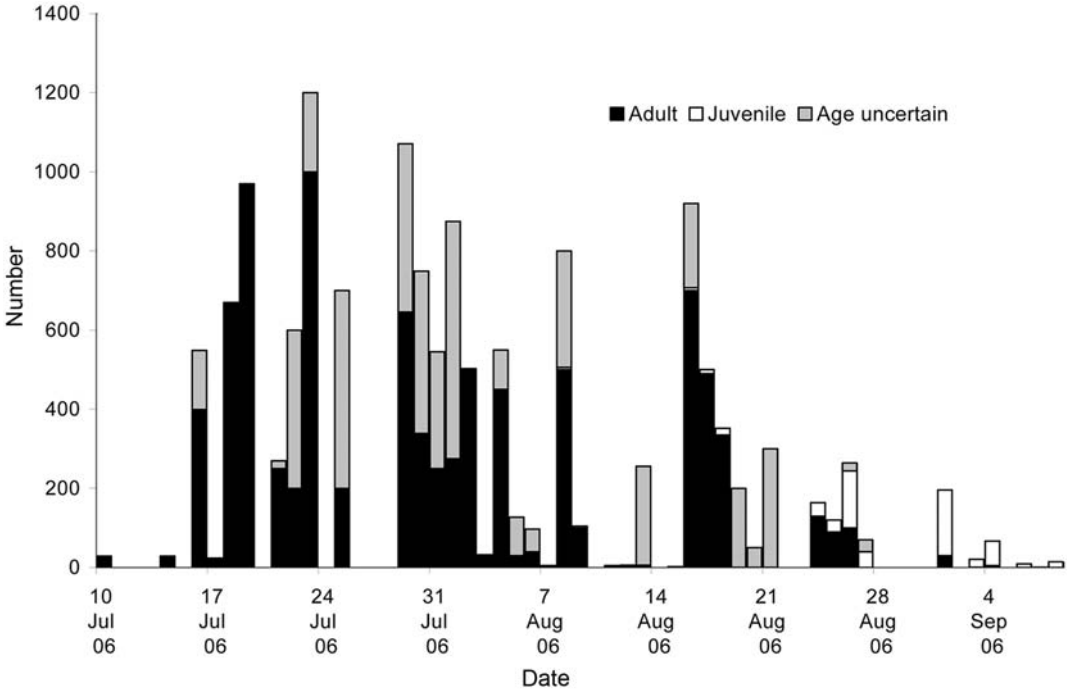

FIGURE 49. Counts of Red Knots on four islands (Nue, Grande, Quarry, and Niapiskau) of the Mingan archipelago in the Gulf of St Lawrence, Quebec, Canada, during July–September 2006 (Y. Aubry, pers. comm.).

2006. The islands are granitic and their shores are mostly rocky. However, on their southern sides there are small intertidal flats of gravel or sand that support an abundance of invertebrates (*Mytilus*, *Littorina*, and *Gamarus* spp.) suitable for foraging Red Knots. These invertebrates are mostly attached to the *Fucus* spp.and the other algae that cover the flats.

Up to the early 1980s, Red Knots were moderately numerous during southward migration in the upper Bay of Fundy, but fell rapidly to low levels in the mid 1980s and have remained at low levels since then. This may represent a withdrawal from relatively peripheral areas as the population started decreasing. Trend analyses of data from both Quebec and the Atlantic provinces of Canada have indicated significant declines (Morrison et al. 2006).

THREATS

Under section 4 of the Endangered Species Act 1973 (ESA), a species that is endangered or threatened may be listed as such if it is endangered or threatened because of: (1) the present or threatened destruction, modification, or curtailment of its habitat or range, and/or (2) overutilization for commercial, recreational, scientific, or educational purposes, and/or (3) disease or predation, and/or (4) the inadequacy of existing regulatory mechanisms or other natural or man-made factors affecting its continued existence.

