990s in the range 100,000-150,000 (Harrington *et al.* 1988, Morrison and Harrington 1992). These estimates were all made on the assumption that *rufa* includes all birds passing through Delaware Bay, i.e. those wintering in Maranhão and Florida as well as Tierra del Fuego which are consistent with the information presented in Fig..6. Later, however, Morrison *et al.* (2001) suggested that *rufa* numbered as many as 170,000 around the turn of the century by including 18,700 using the Interior Flyway. This is presumably why the same figure is mentioned in the *U.S. Shorebird Conservation Plan 2001* (Brown *et al.* 2001). However, this figure appears to have been an over-estimation by a factor of almost three. There are two reasons: (1) Baker *et al.*

(1999a) had already published a much reduced estimate of only 60,000, and (2) the figure of 18,700 is the sum of maximum counts for all sites along the Interior Flyway for January to June (Skagen *et al.* 1999), which might involve duplication.

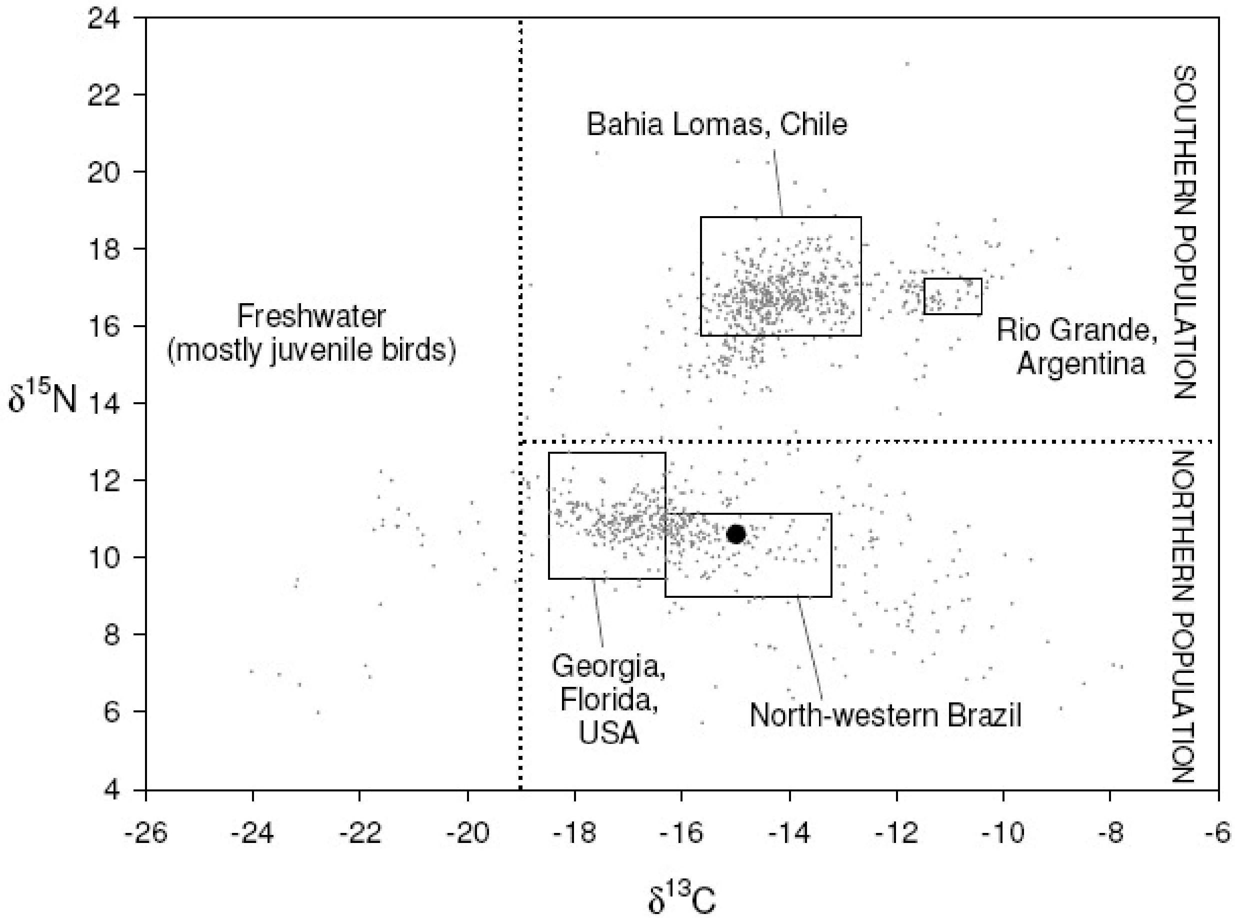


Figure 8. Stable isotope signatures of primary coverts taken from 1,150 Red Knot on spring migration through Delaware Bay in May and June 2004 (Atkinson unpublished data). Boxes mark the 90% confidence intervals of birds of known wintering origin. The large dot represents the signature of a tertial taken from a bird nesting on Southampton Island, Nunavut, Canada. Dotted lines show the approximate separation between juvenile birds (with a freshwater Arctic signature) and the northern and southern wintering populations.

Baker *et al.* (2004) showed that the reason the Tierra del Fuego population fell by almost 50% between 2000 and 2002 (Morrison *et al.* 2004) (Fig. 4) was because adult survival declined from an average of 85% in 1994-1998 to only 56% during 1999-2001. They also calculated trends in the population that could be expected if survival either recovered to 85% (Fig. 9a,the "best case scenario") or remained at 56% (Fig. 9b, the "worst case scenario"). Subsequent counts during 2003-2005 (added to Fig. 9b) show that although the population held up in 2003-2004, the sudden drop to only 17,653 in 2005 brought it right back towards the track of the worst case scenario, indicating an increased risk of extinction within the next decade.

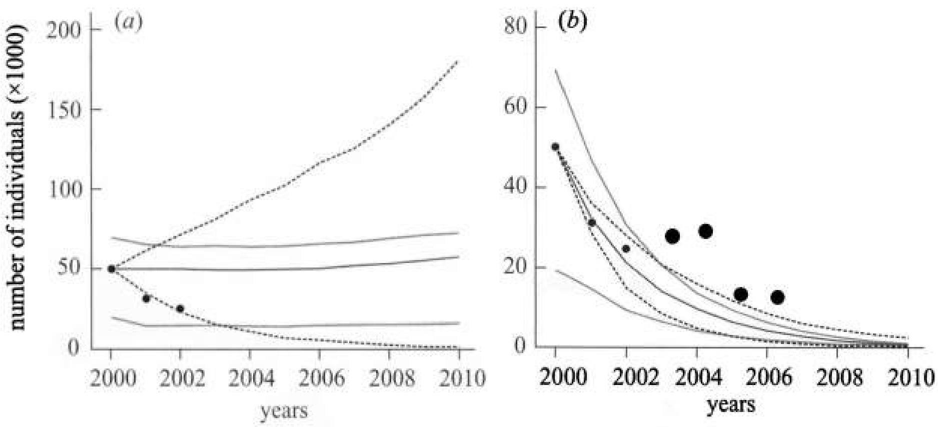


Figure 9. Predicted population trends and associated 95% confidence limits of adults (dashed lines), juveniles (lower gray line) and both combined (top gray line) for 10 years from 2000, with (a) constant adult survival of 85% and juvenile survival being half that of adults (λ = 1) and (b) constant adult survival of 56% and juvenile survival being half that of adults (λ = 0.66). The small dots represent the aerial censuses of the over-wintering flock of adults in Tierra del Fuego during 2000-2002, and the large dots are the counts during 2003-2006. The 95% upper and lower confidence limits are based on 1,000 bootstrap iterations. Modified from Baker *et al.* (2004) and published in this form in Baker *et al.* (2005a).

Since Fig. 9b was first published, it has been the subject of some misinterpretation. Therefore, it is emphasized that its purpose was to demonstrate the consequences of adult survival remaining as low as 56% and not recovering. It assumes constant adult survival, but all studies show that in the real world adult survival varies from year to year. Thus there is no expectation that it will remain fixed at any particular value. The fact that the 2003 and 2004 counts were above the 95% confidence limits means that survival was more than 56%; the sudden drop in 2005 suggests that survival was much less than 56%. Therefore although Fig. 9b predicts possible extinction as early as 2010, the year of extinction is unknowable, neither is extinction certain. The relevance and value of the model is that, combined with the recent counts, it shows that the current population trend is one that carries a considerably increased risk of extinction unless there is effective short term conservation action.

3. Population Size and Trends of *C. c. roselaari*

C. c. roselaari is thought to breed in Alaska and on Wrangel Island, Russia, and winter in the Americas, whereas *rogersi* breeds in NE Siberia, mainly the Chukotski Peninsula and winters in Australasia (Tomkovich 1992). *Roselaari* are slightly larger than *rogersi* and more intensely colored in breeding plumage on the belly and under-tail coverts.

If all knots seen in Alaska are *roselaari* and if all *roselaari* winter in the Americas, then it is very difficult to account for them in winter. In the mid-1980s, Morrison and Ross (1989) carried out an aerial count of shorebirds along the entire coast of South America. The only significant numbers of knots recorded were 67,500 *rufa* between Tierra del Fuego and Río Negro province, Argentina, and 8,100 of uncertain status in Maranhão, Brazil. Farther north, there is no evidence that numbers wintering along the Pacific coast of the U.S. and Mexico ever exceeded more than about 10,000, with another 10,000 in Florida and perhaps 5,000 in Texas. These figures total approximately 100,000. Subtract the definite *rufa* population and only 33,000 knots are left that could contribute to the 150,000 *roselaari* there were once reported to be in Alaska. Similarly, if the present *roselaari* breeding population is 35,000-50,000, it is only possible to account for 9,000-27,000 in the Americas in winter (Table 2). It seems that any of the following hypotheses could explain this situation:

H1: Many of the birds seen in Alaska in spring are not *roselaari* but *rogersi* (which migrate to Australasia). If so, the current *roselaari* population may be only the 9,000-27,000 suggested by winter counts, and it may be even more threatened than *rufa*.

H2: Part of the *roselaari* population winters outside the Americas; if so, no one knows where.

H3: Major *roselaari* wintering grounds in the Americas remain to be discovered.

The resolution of which wintering populations are *roselaari* and which are *rufa* is important for the effective conservation of both subspecies, especially if one or the other turns out to far less numerous than has previously been supposed.

4. Summary of Population Trends

Shorebird life-history traits comprise low fecundity (clutch size ≤4 eggs, high nest failure, only one brood per year), delayed maturity and high annual survival (70-90%) (Sandercock 2003). In these respects, the Red Knot is an exemplar of a shorebird. As with most Arctic-breeding species, productivity is generally low and in some years can be virtually zero. Productivity depends on the weather, especially its effect on the chicks' thermoregulation requirements and the availability of their invertebrate food, and predator abundance. The latter tends to be cyclic with a 3-4 year period that is closely tied to the abundance of lemmings (Underhill *et al.* 1993). Years when there are few lemmings and many predators can be extremely unproductive for knots. However, predator cycles are usually not uniform across all breeding areas so most years there is generally some production of young.

To some extent, periodic changes in the numbers of knots may be related to Arctic breeding conditions. However, other shorebird populations that breed in the same areas of the Arctic as knots have experienced these conditions, but have not shown the same decline (Fig. 10). Therefore, although some changes in knot populations can be ascribed to Arctic breeding conditions, they are unlikely to be the primary cause of the long-term decline.

Climate change is predicted to have adverse consequences for many Arctic-breeding shorebirds (Rehfisch and Crick 2003). However, we are not aware that this has yet had an impact on Red Knot populations. Certainly, Arctic breeding conditions, though variable from year to year, have not shown any systematic change in the Southampton Island study area since 2000.

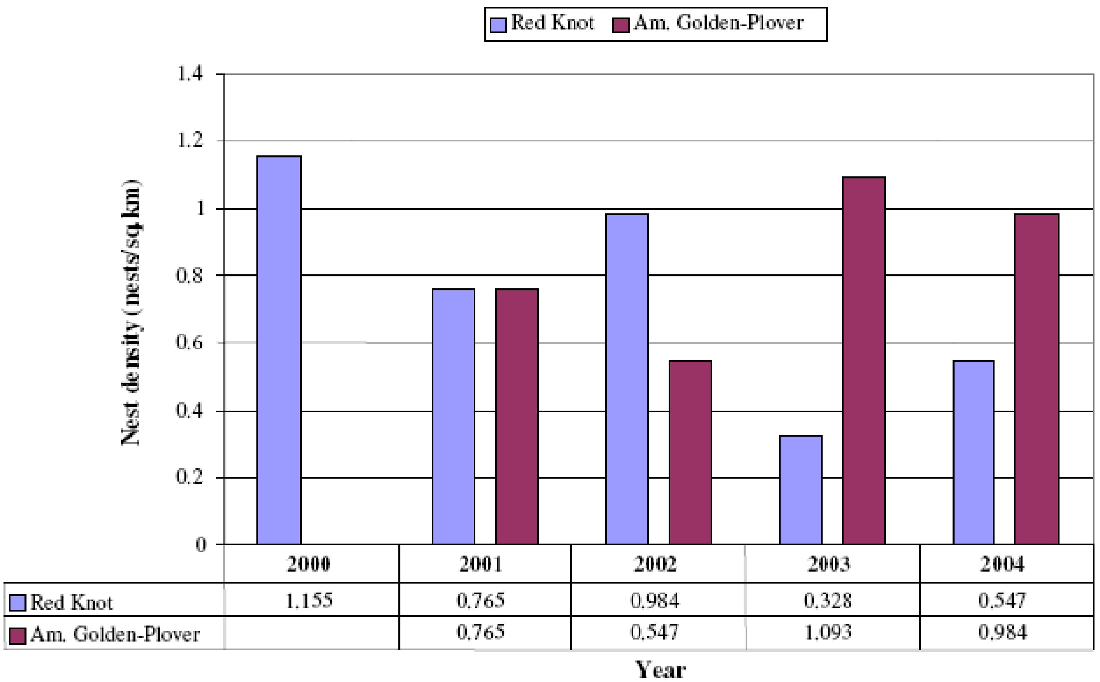


Figure 10. Density of the nests of Red Knots and American Golden-Plovers in a 9.2 km^2 study site on Southampton Island, Nunavut, Hudson Bay, Canada during 2000-2004. American Golden-Plovers were not included in the survey until 2001.

Intensive studies of *rufa* throughout the West Atlantic Flyway only began in 1997, by which time the population had already dropped from the 100,000-150,000 reported in the 1970s and 1980s to close to the 60,000 estimated in 1999 (Baker *et al.* 1999a). Therefore we have little information about the cause of this initial decline. Studies since 1997 have shown:

- the majority of the populations that winter in Tierra del Fuego, Maranhão and Florida pass through Delaware Bay during northward migration;
- the Tierra del Fuego population has suffered a major decline, but there has been no discernible trend in the birds from Florida or Maranhão;
- a major reduction in the survival of the Tierra del Fuego population from an average of 85% during 1994-1998 to 56 % during 1998-2001 coupled with lower rates of recruitment (Baker *et al.* 2004) was responsible for the decrease in the Tierra del Fuego population from over 50,000 in 2000 to 30,000 in 2002-2004;

- continued low survival exacerbated by poor Arctic productivity was likely responsible for the further decline in the Tierra del Fuego population from 30,778 in January 2004 to 17,653 in January 2005 (Atkinson *et al.* 2005);
- birds caught in Delaware Bay in May at a low weight during 1998-2002 had significantly lower survival than birds caught at a higher weight (after controlling for the general increase in weights that takes place during the stopover) (Baker *et al.* 2004);
- between 1997 and 2003, the proportion of well-conditioned knots in Delaware Bay around the normal departure date at the end of May declined by 70% (Baker *et al.* 2004);
- in recent years, especially in 2003 and 2005, substantial numbers of Tierra del Fuego birds have arrived in Delaware Bay later than usual; and
- after about 1996 there has been an order of magnitude decline in the availability of horseshoe crab eggs in Delaware Bay (as detailed elsewhere in this review).

Worldwide, studies of Arctic-breeding shorebirds show that declining populations are often associated with food supply problems at the final spring stopover. These include the Wadden Sea in Europe and the Yellow Sea, between Mainland China and the Korean peninsula. Although the precise reason(s) for the decline in the Tierra del Fuego *rufa* population is/are not entirely clear, the reduction in the availability of horseshoe crab eggs in Delaware Bay is a major threat to its future.

ABUNDANCE AND DISTRIBUTION

1. The Annual Cycle

Our diagrammatic representation of the annual cycle of a typical Tierra del Fuego wintering Red Knot (Fig.11) is based on the approximate dates that knots occur at different sites, more fully set out elsewhere in this review, and is merely intended to assist the reader. It is not suggested that any individual knot makes exactly the movements shown.

Soon after the chicks hatch in mid-July, the females leave the breeding grounds and start moving south. Thereafter, parental care is provided solely by the males, but about 25 days later (around August 10) they also abandon the newly fledged juveniles and move south. Not long after, they are followed by the juveniles, which start to appear along the northeast coast of the U.S. in the second half of August. Throughout the flyway, the adults generally precede the juveniles as they move south from stopover to stopover. At each, the adults gradually replace their red breeding plumage with white and gray, but do not molt their flight or tail feathers until they reach their winter quarters.

During southward migration and in some parts of the winter quarters, the number of juveniles gives a good indication of breeding success, showing some correlation with predator/prey cycles in the Arctic and with weather conditions on the breeding grounds. In some years, when there are many Arctic predators and few prey (mainly lemmings, *Lemmus* and *Dicrostonyx*), and/or when there is unseasonably cold weather, breeding success may be extremely low and many adults may abandon their breeding territories and move south earlier than usual. In other years, good breeding conditions may mean that substantial proportions of all knots in the flyway are juveniles. However, it seems that although some juveniles of the Tierra del Fuego wintering population migrate all the way to Tierra del Fuego, others winter farther north in South America (González unpublished data).

Arrival in Tierra del Fuego is from late September through October. As soon as they arrive, the adults start their annual molt of flight and tail feathers, which they finish in January. Although some depart before the end of January, the main movement north is not until February. At each stopover as they move north along the coast of South America they molt into breeding plumage with most of the change from white/gray to red taking place during March and early April. From Maranhão in northern Brazil, most probably fly direct to Delaware Bay or to the southeastern U.S. In Delaware Bay, they refuel on horseshoe crab eggs, and in about two weeks almost double their weight and depart at the end of May on the 3,000-km flight to their Arctic breeding grounds.

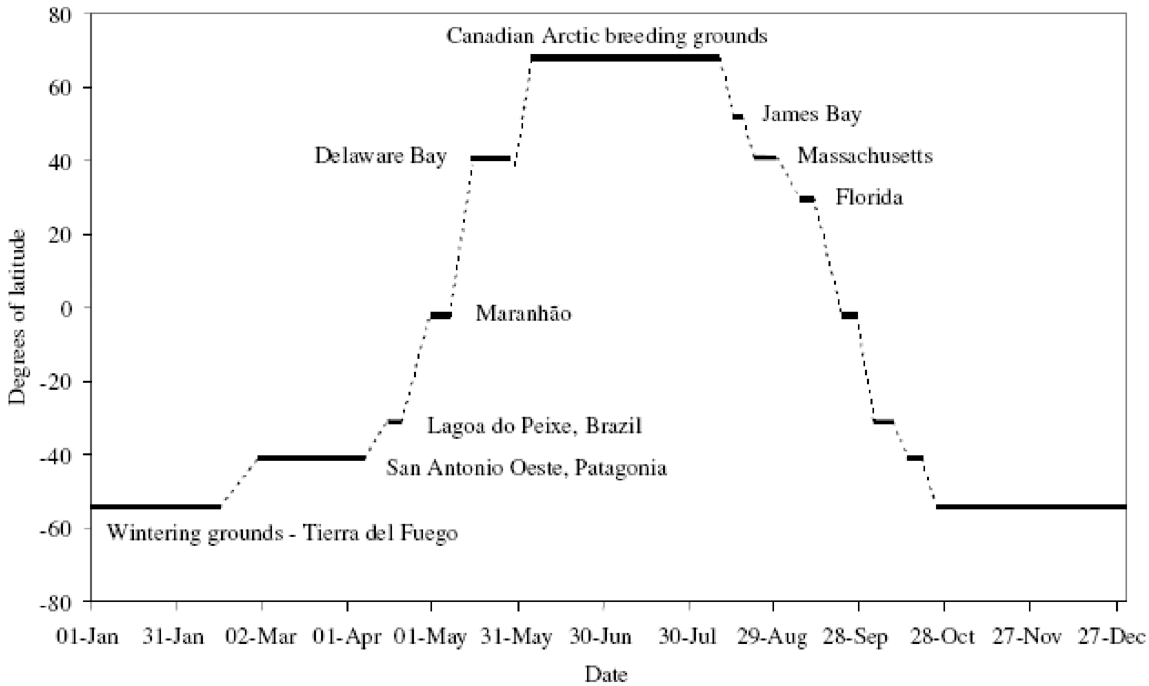


Figure 11. Diagrammatic representation of the annual cycle of a typical Tierra del Fuego wintering Red Knot *C. c. rufa* in terms of latitudinal location and date. Horizontal lines represent periods when birds stay on the breeding or wintering grounds or stopover while on migration; dotted lines represent largely non-stop migratory flights.

It is thought that most or all of the juveniles of the Tierra del Fuego population remain in South America during their first boreal summer, the breeding season for adults. Those juveniles that have spent the austral summer in Tierra del Fuego move northward, while others that have wintered in the mid- or northern latitudes of the continent may move relatively little. Eventually, about September, all the juveniles move to Tierra del Fuego in advance of most of the returning adults and commence their first molt of flight and tail feathers. After spending the austral summer in Tierra del Fuego, these immatures migrate with the rest of the adults to the Arctic where they breed for the first time, aged two.

2. Breeding Range

Morrison and Harrington (1992) considered that the breeding range of *rufa* extended across the central Canadian Arctic, from Southampton Island to Victoria Island, but pointed out that lack of coverage created uncertainty as to whether the species occurred in all parts of this range. In May 1999, biologists from NJDFW and the Royal Ontario Museum (ROM) attached radio transmitters to 65 Red Knots passing through Delaware Bay on their way to the breeding grounds. In July 1999, aerial radio-tracking was carried out on Southampton Island where eight birds were relocated. Six were found in the barren tundra uplands characteristic of most of the island, but two were found in the coastal wetlands. In a subsequent ground search, the first *C. c. rufa* nest was located.

Using land cover characteristics at the sites of the eight relocated knots, biologists with the NJDFW, ROM and Rutgers University Center for Remote Sensing and Spatial Analysis (CRSSA) developed a simple model based on three main characteristics: elevation, amount of vegetation cover, and distance to ocean coast. Using land cover images of the entire eastern Arctic the team created a map predicting the location of Red Knot habitat (Fig. 12). Additional refinements to the habitat predictive model were added based on results from the radio tracking work.

Over the next three years, 200 more transmitters were attached to birds in Delaware Bay. They were tracked throughout the Canadian Arctic as far west as Victoria Island, east to Baffin Island, north to Prince of Wales Island and south to Coats and Mansel Islands. In all, 20 birds were relocated, all within areas predicted to be Red Knot habitat. Additional refinements to the habitat predictive model were added based on the new relocated birds.

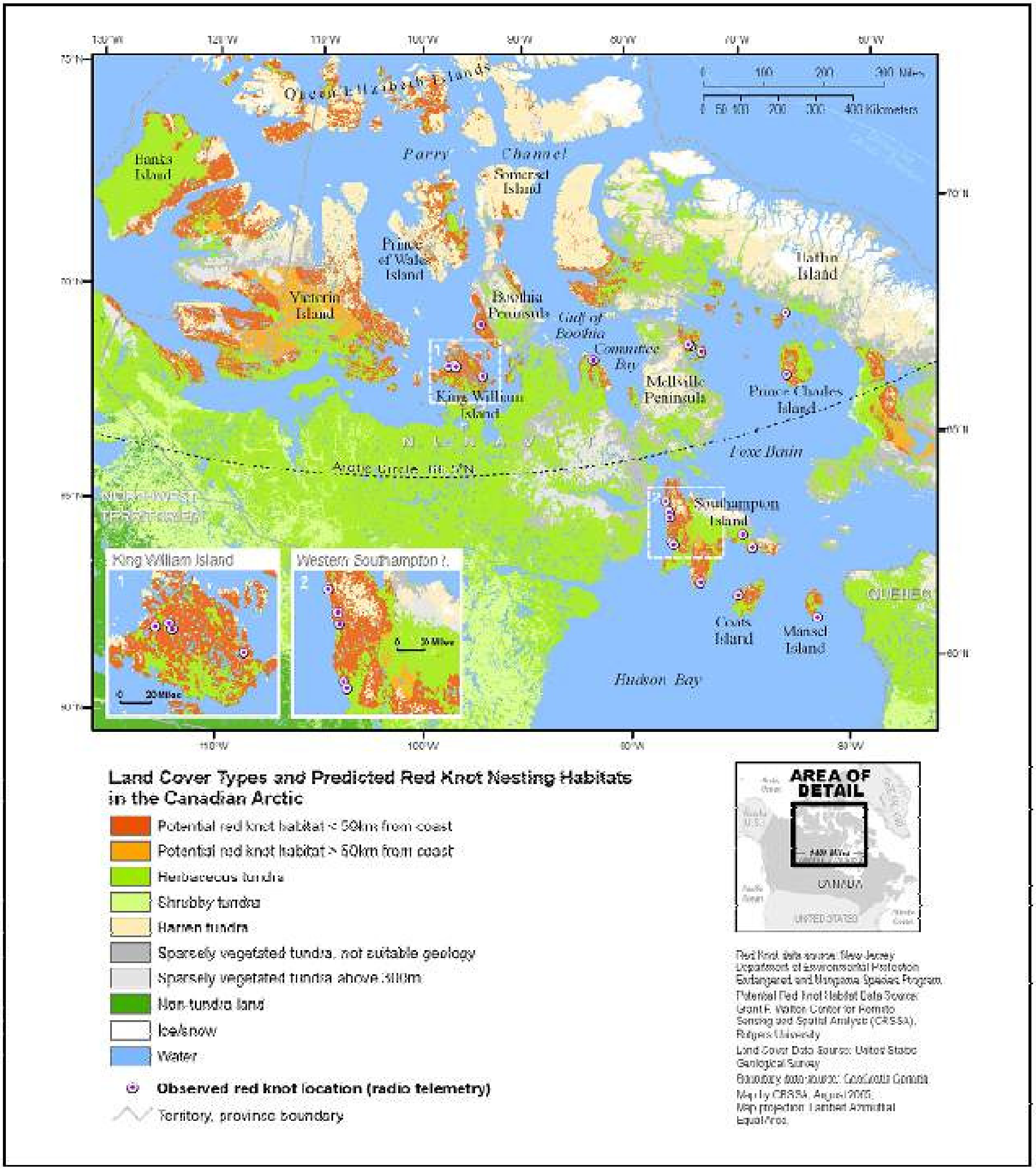
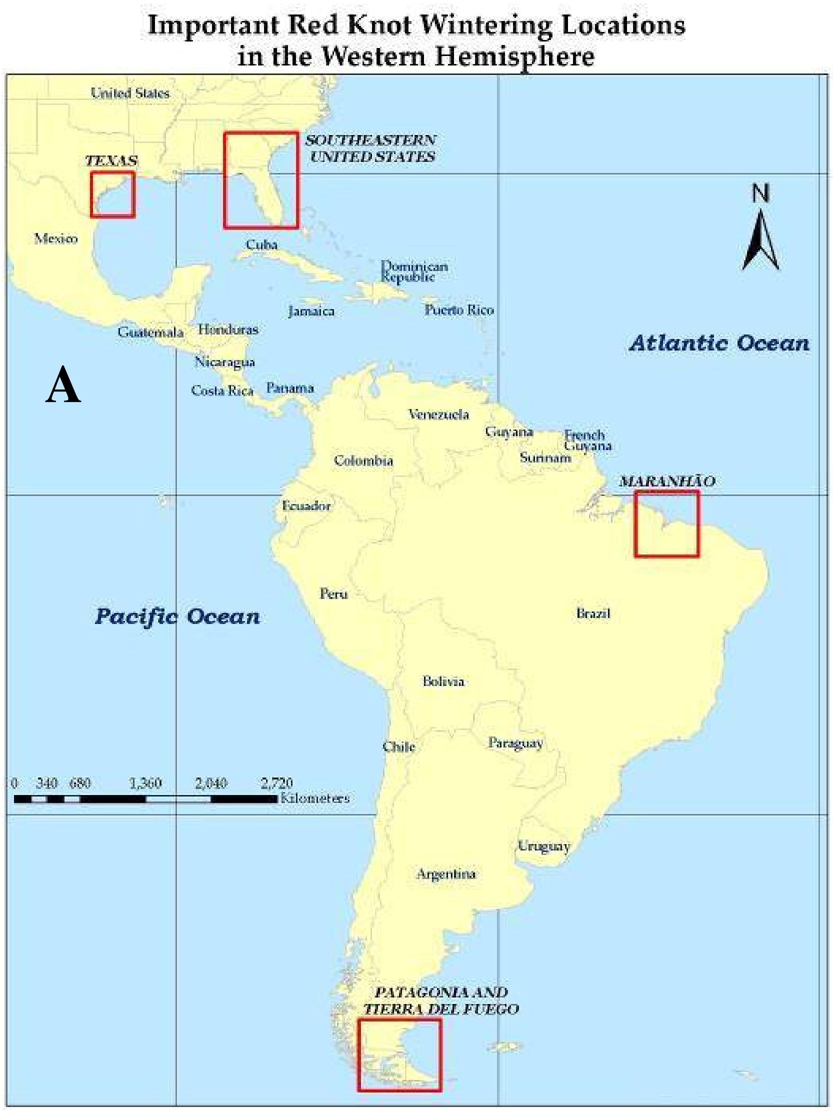


Figure 12. Predicted Red Knot nesting habitats based on land cover types in the Canadian Arctic and point locations of Red Knots obtained by radio telemetry.

3. Winter (non-breeding) Range

After breeding, all Red Knot populations migrate south to spend the northern winter in large flocks at a relatively small number of key intertidal wetlands. These invariably provide hard-shelled bivalves as the knots' main food resource. These are swallowed whole, the shells being crushed in the gut and excreted by defecation.

Red Knots winter in four distinct areas of the Western Hemisphere (Fig. 13): 1) the southeastern United States, mainly Florida and Georgia, with small numbers in South Carolina; 2) Texas; 3) Maranhão in northern Brazil; and 4) Tierra del Fuego, mainly Bahía Lomas, Chile, and Bahía San Sebastián and Río Grande, Argentina, with smaller numbers northwards along the coast of Patagonia. Other knots, presumed to be *roselaari* winter on the Pacific coast of California and Baja California, parts of the Pacific Northwest coast of Mexico in the Gulf of California, and probably also further south (Morrison and Ross 1989, Morrison *et al.* 1992, 2004, Baker *et al* 2005a, Baker *et al.* 2005b, Page *et al.* 1997, Page *et al.* 1999).



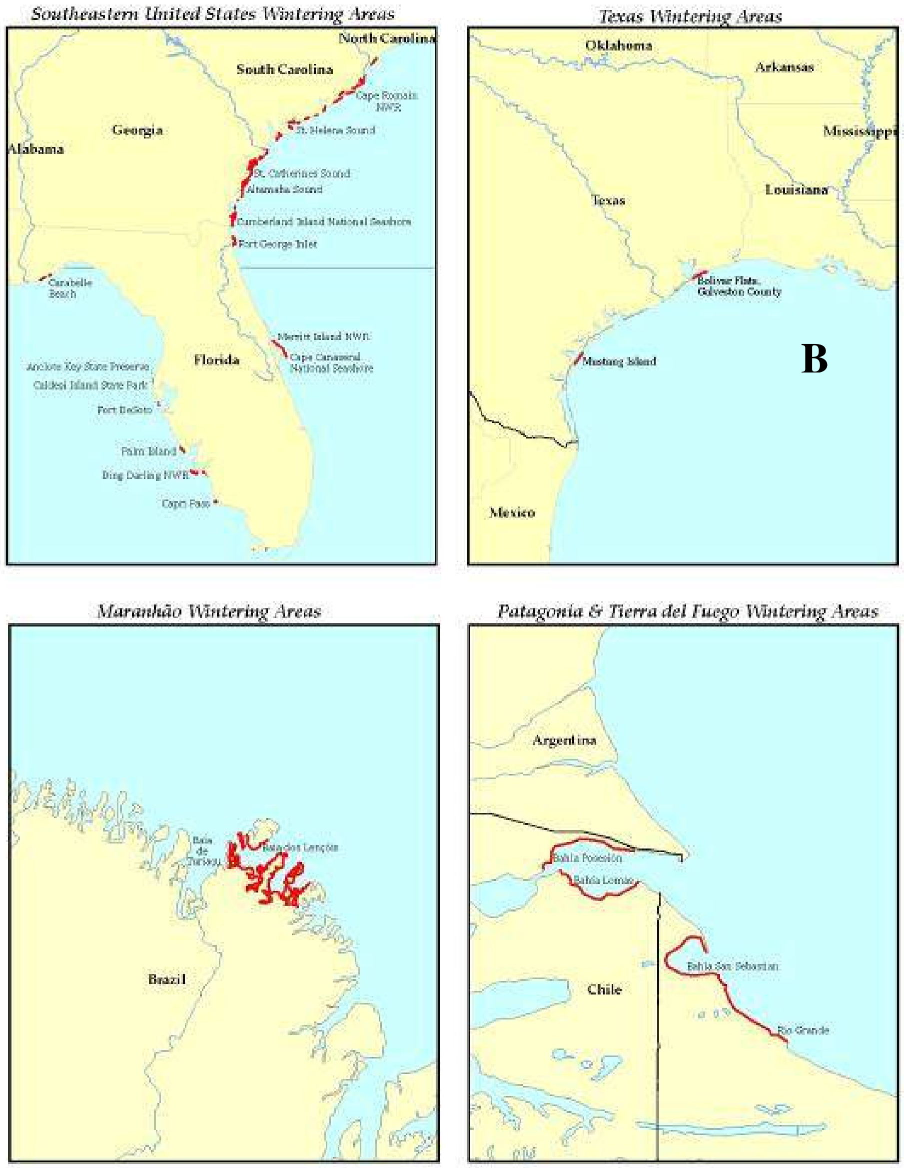


Figure 13. Red Knot wintering areas in the Western Hemisphere (A). Each area outlined in red (A) are shown in greater detail and delineated in red (B).

In the 1982-1985 survey of South America (Morrison and Ross 1989), Red Knots were found wintering along coastal Patagonia from Tierra del Fuego north to Buenos Aires Province in Argentina. However, as the southern wintering population has declined, only extremely low numbers of Red Knots have been observed in Patagonia north of Tierra del Fuego, with no birds found in some years (Morrison *et al.* 2004).

In the southern U.S., the wintering Red Knot population is believed to be distributed variably from year-to-year among Florida, Georgia and South Carolina (Fig. 14), relative to invertebrate prey abundance (Harrington and Winn pers. comm. 2005).

The number of wintering knots in Georgia varies between and within years. Results of an annual winter ground survey for the entire Georgia coast during the last two weeks in January into early February show the minimum number of knots to be in the hundreds and the highest to be nearly 5,000. The distribution of wintering knots is generally unpredictable and dispersed over much of the barrier coast and appears to be linked closely with the abundance and availability of dwarf surf clams, *Mulinia lateralis*. The knots feed primarily on dwarf surf clams and secondarily on coquina clams, *Donax variablis*.

In Florida, frequent beach replenishment in areas such as Fort Myers and Estero Island (Douglass pers. comm. 2005) may cause the loss of invertebrate prey populations and displace wintering Red Knots to more productive foraging areas elsewhere in Florida and Georgia.

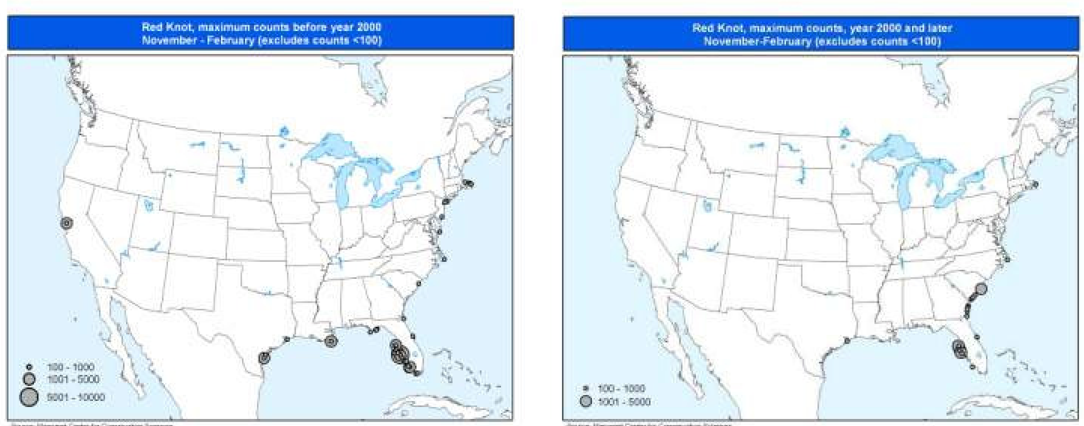


Figure 14. International Shorebird Survey Data showing distribution of Red Knots in winter in the U.S. before year 2000 (left) and during 2000 – 2004 (right). Note: the level of ISS survey effort declined after 2000; the differences in survey numbers prior to and after 2000 partly represent reduced survey effort. Source: Brian Harrington, Manomet Center for the Conservation Sciences.

MIGRATION

While migrating, all knot populations are dependent on a limited number of stopover sites. The stopover sites act like stepping-stones, in that if one is lost because the food supply fails, a whole population of knots may be jeopardized. Major stopover sites used by Red Knots worldwide include the Wadden Sea in northwest Europe, the Yellow Sea in Asia, and Delaware

Bay in the U.S. For the subspecies *C. c. rufa*, Delaware Bay is a particularly vital link in its migration between Tierra del Fuego and the Canadian Arctic, since it is at this final stopover area that the birds need to be able to accumulate both fuel for the journey and additional body stores to enable them to survive and attain proper breeding condition after arrival in the Arctic. Most fly non-stop from the north coast of Brazil to Delaware Bay and then from Delaware Bay to their Arctic breeding grounds.

The southbound 15,000-km migratory journey of *rufa* begins in August and takes it from its breeding grounds in the central Canadian Arctic through most of the east coast states of the U.S. (Fig. 15). At this time, they tend to use northern sites in Massachusetts, Connecticut, and Rhode Island more than they do in spring. After a final U.S. stopover in Georgia or Florida, they fly non-stop to northern Brazil and then on through Argentina to Tierra del Fuego. The majority of the population winters on the main island of Tierra del Fuego, where most of the population can be found in Bahía Lomas from November to February (Morrison and Ross 1989, Morrison *et al.* 2004). Other Red Knot populations begin their migration from the Arctic with the Tierra del Fuego birds, but stop to over-winter in the southeast U.S. (mainly Florida) and Maranhão, Brazil (Morrison and Ross 1989, Baker *et al.* 2005b). As discussed in the Taxonomy section of this volume, the subspecific status of these populations is uncertain.

In comparison with the southward migration, the northbound flight to the Arctic is more time-constrained and demanding because it is important for successful breeding and survival that the adults arrive on their Arctic breeding grounds at the right time and in good condition for breeding, and with sufficient resources to sustain themselves while Arctic food is in short supply.

After departing Tierra del Fuego, major stopover sites are found at Río Gallegos, Península Valdés, San Antonio Oeste and Punta Rasa in Argentina and Lagoa do Peixe in southern Brazil. From there, the birds fly across Amazonia to a possible last refueling stop in South America in the Maranhão region of northern Brazil (Fig. 16). From Maranhão, the majority fly direct to Delaware Bay, with a lesser proportion making landfall farther south along the U.S. east coast, anywhere from Florida to Virginia (Fig. 17). The knots that have wintered in Maranhão are also thought to fly direct to the U.S. east coast, but it is not known whether they migrate with or at the same time as the birds from Tierra del Fuego. The evidence is sparse, but there is the possibility that at least some Tierra del Fuego birds migrate direct from Lagoa do Peixe to Delaware Bay, a distance of 8,000 km, which is around the limit of a knot's potential flight range (Harrington and Flowers 1996). Some birds arrive in Delaware Bay in a greatly depleted condition, weighing as much as 30% below their normal fat-free weight. There they spend about two weeks feeding on horseshoe crab eggs and virtually double their mass. Some of the birds that have spent the winter in Florida pass through Delaware Bay, but it seems that many migrate northwards along the Atlantic coast of the U.S. feeding on bivalves (mainly *Donax* and blue mussel *Mytilus edulis* spat) and bypass Delaware Bay altogether (Atkinson *et al.* 2006a, Karpanty pers. comm. 2006). At the end of May, *rufa* depart on the last leg of their flight to the Arctic. In the final days before departure, the birds almost cease feeding and undergo physiological changes to prepare for migration including reducing their digestive organs and increasing flight muscle size (Piersma & Gill 1998, Piersma *et al.* 1999). They leave Delaware Bay heading inland north-northwest toward their breeding grounds. This route takes them across the vast boreal forest and low tundra of Canada, which in late May to early June can be a hostile environment to shorebirds. Many pass through and along the coasts of James Bay and Hudson Bay, although they are not believed to stop in these areas for any significant period (Morrison unpublished data, Peck unpublished data).

Once they arrive on their breeding grounds, their digestive systems are restored, but often there is very little food available so their survival and their ability to attain proper breeding condition may depend on surplus fat resources brought to the breeding grounds (Morrison *et al.* 2005) from Delaware Bay.

Delaware Bay is one of the most critical sites visited by *C. c. rufa* (Myers 1986, Harrington and Flowers 1996). Without the ability to obtain sufficient resources in Delaware Bay, both the survival of the adult birds and their productivity may decline (Baker *et al.* 2004). As early as 1986, the importance of Delaware Bay to knots and at least five other shorebird species was recognized when it became the first Western Hemisphere Shorebird Reserve. This recognition was also the impetus for the development of shorebird reserves throughout the Western Hemisphere (Myers 1986).

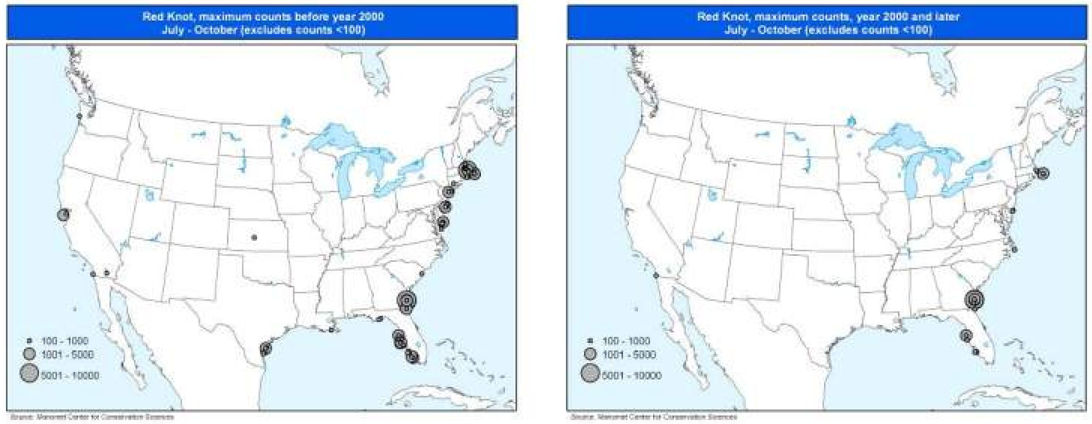


Figure 15. International Shorebird Survey Data showing distribution of Red Knots during fall migration in the U.S. before year 2000 (left) and during 2000 – 2004 (right). Note: the level of ISS survey effort declined after 2000; therefore the differences in survey numbers prior to and after 2000 may partly represent reduced survey effort. Source: Brian Harrington, Manomet Center for the Conservation Sciences.

Figure 16. Critical stopover sites used by Red Knots during northward and southward migration in South America.

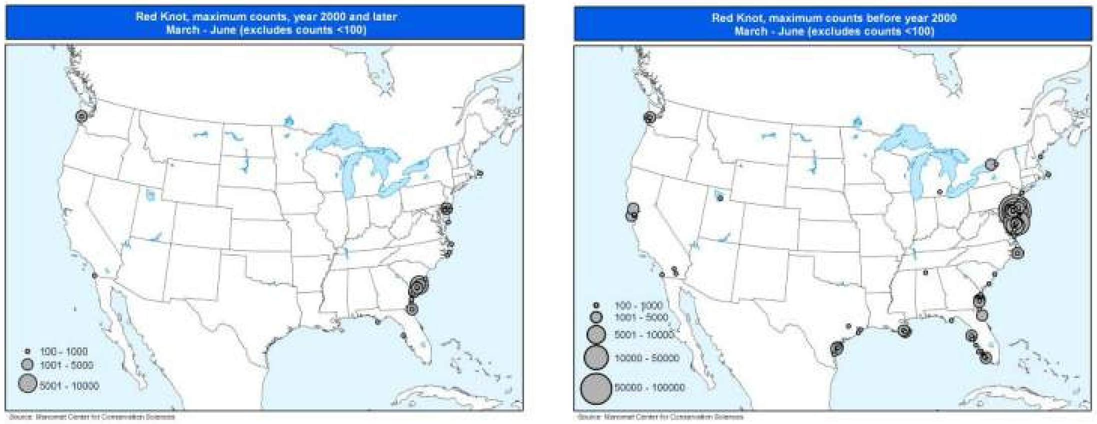


Figure 17. International Shorebird Survey Data showing distribution of Red Knots during spring migration in the U.S. before year 2000 (left) and during 2000 – 2004 (right). Note: the level of ISS survey effort declined after 2000; therefore the differences in survey numbers prior to and after 2000 may partly represent reduced survey effort. Source: Brian Harrington, Manomet Center for the Conservation Sciences.

MAJOR HABITAT TYPES

Except as otherwise stated, this account of the habitats used by *C. c. rufa* is based on the species text in the *Birds of North America* (Harrington 2001), itself deriving from an extensive review of the literature; the works cited therein are not repeated here.

Red Knots use very different habitats for breeding and for wintering/migration. Breeding habitats are located near the Arctic coast. Wintering and migration habitats are similar: generally coastal with large areas of intertidal sediments. Selection of preferred microhabitats on breeding grounds may vary depending on the amount of snow-cover individuals encounter when they arrive. Nests are usually located on sparsely vegetated, dry, sunny, elevated, windswept ridges or slopes. Nests are also usually located near wetlands and lake edges, which then become the preferred microhabitat after hatching. Preferred wintering/migration microhabitats are muddy or sandy coastal areas, more specifically, the mouths of bays and estuaries, unimproved tidal inlets and tidal flats.

1. Breeding Habitat

Red Knot nests are located principally at elevations below 150 m, often near damp habitats, though they frequently nest in drier sites in close proximity to damp habitats. Nest sites are often in slightly elevated situations where little winter snow has accumulated and/or where spring snowmelt is earliest. Twenty-one nests on Southampton Island were on average within 360 m of a glacial ridge/esker and within 200 m of a wetland greater than two hectares in size, allowing suitable foraging habitat for parents and young after the eggs hatch (Niles *et al.* in prep.). Red Knot nests also tend to be widely separated, usually at least 0.75-1.5 km apart. Red Knots and their fledglings forage in shallow sedge meadows and on sparsely-vegetated lake edges proximate to nest sites (Fig. 18).

Figure 18. Typical Arctic foraging habitat of Red Knots in shallow sedge meadows (left) and sparsely vegetated lake edge; Red Knot in foreground (right) (NJDFW).

Red Knot nests may be scraped into the main body or edges of mountain avens patches or in low, spreading vegetation on hummocky ground containing lichens, leaves and moss (Figs. 19, 20). Isolated patches of stunted willow, *Salix species* and/or mountain avens often dominate vegetation in the area. Selection of sites may vary with snow or other conditions. On Southampton Island, nests were most often found on small patches (~0.5 m diameter) of mountain avens and located in exposed areas of glacial/shattered rocks and mudboils. The amount of vegetative cover averaged 33% within one meter of the nest and 25% within ten meters of the nest (Niles *et al.* unpublished data).

Figure 19. Red Knot nest with eggs on Southampton Island, Nunavut, Canada (NJDFW).

Figure 20. Nest (in foreground) on the tundra on Southampton Island, Nunavut, Canada (NJDFW).

At the landscape scale, a model of potential breeding habitat in the Arctic was developed by New Jersey ENSP and Rutgers University using remotely-sensed land-cover characteristics. The model showed that Red Knot breeding habitat is generally found at elevations <150 m above sea level, <50 km from the coast and where vegetation cover is <5% (See Fig. 12). This predictive model was developed using 1999 telemetry data and validated with 2000-2002 telemetry locations of breeding Red Knots.

2. Migration / Stopover Habitat

a. Canada

The critical staging areas for Red Knots during spring and fall migration in Canada are along sandy beaches and tidal mudflats in James Bay and tidal mudflats and salt marshes in the northern Bay of Fundy (Morrison pers. comm. 2005, Peck pers. comm. 2005, Ross pers. comm. 2005). In the Bay of Fundy, Red Knot are rare migrants in the spring and more common in the fall (Hicklin 1987), (Map 1).

b. United States of America – Northeast

It is not believed that Maine (Tudor pers. comm. 2005), New Hampshire (Raithel pers. comm. 2005), Connecticut and Rhode Island (Raithel pers. comm. 2005, Dickson and Varza pers. comm. 2005) have large numbers of Red Knots during migration. In the northeast United States (New Jersey to Maine), critical Red Knot staging occurs mainly along New Jersey, New York and Massachusetts coastlines (Maps 2, 3). In Massachusetts, Red Knots use sandy beaches and tidal mudflats during fall migration near Scituate, Duxbury and Plymouth Beach, and along the shoreline of Cape Cod south to Monomoy (Harrington pers. comm. 2005), (Map 4). New York's Jamaica Bay Wildlife Refuge has a concentration of migratory Red Knots during spring and fall along sandy beaches and most commonly within the impoundment (Tripp pers. comm. 2005), (Map 6). Along the Atlantic Coast in New Jersey, Red Knots utilize sandy beaches during spring and fall migration for foraging (Clark pers. comm. 2005, Hernández pers. comm. 2005, Niles pers. comm. 2005, Sitters pers. comm. 2005), (Maps 7, 8).

c. United States of America – Delaware Bay

The Delaware Bay is normally used by the whole or a large proportion of the *rufa* population. Beaches typical of the Delaware Bay shore are a mixture of sand and smooth gravel, and shorebirds are distributed on Delaware Bay relative to availability of horseshoe crab eggs (Fig. 21). Red Knots spend 2-3 weeks staging in Delaware Bay feeding on horseshoe crab, *Limulus polyphemus*, eggs in the latter half of May.

Most horseshoe crabs spawn on sandy beaches around high tide, burying their eggs close to the high tide line. Spawning activity usually peaks during the latter half of May, which coincides with the main Red Knot stopover. The most important habitats in Delaware Bay (maps 19 and 20) for spawning crabs are the sandy beaches along the New Jersey shore mainly from

Town Bank to Gandys Beach and along the Delaware shore mainly from Slaughter Beach to Port Mahon. In New Jersey, Red Knots also make extensive use of the Atlantic coast, particularly the sand-spits and sandbanks around Stone Harbor Point and Hereford Inlet for roosting and occasionally for foraging on surf clams, *Donax variablis*. They also forage on spat of the blue mussel, *Mytilus edulis*, in the protected intertidal marshes behind the Atlantic coast. In Delaware, knots sometimes roost day and night in an area of relatively unvegetated marsh about 1.7 km inland from the bayshore and 500 m north of the Mispillion River. This is the only known place in the world where Red Knots have an inland nocturnal roost. In 2004 and 2005, this site became flooded and many knots regularly commuted from the Delaware shore, where they fed by day, to roost at Hereford Inlet on the Atlantic coast of New Jersey at night, a round trip of 94 km (Sitters 2004, 2005).

Figure 21. Typical sandy beach foraging habitat for Red Knots on Delaware Bay, New Jersey (NJDFW).

Extensive coastal marshes and mudflats that are typically fronted by a sandy barrier beach fringe Delaware Bay. These sandy beaches mainly 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 (Phillips 1986a). The back beaches, above normal high tide, form a low dune and are often colonized by common reed, *Phragmites australis* (Phillips 1987). The intertidal portions of the sandy beaches are of special significance as these are the focus of horseshoe crab spawning activity and of Red Knot foraging. Horseshoe crabs prefer beaches dominated by coarse sandy sediments and avoid beaches that have a high amount of peaty sediments or are adjacent to exposed peat banks (Botton *et al.*, 1988). These factors were used by Botton *et al.* (1988) to develop a classification scheme that ranked beaches as either preferred or avoided habitat for horseshoe crab spawning. Horseshoe crabs deposit most of their eggs 10-20 cm deep in sandy beach sediments (Botton *et al.* 1992) (Fig. 22); eggs are then redistributed to shallower depths by subsequent spawning and wave action where they are then available for shorebird foraging.

Starting in 1999, systematic surveys were conducted to count intertidal (i.e., spawning) horseshoe crabs and their deposited eggs throughout Delaware Bay (Smith *et al.*, 2002a; 2002b). These showed that crab egg densities vary by several orders of magnitude, sometimes exceeding 10^6/m of shoreline (Smith *et al.*, 2002b). Smith *et al.* (2002b) found that beach morphology and wave energy interacted with density of spawning females to explain variation in the density and distribution of eggs and larvae between the study beaches. Horseshoe crabs showed a preference for spawning on narrow, low-energy (i.e. wave-protected) sandy beaches. While the surveys only sampled bay-front beaches, beaches along tidal creeks were also noted as being potential hotspots for crab spawning and shorebird foraging. At a broader baywide scale, the use of intertidal beaches as horseshoe crab spawning habitat is limited in the north by low salinity (i.e. at Sea Breeze in New Jersey and Woodland Beach in Delaware) and by ocean generated energy in the south (i.e. at North Cape May, New Jersey and Broadkill, Delaware).

Figure 22. Horseshoe crab on beach in Delaware Bay depositing eggs in the sand (NJDFW).

Not surprisingly, migratory shorebird abundance is spatially variable within the Delaware Bay estuary as a consequence of these larger baywide patterns of horseshoe crab abundance and spawning activity. Migratory shorebirds in Delaware Bay show a strong preference for beaches with higher numbers of crab eggs (Botton *et al.* 1994). Shorebirds aggregate near shoreline discontinuities, such as salt marsh creek deltas and jetties, which act as concentration mechanisms for passively drifting eggs (Fig. 23). Human disturbance can greatly reduce the value of foraging habitat for knots, as discussed in the Threats section of this review. The various studies outlined above show that a complex array of factors determine the value of Delaware Bay beaches as horseshoe crab spawning and shorebird foraging habitat.

Figure 23. Shorebirds and gulls foraging near a managed area (experimental gull exclosure center frame) on Delaware Bay, New Jersey (NJDFW).

While it is the intertidal beaches that comprise the most important Red Knot habitat in Delaware Bay, Burger *et al.* (1997) have shown that migrant shorebirds, including knots, move actively between the Bay's habitats using them for foraging, resting and other behaviors according to the state of the tide, date and time of day. Though the beaches are of critical importance, during high tides (especially spring tides), the birds would be restricted to beach areas without sufficient food for profitable foraging and too close to vegetation and structures that could harbor predators. Therefore they often go elsewhere, including nearby salt marshes, sand spits and islands. On some occasions, Red Knots fly all the way across the Cape May Peninsula to use the extensive sandy beach, mud flats and salt marshes in the vicinity of Stone Harbor for both foraging and roosting.

d. United States of America – Southeast

In the southeastern United States, Red Knots forage along sandy beaches during spring and fall migration from Maryland through Florida and in Texas. Red Knots also use the tidal mudflats in Assateague Island National Seashore in Maryland and along the barrier islands in North Carolina during migration (Cameron and Therres pers. comm. 2005), (Map 9). In addition to the sandy beaches, Red Knots forage along peat banks for mussel spat in Virginia (Rice pers. comm. 2005, Truitt pers. comm. 2005, Watts pers. comm. 2005), and along small pockets of peat banks where the beach is eroding in Georgia (Winn pers. comm. 2005) (Maps 10, 11, 12, 13). Red Knots in Florida also utilize salt marshes, brackish lagoons, and tidal mudflats, in addition to mangroves in southern Florida (Douglass and Leary pers. comm. 2005, Sprandel *et al.* 1997). In Texas, migratory knots concentrate at the Bolivar Flats in Galveston County with smaller numbers at the outer beaches utilizing the tidal mudflats and salt marshes (Burkett and Ortega pers. comm. 2005) (Maps 14, 15, 16).

e. Panama

The Upper Panama Bay is a critical staging area for shorebirds during the spring. Red Knots forage along the intertidal mudflats that extend several kilometers at low tide. They may also forage within mangroves and sandy beaches near Chitré (Buehler 2002), (Map 17).

3. Wintering Habitat

a. United States

From South Carolina through Florida, Red Knots winter along sandy beaches. They may also utilize peat banks in Georgia and salt marshes, brackish lagoons, tidal mudflats, and mangroves in Florida. In Texas, wintering shorebirds occur along sandy beaches on Mustang Island and other outer beaches and tidal mudflats and salt marshes on Bolivar Flats (Maps 14. 15, 16).

b. Brazil

Red Knots winter in Brazil from Maranhão south to Lagoa do Peixe National Park. They forage along sandy beaches, tidal mudflats, and mangroves in Maranhão and along sandy beaches and brackish lagoons in Lagoa do Peixe (Serrano pers. comm. 2005), (Maps 18, 19, 20).

c. Chile

Red Knots predominately use the intertidal mudflats in Bahía Lomas, Tierra del Fuego for foraging and roosting during the winter (Figs. 24, 25), (Maps 24, 25, 26).

Figure 24. Bahía Lomas tidal flat at low tide (Antonio Larrea).

Figure 25. Bahía Lomas tidal flat at high tide; the dark line at the water's edge is a large roosting flock of Red Knots and Hudsonian Godwits (Antonio Larrea).

d. Argentina

Wintering areas for Red Knots in Argentina include Bahía San Sebastián and Río Grande in the Province of Tierra del Fuego. Knots feed mainly within the mudflats of Bahía San Sebastián and along sandy beaches, mudflats, and *restingas* in Río Grande (González pers. comm. 2005) (Maps 21, 22, 23).

CONSERVATION SITES

IMPORTANT SITES

Important Red Knot breeding, migratory, and wintering sites are listed with general habitat types in Table 3 and shown in Figure 24. See Appendix A for maps of all sites utilized by Red Knots.

Table 1. Habitat types utilized by foraging Red Knots on breeding grounds (B), spring migration (S), fall migration (F), and wintering grounds (W). The numbers correspond to those on Fig. 26.

Table 6. Habitat types utilized by foraging Red Knots on breeding grounds (B), spring migration (S), fall migration (F), and wintering grounds (W). The numbers correspond to those on Fig. 22.

#	Location	Sandy Beach	Tidal Mudflat	Peat Bank	Restinga/ Inter-tidal Rocky Flat	Salt Marsh	Mangrove	Brackish Lagoon/ Impoundment	Rocky Barrens	Source
1	King William Island, CAN								B	Morrison unpublished data; Peck unpublished data; Ross pers. comm. 2005
2	Southampton Island, CAN								B	Morrison unpublished data; Peck unpublished data; Ross pers. comm. 2005
3	James Bay, CAN	S,F								Morrison unpublished data; Ross pers. comm. 2005
4	Mingan Archipelago, CAN				F					Aubry pers. comm. 2007
5	Northern Bay of Fundy, CAN		S,F			S,F				Hicklin 1987; Morrison unpublished data.; Peck unpublished data
6	Massachusetts, USA	F	F							Harrington unpublished data
7	New York, USA	S,F						S,F		Harrington unpublished data; Tripp pers. comm. 2005
8	Atlantic Coast New Jersey, USA	S,F								K. Clark unpublished data; Hernandez unpublished data; Niles unpublished data; Sitters unpublished data

#	Location	Sandy Beach	Tidal Mudflat	Peat Bank	Restinga/ Inter-tidal Rocky Flat	Salt Marsh	Mangrove	Brackish Lagoon/ Impoundment	Rocky Barrens	Source
9	Delaware Bay, USA	S,F				S				Bennett unpublished data; K. Clark unpublished data; Kalasz unpublished data; Sitters unpublished data
10	Maryland, USA	S,F	S,F							Therres pers. comm. 2005
11	Virginia, USA	S,F		S,F						Rice pers. comm. 2005; Truitt pers. comm. 2005; Watts pers. comm. 2005
12	North Carolina, USA	S,F	S,F							Cameron pers. comm. 2005
13	South Carolina, USA	S,F, W?								Sanders pers. comm. 2005
14	Georgia, USA	S,F, W?		S,F, W?						Winn pers. comm. 2005
15	North Florida, USA	S,F, W	S,F, W			S,F ,W		S,F,W		Douglass pers. comm. 2005; Leary pers. comm. 2005; Sprandel *et al.* 1997
16	South Florida, USA	S,F, W	S,F, W			S,F ,W	S,F ,W	S,F,W		Douglass pers. comm. 2005; Leary pers. comm. 2005; Sprandel *et al.* 1997
17	Texas, USA	S,F, W	S,F, W			S,F ,W				Arvin, pers. comm. 2005; Burkett, pers. comm. 2005; Ortego, pers. comm. 2005
18	Panama Bay, PAN	S	S,W				S			Buehler 2002
19	Maranhão, BRA	S,F, W	S,F, W				S,F ,W			Serrano unpublished data
20	Lagoa do Peixe, BRA	S,F, W						S,F,W		Serrano unpublished data
21	Punta Rasa, ARG	S,F								González unpublished data
22	San Antonio Oeste, ARG	S,F	S,F		S,F					González unpublished data
23	Chiloe Island, CHL	S								Espinosa pers. comm. 2005
24	Río Gallegos, ARG	S,F	S,F		S,F					González unpublished data
25	Bahía Lomas, CHL		W							Espoz pers. comm. 2005; Matus unpublished data
26	Bahía San Sebastián, ARG		W							González unpublished data
27	Río Grande, ARG	W	W		W					González unpublished data

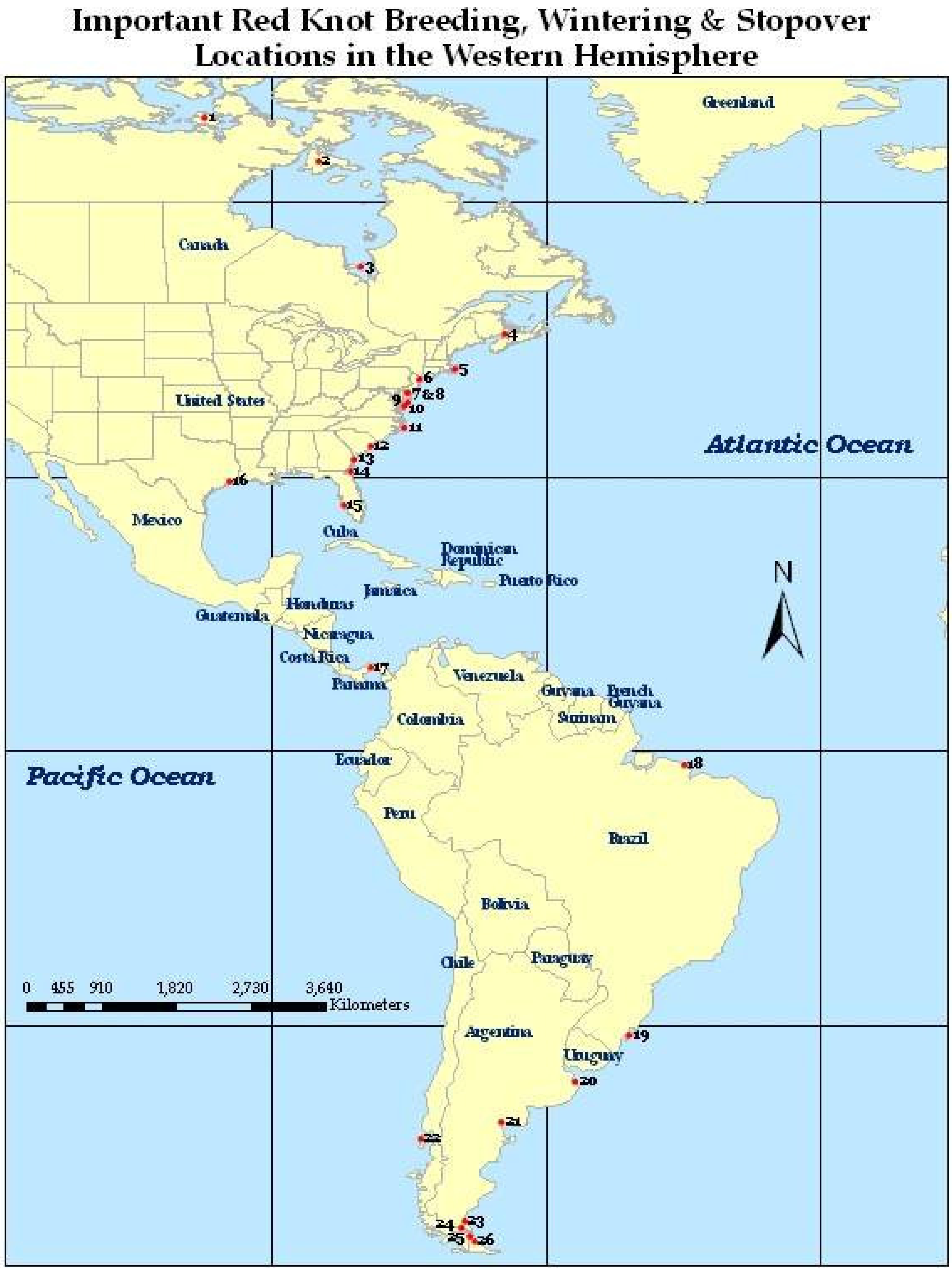


Figure 26. Critical breeding, migration stopover, and wintering habitat for the Red Knot, *C. c. rufa.* Numbers on the map correspond with the numbers on Table 3.

MOST IMPORTANT SITES

1. Delaware Bay, New Jersey and Delaware, United States

About 30% of Delaware Bay shore has some form of conservation protection (Figs. 27, 27). The New Jersey shore includes state-owned lands at Dennis Creek, Heislerville and Egg Island Wildlife Management Areas, USFWS-owned land (Cape May National Wildlife Refuge [NWR]), The Nature Conservancy (TNC) land, and the Public Service Electric and Gas Company (PSE&G) land managed by TNC. The Delaware shore includes large areas in USFWS ownership at Bombay Hook and Prime Hook NWRs, state-owned land (Little Creek and Milford Neck Wildlife Areas and Cape Henlopen State Park), and conservation lands.

a. Critical Red Knot Habitat

During 1986-2006, weekly aerial shorebird surveys were carried out along the Delaware Bay shore over the 6-week period of the spring stopover from the beginning of May to early June (Clark *et al.* 1993). These data have been examined to determine which Delaware Bay beaches are most important for Red Knots. For the survey, the bayshore was divided into 81 segments of about 3 km (48 in New Jersey and 33 in Delaware), which were geo-referenced for mapping. The survey data have been summarized for 5-year periods. For each period, the aggregate number of Red Knots counted in each segment was expressed as a percentage of the total aggregate number summed across the whole study area for the entire 5-year period. The survey data were analyzed as percentages to examine the spatial distribution of beach use on a relative, rather than absolute basis.

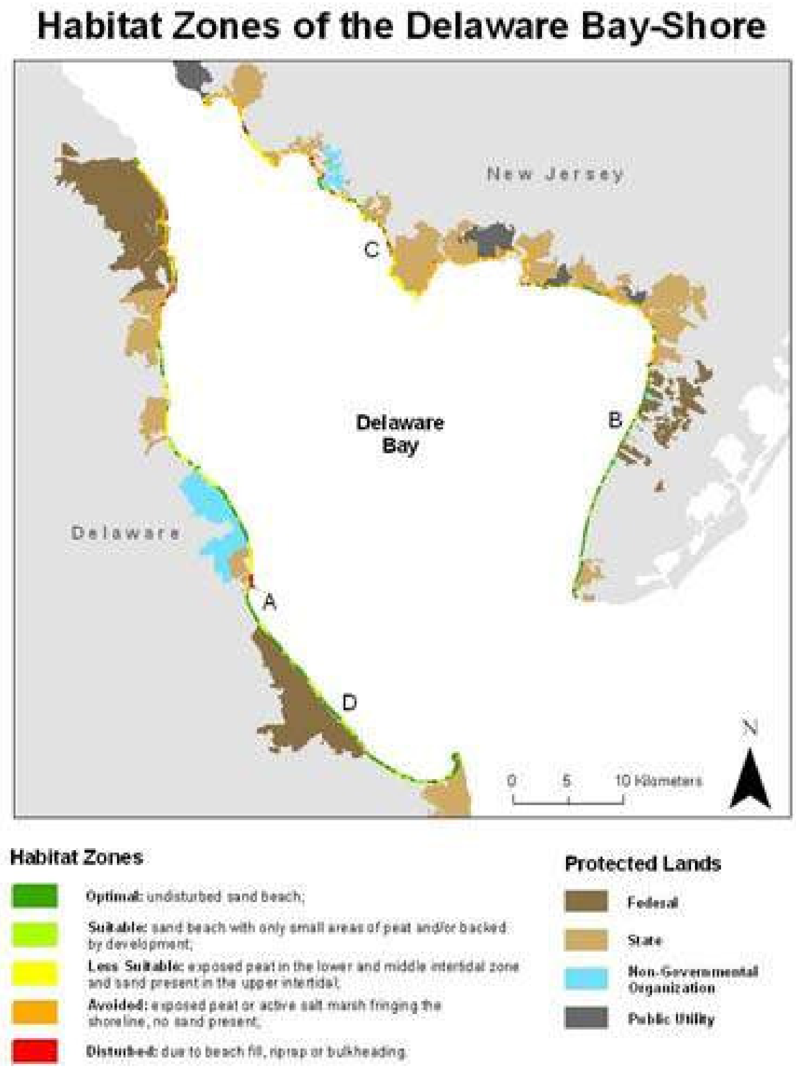


Figure 27. Map of horseshoe crab spawning habitat suitability with location of protected conservation lands. Several key locations have been annotated: A) Slaughter Beach; B) Cape May NWR; C) Fortescue; and, D) Broadkill Beach. Protected Lands GIS Data Sources: NJ DEP, NJ Green Acres, The Nature Conservancy-NJ Chapter, DE Parks and Recreation.

Comparison of the maps for the first and last 5-year periods suggests that the spatial distribution of Red Knot use has changed (Fig. 29). During 1986-1990, the knots were relatively evenly distributed along the New Jersey shore from Reeds Beach to Ben Davis Point. However, during 2001-2005, there was a greater concentration from Norbury's Landing to Reed's Beach and from Egg Island Point to Gandy's Beach. During 1986-1990, the knots were relatively evenly distributed along Delaware shore from Bowers Beach through Bombay Hook National

Wildlife Refuge with a major concentration in the Slaughter Beach-Mispillion Harbor area. During 2001-2005, however, there was a much greater concentration around Slaughter Beach-Mispillion Harbor and around Bowers Beach. Mispillion Harbor consistently supports high concentrations of Red Knots, sometimes more than 20% of the entire bay population.

Other areas of the Bayshore were little used by Red Knots; for example, in New Jersey, the Cape May Peninsula south of Norbury's Landing, and in Delaware, the central and lowest sections (Big Stone Beach and Broadkill Beach to Cape Henlopen). These low knot-use sections coincide with areas of low horseshoe crab spawning activity as recorded by Smith *et al.* (2002b). There are other parts of the bayshore that Lathrop and Allen (2005) classified as "less suitable" and even "avoided" as crab spawning habitat in 2002, that were recorded as having medium-high Red Knot use in 1986-1990. In many cases, Red Knot use of these beaches had diminished by 2001-2005; for example the Bombay Hook NWR in Delaware and the Maurice River area in New Jersey (Fig. 29). Whether these changes are due to beach erosion and/or reduced numbers of horseshoe crabs or spawning activity is unknown.

In addition to the aerial surveys, ground surveys have been conducted by the New Jersey ENSP to identify other high use areas for Red Knots during both spring and autumn stopover. In particular, large numbers of Red Knots have been recorded using the Hereford Inlet area on the Atlantic coast of Cape May and the adjacent marshes in spring. Fall ground surveys have also recorded significant numbers of Red Knots in the Hereford Inlet area. Stone Harbor Point and the nearby Nummy, Champagne and Humphrey Islands include undeveloped sand beach, sandbar, mudflat, and salt marsh habitats that afford critically important roosting areas, especially on spring high tides and at night. This area is also important for supplementary foraging by Red Knots in spring and as a main foraging area in autumn when surf clams, *Donax variablis*, and mussel spat, *Mytilus edulis*, are available.

The maps showing the distribution of horseshoe crab spawning habitat and Red Knot use in Delaware Bay (Figs. 25, 26, 27) together identify the main areas that should be considered as critical habitat to support the Red Knot's spring stopover. Knot-use is probably the better criterion because it not only reflects areas of high egg density but also the birds' other requirements, such as safety from predators and suitable and safe high water and nighttime roost sites. For example, coastal areas of Egg Island modeled as "less suitable" or "avoided" by spawning crabs, are nevertheless valuable Red Knot habitat because they are used for roosting during day and night high tides. Their attraction is that they are protected by water channels from ground predators and are free from human disturbance.

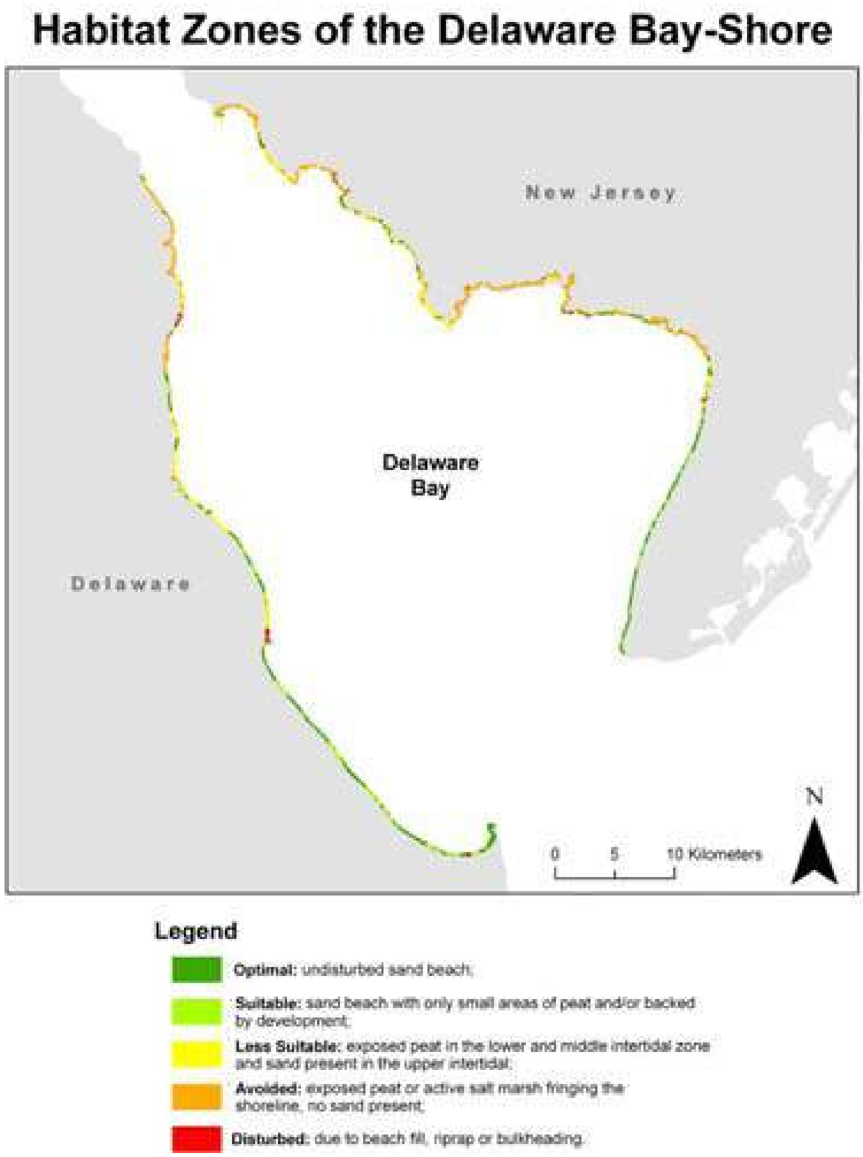


Figure 28. Map of horseshoe crab spawning habitat suitability based on beach sediment and development characteristics (from Lathrop and Allen 2005). Note that this mapping does not include consideration of beach morphology or wave energy characteristics that may be also be important in determining the suitability of the beach as horseshoe crab spawning habitat or other human disturbance or habitat factors that might influence bird usage.

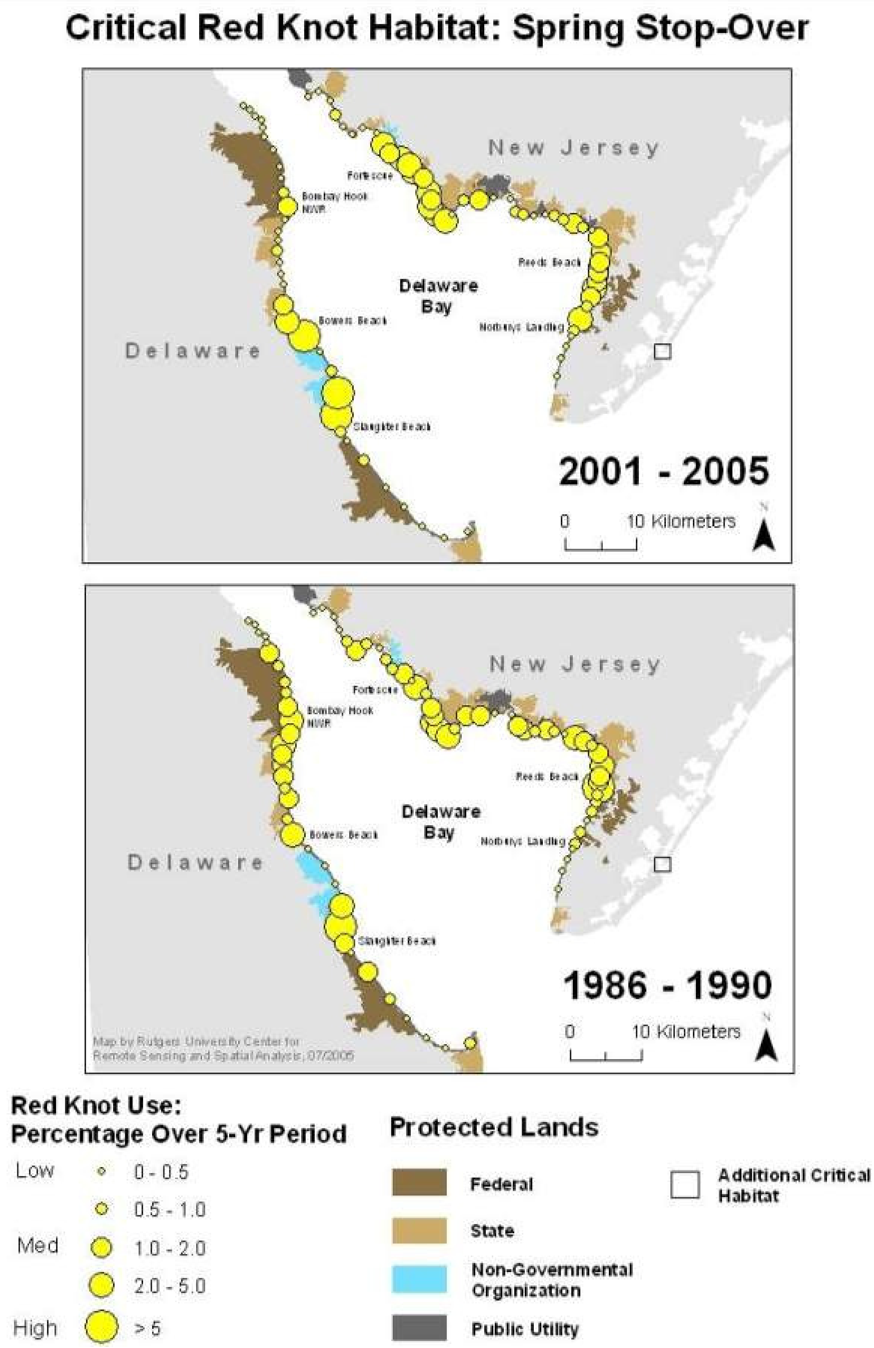


Figure 29. Map of percent Red Knot use between 1986-1990 and 2001-2005. Survey data summed across the 5-year period and percent of total calculated for each beach segment (Clark unpublished data).

On the basis of the most recent as well as the 1980s data, the Delaware Bay shore in New Jersey from Norbury's Landing to Dennis Creek should be considered critical Red Knot habitat. This portion of the Cape May Peninsula has been the focus of land conservation acquisition as part of the Cape May National Wildlife Refuge. However, there are still significant gaps in the existing refuge boundaries (Fig. 27) that should be a high priority for future acquisition or conservation management. Likewise there are important stretches of shoreline in the Fortescue and Gandys Beach areas that should be considered critical Red Knot habitat and prioritized for protection. The Hereford Inlet area, between Stone Harbor and Wildwood, and Stone Harbor Point should also be considered critical habitat due to its importance during both spring and fall migration.

The survey data suggest that some parts of the New Jersey shore between East Point and Moores Beach had higher relative use by knots during 1986-1990 than more recently. This area has experienced considerable beach erosion and some stretches have a history of development and beach armoring. Therefore it would seem possible that beach restoration might be feasible in this area (e.g. at Thompson's Beach). Probably the most southerly portion of the Cape May Peninsula (i.e. south of Villas), while mapped as optimal/suitable horseshoe crab spawning habitat (and appearing as major gaps in conservation protection in Fig. 27), need not be considered as important Red Knot habitat due to its lower usage by spawning crabs and foraging knots.

In Delaware, the shores in the vicinity of Bower's Beach and Slaughter Beach-Mispillion Harbor were recorded as critically important for Red Knots, but they are significantly lacking in protection. These areas should be given priority for conservation acquisition or management in future. The area of Slaughter Beach-Mispillion Harbor should receive special consideration due to its outstanding concentrations of Red Knots. The lowest section of the Delaware shore (i.e. south of Broadkill Beach), while mapped as optimal/suitable horseshoe crab spawning habitat (and appearing as major gaps in conservation protection in Fig. 27), should probably not be considered as critical Red Knot habitat due to its lower usage by spawning crabs and foraging shorebirds.

2. Bahía Lomas, Tierra del Fuego, Chile

Bahía Lomas is known as the main wintering area for *C. c. rufa* in South America (Morrison and Ross 1989, Morrison *et al.* 2004). It is located near the east entrance of the Straits of Magellan in the northern coast of the main island of Tierra del Fuego (52°28'08''S; 69°22'54''W) (Fig. 30) and dominated by intertidal mudflats, which tend to be smooth and sandy towards the edges and highly channelled towards the middle. The flats extend for about 50 km and on spring tides, the intertidal distance reaches seven kilometers in places. The substrate of the bay comprises a large area of mud slopes with channels that diminish towards the low water.

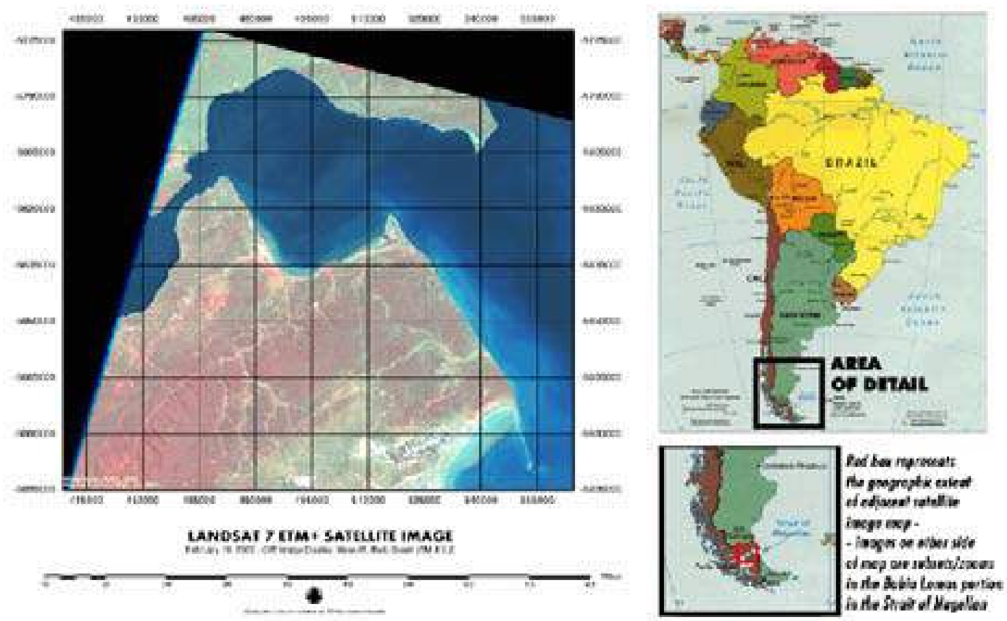


Figure 30. Location of Bahía Lomas in Tierra del Fuego, Chile.

3. Pampas and Patagonian Region, Argentina

a. Pampas Region

In this region, available shorebird habitat is found along more than 1,200 km of shoreline, from Buenos Aires, in the mouth of Río de la Plata estuary, to Punta Alta near Bahía Blanca.

Bahía de Samborombón and Bahía Blanca estuaries contain extensive marshes and mudflats (with or without crab colonies). Tidal amplitude is reduced (2 m in average) and huge intertidal mudflats are limited to low slopes at Samborombón and Bahía Blanca. South of Bahía de Samborombón (Punta Rasa) are sandy beaches, and Laguna Mar Chiquita (not to be confused with the hypersaline lake of the same name in Córdoba Province) contains a shallow permanent brackish lagoon connected to the sea.

The highest numbers of Red Knots have been seen during spring migration on ocean sandy beaches backed by dunes, southwards from Punta Rasa where the area has been heavily modified by urbanization to create appropriate conditions for tourism in summer. Feeding studies showed that Red Knot's primary prey is the mud snail, *Littoridina australi*s (Ieno *et al.* 2004).

b. Patagonian Shoreline

The Patagonian shoreline consists of the southern part of Buenos Aires Province coastline (south of Bahía Blanca) and includes Río Negro, Chubut, Santa Cruz and Tierra del Fuego provinces. Critical feeding areas for Red Knots are associated with extensive sandy beaches and mudflats where the primary prey is clams, *Darina solenoides,* (Escudero *et al.* 2003, Hernández *et al.* 2003, Albrieu *et al.* 2004, González *et al* unpublished data). Other prey items include polychaetes e.g. *Travisia olens* (Hernández *et al.* 2003) and small crustacea (González *et al.* unpublished data). Other critical feeding habitats for Red Knots are the *restingas* (broad, wave-cut rocky platforms extending to the lower intertidal zone) where they usually feed on mussels, *Mytilus edulis* or *Brachidontes rodriguez*i (González *et al.* 1996, Escudero *et al.* 2003).

The entire Argentine coast from Bahía Blanca to the Beagle Channel (Tierra del Fuego) contains sandy beaches and sandflats, mudflats, and *restingas*, which are often covered with a rich invertebrate fauna (Canevari *et al.* 1998). Gulfs and embayments are important coastal features, and the Patagonian (Tehuelche) gravels form beaches along the shoreline and occur in many places such as the area surrounding Península Valdés and in the southern part of the Golfo San Jorge. *Restingas* are found in many areas below cliff beaches near San Antonio Oeste.

During high tide, foraging areas are usually covered by water and knots roost along the upper shore of beaches, sandbars and shellbars, marshes, and other expansive coastal areas above high tide line.

4. Maranhão and Lagoa do Peixe, Brazil

a. Maranhão

Maranhão is a migration stopover point during spring and fall for Red Knots. The knots forage on the sandy beaches and mudflats of Campechá Island in the Lençóis Bay and Coroa dos Ovos and Ingleses Island in the Turiaçú Bay. Knots also use extensive mangroves that permeate into the interior through the São Marcos Bay and the lower courses of several rivers. Among the important plant species are the red mangrove, *Rizophora mangle, Avicenia germinans* and

Laguncularia racemosa. The high primary productivity is important to migratory birds (Serrano pers. comm. 2005).

b. Lagoa do Peixe

Lagoa do Peixe National Park is one of the largest stopover grounds for North American migratory birds in the South American continent. The lagoon naturally connects to the sea during the austral winter through wind activities, rain and accumulated water volume in the lagoon, and machine-helped in summer, which keeps a constant influx of salt water and allows a rich fauna of invertebrates all year round. Red Knots use this lagoon and various sandbars in the park for foraging (Serrano pers. comm. 2005).

CONSERVATION THREATS

DELAWARE BAY

1. Evidence of the Decline in Both the Population of Horseshoe Crabs and the Availability of their Eggs for Red Knots

One of the most critical issues for the conservation of the knot population is its dependence on huge quantities of eggs produced by the mass spawning of the largest known population of Atlantic horseshoe crabs (Shuster and Botton 1985) (Fig. 31). Crab eggs are especially important to Red Knots because of time constraints in completing their 15,000-km trans-hemispheric migration from Tierra del Fuego to the Canadian Arctic (Morrison and Harrington 1992, Harrington 2001). To stay on schedule and ensure breeding opportunities, knots must increase body mass in Delaware Bay by 50-100% in 2-3 weeks (Baker *et al.* 2004), one of the most rapid fattening events in birds. Some knots may arrive at or below normal lean body mass of 110 grams and depart at 180-220 grams. Food quality, quantity and availability as well as the time constraints associated with nutrient acquisition (foraging, food processing, and assimilation) are critically linked in achieving this unique anabolic event.

Figure 31. Horseshoe crabs spawning on Delaware Bay (NJDFW).

The number of shorebirds stopping over in Delaware Bay has declined dramatically in the last ten years. In the 1980s and early 1990s, horseshoe crabs "cobbled" the beaches and, in the top 5 cm of sand along much of the bayshore, egg densities often exceeded 50,000 eggs/m^2. At that time, the combined peak counts of the three shorebird species that feed almost entirely on horseshoe crab eggs (Red Knot, Sanderling [*C. alba*] and Ruddy Turnstone [*Arenaria interpres*]) was around 250,000. Now egg densities are mostly less than 4,000 eggs/m^2, and peak shorebird numbers are down to 60,000-70,000 with Red Knots showing the greatest drop from 1980s maxima of 95,000 to 15,000 in 2005 (Clark *et al.* 1993, Clark pers. comm.).

The harvest of horseshoe crabs and the associated reduced availability of their eggs as a food resource for migrating shorebirds, was first identified as a serious threat in the mid-1990s. Until 1992, the crab harvest, mostly for eel and minnow bait, was minimal and probably accounted for no more than 100,000 per year, which were mostly taken by hand or as by-catch. However, in 1992, collapsing fisheries in New England and elsewhere led commercial fishermen to the profitable conch fishery, for which horseshoe crabs are the preferred bait. This brought commercial fishermen to Delaware Bay, where the harvest increased dramatically as the conch fishery expanded in the mid-Atlantic coast. By 1996, the annual harvest, both mechanical and manual, exceeded 2.5 million crabs. According to a Delaware Division of Fish and Wildlife survey, the population of crabs fell by about 85% between 1990 and 1998 (Michels 2000). While minor restrictions were imposed, the intensive harvest of horseshoe crabs continued. By 2000, egg densities had fallen from an average of well over 10,000 eggs/m^2 to fewer than 4,000 eggs/m^2. Only a few places favored by crabs, such as Mispillion Harbor, held significantly greater densities.

Currently several surveys monitor the horseshoe crab population, the overall density of eggs in the beaches and the proportion of eggs in the upper 5 cm of sand and therefore potentially available to the shorebirds. Only two surveys, however, have been running long enough (and using consistent methods) to show how crab and egg numbers have changed over the period of increased horseshoe crab harvest. These are the Delaware Division of Fish and Wildlife Trawl Survey of crabs in Delaware Bay, which has focused on the in-bay population of crabs, and egg density surveys on the New Jersey bayshore since 1990. The egg density survey began in 1985 by Rutgers University and was continued from 2000 by the NJDFW, Endangered and Nongame Species Program. The former shows that there has been a highly significant decline in the number of spawning crabs in Delaware Bay (Fig. 32) and the latter shows that there has been a highly significant decline in the density of eggs in the upper 5 cm of sand in New Jersey (Fig. 33).

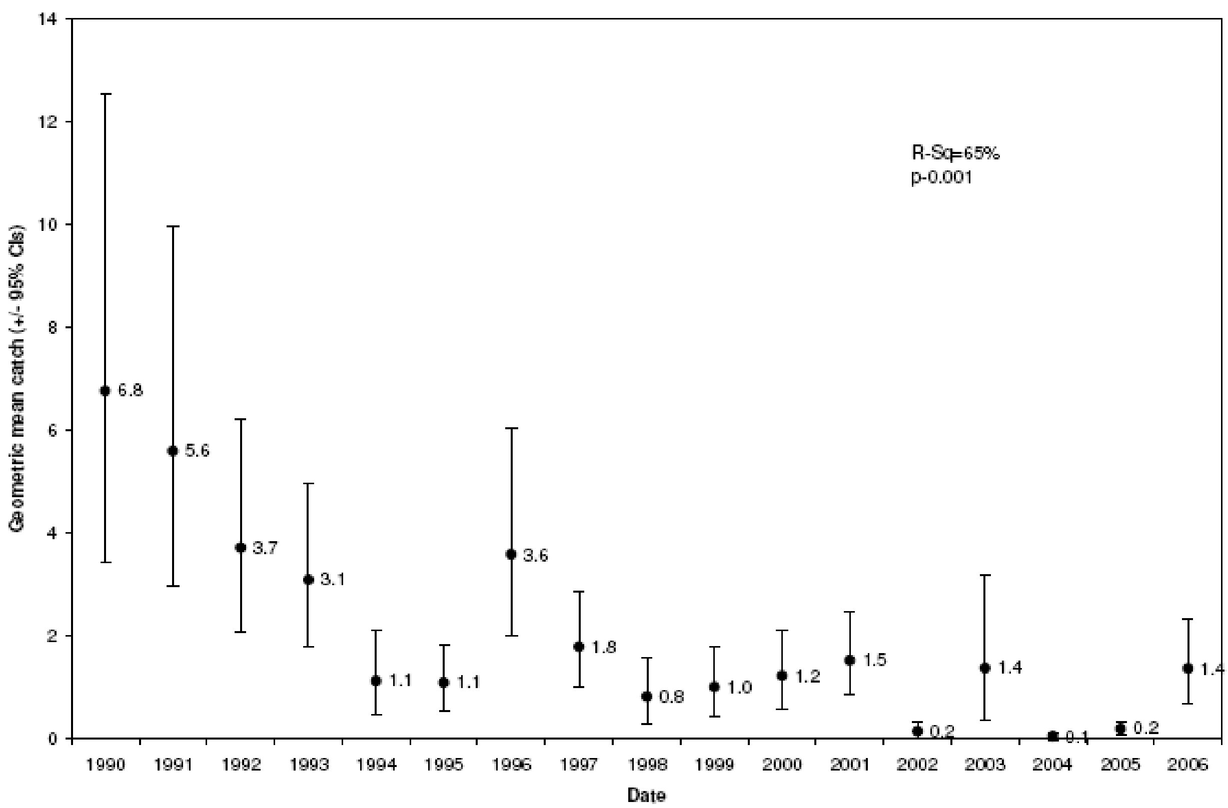


Figure 32. Number of horseshoe crabs in 30-foot trawls in Delaware Bay during May 1990-2004 (Delaware Division of Fish and Wildlife Service, see Morrison *et al.* 2004). The declining trend is highly significant (R-Sq = 65%, p<0.001).

Horseshoe crab spawning is greatly reduced by heavy on-shore wave action (Botton and Loveland unpublished data) and occasionally (as on the Delaware shore in May 2003 [Clark pers. comm. 2005]) a storm will deposit large quantities of new sand on exposed beaches so that eggs already laid become buried so deep that they are completely inaccessible to the shorebirds. These factors, as well as variation in the quality of different beaches as spawning habitat and depletion of eggs by foraging shorebirds and gulls, mean that in any season there is considerable spatial and temporal variation in the availability of eggs to knots. This results in knots moving around the bay in response to the availability of eggs (Botton *et al.* 1994). In some years, long periods of winds from a particular direction lead to more crab spawning on one side of the bay (the sheltered side, where the wind is offshore) than the other. For example, in 1997 this led to far more spawning in Delaware than in New Jersey, but the reverse occurred in 2003. However, the fact that more Red Knots fed in New Jersey than Delaware every May from 2002 to 2005 (Fig. 34) indicates that on-shore winds alone are not responsible for the decreased densities of eggs on the New Jersey shore shown in Figure 31.

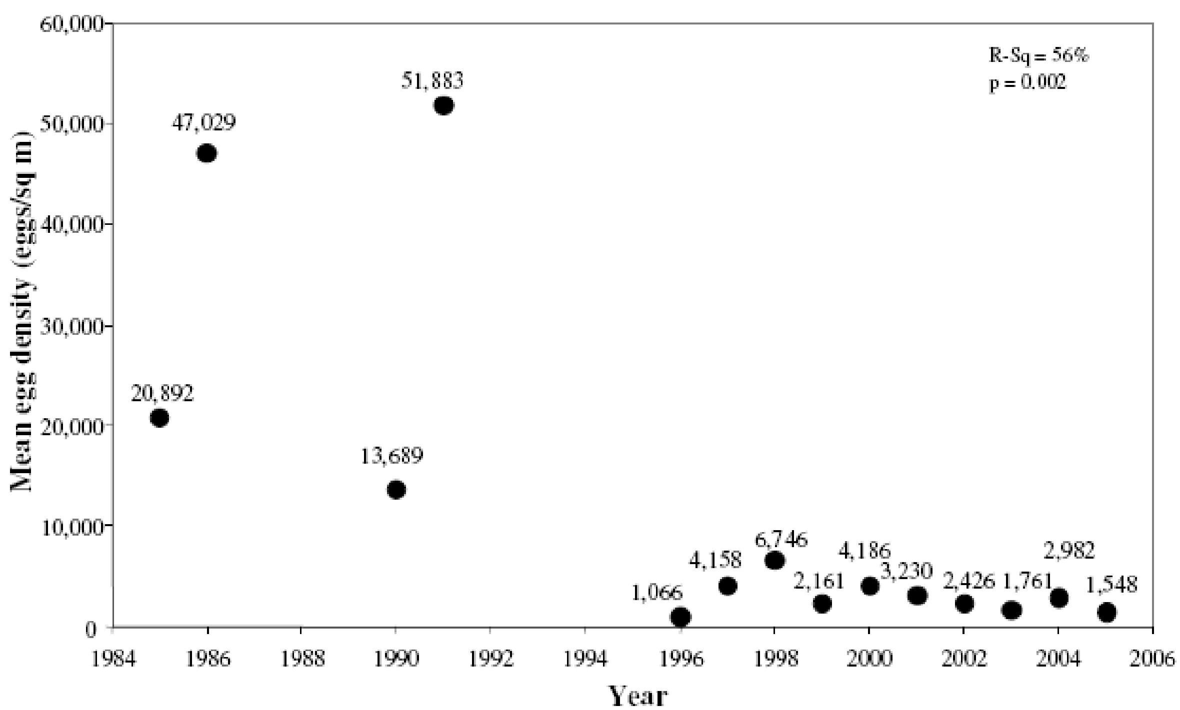


Figure 33. Density of horseshoe crab eggs in the upper 5 cm of sand in the Delaware Bay beaches of New Jersey during late May 1985-2005. The declining trend is highly significant (R-Sq = 56%, p = 0.002). Source: 1985-1999 – Botton and Loveland (unpublished data); 2000-2005 – New Jersey ENSP

(unpublished data). Confidence intervals are not plotted because the raw data are not available for the earlier period, and for the latter period they are very small in relation to the scale. All data points relate to 2-6 sampling dates spread over May and early June and to core samples taken along transects between the high and low tide lines at 3 m intervals.

Egg-density sampling has not been carried out in Delaware for as long as in New Jersey and differences in methodology make comparison of decreases between states difficult. However, sampling in Delaware has demonstrated that one site, Mispillion Harbor which is very well sheltered by long groynes, is by far the most important horseshoe crab spawning location in the entire bay and often has eggs densities that are an order of magnitude greater than any other site sampled (Fig. 35.)

The peak of horseshoe crab harvest took place during 1996-1999. Crabs do not breed until about eight years of age so that even if there were now to be a complete cessation of all further harvest, no recovery can be expected for several years.

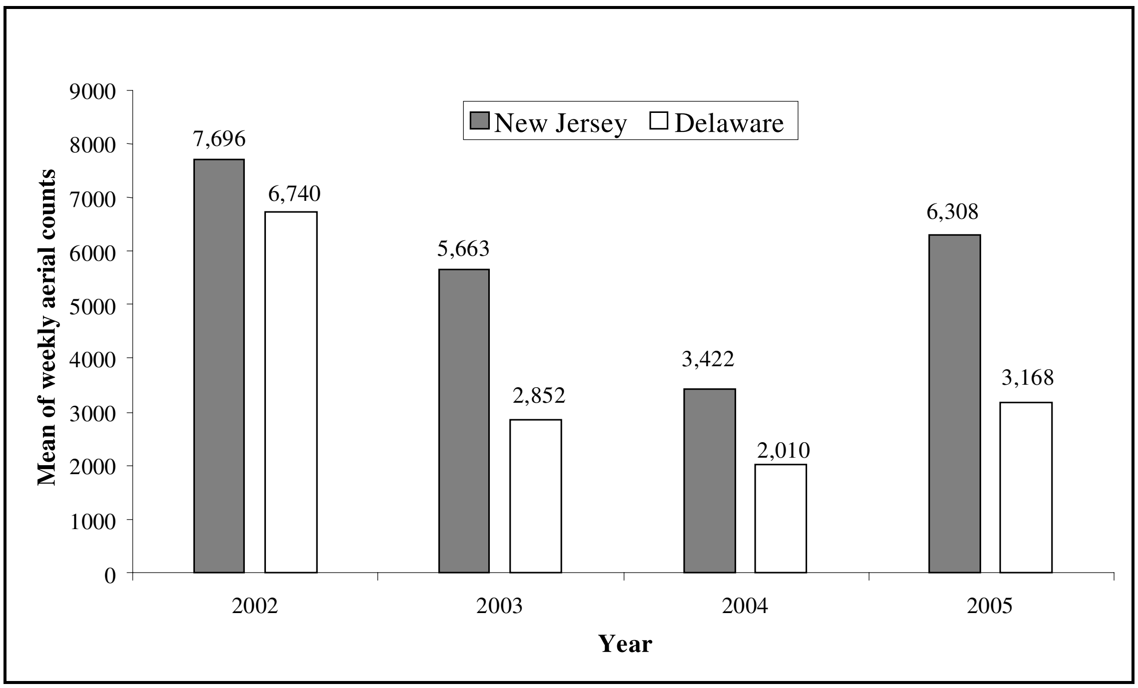
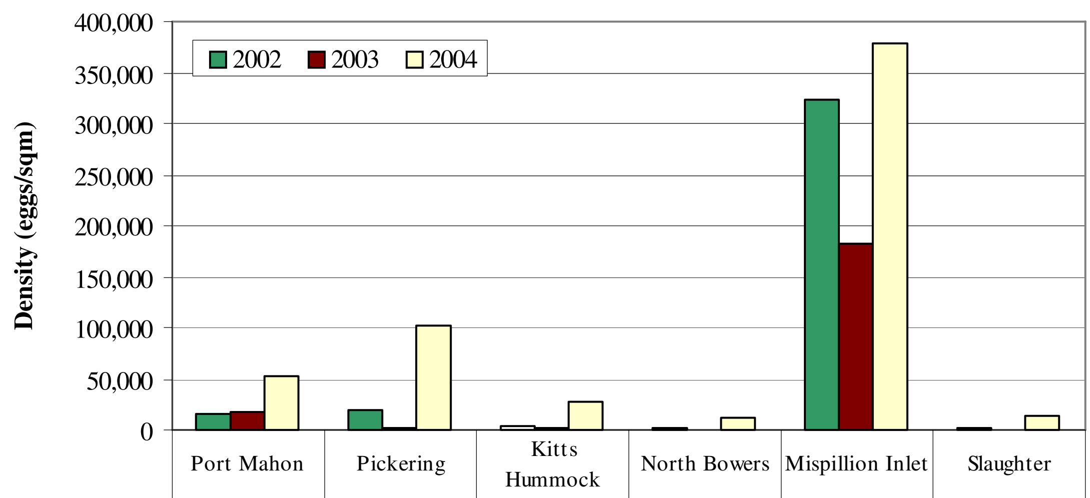


Figure 34. Mean of weekly aerial counts Red Knots in New Jersey and Delaware in May 2002-2005.



	Port Mahon	Pickering	Kitts Hummock	North Bowers	Mispillion Inlet	Slaughter
2002	15000	20500	4500	1341	323000	1500
2003	17000	2500	1597	948	181500	568
2004	53500	102000	27500	11000	378000	13500

Beach

Figure 35. Mean densities of horseshoe crab eggs in the upper 5 cm of sand from beach transects sampled in late May and early June at six sites on the Delaware shore of Delaware Bay during 2002-2004 ordered from north (Port Mahon) to south (Slaughter Beach) (Weber 2003, 2004). At each site on each sampling date, 20 core samples were taken along each of two transects covering 83% of the distance between the nocturnal high tide line and the tidal flat. Only the means for both transects are given by Weber so confidence intervals are not available.

As discussed in the Population Estimate and Trends section, a greater or lesser proportion of three wintering populations of Red Knots pass through Delaware Bay during northward migration. However, as far as can be ascertained, only the Tierra del Fuego wintering population has undergone a major decline. Those wintering further north, in the southeast U.S. and Maranhão, have shown no clear trend. The main difference between these populations is that the Tierra del Fuego birds have a much longer, time-constrained migration that carries a greater risk of arriving in Delaware Bay in poor condition and/or late; the latter fly a relatively short distance and may arrive on time and in better condition. Either way, the Tierra del Fuego birds have a greater need for an abundant food supply in Delaware Bay than the others. Therefore, the decline in the availability of food resources, especially *Limulus* eggs, may have the greatest impact on the long-distance migrants rather than those that have not traveled as far. Alternatively, the lack of food in Delaware Bay is not the immediate problem, but the birds are arriving there late and/or in poor condition because of difficulties further south along their migration route. Therefore they have lower survival because they have less time to obtain the resources they require.

Although the precise role of reduced food supplies in Delaware Bay has not always been clear, there have been some years when its impact has been patent. In 2003, for example, crab spawning was delayed probably as a result of low water temperatures (Weber 2003) and although the knot stopover was also later than usual, the birds failed to achieve their normal rate of mass gain (Niles *et al.* in prep.). In contrast, in 2004 the stopover and the availability of crabs' eggs was more closely synchronous and the birds achieved good weight gains despite the fact that that overall egg densities were little different to the previous year (Niles *et al.* in prep.).

When the knots leave for the Arctic, they not only need the resources for the 3,000-km non-stop flight across territory without food supplies, but they also need additional resources to ensure their survival during the first few weeks after arrival when little food is available. Therefore the food supply in Delaware Bay is crucial for their survival and ability to reproduce successfully. This is demonstrated by studies that show that birds caught at a lower weight in Delaware Bay (controlling for date) have lower survival than heavier birds (Baker *et al.* 2004).

Without doubt, the main reason for the reduced availability of crabs' eggs (Fig. 33) for shorebirds on the Delaware Bay beaches is the over-exploitation of the adult crabs (Fig. 32). However, three factors exacerbate the situation and have the effect of reducing the availability of eggs further: (a) beach erosion reducing the amount of optimal crab spawning habitat, (b) disturbance by people and dogs and (c) competition from gulls, especially Laughing Gulls, *Larus atricilla*. These are considered below.

2. Beach Erosion

Delaware Bay's sandy barrier beaches are dynamic features that respond in a generally predictable manner, migrating landward by storm overwash as the bayward shoreline is also retreating landward from continued sea level rise (Phillips 1986a). While future rates are difficult to predict, the current sea level rise in Delaware Bay is about 3 mm/yr (Phillips 1986a). This has resulted in erosion of the Bay's shorelines and a landward extension of the inland edge of the marshes. During 1940-1978, Phillips (1986a) documented a mean erosion rate of 3.2 m/yr for a 52-km long section of New Jersey's Delaware Bay Cumberland County shoreline and indicated that this was a high rate of erosion compared to other estuaries. The spatial pattern of the erosion was complex with differential erosion resistance related to local differences in shoreline morphology (Phillips 1986b). Phillips's shoreline erosion studies (1986a, 1986b) suggest that bay-edge erosion is occurring more rapidly than the landward/upward extension of the coastal wetlands and that this pattern is likely to persist.

Galbraith *et al.* (2002) examined several different scenarios of future sea level rise as a consequence of global climate change and projected major losses of intertidal habitat in Delaware Bay. Under the 50% probability scenario (i.e., the most likely scenario), Delaware Bay is predicted to lose 60% or more of the shorebird intertidal feeding habitats by 2100. Under more extreme sea level rise, Delaware Bay may actually have a net gain of intertidal flats as the coastline migrates further inland converting dry land to intertidal habitat. However, this prediction assumes that the coastal protection structures do not constrain the ability of shorelines to migrate landward. Within the Delaware Bay system, as elsewhere in the Mid-Atlantic region, coastal development and shoreline protection activities are expected to interfere with the longer-term landward migration of shorelines (Najjar *et al.* 2000). Though Delaware Bay is less developed than many similar stretches of Mid-Atlantic coastline, some optimal crab-spawning beach habitat is also the site of existing shoreline residential development.

Significant sections of the Delaware Bay shoreline have already been affected by shoreline stabilization projects. Coupled with continuing sea level rise and shoreline erosion, the demand for additional shoreline protection structures is expected to increase (Najjar *et al.* 2000). Shoreline stabilization or armoring projects employing bulkheading, riprap or other solid beach-fill can eliminate intertidal sand beach habitat or sufficiently alter sediment quality and beach morphology to degrade the suitability of the remaining habitat for horseshoe crab spawning (Myers 1986; Botton *et al.* 1988).

Beach replenishment through offshore pumping of sandy sediments (as carried out along several sections of the Delaware shore, but not New Jersey) provides an alternative means of beach stabilization as well as creating potential crab-spawning habitat. However, the value of beach replenishment as a crab-spawning habitat restoration strategy has not yet been fully evaluated. The fact that during 2002-2005, more knots on average fed on the New Jersey side of the bay than on the Delaware side (see Fig. 34) suggests that beach replenishment may not have a major impact on the value of beaches as crab-spawning habitat. Besides affecting crab-spawning and knot-feeding habitat, erosion has also led to loss of sites used by knots for roosting, especially around Mispillion Harbor.

3. Disturbance by People and Dogs

In both states in the Delaware Bay, there are large areas of shoreline in private ownership and subject to habitat disturbance and loss. In New Jersey, while the intertidal beach is publicly owned, there are key beaches immediately adjacent to residential development, including Villas, Reed's Beach, and Fortescue. In Delaware, a similar residential situation exists at Pickering and Kitts Hummock and Slaughter beaches. Port Mahon and Mispillion Inlet are different in that commercial use and bulkheading threaten critical Red Knot habitat. Regardless of residential proximity, human disturbance is a threat that can reduce the value of habitat for Red Knots where the bayfront is accessible by car.

It is well established that human disturbance can have an adverse on shorebird fitness. First, it compels them to pay the high energetic cost of flying; second it may reduce the amount of time that the birds are able to feed; third it can deprive them from feeding in the most profitable sites. Any overall reduction in energy intake as a result of these responses is the net impact of disturbance on energy budgets and hence survival (Davidson and Rothwell 1993).

The spectacle of shorebirds and spawning horseshoe crabs draws hundreds of bird watchers to Delaware Bay beaches during the spring migratory stopover (Burger *et al.* 1995). The beaches are also vulnerable to the usual beach activities, such as walking, jogging, fishing and dog walking. Disturbance along the New Jersey shore of Delaware Bay was first investigated in 1982, with further studies in the 1980s, 1990 and 2002 (Burger *et al.* 2004). The results show that the average period that a beach was disturbed during any hour of the day dropped from 32.9 minutes in 1982 to 3.2 minutes in 2002. This was the direct result of increased management efforts by the NJDFW. Though the length of disturbances decreased during this period, it appears that the birds' sensitivity to disturbance increased. In 1982, 30% of shorebirds disturbed at Reeds Beach South and 98% at Reeds Beach North flew away when disturbed by people and did not return within ten minutes. In 2002, 98% and 93% respectively did not return, with an increasing proportion of disturbance coming from dogs.

When shorebirds are disturbed by people and dogs on their foraging beaches, they usually respond by flying away. When there were no restrictions on disturbance in the 1980s, shorebirds were disturbed for over half of the time by day, and when all beaches were disturbed the shorebirds often returned to the same beaches (Burger *et al.* 2004). When most beaches were protected from disturbance in 2002, the shorebirds were able to move to nearby beaches that were undisturbed. Therefore management that restricts human activities on Delaware Bay beaches is shown to be effective in creating disturbance-free beaches necessary for feeding and resting shorebirds.

Starting in 2002 major sections of the New Jersey shore have been closed to human use during the peak of the stopover at the initiative of the NJDFW in order to reduce disturbance to shorebirds by people and dogs. Before this, disturbance of the beaches was a particular problem, especially during Memorial Day weekend. In 2001, for example, all 18,000 Red Knots that had previously been feeding on the bayshore spent Memorial weekend on the Atlantic coast in the vicinity of Stone Harbor (Sitters 2001).

4. Competition from Gulls

Gulls are both competitors for food and potential predators on shorebirds. They take advantage of abundant horseshoe crab eggs, particularly on that part of the New Jersey bayshore that lies close to their Atlantic coast breeding colonies. During 1979-2004, the size of these colonies did not change (Table 4), and neither was there any increase in the knots' use of the New Jersey bayshore for feeding (Sutton 2002 unpublished report to NJDFW). During 1992-2002, the number of gulls recorded in single-day counts on accessible New Jersey beaches ranged from 10,000 to 23,000. Gull populations are not as significant an issue on the Delaware shoreline because breeding colonies are not located close to the bayshore beaches in that state.

Table 2. Aerial survey counts of gulls on the Atlantic Coast of New Jersey (Jenkins unpublished data)

	Laughing Gull		**Herring Gull**		**Greater Black-backed Gull**	
Year	***# of adults***	***# of colonies***	***# of adults***	***# of colonies***	***# of adults***	***# of colonies***
1979	59,914	66	5,802	55	128	35
1983	58,267	80	5,237	71	260	41
1985	54,434	71	4,720	59	226	48
1989	58,797	91	7,097	91	293	50
1995	39,085	117	6,828	121	781	73
2001	80,253	112	9,814	94	1,036	65
2004	52,765	96	5,347	74	795	58
Mean	**57,645**	**90**	**6,406**	**81**	**503**	**53**

While gull numbers have not significantly changed, the effect of their competition on the shorebirds may be increased by the decline in the availability of horseshoe crab eggs. Burger *et al.* (2005) found that gulls are more tolerant of human disturbance than shorebirds. When disturbed by humans, gull numbers returned to pre-disturbance levels within 5 minutes. Even after 10 minutes, shorebird numbers failed to reach pre-disturbance levels. Shorebirds showed a particularly strong reaction to dogs. When disturbed by a dog, shorebirds did not return to the same beach. Red Knots are also more vigilant when feeding near gulls and must spend more time in aggression than if they are not near gulls (Burger 2005 *in press*).

Thus the size and aggression of gulls, coupled with their greater tolerance of human disturbance, give them the advantage over shorebirds in prime feeding areas. In the present scenario of limited availability of good feeding beaches, gulls appear to be an increasing threat to Red Knots in the Delaware Bay.

The influence of gulls on horseshoe crab egg densities has been shown to be significant through exclosure experiments conducted by Virginia Polytechnic Institute (Karpanty pers. comm. 2005). Burger *et al.* (2004) found that gulls out-compete all shorebird species including Red Knots for horseshoe crab eggs, and that the influence of gulls increases with repeated disturbance.

BAHÍA LOMAS, CHILE

The Magellan region of Chile has been an important producer of oil and natural gas ever since the first oil discovery was made there in 1945. Local oil activity has diminished over the last 20 years and only covers a small percentage of national demand. Bahía Lomas, located at the eastern end of the Magellan Strait on the northern coast of Tierra del Fuego has several oil platforms. Most are static, and several have been closed within the last year as the oil resource has been depleted. Apparently, there is no incentive to continue drilling in the Straits of Magellan. However, on the nearby Atlantic Ocean coast of Argentina, oil drilling has increased over the last 10 years. The boat traffic from oil production in the Straits of Magellan is another potential risk as significant oil spills may occur with detrimental consequences similar to two recorded incidents in the vicinities of the bay (53,500 tons from the *Metula* in 1974 and 100 tons from the *Berge Nice* in 2004).

Although the potential threat to the Red Knot population would appear to be significant, there have been no reported incidents of knots being affected by oil either directly by major contamination of the plumage or indirectly through their food supplies (though small amounts of oil have been noted on some birds caught (Dey and Niles pers. comm. 2005). However, major declines at Bahía Lomas have not been mirrored at nearby Río Grande (Fig. 36). This suggests that there could be a problem at Bahía Lomas. If there is, it is more likely to be connected with the oil industry than anything else because that is virtually the only significant human activity in the area.

The possibility that problems at Bahía Lomas are entirely responsible for the *rufa* population crash would seem unlikely in view of the observation that it is birds at a lower weight in Delaware Bay that have lower survival (Baker *et al.* 2004). Nevertheless there could be a connection between birds leaving Bahía Lomas in poor condition and arriving in Delaware Bay in poor condition. Another scenario is that, though much smaller than Bahía Lomas, Río Grande is a preferred site. Therefore, just as knots have deserted sites further north along the Patagonian coast since 1985 becoming more and more concentrated in what is presumably the better non-breeding area of Tierra del Fuego, they may now be doing the same within Tierra del Fuego, deserting Bahía Lomas for Río Grande. These matters deserve further investigation.

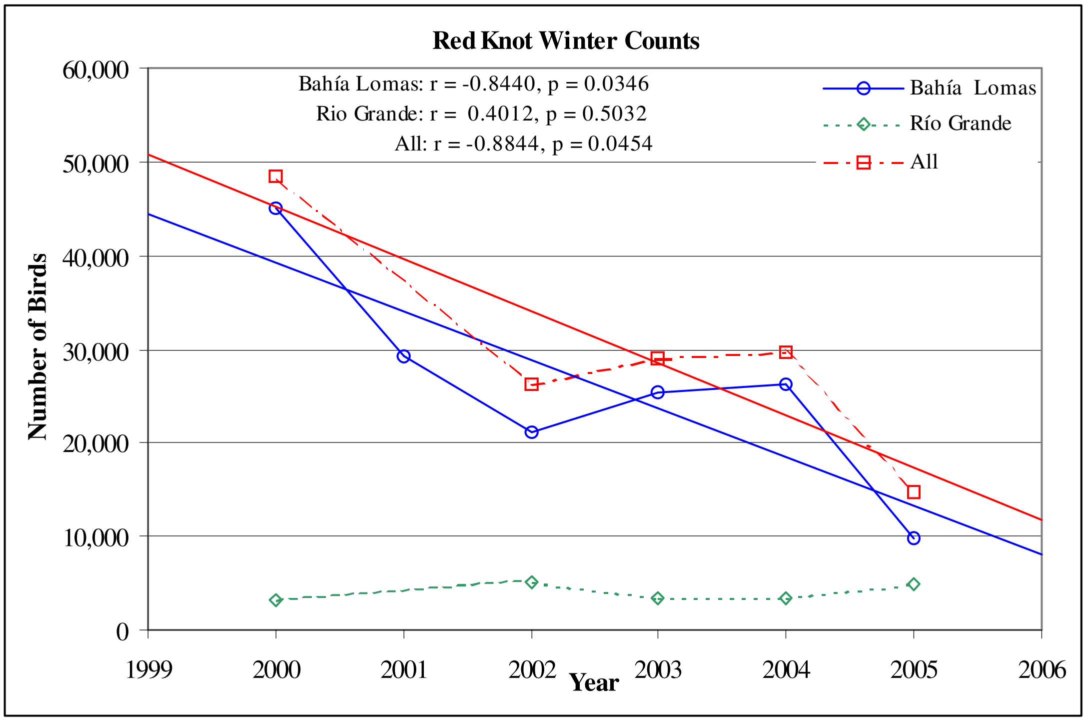


Figure 36. Aerial counts of Red Knots (*Calidris canutus rufa*) on major wintering areas in southern South America, January-February 2000-2005: Bahía Lomas, Río Grande, All = all sites in main wintering area (Morrison *et al.* 2004).

ARGENTINA

Most of the sites used by Red Knots at Río Grande on the Atlantic coast of the Argentine part of Tierra del Fuego are within the Reserva Costa Atlántica de Tierra del Fuego created in 1992. However, as at Bahía Lomas, the area is important for on- and off-shore oil production with the potential for oil pollution, especially from oil tankers loading around Río Grande City. Again, there is no direct evidence of knots having being affected by oil pollution but it remains a threat.

The knots frequently suffer human disturbance while feeding and roosting around Río Grande city, especially by people using all terrain vehicles and motorcycles, as well as from walkers, runners, fishermen and dogs.

MARANHÃO AND LAGOA DO PEIXE, BRAZIL

Among the most important threats to conservation of Red Knots in Maranhão is offshore petroleum exploration on the continental shelf; iron ore and gold mining, which leads to loss of coastal habitat through soil embankment; oil pollution; mercury contamination; and uncontrolled urban spread along the coast. Mobile sand dunes, mangrove clearance and fishing activities are among other activities that have had a negative impact on Red Knot habitat.

At the Lagoa do Peixe National Park, the main management activities are those related to environmental dynamics, and therefore influence birds directly including harvesting of *Pinus* spp. and opening of the sandbar connection to the sea. There were *Pinus*-forested areas previous to the creation of the Park. However, *Pinus* plantations are spreading in the region without control, possibly leading to lower levels of aquifer (IBAMA, unpublished data). In some areas, they seem to help siltation of the lagoon by movement of dunes. *Pinus* harvesting leads to the appearance of crevices, which contribute to higher erosion of the area. According to the management plan (IBAMA 1999), there are studies to be conducted on the impact of *Pinus* forest, but thus far, no results have been published.

Connection between the lagoon and sea occurs in winter and spring at Lagoa do Peixe National Park, extending to part of summer. Closure of the sandbar occurs by deposition of sand in the lagoon mouth due to northerly and northeasterly winds. During winter, rain and countryside flooding around the lagoon border naturally open the sandbar due to water pressure and southerly winds. In this case, farmers use machines to drain water from their lands. There are records of damage to rice, onion, and cattle farms when the sandbar opens late in season. During drought years, like 1997, the sandbar cannot be closed due to strong continental drainage that limits deposition at the mouth of the lagoon. It is this periodic exchange with the sea that allows movements of species between lagoon and ocean and provides an appropriate environment for migratory birds.

Hunting migratory birds for food used to be common among local communities. They provided an alternative source of protein and birds with high subcutaneous fat content for long migratory flights were particularly valued (Serrano pers. comm. 2005). According to locals, the most consumed species were Red Knot, Black-bellied Plover, *Pluvialis squatarola,* and Whimbrel, *Numenius phaeopus*. Local people say that although some shorebirds are still hunted, this has greatly decreased over the past decade.

On 7 April 1997, 26 Red Knots, ten White-rumped Sandpipers, *Calidris fuscicollis*, and three Sanderlings, *C. alba* were found dead or dying along 10 km of beach at Lagoa do Peixe, southern Brazil. The following day, another 13 dead or sick knots were found along 35 km of beach nearby (Baker *et al.* 1999b). Some, but not all of these birds, were infected with hookworms, *Acanthocephala.* Although hookworms can cause death, it would seem more likely that the mortality had another cause. Smaller mortalities of spring migrants with similar symptoms of malaise have also been reported from Uruguay in recent years.

Since 2002, migratory birds in Brazil have been tested for viruses including West Nile, Newcastle and avian influenza, by the National Health Foundation in collaboration with *Instituto Brasileiro do Meio Ambiente dos Recursos Naturais Renováveis* and *Centro Nacional de Pesquisa para Conservação das Aves Silvestres*. To date, avian influenza type H2 has been found in one Red Knot, Mayaro virus in seven knots and Equine Encephalitis virus in another (Araújo *et al.* 2003).

Since December 2003, blood and feather samples have been collected in Brazil not only from Red Knots but also from several other shorebird species for genetic variability studies and radioisotope analysis. In February 2005, all 38 knots caught in Maranhão were heavily infected with ectoparasites. The birds were also extremely light, less than the usual fat-free mass of knots (Baker *et al.* 2005a). Recent studies have shown that tropical wintering shorebirds have a higher incidence of parasites and pathogens than those wintering at higher latitudes (Mendes *et al.* 2005). However, without further studies there is no means of knowing whether this observation is typical of knots wintering in that area or peculiar to one winter; whether such infestation leads to significant mortality; and whether it can be passed on to other populations, such as when Tierra del Fuego birds stopover in Maranhão during northward or southward migration. Nevertheless the potential importance of this observation is considerable. Birds caught at a lower weight in Delaware Bay in May (controlling for date) have lower survival than heavier birds (Baker *et al.* 2004). One reason why birds may be lighter is that they were in poor condition because they were infected with ectoparasites (as was the case with the birds caught in Maranhão). No systematic effort has yet been made to assess the parasite load of birds passing through Delaware Bay, but fieldworkers have noticed ectoparasites on a substantial number of knots caught there (Minton and Niles pers. comm. 2005). It would therefore seem possible that a significant factor in the decline of *rufa* could be infection with ectoparasites. This is by no means proved on present evidence but it is clearly a factor worthy of further investigation. It is also a factor that would be exacerbated by a decreased food supply in Delaware Bay.

SOUTHAMPTON ISLAND, CANADA

In the Arctic, 3 to 4-year lemming cycles give rise to similar cycles in the predation of shorebird nests. Therefore, when lemmings are abundant, Arctic foxes and jaegers concentrate on them and shorebirds breed successfully, but when lemmings are in short supply few shorebird eggs or chicks survive (Summers and Underhill 1987). It is evident that these cycles have always affected the productivity of Arctic-breeding shorebirds and lead to fairly minor year-to-year changes in otherwise stable populations. We have no reason to suppose that increased Arctic nest predation has been responsible for the long-term decline in the *rufa* population. However, unsuccessful breeding seasons have contributed to at least some recent reductions in the population.

FLORIDA

It appears that the most immediate and tangible threat to Red Knots wintering in and migrating through Florida is chronic disturbance. With the exception of a few federally owned sites, most beaches experience very high--and increasing-- human disturbance rates. Shoreline hardenings, dredging, beach-raking, and deposition, including beach nourishment activities, are significantly altering much of the coastline. Despite the fact that all of these activities require permits, there is no centralized documentation of their location or extent. Furthermore, the impacts on knots and other shorebirds is not well known but is thought to be significant.

While almost all foraging habitat and most roosting sites are in public ownership, very few locations are managed for winter or passage shorebirds. Some sites receive incidental protection under restrictions designed to protect other resources (combustible motor exclusion zones to protect sea grass beds or homeland security restrictions at ports, military installations, space center, etc.).

An epizootic disease resulting in large-scale mortality of knots reported from the Florida West Coast in December 1973 and November 1974 was caused by a protozoan parasite, most likely an undescribed sporozoan species (Harrington 2001). Further reports on knot mortality in Florida in 1981 were due to *Plasmodium hermani* (Harrington 2001).

In 1981 there was a report of an adventitious molt in knots caused by a mallophagan parasite (Mallophaga: Menoponidae) in feather shafts (Harrington 2001).

OTHER THREATS

The study of shorebirds over most of the past thirty years has been conducted in what Butler *et al.* (2003) called a "predator vacuum" arising from greatly depleted raptor populations caused by persecution and pesticide poisoning. Only in the past decade have these shown recovery to pre-WWII levels in temperate North America. Butler *et al.* (2003) have demonstrated how recovering raptor populations appear to have led to changes in the migratory strategies of some shorebirds. These include lower numbers of shorebirds, reduced stopover length and lower mass in the more dangerous sites. However, increased raptor numbers have not yet been shown to affect the size of shorebird populations. Given that Red Knots spend most of the year in regions where raptor populations were never greatly affected by persecution and poisoning (Arctic Canada and South America), it would seem unlikely that increased raptor predation has been responsible for the population decline.

The threat to *rufa* may become further increased if the population drops below about 10,000 because Baker *et al*. (2005a) has shown that, due to their low genetic variability, the effective size of shorebird populations is much smaller than numbers censused (i.e., not all individuals contribute to the gene pool). As a result, census populations of 5,000-10,000 are likely to be especially vulnerable to the accumulation of harmful genetic mutations.

THE INADEQUACY OF EXISTING REGULATORY MECHANISMS

There are a number of regulatory issues that have negatively influenced the protection of Red Knots. Most have arisen because they range over such a large area that coordinating conservation regulations is not just an interstate issue in the U.S. but also the subject of international diplomacy.

C. c. rufa breeds in one country (Canada), uses stopovers in at least four countries (U.S., Brazil, Argentina and Chile) and winters in mostly different locations in the same four countries. The birds also use spring stopovers in all Atlantic coast states from Florida to New Jersey, wintering sites in at least three states, and autumn stopover sites in all eastern states from New England to Florida

In the U.S., the Red Knot is protected from hunting but has special status in only two states: New Jersey where it is has "threatened" status and Georgia where it is a "species of special concern."

In April 2007, the Committee on the Status of Endangered Wildlife in Canada determined that *rufa* was endangered. In Brazil it is being proposed for listing as endangered.

In Chile, both the Red Knot and its habitat are protected. The federal law that regulates hunting (LEY No. 19.473) includes the Red Knot in the list of protected species. All coastal habitats (extending to 300 m inland from the high tide line) are managed by the Chilean Navy and are the property of the national government.

Argentina does not allow the Red Knot to be hunted and specifically protects it from subsistence hunting. Both Chile and Argentina are among the 101 parties to The Convention on the Conservation of Migratory Species of Wild Animals which, at its meeting in November 2005, determined that the *rufa* subspecies of the Red Knot was endangered and as such added it to Appendix 1 of the Convention. Under the terms of the Convention the Parties agree "to strive towards strictly protecting animals listed in Appendix 1, conserving or restoring the places where they live, mitigating obstacles to migration and controlling other factors that might endanger them" (www.cms.int). The U.S., Canada and Brazil are among the minority of countries that are not yet parties to the Convention.

1. Inadequacies of the Federal and Regional Regulatory System

The existing regulatory system creates a number of problems for the conservation of Red Knots stopping over in Delaware Bay in that different agencies have jurisdiction over the protection of horseshoe crabs (and their eggs) on the one hand and Red Knots on the other. The birds are under the legal jurisdiction of the USFWS, and the horseshoe crabs are under the legal jurisdiction of the Atlantic States Marine Fisheries Commission (ASMFC) which has the authority to set quotas for adoption by the states. The ASMFC is overseen by the National Marine Fisheries Service (NMFS) which has ultimate responsibility for the management and conservation of living marine resources. Presently NMFS has limited it involvement to participating in the ASMFC subcommittees and has not taken any regulatory action to protect crabs or birds. Individual states have authority to implement more restrictive harvest regulations than those set by the ASMFC and have done so on numerous occasions.

The ASMFC has promulgated a horseshoe crab management plan to conserve the horseshoe crab resource based on the current commercial uses of the crab for bait and for the biomedical industry, and the competing needs of migratory shorebirds and the federally-listed, (threatened) loggerhead turtle. The protection of the adult horseshoe crab population as food source for the loggerhead turtle is specifically identified in the plan with the recognition that the plan should be coordinated with the federal agencies having jurisdiction over the turtle population (NMFS). Migratory shorebirds, and specifically the Red Knot, and their reliance on horseshoe crab eggs are also identified and discussed in the management plan. The plan specifically protects the food resource of the loggerhead turtle pursuant to Section 7(a)(2) of the ESA; the food resource of the Red Knot is not similarly protected. Although the ASMFC does not have direct legal jurisdiction to protect the food resource for the Red Knot, it has taken steps to improve horseshoe crab egg availability including decreasing harvest quotas, more efficient use of crabs as bait and facilitating a horseshoe crab sanctuary at the mouth of Delaware Bay.

In contrast the USFWS does have authority to protect the birds under the Migratory Bird Treaty Act (40 Stat. 755; 16 U.S.C. 703-712) (MBTA) which provides that no migratory bird can be taken, killed or possessed unless in accordance with the provisions of the Treaty. The MBTA is the only current federal protection provided for the Red Knot. The MBTA prohibits "take" of any migratory bird, which is defined as: "to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect." However, other than for nesting sites, which are not located in the United States, the MBTA provides no authority for protection of habitat or food resources. Human disturbance is cited as one of the major threats to Red Knots throughout it migratory range within the United States. Therefore, the MBTA provides inadequate protection to the Red Knot in that it does not afford Red Knots protection from human disturbance on migratory and wintering areas or ensure protection of food resources.

Under the Endangered Species Act 1973, a species may be designated as threatened or endangered. However, this may be precluded through lack of resources if there are species of higher conservation priority. Therefore species whose listing is warranted may receive none of the benefits of listing including those involving little or no cost. This is a shortcoming that needs to be addressed.

2. Inadequacies of Regulatory Systems in Individual States in the U.S.

Without adequate federal coordination, the attempts of individual states to conserve Red Knots have lacked consistency. This has led to substantial gaps in protection, especially when horseshoe crab fishermen have exploited differences in regulations among states.

In 1996, New Jersey restricted the harvest of horseshoe crabs when it was confronted with mounting evidence of the decline of crabs, eggs and shorebirds, particularly Red Knots. In response, the horseshoe crab fishermen took crabs but landed them in Delaware and Maryland. The following year, Delaware and Maryland followed New Jersey's lead and instituted increased restrictions on the horseshoe crab harvest. That year the fishermen harvested crabs but landed them in Virginia. Subsequently, the ASMFC imposed modest restrictions to the harvest and fishermen attempted to land crabs in Pennsylvania while Virginia disregarded the ASMFC restrictions. After the development and implementation of the Horseshoe Crab Management Plan, which regulated landings coast-wide, the problem was solved, but this experience makes it clear that individual states alone without federal or regional coordination cannot adequately protect wide-ranging inter-jurisdictional species such horseshoe crabs or shorebirds.

Another inadequacy of regulatory mechanisms relates to the protection of Red Knots from disturbance. New Jersey Division of Fish and Wildlife has been protecting beaches used by shorebirds from disturbance since 1985. In 2003, the Division closed seven beaches to all human use during the peak of the shorebird stopover. The reason for the closure was to increase the availability of eggs for shorebirds by preventing repeated disturbances, which have been demonstrated to be significantly detrimental to the birds' ability to feed (Burger *et al.* 2005). Moreover, disturbance by humans and dogs often increases the competitive advantages of gulls because gulls adapt more easily than shorebirds to repeated disturbance (Burger *et al.* 2005, Fig. 37). Only in the state of New Jersey is the Red Knot listed as a threatened species and as such provided with legal protection. In all other states, there is no legal basis for preventing disturbance (Fig. 38). The need to protect Red Knots from repeated disturbance on beaches also applies during southward migration in autumn as shown by recent studies (Mizrahi pers. comm. 2005).

In Delaware, even if the Red Knot was listed as a State Endangered Species, the listing would only pertain to collection, possession, transportation, and sale. There are no regulatory mechanisms to protect the habitat of Delaware state-listed species or to regulate "take" due to activities such as chronic disturbance, destruction of habitat, or removal or depletion of food resources.

Regulation of human use of the inter-tidal zone is greatly complicated by variation between states in ownership and jurisdiction of the foreshore. In New Jersey, for example, most inter-tidal areas are owned by the state and managed by the state's Tideland Council, whereas in Delaware lands can be privately owned to the mean low tide line. Thus, in New Jersey restrictions on activities that may interfere with shorebird foraging or roosting apply statewide. In eight sections of beach, use can be eliminated entirely. However, in Delaware restrictions can only be applied to state-owned lands and lands designated as Delaware River and Bay Shoreline Refuge (Smyrna River to St. Jones River). At present Delaware does not have legal authority to restrict or eliminate activities that would disturb shorebirds on all privately owned beaches including the harvest of horseshoe crabs unless the beach is voluntarily registered as a Horseshoe Crab Sanctuary. Similar legal barriers to restrict disturbance of wintering shorebirds exist in nearly all Atlantic coast states. These state-by-state variations in jurisdiction create significant impediments to region-wide or nationwide restrictions to protect shorebirds and horseshoe crabs.

Figure 37. Unrestrained dog and parked cars on the beach at Fort George Inlet, Duval County, Florida (Patrick Leary).

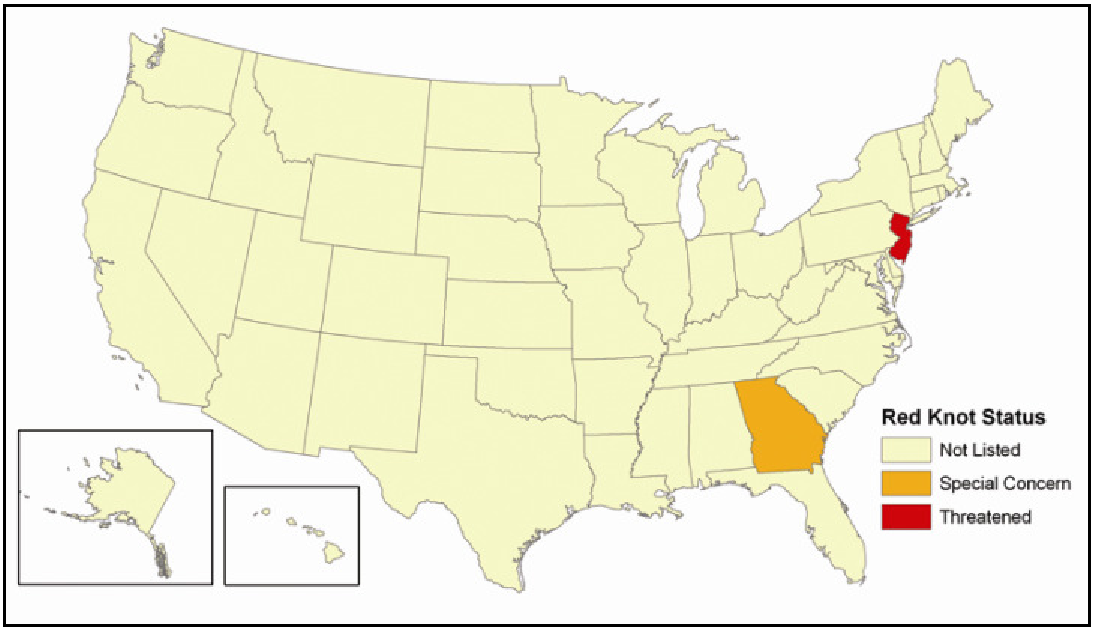


Figure 38. Red Knot state legal status in the United States.

EXISTING CONSERVATION STRATEGIES AND ACTIONS: PAST AND CURRENT CONSERVATION AND HABITAT MANAGEMENT ACTIVITIES UNDERTAKEN TO BENEFIT THE SPECIES

As part of this assessment, biologists representing each relevant state and country asked to outline the management efforts for Red Knots in their jurisdiction. There were no management efforts directed specifically at Red Knots along the entire length of the flyway except in the area of Delaware Bay. However, many global, national, regional, and State-specific management and conservation efforts have been implemented to benefit shorebirds in general, including the Red Knot.

GLOBAL LEVEL

The Ramsar Convention on Wetlands

The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. There are presently 146 Contracting Parties to the Convention, with 1463 wetland sites, totaling 125.4

million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance.

Mission Statement: "The Convention's mission is the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world" (Ramsar COP8, 2002

Western Hemisphere Shorebird Reserve Network (WHSRN)

WHSRN is a voluntary, non-regulatory coalition of hundreds of private and public organizations in nine countries whose mission is to conserve shorebird species and their habitats through a network of key sites across the Americas. Sites qualify based on two criteria: 1) hosting at least 20,000 shorebirds/yr, or at least 1% of a biogeographic population of a shorebird species; and 2) the explicit agreement of the landowner to protect and manage habitat for shorebirds. Membership in WHSRN provides a site with international recognition as a major host for shorebirds.

To date, WHSRN includes 67 sites, with partners that are responsible for managing over 22 million acres for shorebirds. Member sites are located in Argentina, Brazil, Peru, Suriname, Panama, Mexico, the USA, and Canada. WHSRN’s Executive Office is a program of the Manomet Center for Conservation Sciences, in Manomet, Massachusetts, USA.

Important Bird Areas Program (IBA)

Audubon, as the Partner for BirdLife International, is working to identify a network of sites that provide critical habitat for birds. This effort known as the Important Bird Areas Program (IBA) recognizes that habitat loss and fragmentation are the most serious threats facing populations of birds across America and around the world. By working through partnerships, principally the North American Bird Conservation Initiative, to identify those places that are critical to birds during some part of their life cycle (breeding, wintering, feeding and migrating) it is hoped to minimize the effects that habitat loss, and degradation have on bird populations. Unless the rapid destruction and degradation of habitat can be slowed, populations of many birds may decline to dangerously low levels. The IBA program is a global effort to identify areas that are most important for maintaining bird populations, and focus conservation efforts at protecting these sites. In the U.S. the IBA program has become a key component of many bird conservation efforts, for example: Partners in Flight, North American Waterbird Conservation Plan, and the U.S. Shorebird Conservation Plan.

Convention on the Conservation of Migratory Species of Wild Animals (CMS/Bonn Convention)

The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention) aims to conserve terrestrial, marine and avian migratory species throughout their range. It is an intergovernmental treaty, concluded under the aegis of the United Nations Environment Program, concerned with the conservation of wildlife and habitats on a global scale. Since the Convention came into force, its membership has grown steadily to include 101 Parties (as of 1 January 2007) from Africa, central and South America, Asia, Europe and Oceania (Fig. 39). At the instigation of Argentina, the Conference of the Parties to the Convention meeting in November 2005 determined that the *rufa* subspecies of the Red Knot was endangered and as such added it to Appendix 1 of the Convention. Under the terms of the Convention the Parties agree "to strive towards strictly protecting animals listed in Appendix 1, conserving or restoring the places where they live, mitigating obstacles to migration and controlling other factors that might endanger them." (www.cms.int)

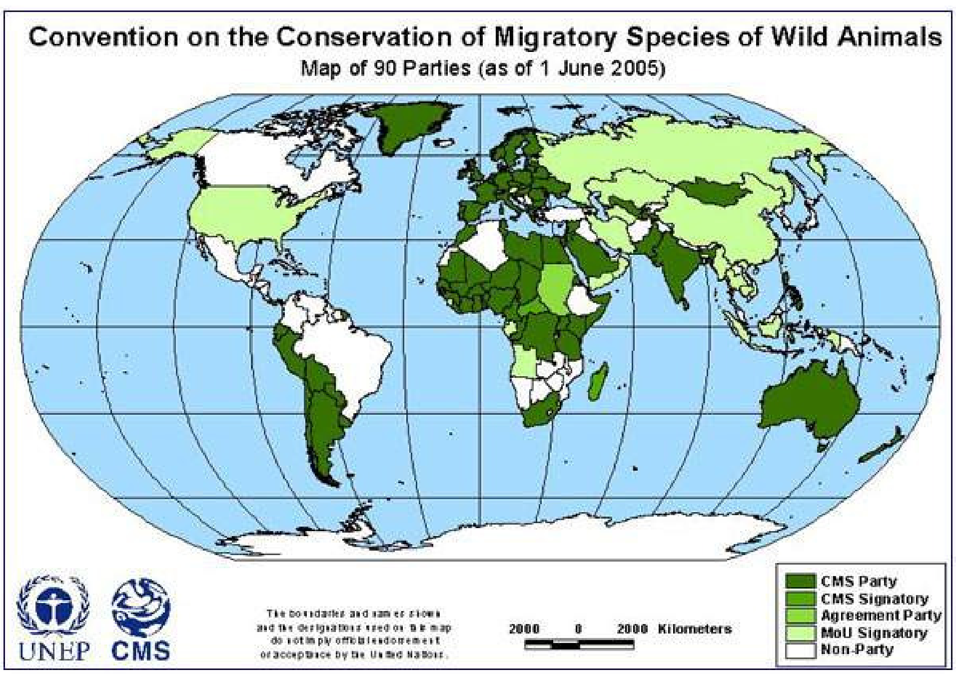


Figure 39. Participating countries of the Bonn Convention.

NATIONAL LEVEL

National Wildlife Refuges

Refuge Managers in USFWS Regions 2, 4 and 5 (Southwest, Southeast and Northeast U.S., respectively) were solicited for information on management plans that might affect Red Knots.

Management efforts for shorebirds are taking place in many wildlife refuges in the flyway, but most focus on impoundment management that aim primarily at species likely to forage in moist soil, such as Semipalmated Sandpiper, *C. pusilla*, Dunlin, *C. alpina*, Short-billed Dowitcher, *Limnodromus griseus* and Greater Yellowlegs *Tringa melanoleuca*. The Red Knot feeds primarily on small mussels and clams normally associated with tidal sands, and would only benefit indirectly from impoundment management for shorebirds. While not the focus of specific management efforts, Red Knots benefit from the creation of safe high tide or nighttime roosts on the small islands formed by the natural topography of shallow water impoundments.

The International Shorebird Survey (ISS), and Program for Regional and International Shorebird Monitoring (PRISM)

In 1974 the Manomet Center for Conservation Sciences organized the International Shorebird Surveys (ISS) to gather information on shorebirds and the wetlands they use. Information gathered by ISS cooperators over the last 30 years show some disturbing trends. The data have long suggested that several shorebird species were declining rapidly, but until recently the design of the ISS did not allow for a sensitive statistical analysis. A new initiative called the *Program for Regional and International Shorebird Monitoring* (PRISM) is underway to coordinate and expand on existing shorebird survey efforts, including the ISS, the Western Shorebird Survey (WSS) and the Canadian Maritimes Shorebird Survey (MSS). The closer coordination and expanded survey effort will increase the power of statistical analyses and more clearly define shorebird conservation issues on a continental scale. Volunteer participation in the ISS has declined since 2000 (Harrington pers. comm. 2005) and the level of effort from year-to-year and state-to-state is highly variable. Concerted effort should be made by state and federal agencies to reinvigorate survey efforts through PRISM.

REGIONAL LEVEL

Delaware Bay

1. Increase Availability of Horseshoe Crab Eggs by Protecting Crab Population.

Management in the Delaware Bay aims primarily at the protection of horseshoe crabs and spawning beaches, which increases the availability of horseshoe crab eggs, the Red Knot's prime food resource. Central to the protection of horseshoe crabs is the ASMFC Management Plan for the Horseshoe Crab. The plan, adopted in 1998, along with subsequent addenda in 2000, 2001, and 2004 has provided the coast-wide framework for the protection of horseshoe crabs. The protection of horseshoe crabs has been achieved through tighter restrictions on the harvest of crabs as bait. This is covered in the section on history of regulations. However, past restrictions on the harvest have not created an increase in the spawning population or crab egg numbers to date, partially because it takes nine years for crabs to reach breeding age. Thus other options have been explored to improve egg availability in the short and mid-term periods.

2. Increase Availability of Horseshoe Crab Eggs by Excluding Gulls from Prime Spawning Areas.

The second effort to increase the availability of horseshoe crab eggs is to develop management solutions to the high gull numbers along the New Jersey and Delaware Bay shore. The impact of gull numbers is greatest on bayshore beaches that are closest to gull colonies on the Atlantic Coast, namely those along the shore of the Cape May peninsula. These beaches, including Norbury's Landing, Kimbles Beach and Reed Beach were among those where shorebird numbers were the greatest (B. Harrington unpublished, Clark et al. 1993, K. Clark unpublished data). In 2003-2004, shorebirds shifted to beaches most distant from gull colonies on the Atlantic Coast: Fortescue Beach and Gandy Beach. Birds returned to Reeds Beach in 2005 coinciding with the introduction of an experimental gull exclosure. Created by the NJDFW Shorebird Team, the exclosure consisted of metal conduit supporting strands of 200lb test monofilament approximately 1-3 meters high (C. Minton, unpublished report to the NJDFW). The team applied a number of variations that prevented gull predation on eggs but also restricted shorebird use. However, flocks of up to 3,000 knots roosted and foraged in areas adjacent to and within the exclosure for most of the latter half of the May. Further experimentation is planned for 2006.

The gull exclosure is considered to be only a short-term solution to the low density of horseshoe crab eggs in New Jersey. A longer-term solution is the control of gulls. Although the killing of gulls would provide an immediate solution, the control of gull productivity presents a more publicly acceptable management alternative. In 2006, the NJDFW will initiate management that will reduce productivity and ultimately the number of Laughing Gulls breeding on the Atlantic coast adjacent to the Delaware Bay coast. The project will be done in partnership with appropriate federal agencies.

3. Increase Availability of Horseshoe Crab Eggs and Duration of Undisturbed Foraging for Shorebirds by Reducing Human/Dog Disturbance.

Management efforts to increase the availability of horseshoe crab eggs have taken several forms. The first is protecting beaches important for crabs and birds from repeated disturbances by people and dogs. The first part of the protection is the Shorebird Steward Program conducted by NJDFW, USFWS, New Jersey Audubon Society, the Nature Conservancy and other groups, and the former Shorebird Ambassador Program conducted by the Delaware Division of Fish and Wildlife. In this program, volunteers (who were reimbursed for expenses incurred) form a corps of stewards, educating beach users about the effects of disturbance on shorebirds and warn them of regulations that protect shorebirds. This effort is supported by agency staff, who provide logistical support in the form of outreach materials, signs and post-and-string symbolic fencing.

The second part of protection is conservation law enforcement, which has become necessary to obtain full compliance at the protected beaches. In New Jersey, the Red Knot is a state-listed Threatened Species and conservation officers have authority to issue summonses for disturbance. In three spring seasons, only a small number of warnings and one summons have been issued. Conservation officers have become the backup for shorebird beach stewards who may encounter difficulties with the public. Finally, the ASMFC approved addendum III to the horseshoe crab management plan. In addition to reducing the Delaware Bay harvest to 300,000 crabs annually, this addendum prohibits the collection of horseshoe crabs during the shorebird migratory period of 1 May through 7 June. By prohibiting the collection of crabs during the spawning period, females are free to spawn, providing much-needed eggs, and disturbance to foraging and roosting shorebirds due to beach harvesting is eliminated.

4. Protect Roosting Sites

The fourth management focus on Delaware Bay is to create secure day and nighttime high tide roosts. Shorebirds at stopover sites require not only an adequate food supply but also safe and disturbance-free sites that are close to their feeding grounds where they can roost when not feeding and be relatively free from ground predators (Rogers 2003, Sitters *et al.* 2001). As is typical worldwide, the main roosting sites used in New Jersey have always been the sand-spits and sand islands, in this case, in Hereford Inlet on the Atlantic coast between Stone Harbor and Wildwood. In contrast, the bayshore of Delaware has no similar roosting site so birds tend to roost in areas of open marshland about 1.7 km inland near Mispillion River (Sitters *et al.* 2003 unpublished data). Presently, this is the only place in the world where Red Knots have been recorded as roosting inland at night.

In 2004, radio-tracking showed birds commuting from diurnal feeding areas on the Delaware coast to roost at night at Hereford Inlet, New Jersey, a 94-km round trip. In 2005, perhaps because of tidal flooding just before the main arrival of knots, most, if not all, knots that fed in Delaware commuted to Hereford Inlet every night. On some nights, when high water occurred in the evening, the whole of the Delaware Bay stopover population of up to 20,000 knots roosted at Hereford Inlet.

In response to the increasing numbers of shorebirds roosting on the Atlantic coast at Stone Harbor Point, in 2005 NJDFW created protection zones on two areas covering approximately 300 acres. By the end of May, over 20,000 Red Knots and thousands of Dunlins and Sanderlings were using the protected area as a night time roost, and as many as 2,000 Red Knots were roosting in the same area during daytime high tides. In 2006, NJDFW will partner with the municipality of Stone Harbor to create year-round protection of Stone Harbor Point with emphasis on spring, fall and winter populations of all shorebirds, and spring and fall populations of Red Knots. Protection efforts will include physical barriers to disturbance, outreach materials, a full time naturalist on duty at critical periods, and the development of plans for long-term protection.

On the southbound journey the same consideration for safe and secure roosts and foraging areas also applies. In a study conducted on the Two Mile Beach Unit of the Cape May National Wildlife Refuge, which is closed to beachgoers during the period of the southbound migration, Red Knots and other shorebird species occurred ten times more often than on beaches open to the public (Mizrahi 2003).

5. Reduce Disturbance by Minimizing Research Activities

Research efforts on Delaware Bay, including trapping, banding and resighting efforts, have been minimized to reduce disturbance to foraging shorebirds. Trapping and banding effort was reduced to the minimum necessary to 1) monitor weight gains of Red Knots, Ruddy Turnstones and Sanderlings during the migratory stopover period, and 2) individually mark enough birds to perform survival analyses via resightings of marked individuals. Catch effort is limited to six catches of 50 – 75 individuals of each species across the migratory stopover period (approximately May 10 to June 7), and catches are spaced three to five days apart. Catch-effort is spread out over various locations to avoid frequent disturbance to individual beaches. Researchers strive to catch all three species in one attempt to reduce disturbance and catch frequency. Birds are weighed, measured and banded within two hours of capture, and banding activities take place away from foraging beaches to allow shorebirds to return to forage. Harrington (unpublished) found no difference between either the frequency or flight duration of researcher-caused disturbance compared to control periods without such disturbance.

Researchers carrying out systematic resighting surveys for individually-marked shorebirds are restricted to “safe” viewing areas including viewing platforms constructed for shorebird viewing, roads, and occasionally from beachfront property with the permission of the landowner.

Shorebird banding teams are lead by biologists from NJ and DE Divisions of Fish and Wildlife and comprise professional local and foreign shorebird biologists as well as experienced local and foreign bird banders. The Delaware Bay Shorebird Project began in 1997 and employed a method of trapping (cannon-netting) widely used in Europe and Australia. Because this method is not widely used in the U.S., certified cannon netters from the United Kingdom and Australia, all with decades of experience, trained U.S. teams in this trapping technique. This dedicated corps of experienced cannon netters, many of whom are professional shorebird biologists (active or retired) in their respective countries, have returned each year since 1997 to help carry out this project.

All research activities are carried out with the utmost care, respect, and highest ethical conduct with regard to the shorebirds, landowners and visitors on the Delaware Bay.

6. Monitor numbers of Migratory Shorebirds on the Delaware Bay Stopover

In 1986, the NJ and DE Divisions of Fish and Wildlife began weekly aerial surveys of the Delaware Bay coastline (Fig. 7) to document shorebird abundance during the migratory stopover (May through early June). This long-term survey has tracked the decline of the migratory stopover in terms of shorebird abundance has been used to track changes in shorebird distribution relative to horseshoe crab egg densities on bayshore beaches. This survey has been conducted by the same observers throughout its nearly 20-year duration and continues to be one of the most valuable long-term monitoring programs in place on the Delaware Bay stopover.

7. Past and Current Management Actions for Shorebird Populations

- 1986: Delaware Governor Michael Castle and New Jersey Governor Thomas Kean designated the bay-shore as a Sister Reserve, the first such commitment under WHSRN. The WHSRN ties together critical shorebird stopovers in North, Central and South America.
- 1987: NJDFW-ENSP with DEDFW conducted bay wide aerial surveys of shorebirds. This survey has been conducted every year since 1987.
- 1992: NJDFW contracted a study of shorebird/shorebird habitat vulnerability to oil spills in the bay. This study projected the likely impact areas of spills from different locations under different weather conditions to provide information necessary for response planning.
- 1993: In May 1993, the NJDFW-ENSP convened a two-day Delaware Bay Shorebird Workshop, which resulted in the "Comprehensive Management Plan for Shorebirds on Delaware Bay." The workshop included over 100 people representing 22 organizations, and aimed to improve communication and develop a framework for conservation actions across two states and multiple government and non-governmental organizations.
- 1994: In May 1994 the NJDFW-ENSP convened a single day Delaware Bay meeting to finalize the management plan drafted after the 1993 workshop. The final plan was printed and distributed to regulatory agencies and conservation groups in the region. NJDFW-ENSP

completed mapping of shorebird distribution and suitable habitats, and made it available to emergency response and planning agencies.

- 1994: New Jersey convened a Shorebird Outreach Team as a result of the 1993 planning meeting, including representatives from NJDFW-ENSP, DEDFW Nongame and Endangered Spesies Program (NGES), New Jersey Audubon, Bay Shore landowners (The Nature Conservancy, New Jersey Natural Lands Trust, New Jersey Conservation Foundation, USFWS) and the Wetlands Institute. This team developed educational materials including fact sheets on shorebirds and safe viewing locations.
- 1995: New Jersey hosted a two-day Delaware River and Bay Oil Spill Emergency Workshop, assembling all agencies responsible for spill response on the bay. The results of this workshop were incorporated into the Area Contingency Plan, the chief reference document in the case of a spill.
- 1997: Delaware Coastal Management Program (DECMP) and WHSRN host a shorebird management workshop for Delaware Bay. The goal of the workshop was to provide information that can be used to integrate shorebird management into traditional environmental practices and programs in the Delaware Bay Region such as wetlands management, public access management, and the beneficial use of dredged material.
- 2003: NJDFW-ENSP and DEDFW-Natural Heritage and Endangered Species Program (NHESP) conducted bay-wide aerial shorebird surveys during the fall migratory period.
- 2005: NJDFW-ENSP, Richard Stockton University in New Jersey, and DEDFW-NHESP carried out the first year of bay wide horseshoe crab egg surveys using a standardized sampling protocol developed by the U.S. Geological Survey.
- 2004: ASMFC approves Addendum III of the horseshoe crab management plan. The addendum limits Delaware Bay harvest to 300,000 crabs annually and prohibits the harvest of crabs during the shorebird migratory period (1 May – 7 June). This closure decreases the number of gravid females collected and limits the disturbance to shorebirds caused by beach harvesting.
- 2006: ASMFC approves addendum IV of the horseshoe crab management plan. In relation to New Jersey and Delaware for the two years from October 1, 2006, this prohibits the directed harvest and landing of all horseshoe crabs between January 1 and June 7 and female horseshoe crabs between June 8 and December 31 and limits the harvest to 100,000 (male) crabs per state per year. In relation to Maryland and for the same two year period, it prohibits the

directed harvest and landing of horseshoe crabs between January 1 and June 7. It also prohibits the landing of horseshoe crabs in Virginia from federal waters between January 1 and June 7.

8. Past and Current Management Actions for the Horseshoe Crab Populations

a. Regulation/closure of the Horseshoe Crab Fishery

- 1991: DEDFW was given authority to regulate horseshoe crabs. Collecting Permits were required and mandatory reporting regulations were established and horseshoe crab dredge licenses were capped at five.
- 1992: DEDFW prohibited horseshoe crab harvesting within 1,000 feet of all state and federal lands from May 1 – June 7 (except Port Mahon on Wednesday, Thursday, and Friday). A personal possession limit of 6 horseshoe crabs was established for non-permitees (i.e. people can have up to 6 to bait a minnow trap or eel pot to catch fish bait).
- 1993: New Jersey passed regulations that prohibited harvest of horseshoe crabs on New Jersey Delaware Bay beaches during daylight hours. Reporting of harvest was voluntary.
- 1994: New Jersey passed regulations that prohibited harvest of horseshoe crabs on New Jersey Delaware Bay beaches or within 1,000' of beaches. Reporting of harvest was mandatory.
- 1995: Regulations limited harvest of horseshoe crabs on New Jersey Delaware Bay beaches to nighttime hours on Mondays, Wednesdays and Fridays only during the period May 1-June 7.
- 1996: An amendment to NJAC 7:25-18.16 to provide added protection to spawning horseshoe crabs and reduce the disturbance to the migratory shorebirds feeding on the Delaware Bay waterfront beaches. Regulations prohibited harvest of horseshoe crabs on Delaware Bay waterfront at any time; hand harvest permitted only in back bays and tidal creeks of the state (minimum of 1,000 feet from bay front) on Tuesdays and Thursdays commenting one hour after sunset until one hour before sunrise. Harvest and landing of crabs was prohibited during May unless by hand.
- 1997: DEDFW instituted an emergency closure of the horseshoe crab fishery in May and closed the dredge fishery and hand harvest (state and federal lands) through June 30.
- 1998: The ASMFC approved the Interstate Fishery Management Plan for Horseshoe Crabs. DEDFW closed horseshoe crab fishery May 1 – June 30 except Tuesday and Thursday

hand harvest at Port Mahon and Monday, Wednesday, and Friday hand harvest on private lands. A 300 cu ft containment limit on hand harvest fishery was established. The dredge fishery was closed from May 1 – June 30 and a 1500 horseshoe crab limit on dredge harvest was imposed. Hand harvest permit eligibility criteria were established (had to have secured 2 permits prior to July 1997). Requirements for timelier reporting were established. Landings from the Exclusive Economic Zone ("EEZ",- 2 - 300 miles) prohibited. Nighttime harvest prohibited.

- 2000: The ASMFC approved Addendum I to the Fishery Management Plan for Horseshoe Crab. The addendum caps bait landings to 25% below reference period landings and recommends a closure of horseshoe crab harvest in Federal waters within 30 nm of the mouth of the Delaware Bay.
- 2001: The NMFS established the Carl N. Shuster, Jr. Horseshoe Crab Reserve. The establishment of this reserve prohibits the harvest of horseshoe crabs in nearly 1,500 square miles of federal waters off the mouth of the Delaware Bay.
- 2004 (March): The ASMFC Horseshoe Crab Management Board agreed to adopt new conservation measures for the horseshoe crab. Specifically, the Addendum capped annual harvest in New Jersey and Delaware at 150,000 crabs per state and set Maryland's annual quota at its 2001 landings level (170,653 crabs). Further, it required the three states to prohibit the harvest and landings of horseshoe crab for bait from May 1 to June 7. Addendum III also encouraged states with both bait and biomedical fisheries to allow biomedical companies to bleed harvested crabs prior to their use as bait. This would eliminate mortality associated with the process of bleeding and returning crabs to the waters from which they were harvested.
- 2003 for 2004 season: New Jersey and Delaware quota reduced to 150,000 horseshoe crabs. Season established to be April 1 through April 30 and June 8 through August 15. No harvest allowed during the period May 1 through June 7. Permit holders must report their harvest each Friday by telephone. The dredge fishery was limited to 35% of total quota prior to May 1. The use of bait savings devices required. DEDFW bans the personal exemption of 6 horseshoe crabs.
- 2006: ASMFC approves addendum IV of the horseshoe crab management plan. In relation to New Jersey and Delaware for the two years from October 1, 2006, this prohibits the directed harvest and landing of all horseshoe crabs between January 1 and June 7 and female horseshoe crabs between June 8 and December 31 and limits the harvest to 100,000 (male) crabs

per state per year. In relation to Maryland and for the same two year period, it prohibits the directed harvest and landing of horseshoe crabs between January 1 and June 7. It also prohibits the landing of horseshoe crabs in Virginia from federal waters between January 1 and June 7.

b. Management Plans

- 1998 (Dec): The ASMFC Fisheries Management Plan for Horseshoe Crab was approved requiring a suite of monitoring requirements - Delaware, New Jersey, and Maryland required to keep current regulations in place.
- Late 1999: ASMFC Horseshoe Crab Management Board approved Addendum I to the Interstate Fishery Management Plan for Horseshoe Crab, which implemented harvest reduction measures along the Atlantic coast for the commercial horseshoe crab bait fishery. Specifically, the Addendum established a state-by-state cap at 25% below 1995-1997 levels of 2,999,491 horseshoe crabs for all states.
- 2000 (May): Addendum I of the Fishery Management Plan approved requiring a cap on the fishery at 361,801 horseshoe crabs.
- 2001: ASMFC (2001) approves Addendum II to the FMP for Horseshoe Crabs allowing or interstate transfer of harvest quotas.
- 2004: ASMFC approves Addendum III to the FMP for Horseshoe Crabs. Addendum III further limits harvest of Delaware Bay horseshoe crabs to 300,000. It also closes harvest from 1 May through 7 June to limit harvesting of spawning crabs and to limit disturbance of shorebirds from harvesters.
- 2006: ASMFC approves Addendum IV of the horseshoe crab management plan. In relation to New Jersey and Delaware for the two years from October 1, 2006, this prohibits the directed harvest and landing of all horseshoe crabs between January 1 and June 7 and female horseshoe crabs between June 8 and December 31 and limits the harvest to 100,000 (male) crabs per state per year. In relation to Maryland and for the same two year period, it prohibits the directed harvest and landing of horseshoe crabs between January 1 and June 7. It also prohibits the landing of horseshoe crabs in Virginia from federal waters between January 1 and June 7.

c. Habitat Protection

- 1999: The Ecological Research Development Group (ERDG) launches its community-based horseshoe crab sanctuary program. The program works with private landowners and communities to establish sanctuaries where crabs cannot be harvested.
- 2000: ERDG works with the community of Broadkill Beach, Delaware to become the first Horseshoe Crab Sanctuary restricting the harvest of horseshoe crabs along a 2.5 mile section of beach.
- 2005: Currently approximately 20 miles are registered as designated horseshoe crab sanctuaries with DE DFW.

d. Bait Bags

- 1999: ERDG initiated phase I of its bait bag initiative dispersing 500 bait bags to Virginia conch fishermen. Bait bags were found to reduce the amount of horseshoe crab bait needed by 25-50%.
- 2000: ERDG completes phase II of its bait bag initiative by manufacturing and distributing 6000 bait bags to commercial fishermen in Maryland, Delaware, and New Jersey free of charge.

NON-BREEDING (WINTER) AND STOPOVER AREA MANAGEMENT AND CONSERVATION

South America

1. Chile

The Red Knot is protected by Chilean hunting law N° 19.473. There are no special protection measurements for Bahía Lomas, the main site of importance to Red Knots in Chile. In 1996, the Corporación Nacional Forestal (CONAF) recommended Bahía Lomas as one of the 21 sites in the "urgent category" stated in the priority sites for the conservation of the biodiversity in Chile (CONAF 1996). No activities were associated with this conservation status. Due to its world importance, Bahía Lomas was recently (December 2004) declared a Ramsar site, the second southern-most after the neighboring Atlantic coastal reserve of Tierra del Fuego in Argentina. Thus far, the Ramsar designation is the only conservation protection that Bahía Lomas has received.

2. Argentina

Argentina is a signatory party to the Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention). Migratory species that need or would benefit significantly from international co-operation are listed in Appendix II of the Convention. The family Scolopacidae is listed in Appendix II. Migratory species threatened with extinction are listed on Appendix I of the Convention. CMS Parties strive towards strictly protecting these animals, conserving or restoring the places where they live, mitigating obstacles to migration and controlling other factors that might endanger them.

At the 12th Scientific Council (ScC) Meeting, held in Glasgow, United Kingdom, 31 March - 3 April 2004, the ScC approved the request from Argentina, presented by Patricia M. González, to include *C. c. rufa* in Appendix I. The Conference of the Parties, the CMS decision-making body, adopted the Sc C's recommendation to amend Appendix I at their November 2005 meeting.

Besides the CMS national and inter-government agreement, different government levels provide legal protection status to Red Knot critical areas as described below. International recognition from the Western Hemisphere Shorebird Reserve Network (WHSRN) and Important Bird Areas (IBA) from BirdLife International are also included:

- Reserva Costa Atlántica de Tierra del Fuego (1992): Provincial Natural Area Protected
    - Ramsar Site (1995)
    - WHSRN Site of Hemispheric Importance
    - IBA area (Bahía San Sebastián is priority IBA area).
- Reserva Provincial (Santa Cruz) para Aves Playeras Migratorias (2001) and Reserva Urbana Costera del Río Chico (2004): Provincial Natural Area Protected and Urban Natural Area Protected
    - WHSRN Site of International Importance
    - IBA area
- Bahía Bustamante: No conservation status
- Península Valdés: Reserva Natural Integral Provincial
    - Patrimony of the Humanity
    - Potential Ramsar and WHSRN Site

- IBA area.

- Bahía Samborombón (1979): Integral Natural Reserve
  - Provincial Integral Natural Reserve with Restricted Access (9,311 ha)
  - Provincial Integral Natural Reserve "Rincón de Ajó" (2,311)
  - "Campos del Tuyú" Private Reserve, Fundación Vida Silvestre Argentina.
  - "Punta Rasa" Biological Station, Agreement between the Naval Hydrography Service (Argentine Navy) and the Fundación Vida Silvestre Argentina
  - Punta Rasa "Traveled Municipal Ecological Reserve" (1991)
  - Ramsar Site (1997)
  - Priority IBA area.
  - Potential WHSRN Site
- Bahía San Antonio Natural Protected Area
  - Potential Ramsar Site
  - Priority IBA area
  - WHSRN Site of International Importance

Management plans are being developed for Reserva Costa de Tierra del Fuego, Reserva Provincial (Santa Cruz) para Aves Playeras Migratorias, and the Reserva Urbana Costera del Río Chico, in conjunction with ongoing shorebird research and public education. Shorebird research is also ongoing at Península Valdés, which has a current management plan and is used as a camp by artisanal fishermen, and Bahía Samborombón, where an Environmental Ordering Plan is implemented. No research or management is being done at Bahía Bustamante.

The Bahía San Antonio Natural Protected Area has an urban management plan which restricts land use near key shorebird areas and actively protects shorebird roosting sites. Besides the CMS national and inter-government agreement, this area has international recognition from the Western Hemisphere Shorebird Reserve Network (WHSRN), is designated as a priority Important Bird Area (IBA) by Birdlife International, and is a potential Ramsar site.

3. Brazil

The Brazilian government through IBAMA (Brazilian Institute of the Environment and Renewable Natural Resources) by CEMAVE has been developing conservation projects on migratory Nearctic species since the beginning of the 1980s.

Besides the Brazilian legislation to protect fauna, bird habitat is protected through the Ramsar Convention in which the country has participated since 1993. Particularly in the coastal areas, the main objective of projects is the monitoring of Pan-American migratory birds to develop strategies of joint conservation action

Over the years, international technical cooperation has been established, the first in 1981 with the American government, through the U. S. Fish and Wildlife Service. This cooperation resulted in training in techniques of capture with net-cannons in Salinas, in the state of Pará. In the same year, a project with CWS (Canadian Wildlife Service) resulted in an aerial survey of the Brazilian coastline to identify areas of occurrence for Nearctic migratory birds. This survey was carried out between 1982 and 1986 along the Brazilian coastline, and the results were published in 1989 in the Atlas of Nearctic shorebirds on the coast of South America.

In 1984, a partnership with the Manomet Bird Observatory (MBO), with financial support from the World Wildlife Fund (WWF), and participation of teachers and researchers of the UNISINOS (University of the Valley of the Sinos River) and FZBRS (Zoobotanical Foundation of Río Grande do Sul), a workshop was promoted in Porto Alegre about techniques and methodologies for monitoring migratory birds. Field activities were developed in Lagoa do Peixe, including banding of captured birds. Afterwards, CEMAVE started an annual monitoring program of birds in Lagoa do Peixe, during the northward migration between April and May, in which activities include capture by mist-nets and net-cannon, banding, collecting biological data (molting, biometry, age estimation, sex), and terrestrial censuses in the region of the Park.

Since 1992 the Center has surveyed, by land and by sea, several points on the coast for ecological characteristics of the areas preferentially utilized by the Nearctic migratory birds. With support from the Executive Management of IBAMA in several Brazilian states, and from trained banders registered in the National Banding System, the center has worked at several other points of the coasts of the states of Amapá, Pará, Maranhão, Ceará, Río Grande do Norte, Pernambuco, Alagoas and Bahía.

Between 1996 and 1998, CEMAVE, in partnership with the Canadian Wildlife Service, with support from the Inter-American Development Bank, and World Wildlife Fund (Canada), developed the project “Surveys of the Nearctic and Neotropical avifauna in the Marshland of the state of Mato Grosso”. These surveys were carried out in the states of Mato Grosso and Mato Grosso do Sul, seeking to identify the main points of occurrence and passage of migratory species, during their migrations after reproduction in the Arctic, between September and October. The results have not been published yet.

Since 1997, the Center has participated in an international cooperative project, "Migration of Red Knots in South America: ecological research to support the conservation of the longest bird flights on earth", with the goal of extending the knowledge of the migration strategies of this species, integrating monitoring activities in the states of Maranhão and Río Grande do Sul, to those carried out in others countries that share these resources, such as Argentina and United States.

Among the achievements, we highlight the creation of Conservation Units, as the Lagoa do Peixe National Park, in November of 1986, as well as of the Reentrâncias Maranhenses as significant international and regional reserves, respectively, to the Western Hemispheric Shorebirds Reserve Network, in 1991; these areas have been included in the Ramsar Convention, on the occasion of the adhesion of Brazil; the presentation of results in international and national congresses, as well as the publication of articles in scientific journals; and participation in the elaboration of the Management Plan of the Lagoa do Park National Park between 1997 and 1999.

The Center has promoted the training and qualification of personnel in techniques of capture, marking, censuses, with participants from others countries, like Argentina, Uruguay, Paraguay, Peru, Chile, Colombia, Venezuela, and Panama. Already forty-five professionals and students of in the Biological Sciences were coached, in six courses of short and medium duration.

It is noteworthy that the activities describe above received 95% of their financing from the Brazilian federal government, which has subsidized the monitoring of migratory birds over the years, despite of the economic instability of the country.

To determine if *Pinus* harvesting impacts shorebirds, field activities were developed in Lagoa do Peixe, including banding of birds captured. CEMAVE started an annual monitoring program of birds in Lagoa do Peixe, during the northward migration between April and May, in which activities include capture by mist-nets and net-cannon, banding, collecting biological data (molting, biometry, age estimation, sex), and terrestrial censuses in the region of the Park. Thus far the results have not been published.

There are no current management activities in Maranhão. However, CEMAVE has promoted scientific expeditions for banding and collecting of biological data in May, during the migration of the birds to the North Hemisphere, and in November. With the goal of integrating local communities in the conservation activities, as well as promoting the objectives of banding and collecting of biological data, CEMAVE has sought to promote the work, through lectures in schools, associations of local fishermen, etc.

United States

1. Florida

The following is a list of key sites with current management for wintering shorebirds:

- Shell Key – Portions of the island closed to entry
- Caladesi Island, Hurricane Pass – Limited posting of signs on a roosting site
- Passage Key – Closed to entry but poorly enforced
- Merritt Island NWR, Black Point Drive – Restricted access
- Ding Darling NWR, tower stop – Restricted access
- Kennedy Space Center – Limited access

2. Georgia

- Little Tybee Island- Heritage Preserve/Natural Area.
- Ogeeche River Bar- Not managed.
- Wassaw Island- Wildlife Refuge.
- Ossabaw Island- Heritage Preserve/Wildlife Management Area.
- St. Catherines Island- Undeveloped, conservation intent.
- St. Catherines Bar- Closed Natural Area.
- Grass Island- Not Managed.
- Blackbeard Island- Wildlife Refuge.
- Sapelo Island- National Estuarine Research Reserve/Wildlife Management Area.
- Wolf Island- Wildlife Refuge/Wilderness.
- Little Egg Island Bar- Closed Natural Area.
- Little St. Simons Island- Undeveloped, conservation intent.
- Sea Island- Developed.
- St. Simons Island, Gould's Inlet- Developed.
- Jekyll Island- Developed.

- Little Cumberland Island- Partially developed.
- Cumberland Island- National Seashore, Some private residences

3. South Carolina

In South Carolina the USFWS closes important Red Knot roosting areas in Cape Romain NWR to public use. SCDNR's closes seabird nesting islands, which are also Red Knot roosting areas, and tags horseshoe crabs to identify their critical spawning and nursery habitat. The state also requires harvesters to estimate and minimize fishery mortality.

STOPOVER HABITAT MANAGEMENT

United States

1. North Carolina

The following is a list of key sites with current management for wintering shorebirds:

- Cape Lookout National Seashore – posting to protect breeding birds (April – August) also benefits migrants.
- Cape Hatteras National Seashore – posting to protect breeding birds (April – August) also benefits migrants.
- Pea Island – posting to protect breeding birds (April – August) also benefits migrants.

2. Virginia

Previous Red Knot aerial surveys conducted in late May and/or early June indicate that the barrier islands located along the seaward margin of Virginia's Eastern Shore harbor the state's greatest densities and abundance of spring migrants and serve as important stopover locations. In addition, most of the islands are remote, free of development, and have for the most part been allowed to revert to their natural state following periods of settlement by humans and livestock over the past several centuries.

Today, most management measures are directed towards minimizing human disturbance, reducing predator populations, and removal and/or control of invasive species. Organizations that own and manage the islands already have in place seasonal and year-round public use policies designed to protect breeding waterbird populations. These include confining recreational activities to areas of the beach below the high tide line, prohibiting dogs and other pets on the islands, temporarily closing portions of the islands that are particularly vulnerable to disturbance, and for a few of the islands, seasonal and year-round closures. It should be noted that there are private inholdings remaining on two of the barrier islands. Owners of these private land parcels work cooperatively with conservation organizations to ensure that their activities do not harm the islands' natural resources. Many of the seasonal closures and public use policies cover the peak Red Knot spring migration period.

Other sites, where Red Knots have been observed during spring migration in substantially lower numbers, include Plum Tree Island National Wildlife Refuge and Goodwin Island; both are located on the western shore of the lower Chesapeake Bay. Very little is known about the use of these sites by Red Knots. They receive very little human disturbance because they are remote and difficult to access (Plum Tree Island NWR is largely off limits to the public because of unexploded ordinances), and therefore will likely not require much management.

3. Maryland

The state of Maryland does not conduct or sponsor any organized surveys that include Red Knots. There are also no research, monitoring or management efforts for Red Knots in the state. Suitable habitats do exist within the state, however. These include Hart Miller Island, Assateague Island and Poplar Island. Hart Miller Island is owned and managed by the state of Maryland. Assateague Island is divided into three areas: Assateague Island National Seashore, managed by the National Park Service; Chincoteague National Wildlife Refuge, managed by the U.S. Fish and Wildlife Service; and Assateague State Park, managed by Maryland Department of Natural Resources. Current management at Assateague Island involves managed areas at the northern end of the island for Piping Plovers, and tidal flats behind the island that are part of a coastal management program. Poplar Island is located off the Chesapeake Bay coastline, about 34 miles south of Baltimore in Talbot County. It is currently managed by the U.S. Army Corps of Engineers, the MD Port Administration, and other Federal and State agencies as a site for habitat restoration and beneficial use of dredged materials.

4. New Jersey

The principle shorebird conservation issues in the Delaware Bay stopover are human disturbance to birds and their habitats and the availability of abundant food in the form of horseshoe crab eggs. While recognition of the shorebird migration was improved with the reporting of bay wide surveys beginning in 1981 (Wander and Dunne 1981), management began in 1989 with the first "shorebird wardens" on three New Jersey beaches.

a. Outreach and Protection

- 1989: NJ ENSP contracted New Jersey Audubon Society to train and supervise shorebird wardens at three New Jersey beaches (Norbury's Landing, Reed's Beach and Fortescue) to reduce disturbance. Educational signs were created and placed at two of those beaches (Reed's and Fortescue), and a brochure was distributed by the wardens.
- 1990: The first year that NJ ENSP provided a viewing platform at Reed's Beach, to limit disturbance of that beach by encouraging use of a single viewing point. ENSP contracted New Jersey Audubon Society to train and supervise shorebird wardens at four New Jersey beaches (Sunray, Norbury's Landing, Reed's Beach and Fortescue) on weekends in May. Wardens distributed an informative brochure to 1,000 people.
- 1992: Viewing areas were put in place at Norbury's Landing, Reed's Beach (2), and Fortescue. A map was created that identified all designated viewing areas
- ENSP trained and supervised 12 shorebird wardens who monitored four beaches on May weekends
- 1994: Viewing areas were set up at Norbury's Landing, Reed's Beach and Fortescue, and other accessible beach access points were posted with information signs warning of the problems of disturbance to feeding and resting shorebirds. A new brochure that included a viewing area map was distributed at all viewing areas and through local nature centers and businesses. New Jersey fielded shorebird wardens at viewing areas on May weekends.
- 1995: The New Jersey Shorebird Outreach Team continued to work together on educational materials for the public. This team developed educational materials including a map of viewing areas with a local business listing on the back. Viewing areas were set up at Norbury's Landing, Reed's Beach and Fortescue, and other accessible beach access points were posted with a new sign designed to clearly indicate the safe viewing point to prevent disturbance to feeding and resting shorebirds. New Jersey fielded shorebird wardens at viewing areas on May weekends. A new brochure that included a viewing area map was distributed at all viewing areas and through local nature centers and businesses.

b. Human use/Disturbance

- 1985: NJ Division of Fish and Wildlife's Endangered and Nongame Species Program (NJDFW-ENSP) began research and survey actions initiating surveys of human use (Clark and Niles 1985).
- 1987: NJ DFW conducted human use surveys on New Jersey bayshore beaches.
- 1988: NJ DFW conducted human use surveys on New Jersey bayshore beaches.

c. Habitat Restoration

- 1991: Fishing Creek marsh was managed to promote shorebird habitat by controlling *Phragmites* and restore tidal flow to its western section.
- 2006: NJ DFW has received funding to remove rubble from Moore's and Thompson's Beach to improve spawning conditions for horseshoe crabs.

d. Radio Telemetry of Shorebirds

- 1989: NJ ENSP initiated a shorebird telemetry study to determine habitat use patterns.
- 1990: A limited telemetry study continued (7 Red Knots) to determine habitat use patterns.
- 2003 - 2005: NJ ENSP, in cooperation with DE Division of Fish and Wildlife and the U.S. Fish and Wildlife Service, initiated a baywide Red Knot telemetry study using stationary receivers to monitor bay wide bird movements and identify critical foraging and roosting sites.

e. Aerial and Ground Surveys

- 1990: NJ ENSP conducted aerial transect surveys across New Jersey Atlantic and Delaware Bay habitats three times per day, once a week for three weeks; continued in 1991.
- 1991: This year saw increased demand for (and harvest of) horseshoe crabs as bait. ENSP conducted aerial transect surveys across New Jersey Atlantic and Delaware Bay habitats three times per day, once a week for three weeks, similar to those done in 1990. Ground surveys of shorebirds in marsh and beach habitats were conducted in 1991 and 1992, resulting in the Burger *et al.* (1996) paper.
- 2004: NJDFW-ENSP and New Jersey Audubon Society began fall shorebird surveys using a modified ISS methodology. Trained volunteers count/estimate flock size of individual

species, determine the ratio of juvenile:adult Red Knots in flocks, collect data on individually marked shorebirds, record sources of disturbance.

- 2005: NJDFW-ENSP and New Jersey Audubon Society conduct spring shorebird surveys using modified ISS methodology. Trained volunteers count/estimate flock size of individual species, collect data on individually marked shorebirds, record sources of disturbance.

f. Monitor Horseshoe Crab Egg Densities

- 1985: NJ Division of Fish and Wildlife's Endangered and Nongame Species Program (NJDFW-ENSP) began research and survey actions initiating surveys of horseshoe crab egg density (Clark and Niles 1985). In 1985 and 1986 egg density was measured at selected Bay Shore beaches (Williams 1986, 1987).
- 2000 - 2005: NJDFW-ENSP took over horseshoe crab egg sampling following a protocol established by Drs. Robert Loveland, Rutgers University, and Mark Botton, Fordham University. This survey will be replaced in 2006 with a method developed by the USGS to be implemented both in New Jersey and Delaware.

g. Monitor Shorebird Mass Gains and Adult Survival

- 1997 - present: NJ ENSP began an intensive shorebird trapping and banding program in NJ and DE to monitor weight gains of shorebirds stopping over on Delaware Bay and color-mark individuals for survival analyses and population estimation. In 1998, the DE CMP took over the trapping effort on the DE side of the Bay. These studies are ongoing and continue to the present under the direction of DE DFW-NHESP.

h. Monitor Winter Population of Red Knots in South America

- 2000 - 2005: NJ ENSP and the Canadian Fish and Wildlife Service instituted a winter survey of Red Knots in South America following the protocol of Morrison and Ross (1989). Continuation of this survey is dependent on availability of funding.
- 2000 - 2005: NJ ENSP and biologists from Chile and Argentina captured and individually marked Red Knots wintering on Bahía Lomas, Chile, to augment adult survival analyses and assess proportion of immature birds in the wintering population.

i. Monitor Breeding Densities on Arctic Breeding Area

- 1999 - 2004: NJ ENSP, the Royal Ontario Museum and Rutgers University instituted a study to relocate Red Knots (outfitted with radio transmitters on the Delaware Bay) on Arctic breeding grounds in 2000, 2001 and 2003, develop a model of potential breeding habitat, and monitor breeding densities on a 10-ha. study site in Nunavut, Canada. Breeding densities were monitored during June-July of 2000 to 2004; limited funding in 2005 was dedicated to aerial survey of winter Red Knot population in South America (see above).

5. Delaware

a. Outreach and Protection

- 1995: DE DFW-NGES established shorebird interpretive signs and viewing platforms at key shorebird viewing areas including Ted Harvey Wildlife Area and Little Creek Wildlife Area at Port Mahon Road.
- 1995 DE DFW-NGES launched the Shorebird Ambassador Program that placed volunteers at key shorebird stopover sites in Delaware during the weekends. The shorebird ambassadors were to provide outreach and education to Delaware Bayshore visitors.
- 1998: DED FW-NGES developed a shorebird viewing guide to promote shorebird conservation and viewing opportunities in Delaware.
- 1998: DE DFW closed horseshoe crab fishery May 1 – June 30 except for limited hand-harvest; landowners were allowed to have their beaches declared sanctuaries.

b. Horseshoe Crab Radio Telemetry

- 2003-2005: DE DFW and DE CMP, in partnership with the USGS have used an array of stationary telemetry receivers located throughout Delaware Bay to track horseshoe crab movement patterns and spawning frequency. In 2004 and 2005 shorebirds were added to the system to simultaneously track horseshoe crabs and shorebirds providing insight into the spatial and temporal overlap of beach use by these species.

c. Aerial and Ground Surveys

- 1992: DE DFW coordinates International Shorebird Surveys (ISS) in Delaware during spring migrations. The ISS surveys were largely conducted by volunteers from the Delmarva Ornithological Society and continued through 1997.

- 2003: DE DFW-NHESP began coordinating fall shorebird surveys for the Program for Regional and International Shorebird Monitoring Program.

d. Monitor Shorebird Mass Gains and Adult Survival

- 1998: DE CMP initiated a shorebird-monitoring program that including intensive survey and banding operations that continues to this day.

e. Horseshoe Crab Egg Densities

- 1997-2005: DE CMP began studying horseshoe crab egg densities for a variety of objectives related to coastal management activities and permitting issues.
- 2005: DE DFW initiated the Delaware portion of a Baywide horseshoe crab egg survey.

f. Land Acquisition

- Acquisition of former Lighthouse Restaurant facility in Mispillion Harbor to create interpretive and research center for horseshoe crab and shorebird outreach, education and viewing opportunities. Facility scheduled to open spring 2007.

6. New York

Jamaica Bay has been designated and mapped as an otherwise protected beach unit pursuant to the federal Coastal Barrier Resources Act, prohibiting incompatible federal financial assistance or flood insurance within the unit. The New York State Natural Heritage Program, in conjunction with The Nature Conservancy, recognizes two Priority Sites for Biodiversity within the Jamaica Bay and Breezy Point habitat complex: Breezy Point (B2 - very high biodiversity significance) and Fountain Avenue Landfill (B3 - high biodiversity significance). Jamaica Bay and Breezy Point have been designated as Significant Coastal Fish and Wildlife Habitats by the New York State Department of State, and the bay up to the high tide line was designated as a Critical Environmental Area by the New York State Department of Environmental Conservation. Jamaica Bay was also designated as one of three special natural waterfront areas by New York City's Department of City Planning. A comprehensive watershed management plan for the bay was completed in 1993 by the New York City Department of Environmental Protection in order to better protect and restore habitats and improve water quality. Wetlands are regulated in New York under the state's Freshwater Wetlands Act of 1975 and Tidal Wetlands Act of 1977; these statutes are in addition to federal regulation under Section 10 of the Rivers and Harbors Act of 1899, Section 404 of the Clean Water Act of 1977, and various Executive Orders. (Source: U.S. Fish and Wildlife Service, http://training.fws.gov/library/pubs5/web_link/text/jb_form.htm).

7. **Massachusetts**

Currently there are management and protection plans in place for some of the important stopover areas in MA. Federally owned areas, Plum Island [southern ¾ only], Nauset Coast Guard Beach, South Beach Island [portions] and Monomoy NWR, are currently managed by their respective agencies. Portions of Sandy Neck are managed by The Nature Conservancy. The remainder of the important areas is municipal / private land and may or may not be managed. Information on the management and protection status of private / municipal-owned important stopover areas was not available at the time of writing.

8. **New Hampshire**

No known management of shorebird stopover locations at the time of writing.

9. **Maine**

During the period 1989 to 1995, the state of Maine began intensive shorebird surveys to locate and designate critical staging areas. Maine biologists identified five critical areas, Stratton Islands, Eastern Egg Rock, Over Point, Petit Manan NWR, and Lubec. These locations have been designated as "Shorebird areas of Management Concern" and are candidate areas under Maine's Natural Resource Protection Act, which allows the Maine Division of Inland Fisheries and Wildlife to review permits relating to development and dock placement.

Panama

The total number of shorebirds using the Upper Bay of Panama during the year has been estimated at 1-2 million,,and as such, the Upper Bay was recognized as a WHSRN Site of Hemispheric Importance in 2005, as well as being named as a Ramsar Wetland of International Significance. An October 2005 celebration of the entrance into WHSRN was attended by the First Lady of Panama and the director of the nation's environmental authority (ANAM). On this occasion, the mayors of Panama City, Chepo, and Chimán, Republic of Panama; Angostura, Mexico (site of the Bahía de Santa María WHSRN site) and Cordova, Alaska, USA (Copper

River Delta WHSRN site) signed a letter that formally recognizes that their communities are linked by thousands of migratory shorebirds and that their coasts and wetlands serve as refuges, not only for these birds, but also for local bird species. The mayors affirmed that it is therefore of the greatest importance to conserve these critical sites, safeguarding not only the birds but also the well-being and health of the communities close to these wetlands as a means of cultural and economic improvement.

Canada

Migration staging areas are along coastal areas in Canada and are either federally or provincially owned. The federal government has many tools and programs for nature conservation. These range from outright ownership and management of various types of formal protected areas to the negotiation of voluntary agreements with private landowners. The federal approach to conservation and protection is to combine this range of approaches and partners, using each tool when and where appropriate.

Within the federal government, Environment Canada, the Parks Canada Agency, and Fisheries and Oceans Canada have the mandate to protect critical habitats by managing complementary protected area programs:

- Environment Canada, directly and/or through partnership arrangements, establishes and manages National Wildlife Areas, Migratory Bird Sanctuaries and Marine Wildlife Areas to protect wildlife habitat, and unique and productive ecosystems. The first two designations also allow Environment Canada to set up marine protected areas off Canada's shores and along the coasts of inland waters.
- Fisheries and Oceans Canada has the authority to establish Marine Protected Areas for a variety of purposes, including the conservation and protection of species at risk and their habitats, the conservation and protection of unique habitats, and the conservation and protection of marine areas of high biodiversity or high biological productivity.
- Parks Canada establishes and manages National Parks and National Marine Conservation Areas, which are intended to protect a representative sample of the features of the country's natural regions and marine natural heritage and to provide opportunities for public education and enjoyment.

Finally, the federal government plays a lead role in managing the implementation of international protected areas programs in Canada, including UNESCO Biosphere Reserves, UNESCO World Heritage sites.

BREEDING HABITAT MANAGEMENT

Nunavut Tunngavik Incorporated (NTI) was set up as a private corporation in 1993 to ensure that promises made in the Nunavut Land Claims Agreement are carried out. The operations of NTI are managed through offices in Iqaluit, Rankin Inlet, Cambridge Bay and Ottawa. Features of the Nunavut Land Claims Agreement include some to the more outstanding of its 41 articles include the title to approximately 350,000 square kilometers of land, of which about 35,000 square kilometers include mineral rights.

OTHER MANAGEMENT CONSIDERATIONS AND OPPORTUNITIES

1. Create High Tide Roost Sites within Impoundments on State and Federal Wildlife Areas.

Recent research conducted by NJ Shorebird team has demonstrated the importance of roosts for migratory shorebirds on Delaware Bay. One series of high tides in late May flooded all available roost on the bay and the entire population of shorebirds moved elsewhere to find safe roosts. This year, DFW biologists will investigate the creation of new roosts sites in Delaware Bay marsh and DFW and USFWS impoundments.

2. The Biomedical Industry

Horseshoe crabs are a vital source of lysate, a antibiotic used to sterilize medical equipment. Major drugs companies purchase lysate from smaller companies that actually bleed crabs, often draining as much as a ¼ of their blood. Once bleed, staff are required to release crabs at the original capture site. The ASMFC estimates 10% of all bled crab die and counts that against a state's quota of harvested crabs. In 2005 the ASMFC estimated coastwide, over 200,000 crabs were killed for biomedical use. The drug companies and crab bleeders could play a major role in 1) supporting survey and monitoring of the horseshoe crab population and 2) identifying ways to reduce crab mortality through improved monitoring (pre- and post-bleeding) to identifying sources of mortality, subsidize improvements to transport and holding facilities, bleeding methods, and reduction of holding time to reduce mortality.

Long-term research to improve/lower cost of a synthetic test for contaminants in injectable drugs would eliminate the need for horseshoe crabs altogether.

PROPOSED CONSERVATION AND MANAGEMENT ACTIONS - A STRATEGY FOR THE CONSERVATION OF RED KNOTS IN THE WESTERN HEMISPHERE

INTRODUCTION

Two subspecies of Red Knot, *Calidris canutus,* breed and winter in the Americas:

1. *rufa,* which breeds in the central Canadian Arctic and mainly winters in Tierra del Fuego; and
2. *roselaari,* which breeds in Alaska and probably winters mainly along the Pacific coast from California southwards.

In the U.S. Shorebird Conservation Plan, the populations of *rufa* and *roselaari* were each considered to be 100,000 to 150,000 in the 1980s. Although likely to be an overestimate because of the lack of historic comprehensive surveys, it is an far higher than the current estimate of *rufa* at 18,000-30,000 and *roselaari* to 5,000-50,000. These wide ranges reflect uncertainty about the size and subspecific status of knots found in certain locations at particular times of the year.

There are three main wintering populations of knots in the Americas:

1. 17,250 in Tierra del Fuego: the main *rufa* population which has declined from 67,000 in 1985,
2. 7,500 on the coast of Maranhao, N Brazil: uncertain subspecific status, no apparent change in numbers since the previous count in 1985, and
3. 3,000-7,000 in Florida: uncertain subspecific status, but has not shared genes with Tierra del Fuego population for 1,200 years; no evidence of significant population trend, but data sketchy.

In the past large flocks of knots, presumed to be *roselaari*, have been seen in Alaska in May, just before they disperse to their breeding grounds, but recent evidence of numbers is sketchy. Up to 10,000 occurred in California on migration in the 1980s and early 1990s, but more recent reports suggest a major decline. However, up to 4,000 were recorded on migration in Baja California in fall 2005.The main threat to *rufa* has been identified as the decline in the availability of horseshoe crab eggs in Delaware Bay through the over-exploitation of the adult crabs. Baker et al (2004) showed that knots caught at a lower weight in Delaware Bay had significantly lower survival than heavier birds. They also found that a fall in adult survival was responsible for the most recent declines in the Tierra del Fuego *rufa* population. If this remained low, it could be expected that *rufa* would go extinct within a decade.

Intensive research and monitoring has been carried out throughout *rufa*'s West Atlantic flyway since 1997. However, this has been largely uncoordinated. Most work has focused on specific sites and, except for Delaware Bay and two sites in Argentina, coverage has been patchy. Although the broad thrust of the research that has taken place has been to study *rufa*'s migration ecology there has been no effort to agree on a hemisphere-wide strategy that seeks to address the core issues and develop effective conservation prescriptions. No Red Knot study group exists. There is an urgent need to form such a group to develop cooperation between all Red Knot researchers. More importantly there is an urgent need to develop a strategy for Red Knot research that identifies key conservation issues and assigns them priority so that effort and resources are effectively and efficiently spent.

What follows is a draft of a global strategy to conserve the Western Hemisphere's Red Knot populations. This strategy lays out a conservation framework for research monitoring and surveys necessary to underpin the conservation actions.

After the conservation strategy is a comprehensive compilation of management, surveys, research, and management projects included in the Red Knot status assessment, developed by the Red Knot status assessment group and collaborators from all relevant states and countries.

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

The U.S. Shorebird Conservation Plan (Brown *et al.* 2001) proposes a tentative target for restoration of the *rufa* population to 240,000. Though we agree that this would be desirable and would ensure *rufa*'s future, it does not now seem to be realistic. Moreover there is no evidence that the population was ever that large. Overall the goal of conservation activities throughout the flyway should be to increase the *rufa* population to at least the figure of 25 years 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 to 70,000- 80,000 birds
2. Brazilian wintering population to 20,000-25,000
3. Florida Wintering Population to 20,000-25,000
4. Other sites 15,000-20,000

The means whereby such population increases might be achieved include:

- By 2015, recover and maintain Delaware Bay horseshoe crab egg densities at levels sufficient to sustain stopover populations of all shorebirds including 80,000 Red Knots. In part this will be supported by:
  a) Continuation of all current yearly studies of shorebird numbers, weight distribution and rate of mass gain, horseshoe crab numbers and egg densities, as continuing inputs for models;
  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.
- By 2008, development of a system for the yearly determination of population demographic status based on survey results, capture data and resightings of banded individuals. This will involve:
  a) Creation of a survival and population status model using existing data, and updated annually with new data;
  b) Development of annual estimates of productivity and juvenile survival as inputs for population models using the framework established for waterfowl population assessments;
  c) Distinguishing the population parameters of each wintering population (Tierra del Fuego, Maranhao and Florida) based on site-specific banding, resightings of marked individuals and stable isotope analyses.
- By 2009, determine the genetic and breeding status of the three main wintering populations (Tierra del Fuego, Maranhao and Florida). This will involve:

a) Identifying the arctic breeding area associated with each wintering subpopulation.
b) Determine subspecific status of each wintering population.
c) Determine the migration routes used by each wintering population.

- By 2011, create a hemisphere-wide system of protected areas for each significant wintering, stopover and breeding area.
- 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, Maranhao, 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. This will lead to:

a) The development of management plans and their integration into local and national conservation systems.
b) The identification of survey and research needs for each site.

- By 2009, identify all important breeding locations in Canada, and recommend protection needs for the top ten sites. This will require:

a) Use of radio telemetry to determine the arctic breeding areas of each winter populations (Florida, northern Brazil and Tierra del Fuego).
b) Use of GIS to determine suitable breeding habitat and extent of important breeding areas.
c) Formulation of recommendations to national governments on protection designations for most important breeding areas.

- By 2009, delineate and propose protection measures for key habitats within the main wintering areas of Maranhao, Tierra del Fuego and Florida, and develop management plans to guide protection. This will involve:

a) Conducting intensive surveys and determining areas of greatest importance within each site.
b) Creating 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) Conducting site-specific research necessary to determine important-use areas as well as existing and emerging threats:
   i) Carrying out studies of food resources;
   ii) Carrying out studies of habitat-use using radio telemetry.

- 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. This will require:
  a) Setting up survey, resighting, 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, Maranhao (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.
- 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.

PROPOSED CONSERVATION AND MANAGEMENT ACTIONS-INDIVIDUAL SURVEYS, MONITORING, RESEARCH, AND MANAGEMENT NEEDS PRESENTED IN THE RED KNOT STATUS ASSESSMENT

The following list of projects is compiled in the status assessment for the Red Knot, which remains under review by the USFWS. This list of projects was developed by the major authors in conjunction with collaborators from locations throughout the flyway. This is a comprehensive list of projects developed by the biologists working on Red Knots or their habitat.

SURVEY NEEDS

South America

1. Argentina

Resighting of individually marked knots to increase the precision of annual survival and recruitment estimates, and to allow the estimation of specific locality-survival-resighting parameters with multi-state models. Training of more local biologists and shorebird rangers at key sites is needed.

2. Chile

Studies on population dynamics of 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.

3. Brazil

- Aerial surveys on the Amazon Coast, especially in the coast of the state of Maranhão, during migration (boreal and austral), as well as during wintering seasons
- Ground surveys on the Río Grande do Sul coast, during the migrations
- Aerial survey on the Amapá and Pará Coast when knots are wintering in Maranhão
- 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)

4. Caribbean countries, northern South America

As 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. Likely areas include the Gulf of Maracaibo, where high hundreds were found during an early March survey in the early 1980s.

Mexico

Confirm numbers and subspecific status of knots wintering and staging on both the east and west coasts. Birds wintering on the east coast may be *C. c. rufa,* those on the west coast, *C. c. roselaari*

United States

1. **Delaware Bay**

Cross-bay commuting for the whole 12-14 day 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. Initiate and continue surveys of fall migrants with emphasis on juevenile/adult ratios and resightings of flagged birds

2. **Virginia**

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

3. **North Carolina**

Additional surveys during migration are needed.

4. **South Carolina, Georgia, Florida**

- The survey of wintering knot numbers in SE USA 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 southeast of the US 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.

- Conduct statewide surveys of Red Knots to document important areas, habitats and timing of migration. Surveys would include color-band resightings. Participate in ISS surveys that have long-term data sets.

5. 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 knots that are currently marked in the West Atlantic and East Asian – Australasian flyways.

6. California

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

7. Washington State

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

MONITORING NEEDS

Monitoring is essential to objectively determine trends in numbers, survival and recruitment to the Red Knot population on an annual basis. As there are several separate, apparently isolated populations, it is important to focus attention on wintering areas (i.e. the discrete wintering populations) as well as staging sites such as Delaware Bay.

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.

Considerable effort is needed in all major sites to locate individually-marked birds to determine which populations use which sites.

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.

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.

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

1. Argentina

- Continue the long-term monitoring programs and management plan development already in place.
- Continue to catch and mark 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.
- Resight individually marked knots to increase the precision of annual survival and recruitment estimates, and to allow the estimation of specific locality-survival-resighting parameters.

2. Chile

- Constant abundance monitoring, both aerial and terrestrial, during every season of the year is needed, especially during the key arrival and departure periods.

- Continue to catch and mark 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.
- Resight individually marked knots to increase the precision of annual survival and recruitment estimates, and to allow the estimation of specific locality-survival-resighting parameters.

3. Brazil

- Monitor Red Knots on the coast of Maranhão during passage and winter stage (September to May), with development of the following activities:
    - Capture knots using cannon- and mist-nets and individually mark;
    - Attach radio transmitters in May to determine date of arrival in Delaware Bay;
    - Biometric data gathering (molt, age, sex, ectoparasites load, collection of feathers for stable isotope analysis, blood sampling for studies of genetic variability and disease transmission such as West Nile Virus, Avian Influenza, etc.);
    - Scans 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.
- Create a field station in the municipality of Cururupu for supporting field work in Maranhão.
- Monitor Red Knots in Lagoa do Peixe National Park during September, October, April and May using same methods as described above.
- 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).
- Monitor shorebird species in the Pantanal (Río Negro) during northward and southward migration.

United States

1. Delaware Bay

- 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 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.
- A program of daily counts and resightings should be undertaken each spring in Delaware Bay to estimate the total number of birds of each wintering population passing through the bay.
- Continuation of the aerial survey during May and early June using consistent methods to ensure the long-term data set is maintained.
- Continuation of the various Horseshoe Crab monitoring programs
- Continuation of fall ground-based shorebird counts, especially in the Atlantic coast of New Jersey.
- Site use should be monitored through aerial and ground surveys. Baywide 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.

2. Virginia

- Regular counts and band resighting to investigate arrival date, departure date and residence time of knots using the barrier islands during spring migration
- Assessment of the body condition of 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. North and South Carolina

- Cannon net flocks and color band

4. Florida and Georgia

- Catch birds using cannon and/or mist-nets and mark as individuals using coded flags in winter.
- 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.
- Resight individually-marked knots to increase the precision of annual survival and recruitment estimates, and to allow the estimation of specific locality-survival-resighting parameters.

Canada and Alaska

Marking 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 over 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

RESEARCH NEEDS

There are several key gaps 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

- **How do birds from different wintering populations use Delaware Bay?** There is good evidence from feather isotope studies that birds from different wintering areas use the foraging resources of Delaware Bay in different ways. It appears that New Jersey-banded knots (based on isotope signatures) are being found in the southeastern USA more frequently than Delaware-banded knots. Collection of these data should be amplified by expansion of individual marking efforts in Tierra del Fuego and in the n. Brazil and s.e. USA migration and wintering areas, with intensified searches for them on Delaware Bay. In addition, a well- designed radio-tracking (telemetry) program should be used to establish whether knots from the various wintering areas use Delaware Bay in the same way with respect to foraging activities. The focus for radio-tracking of knots from the US 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.”

- **About 20% of the Red Knots passing through Delaware Bay have isotope signatures not compatible with known molting areas, why??** Currently, the nonbreeding distribution (migration and wintering) of the northern wintering knots is not well known. The group of knots that winters in the northern hemisphere may now comprise as much as half of the 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 knots have shown a major decline since the 1980s, whereas the northern-wintering group has not declined. If so, the health of the knot population passing through Delaware Bay may substantially depend on the continued well-being of the northern wintering group.

Although it is clear that some of this group winters in the s.e. United States (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 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/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 US-wintering knots and those that spend winter on the coast of N Brazil.

- **Why have there been declines in some wintering areas in southern South America and not others?** There is a need for a better understanding of Patagonian-wintering 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. There is also evidence that the northerly wintering populations (SE USA and N Brazil), of which some 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 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 knot numbers change during the season, monitoring body condition (e.g. plumage-oiling, ectoparasites and general heath, 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.

- **What is the extent of the *roselaari* and *rufa* wintering areas and do they both pass through Delaware Bay?** As discussed in the Taxonomy section of this review, there is a great deal of uncertainty about the subspecific status of knots wintering in southern South America, in comparison with those in Maranhão, in the south east of the USA, on the northern hemisphere Pacific coast (San Francisco Bay, USA; Baja California and Sonora/Sinaloa, Mexico), 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 knot populations should be expanded. This might be achieved as part of the annual January winter waterfowl surveys conducted jointly by the US and Mexico.

- **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 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 International Shorebird Surveys has been low, but appropriate training could change this and increase participation in age-monitoring.

Country-specific research needs

1. South America

a. Argentina

- Trophic ecology studies at San Antonio Oeste, the key site hosting highest numbers of Red Knots in Argentina.
- Monitor food supplies at Río Grande and movements between nearby Bahía Lomas.
- Continuation of individually marking birds with coded flags and resighting of individually-marked birds to allow analyses of site and population specific survival and recruitment rates.
- Collection of a sample of primary covert feathers each year to maintain a current isotopic signature for each major wintering site.

b. Chile

- Studies on geomorphology of the intertidal ecosystem, floristic analysis of the palustrine and steppe communities and ecosystem ecological risk are needed.
- Studies on 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.
- Continuation of individually marking birds with coded flags and resighting of individually-marked birds to allow analyses of site and population specific survival and recruitment rates.

- Collection of a sample of primary covert feathers each year to maintain a current isotopic signature for each major wintering site.

c. Brazil

- Develop studies on food availability in Maranhão and Lagoa do Peixe National Park.
- Studies on potential impact of disease (West Nile Virus, Avian Influenza, Newcastle Virus, etc.).
- Studies on ectoparasites infection during winter and also during different stages of migration, especially in Maranhão.

2. Mexico

- Clarification of the status and number of knots wintering in Baja California, and Sonora/Sinaloa.
- Collection of a sample of primary covert feathers to obtain a current isotopic signature for comparison with passage birds in Delaware and also other wintering sites.
- Initiate marking programs, in conjunction with other knot biologists.
- Collection of genetic material to determine affinity of these populations with others.

3. United States

a. New Jersey and Delaware

- How many crab eggs are enough? To provide a scientific basis for management there is a need for integration of Horseshoe Crab egg data and shorebird behavior 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. A number of approaches are feasible Much of the data required for the models exist, but they still need to be integrated.

- Modeling food availability to Red Knots in Delaware Bay will need baywide 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 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. Complete demographic modeling of the horseshoe crab population is essential to determine the level of harvest that will ensure enough eggs for migratory shorebirds, as well as the long-term viability of the crab population and the migration stopover. Horseshoe crabs do not breed until they are about eight years old and the demographic structure of the population, especially immature survival, is only partly understood.

b. Virginia

- Investigation of which prey knots are targeting on the Virginia barrier islands, with specific attention paid to identifying the availability of prey on peat banks vs. on high energy beaches and the relative importance of each to migrating knots.

c. North Carolina

- Research on impacts of beach stabilization and impacts of human disturbance.

d. South Carolina

- 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.

e. Massachusetts

- High priority needs for the state of Massachusetts include research and monitoring of human disturbance in shorebird habitats, particularly those disturbances associated with commercial and recreational fishing and public access to beaches.
- Monitoring of recruitment through observations of juveniles during fall migration.

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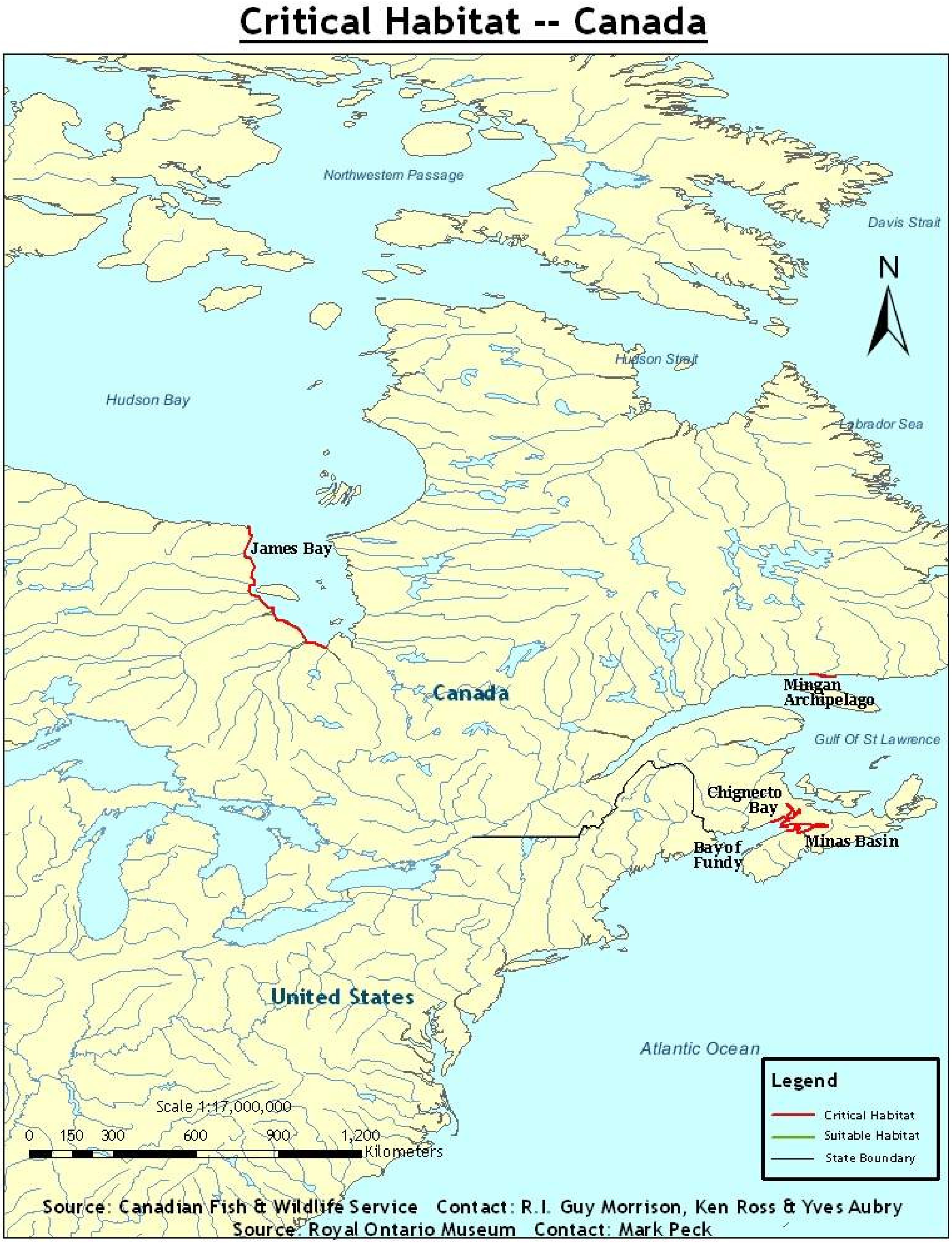
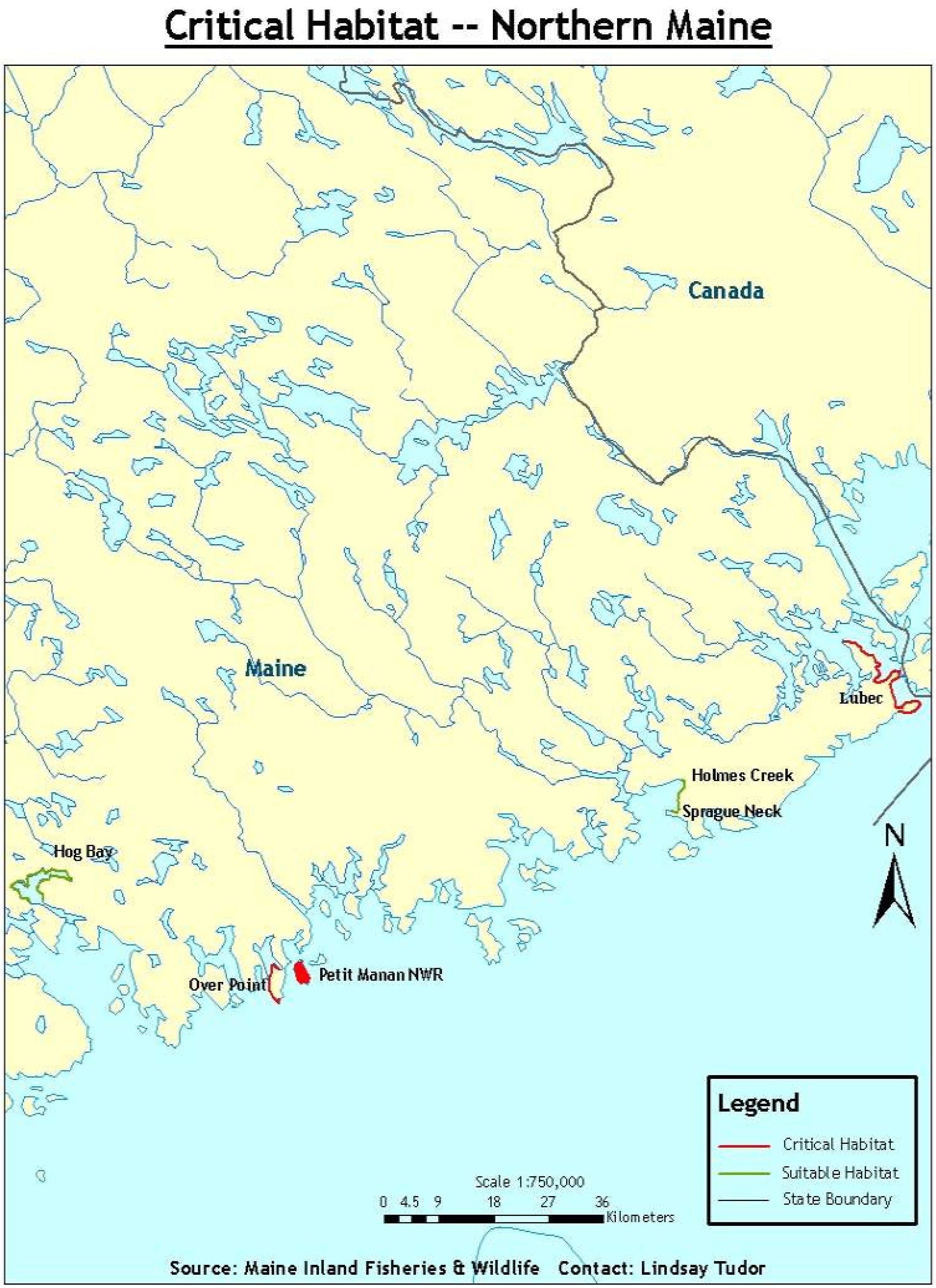
APPENDIX

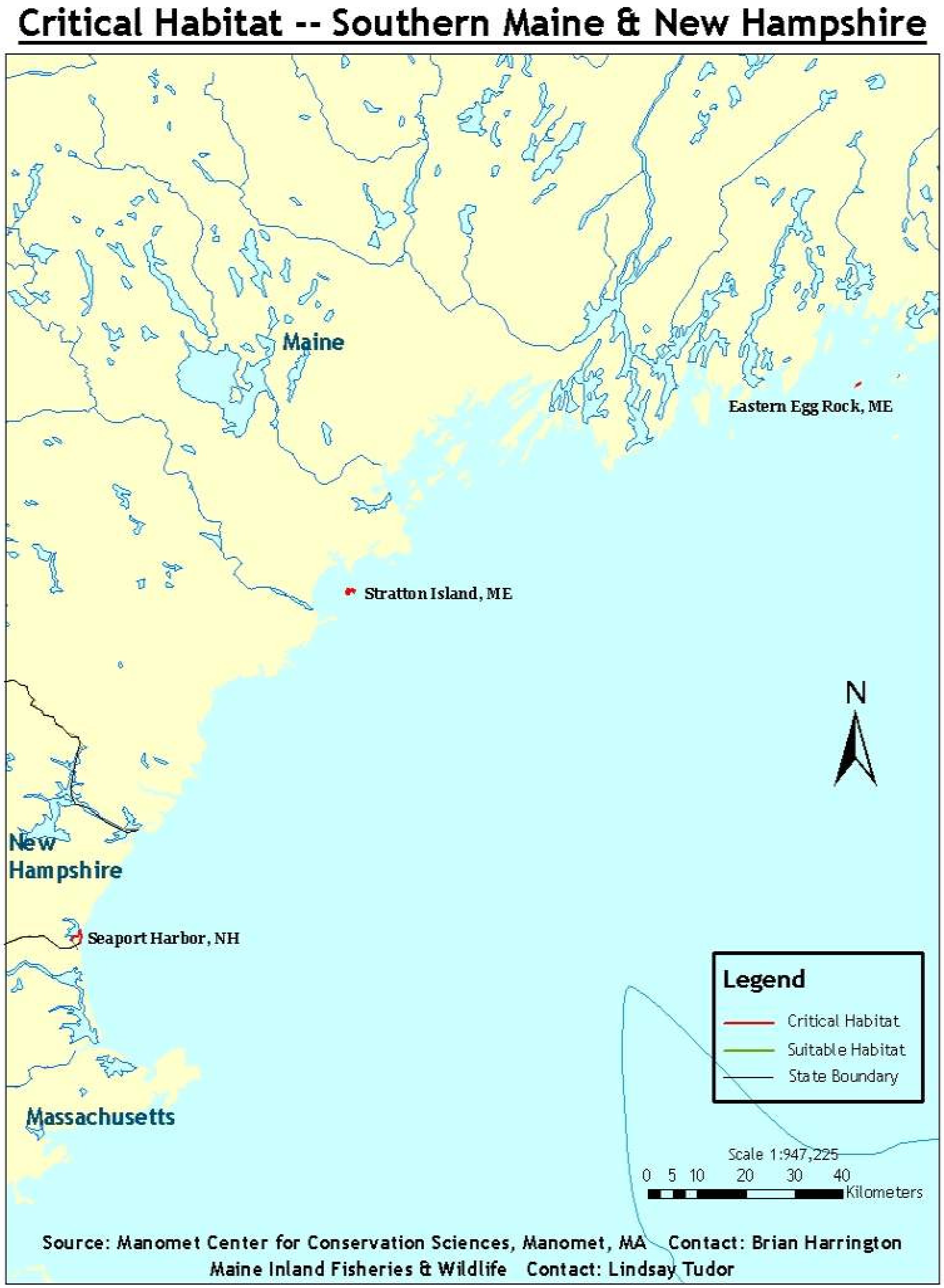
Geographic Region Maps – Red Knot critical habitat (migratory stopover and wintering/nonbreeding areas).


Critical Habitat -- Canada
Northwestern Passage
Davis Strait
N
Hudson Strait
Hudson Bay
Labrador Sea
James Bay
Canada
Mingan
Archipelago
Gulf Of St Lawrence
Chignecto
Bay
Minas Basin
Bay of
Fundy
United States
Atlantic Ocean
Legend
Critical Habitat
Suitable Habitat
State Boundary
Scale 1:17,000,000
0 150 300 600 900 1,200
Kilometers
Source: Canadian Fish & Wildlife Service Contact: R.I. Guy Morrison, Ken Ross & Yves Aubry
Source: Royal Ontario Museum Contact: Mark Peck

Map 1.


Critical Habitat -- Northern Maine
Canada
Maine
Lubec
Holmes Creek
Sprague Neck
Hog Bay
Over Point
Petit Manan NWR
N
Legend
Critical Habitat
Suitable Habitat
State Boundary
Scale 1:750,000
0 4.5 9 18 27 36
Kilometers
Source: Maine Inland Fisheries & Wildlife Contact: Lindsay Tudor

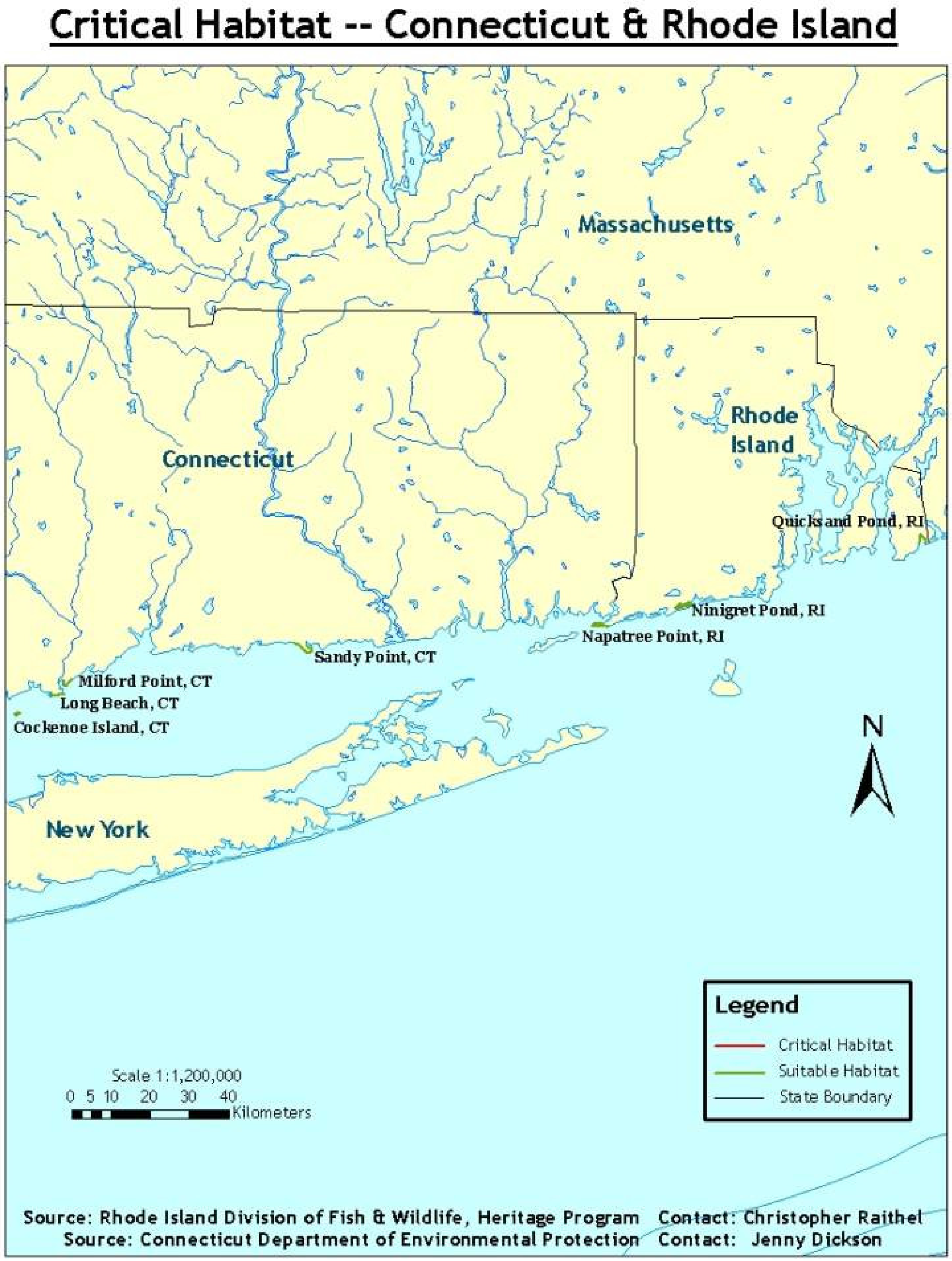
Map 2.


Critical Habitat -- Southern Maine & New Hampshire
Maine
Eastern Egg Rock, ME
Stratton Island, ME
N
New Hampshire
Seaport Harbor, NH
Legend
Critical Habitat
Suitable Habitat
State Boundary
Massachusetts
Scale 1:947,225
0 5 10 20 30 40
Kilometers
Source: Manomet Center for Conservation Sciences, Manomet, MA Contact: Brian Harrington
Maine Inland Fisheries & Wildlife Contact: Lindsay Tudor

Map 3.


Critical Habitat -- Massachusetts
New Hampshire
Newbury Port
Plum Island
Massachusetts
Scituate
Duxbury Beach
Plymouth Beach
Manomet Beach
Rhode Island
Eastham
Sandy Neck
South Beach Island
Monomoy NWR
N
Legend
Critical Habitat
Suitable Habitat
State Boundary
Scale 1:1,000,000
0 5 10 20 30 40
Kilometers
Source: Manomet Center for Conservation Sciences, Manomet, MA Contact: Brian Harrington

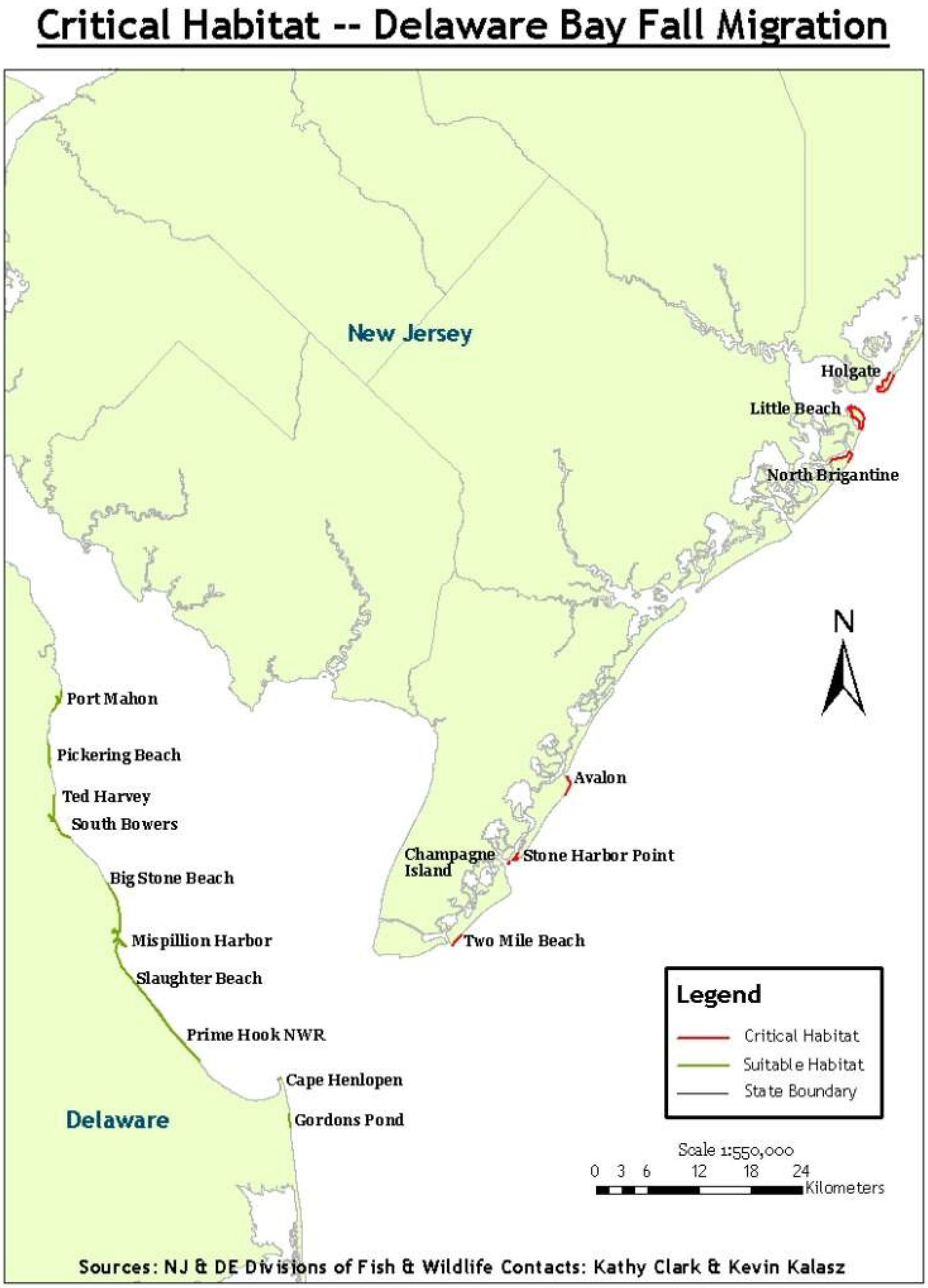
Map 4.


Critical Habitat -- Connecticut & Rhode Island
Massachusetts
Rhode Island
Connecticut
Quicksand Pond, RI
Ninigret Pond, RI
Napatree Point, RI
Sandy Point, CT
Milford Point, CT
Long Beach, CT
Cockenoe Island, CT
New York
N
Legend
Critical Habitat
Suitable Habitat
State Boundary
Scale 1:1,200,000
0 5 10 20 30 40
Kilometers
Source: Rhode Island Division of Fish & Wildlife, Heritage Program Contact: Christopher Raithel
Source: Connecticut Department of Environmental Protection Contact: Jenny Dickson

Map 5.

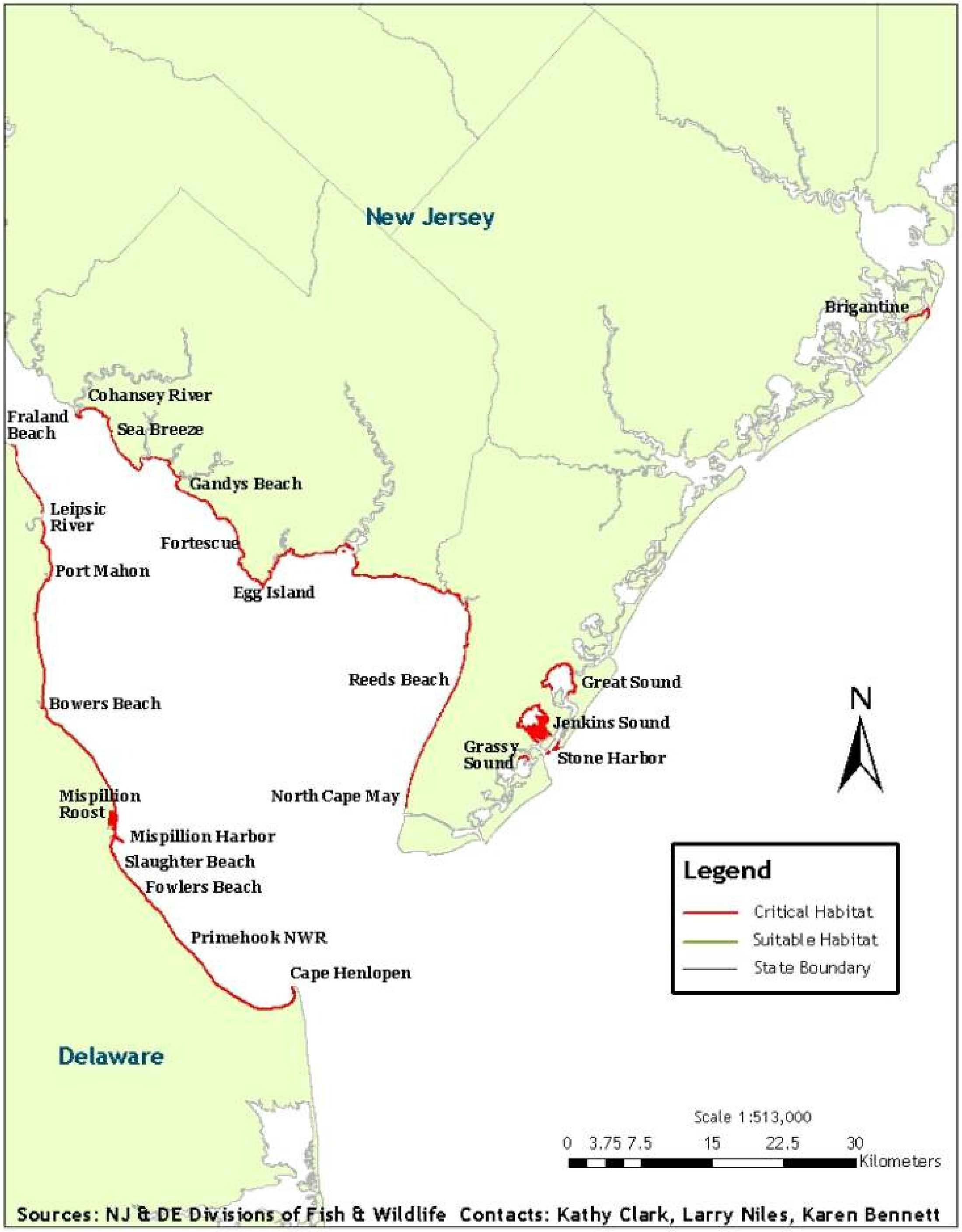
Critical Habitat -- New York

Map 6.

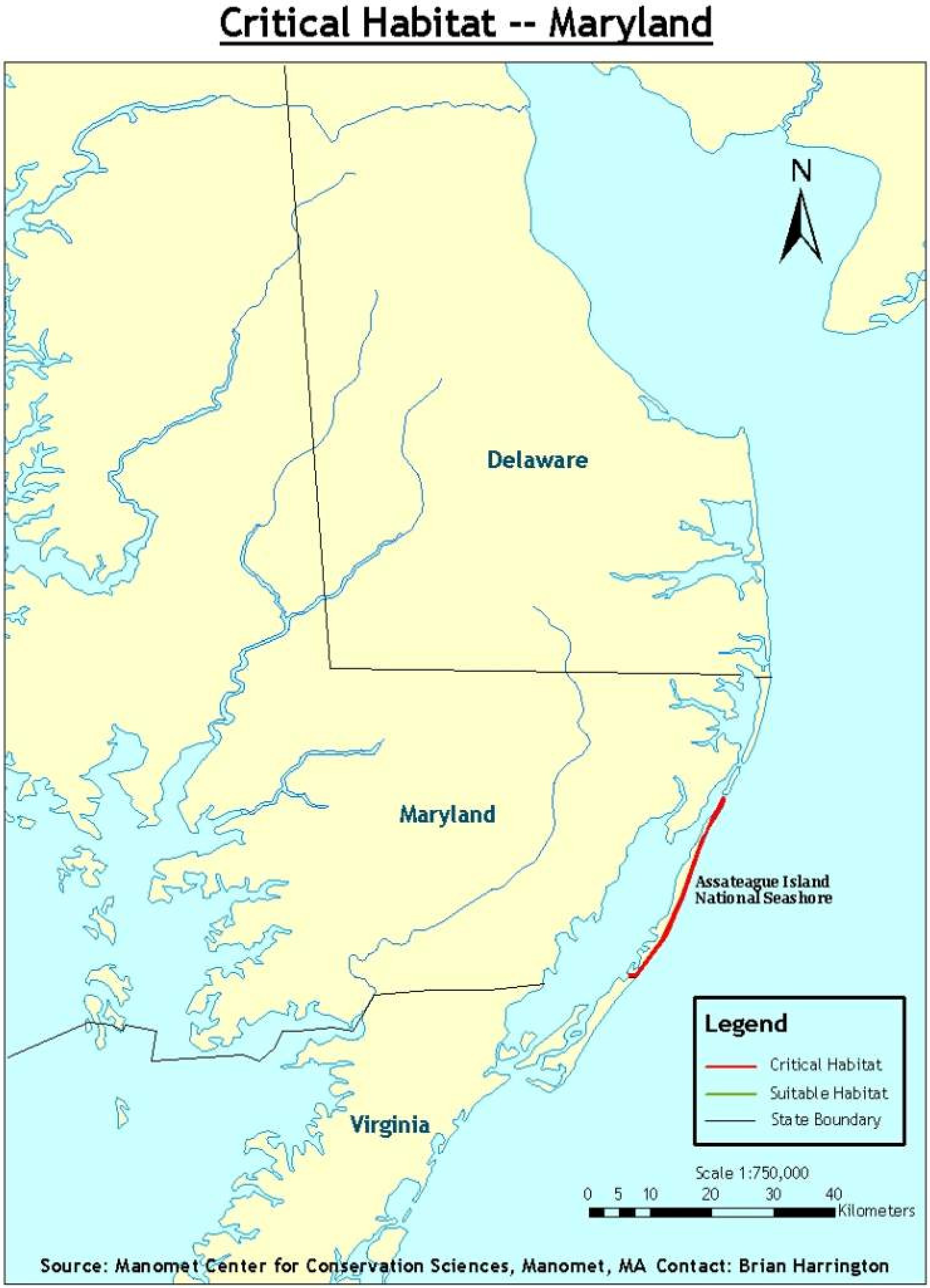

Critical Habitat -- Delaware Bay Fall Migration
New Jersey
Holgate
Little Beach
North Brigantine
N
Port Mahon
Pickering Beach
Ted Harvey
South Bowers
Avalon
Champagne Island
Stone Harbor Point
Big Stone Beach
Mispillion Harbor
Two Mile Beach
Slaughter Beach
Legend
Critical Habitat
Suitable Habitat
State Boundary
Prime Hook NWR
Cape Henlopen
Gordons Pond
Delaware
Scale 1:550,000
0 3 6 12 18 24
Kilometers
Sources: NJ & DE Divisions of Fish & Wildlife Contacts: Kathy Clark & Kevin Kalasz

Map 7.

Critical Habitat -- Delaware Bay Spring Migration

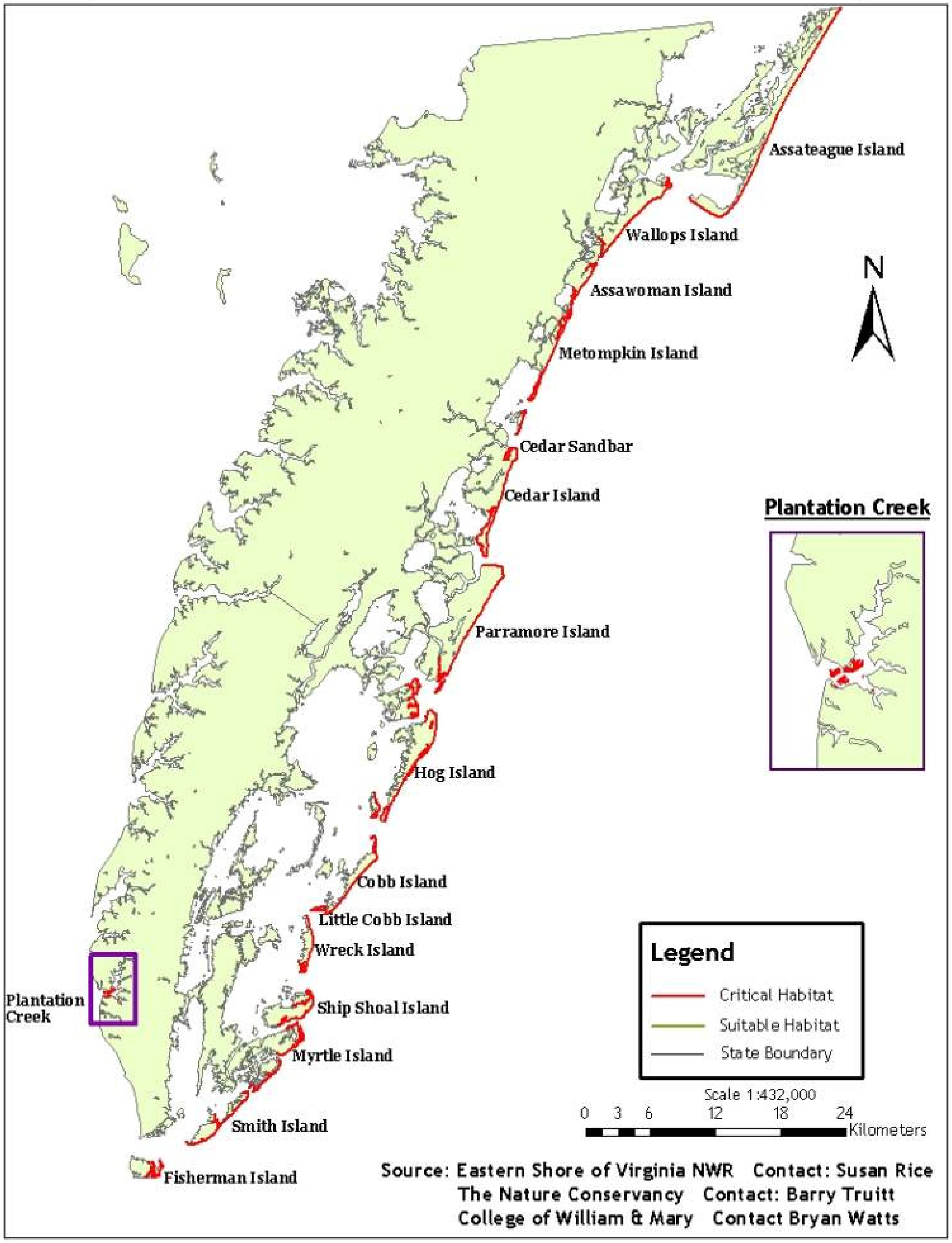


Map 8.


Critical Habitat -- Maryland
N
Delaware
Maryland
Virginia
Assateague Island
National Seashore
Legend
Critical Habitat
Suitable Habitat
State Boundary
Scale 1:750,000
0 5 10 20 30 40
Kilometers
Source: Manomet Center for Conservation Sciences, Manomet, MA Contact: Brian Harrington

Map 9.

Critical Habitat -- Virginia's Eastern Shore



Map 10.

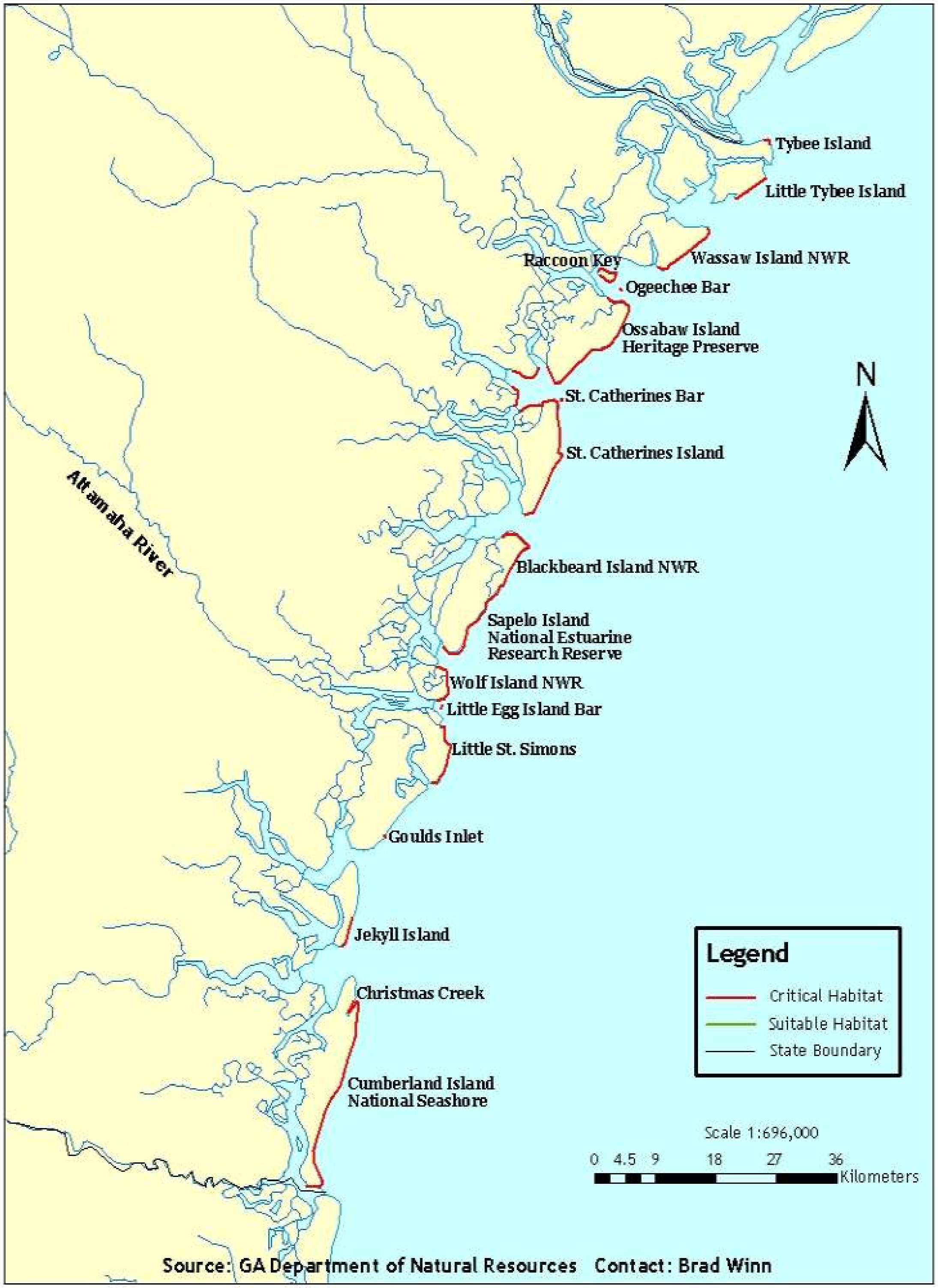

Critical Habitats -- North Carolina
Virginia
North Carolina
Pea Island
Clam Shoals
Ocracoke Island
Cedar Island
North Core Banks
Bird Shoals
South Core Banks
Bear Island
Cape Lookout
Lea/Hutaff Shoals
Fort Fisher
Ocean Isle Beach
Tubbs Inlet
N
Legend
Critical Habitat
Suitable Habitat
State Boundary
Scale 1:1,904,500
0 15 30 60 90 120
Kilometers
Source: North Carolina Wildlife Resources Commission
Contact: Susan Cameron

Map 11.

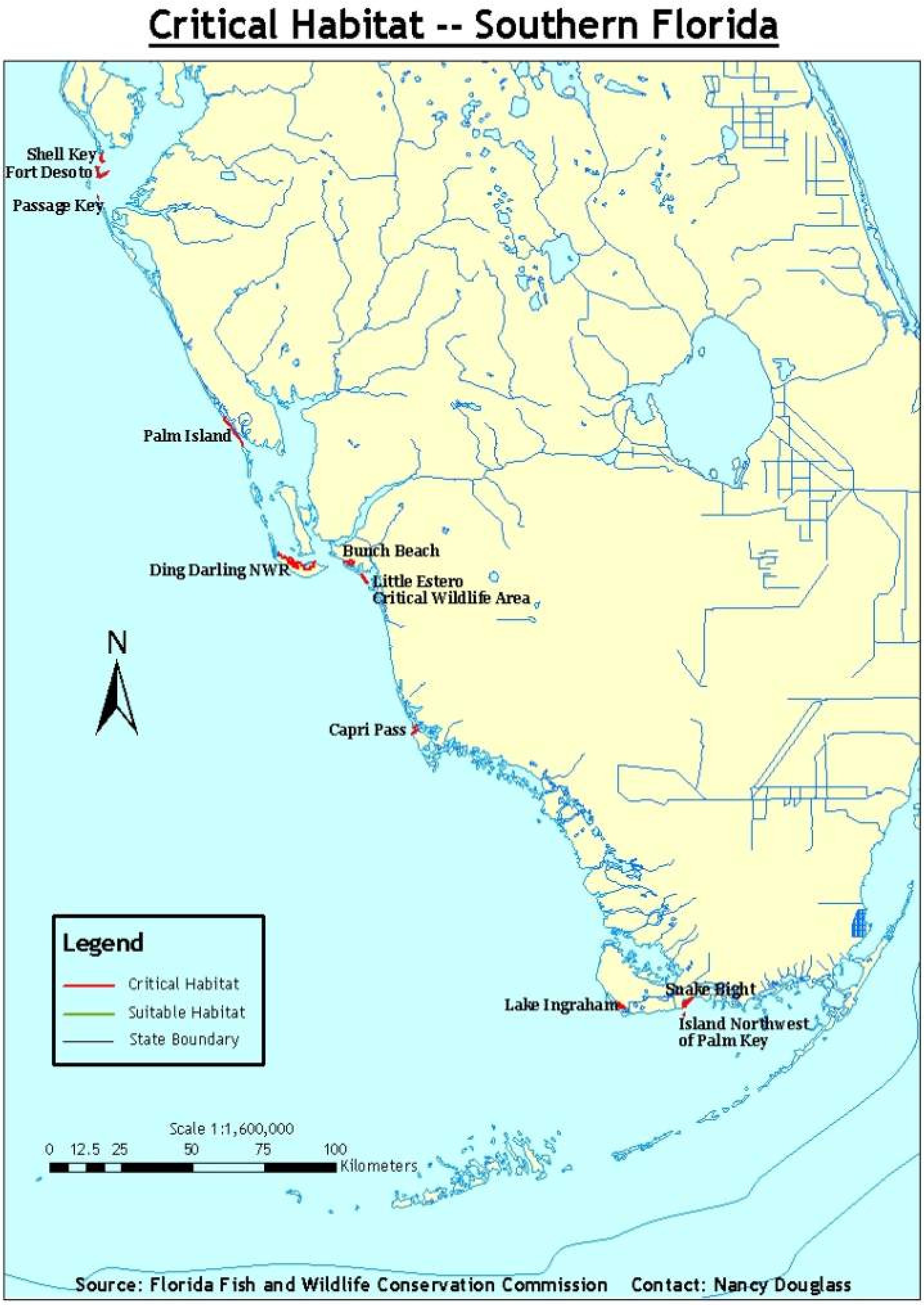

Critical Habitat -- South Carolina
North Carolina
South Carolina
Waites Island
Huntington Beach State Park
North Island
South Island
Murphy Island
Cedar Island
Sandy Point
Cape Island
Marsh Island
Raccoon Key
Bulls Island
Dewees Island
Capers Island
Crab Bank
Folly Beach
Beachwalker County Park
Bird Key Stono
Pine Island
Otter Island
Deveaux Bank
Edisto Beach
St. Helena Sound
Bay Point Island
Hilton Head
Turtle Island
Thompkins Island
N
Legend
Critical Habitat
Suitable Habitat
State Boundary
Scale 1:1,260,00
0 5 10 20 30 40
Kilometers
Source: SC Department of Natural Resources Contact: Felicia Sanders

Map 12.

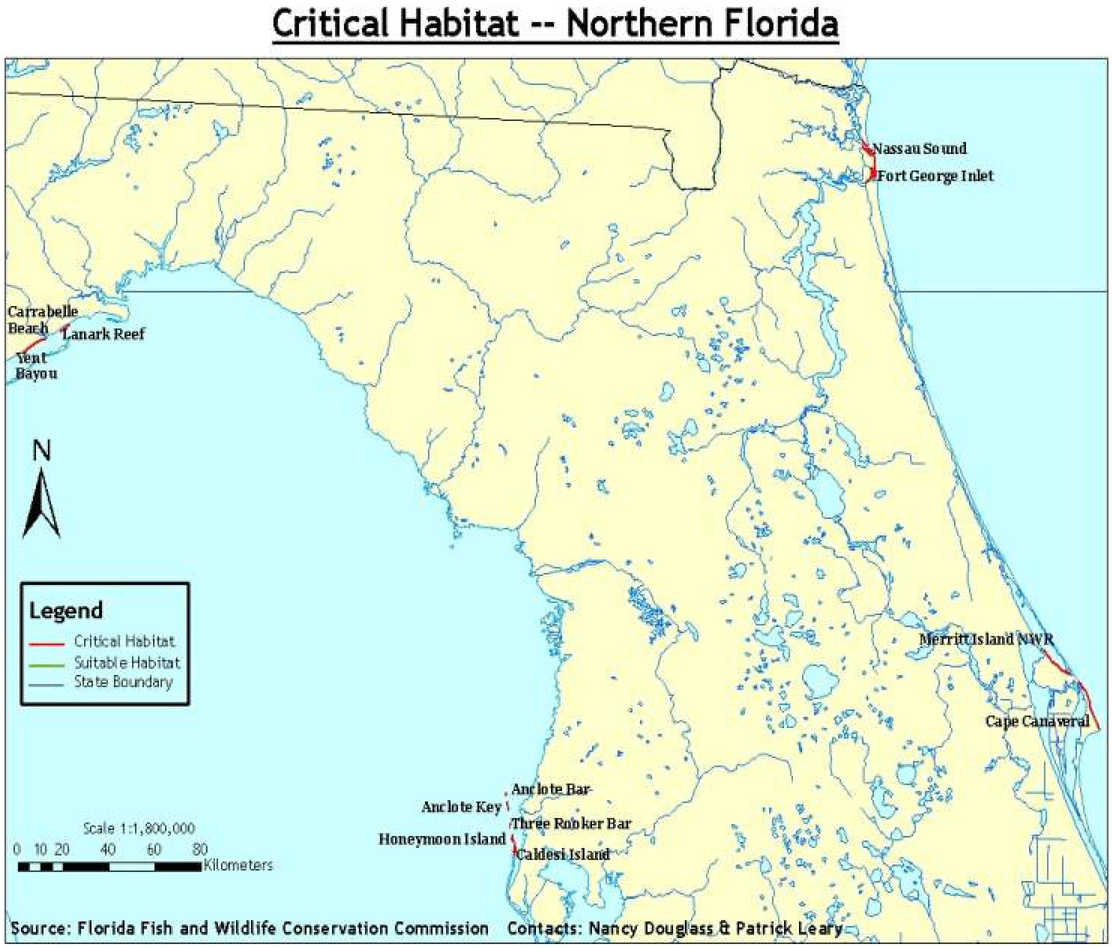
Critical Habitat -- Georgia



Map 13.


Critical Habitat -- Southern Florida
Shell Key
Fort Desoto
Passage Key
Palm Island
Ding Darling NWR
Bunch Beach
Little Estero
Critical Wildlife Area
N
Capri Pass
Legend
Critical Habitat
Suitable Habitat
State Boundary
Lake Ingraham
Snake Bight
Island Northwest
of Palm Key
Scale 1:1,600,000
0 12.5 25 50 75 100
Kilometers
Source: Florida Fish and Wildlife Conservation Commission Contact: Nancy Douglass

Map 14.

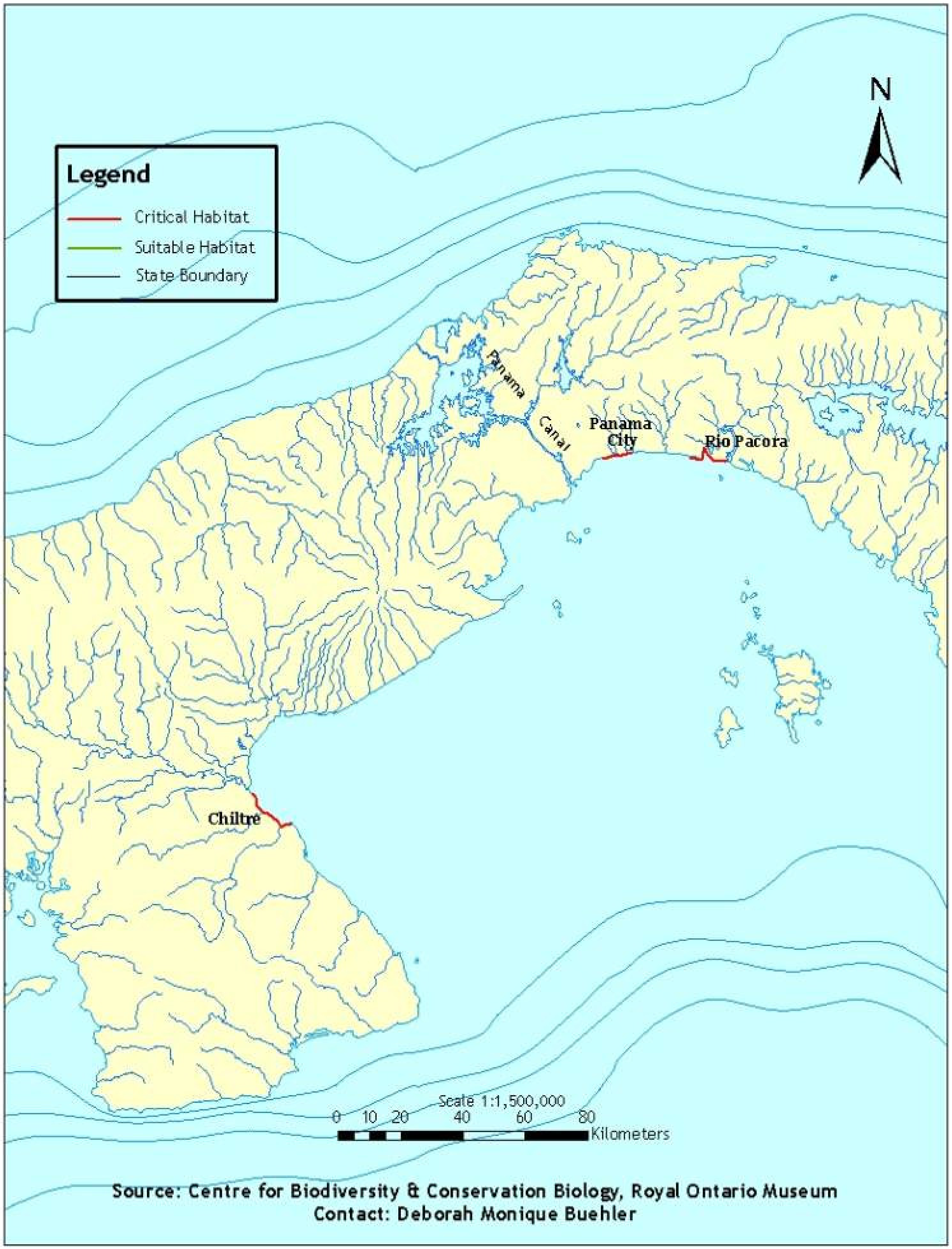

Critical Habitat -- Northern Florida
Nassau Sound
Fort George Inlet
Carrabelle Beach
Lanark Reef
Yent Bayou
N
Legend
Critical Habitat
Suitable Habitat
State Boundary
Merritt Island NWR
Cape Canaveral
Anclote Bar
Anclote Key
Three Rooker Bar
Honeymoon Island
Caldesi Island
Scale 1:1,800,000
0 10 20 40 60 80
Kilometers
Source: Florida Fish and Wildlife Conservation Commission Contacts: Nancy Douglass & Patrick Leary

Map 15.


Critical Habitat -- Florida
Alabama
Georgia
Florida
Nassau Sound
Fort George Inlet
Yent Bayou
Lanark Reef
N
Merritt Island NWR
Cape Canaveral
Anclote Key
Honeymoon Island
Caldesi Island
Fort Desoto
Shell Key
Passage Key
Palm Island
Bunch Beach
Ding Darling NWR
Little Estero
Critical Wildlife Area
Capri Pass
Lake Ingraham
Snake Bight
Legend
Critical Habitat
Suitable Habitat
State Boundary
Scale 1:4,097,600
0 30 60 120 180 240
Kilometers
Source: Florida Fish and Wildlife Conservation Commission
Contacts: Nancy Douglass & Patrick Leary

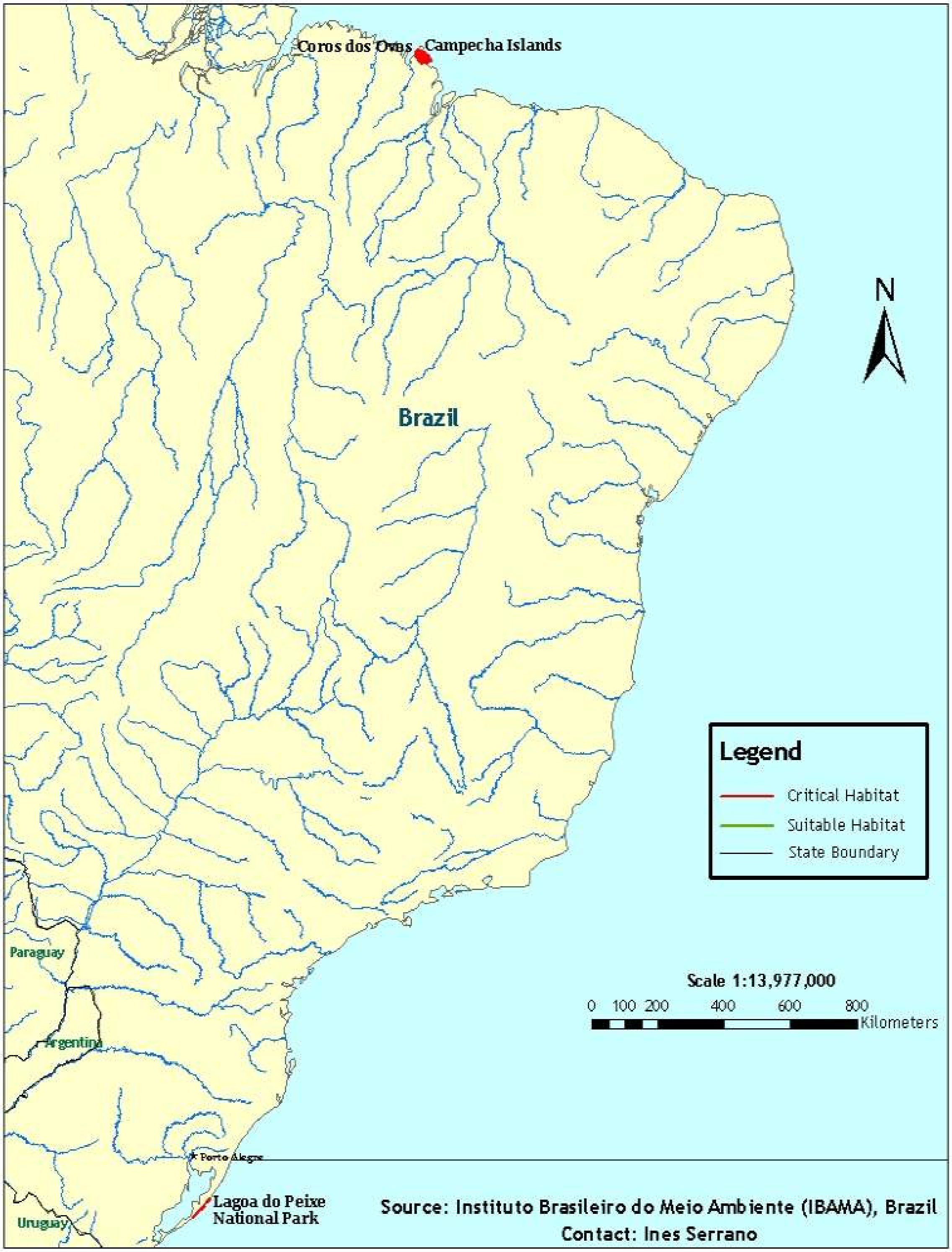
Map 16.

Critical Habitat -- Panama



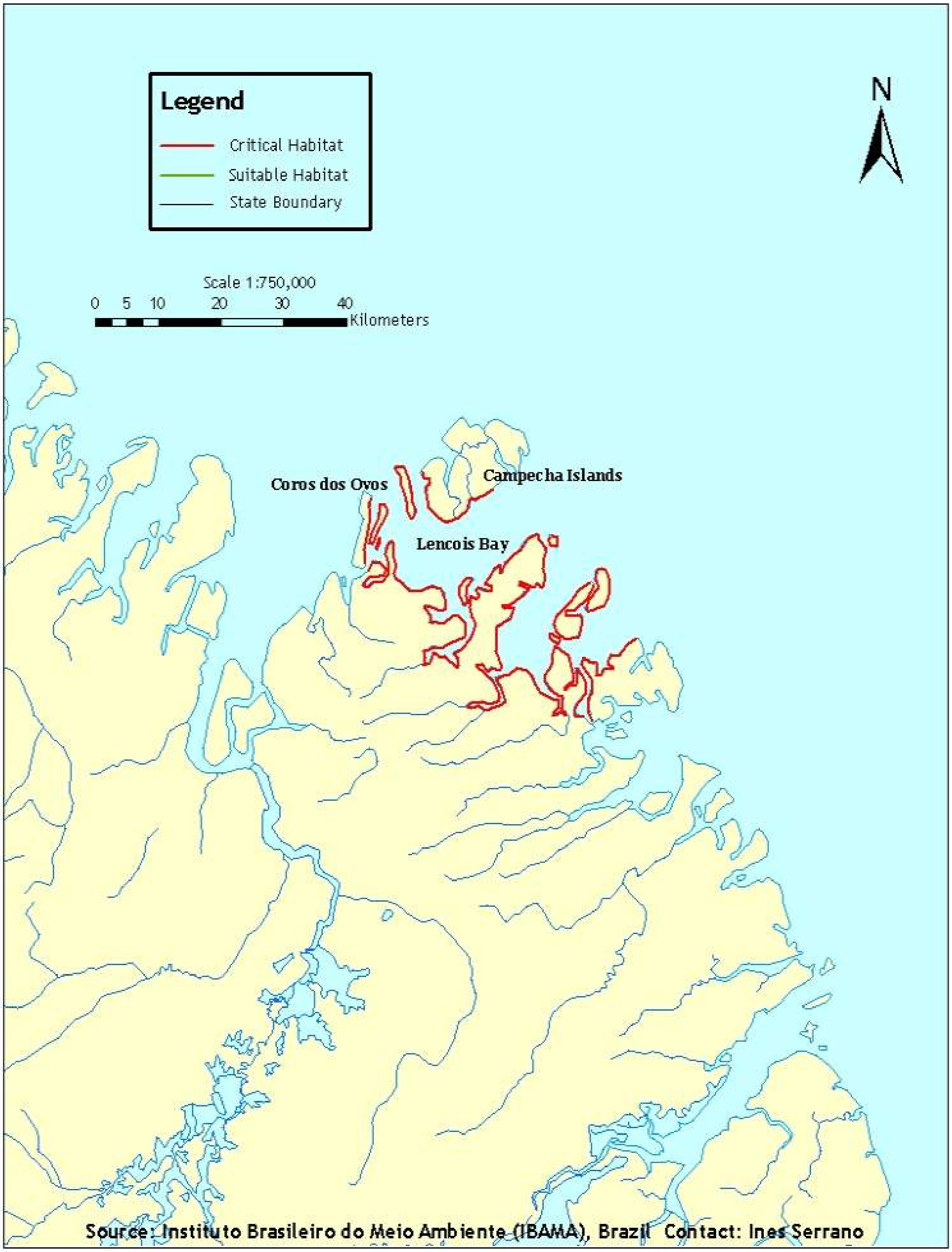
Map 17.

Critical Habitat -- Brazil



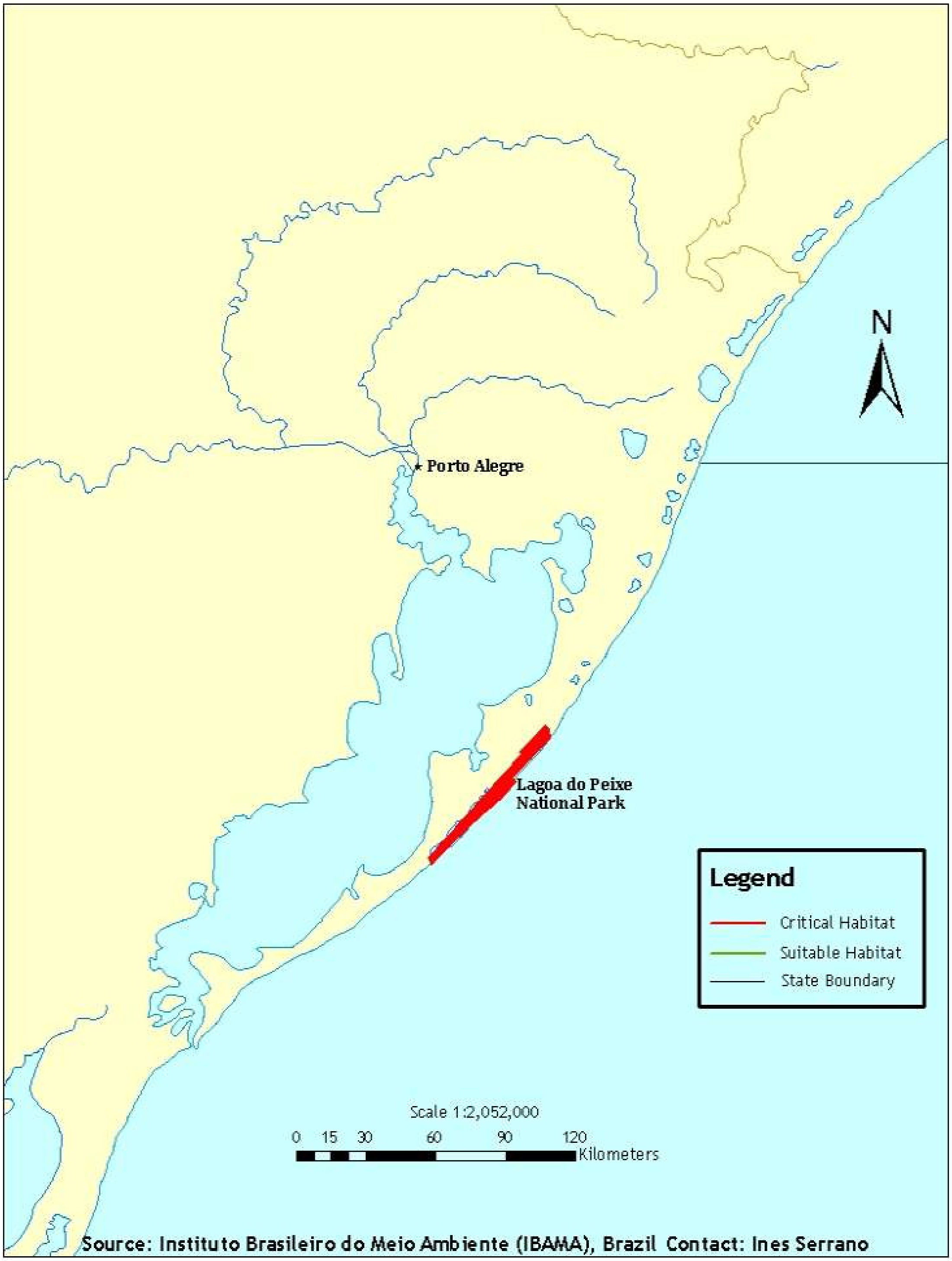
Map 18.

Critical Habitat -- Northern Brazil



Map 19.

Critical Habitat -- Southern Brazil



Map 20.

Critical Habitat -- Argentinian Coastline

Map 21.

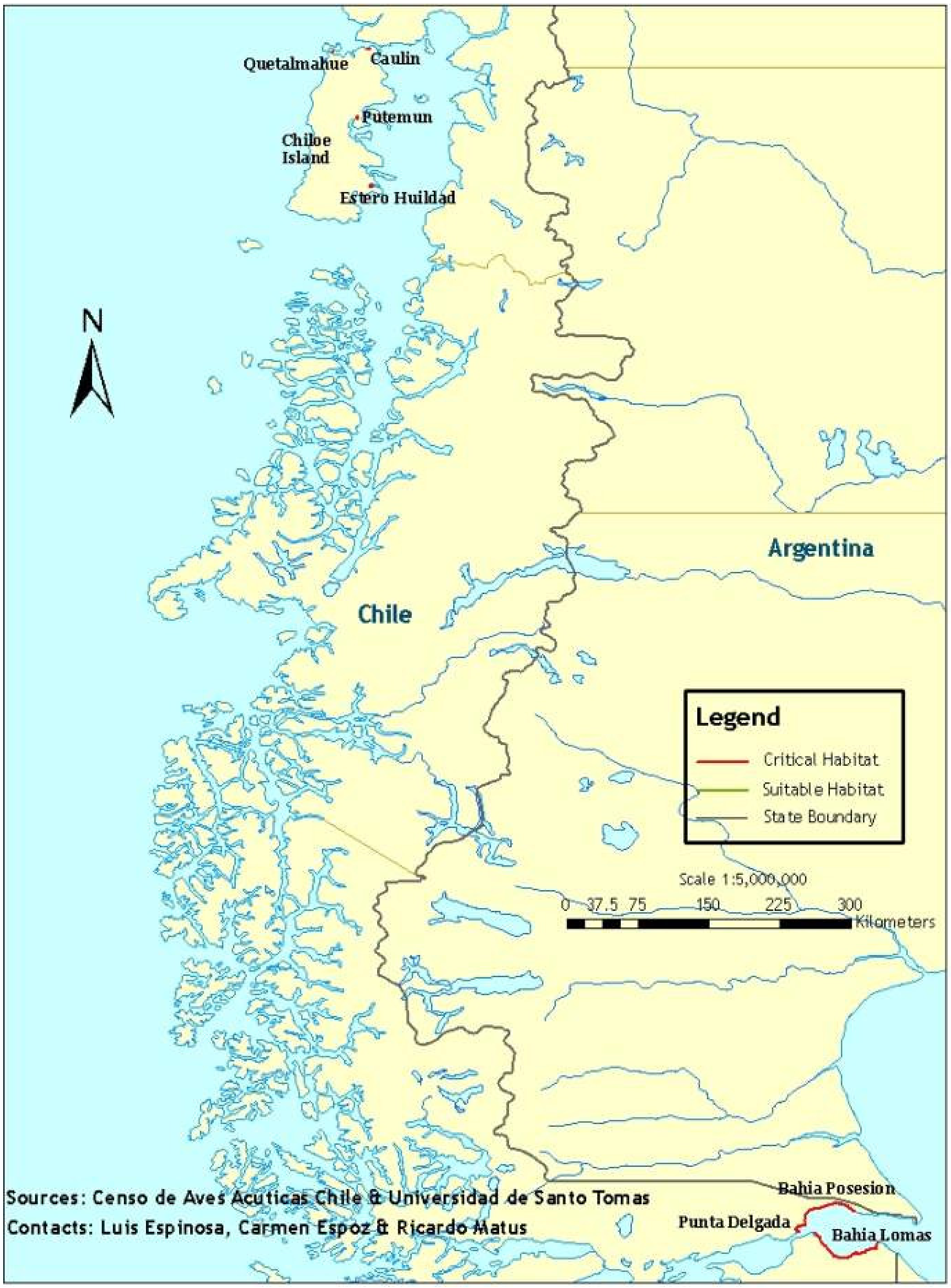
Critical Habitat -- Argentinia North Atlantic

Map 22.

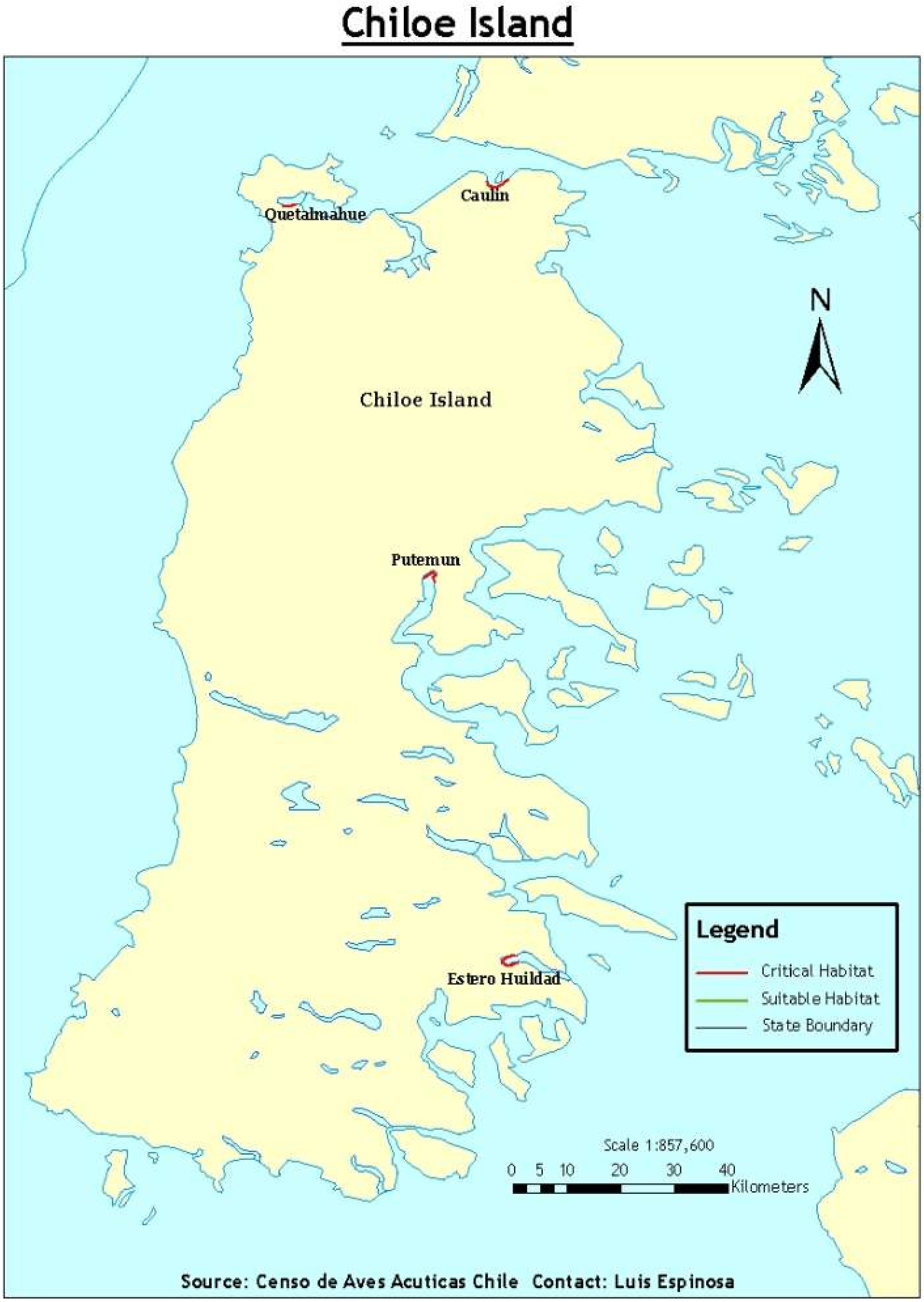

Critical Habitat -- Argentinia South Atlantic
Bahia Bustamente
N
Golfo San Jorge
Cabo Blanco
Puerto Deseado
Argentina
Punta Medanosa
Cabo Danaso
Bahia San Julian
Puerto Santa Cruz
Rio Gallegos
Legend
Critical Habitat
Suitable Habitat
State Boundary
Chile
Bahia San Sebastian
Scale 1:4,660,750
0 35 70 140 210 280
Kilometers
Rio Grande
Source: Fundacion Inalafquen, Argentina Contact: Patricia Gonzalez

Map 23.

Critical Habitats -- Chile

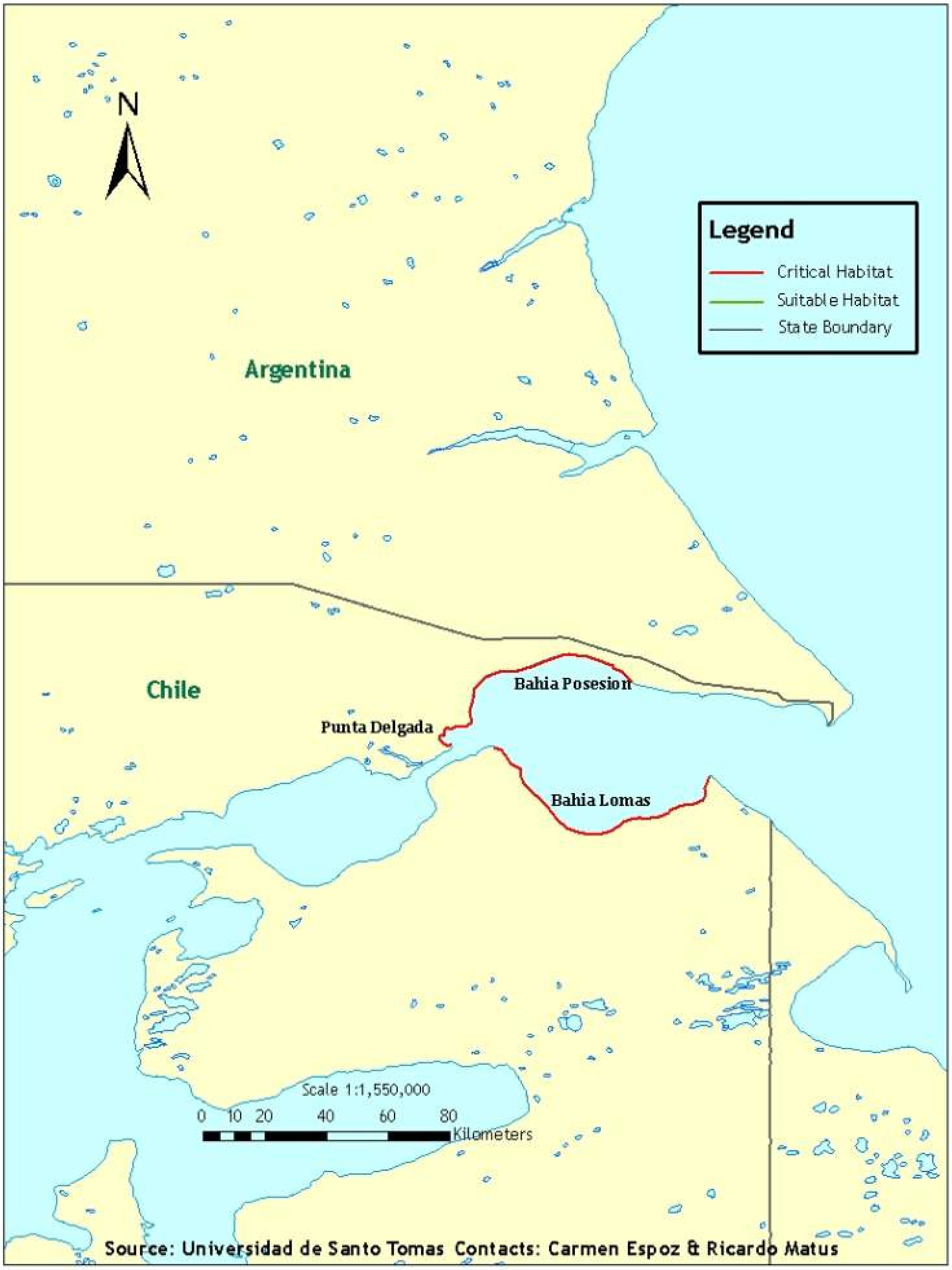


Map 24.

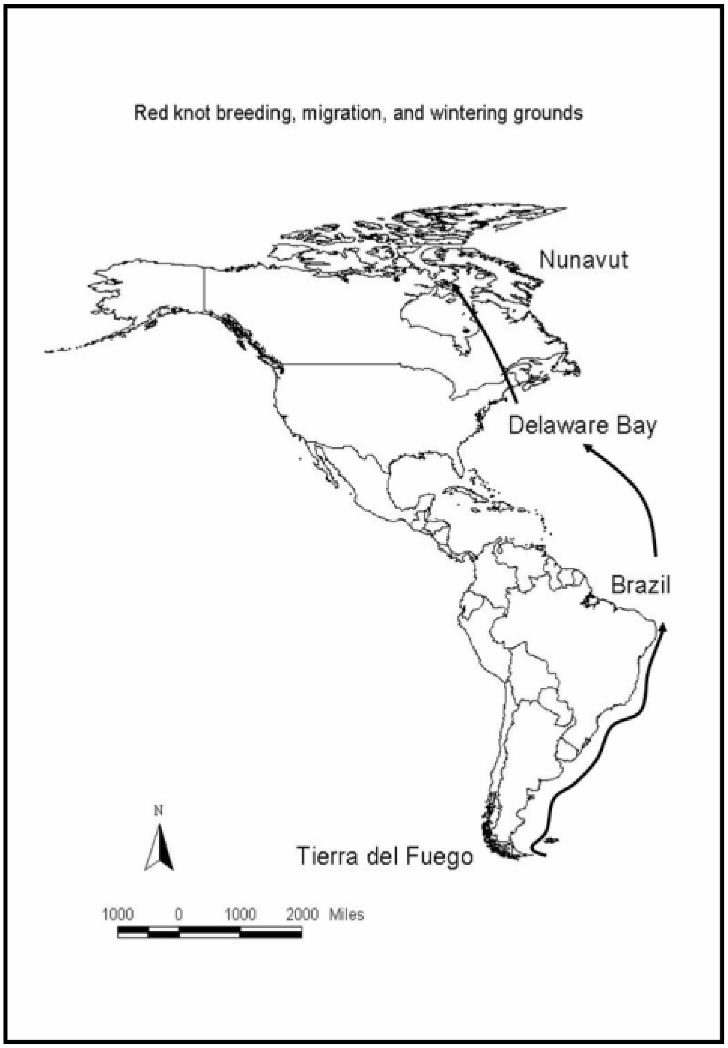

Chiloe Island
Quetalmahue
Caulin
Chiloe Island
Putemun
Estero Huildad
N
Legend
Critical Habitat
Suitable Habitat
State Boundary
Scale 1:857,600
0 5 10 20 30 40
Kilometers
Source: Censo de Aves Acuticas Chile Contact: Luis Espinosa

Map 25.

Critical Habitat -- Bahia Lomas



Map 26.



Map 27. Migration route of *C. c. rufa* between its wintering grounds on Tierra del Fuego, South America, stopover areas along the Patagonian Coast of Argentina, and in the northeastern United States, and breeding grounds in the Canadian Arctic.