Threats are therefore listed under these headings. In principle, a threat is only important if it has or may have an adverse impact on an animal's evolutionary fitness—its ability to survive and reproduce. In conservation science, perceived threats are often assumed to have fitness implications, but except where actual mortality occurs this is seldom proved. Therefore, a major focus of *C. c. rufa* studies has been to measure adult survival and attempt to identify those factors that lead to its reduction. This has met with some success, as described below. Nevertheless several threats are identified which in our opinion are likely to have fitness consequences, but we are unable to prove that this is the case.

Threats to Habitats in Delaware Bay During Spring Migration

The principal known threat to a substantial proportion of Red Knots in the Americas is the dwindling supply of their main food resource at their final spring stopover in Delaware Bay, the eggs of the horseshoe crab. As described in the habitats section, this once abundant resource

has declined through the exploitation of the adult crabs.

As discussed in the population size 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 farther north, in the southeastern 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, whereas 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 horseshoe crab 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 farther 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, in some years 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 Red Knot stopover was also later than usual, the birds failed to achieve their normal rate of mass gain (Atkinson et al. 2007, L. J. Niles et al., unpubl. data). 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 (Atkinson et al. 2007; L. J. Niles et al., unpubl. data).

When the Red Knots leave for the Arctic, they not only need resources for the 3,000-km nonstop 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) were less likely to be observed in future years than heavier birds and were therefore assumed to have lower survival (Baker et al. 2004).

Without doubt, the main reason for the reduced availability of horseshoe crab eggs (Fig. 22) to shorebirds on the Delaware Bay beaches is the over-exploitation of the adult crabs (Figs. 13 and 21). However, three factors exacerbate the situation and have the effect of reducing the availability of eggs further: (1) beach erosion reducing the amount of optimal crab spawning habitat, (2) disturbance by people, dogs, and potential predators, and (3) competition from gulls, especially Laughing Gulls (*Larus atricilla*). These are considered below.

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 in the face of continued sea-level rise (Phillips 1986a). While future rates are difficult to predict, the current level of sea-level rise in Delaware Bay is generally thought to be 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' (1986a, 1986b) shoreline erosion studies 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 project major losses of intertidal habitat in Delaware Bay due to continued sea-level rise. Under the 50% probability 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 moves further inland converting dry land to intertidal habitat. However, this prediction assumes that the coastal protection structure do not constrain the ability of shorelines to move 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 impacted 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 either completely eliminate intertidal sand beach habitat or sufficiently alter sediment quality and beach morphology to negatively affect the suitability of the remaining habitat for horseshoe crab spawning (Botton et al. 1988, Myers 1996). 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. Smith et al. (2002c) evaluated the effects of beach nourishment on spawning activity, egg density, egg viability and sediment-beach characteristics on Delaware Bay beaches; however, all factors that affect the function of beach replenishment for crab-spawning and shorebird foraging habitat have not yet been fully evaluated. The fact that during 2002–2005 more Red Knots on average fed on the New Jersey side of the bay (where no replenishment has taken place) than on the Delaware side (Fig. 23) suggests that beach replenishment may not have a major impact on the value of beaches as crab-spawning habitat. Besides affecting crab-spawning-Red Knot-feeding habitat, erosion has also led to loss of sites used by Red Knots for roosting, especially around Mispillion Harbor.

Threats to Habitat in Massachusetts

Potential threats to Red Knot habitats in Massachusetts include human development and beach replenishment.

Threats to Habitat in North Carolina

Along the coast, threats to migrant and wintering Red Knot habitat include beach stabilization works (nourishment, channel relocation, and bulkhead construction), and housing development. This particularly applies at Tubbs Inlet.

Threats to Habitat in South Carolina

A large area of the South Carolina coast is protected due to public ownership and conservation easements. Few opportunities exist to increase the amount of protected coastal land. Coastal counties are experiencing annual human population growth rates of 2–3%. Wetlands are being degraded by pollution, development, and oil spills; invertebrates are declining due to pollution; and horseshoe crabs are over-harvested.

Threats to Habitat in Florida

Shoreline hardening, dredging, and deposition, including beach-nourishment activities, are significantly altering much of Florida's coastline. Similarly, beach-raking activities alter the natural characteristics of the beach zone. Despite the fact that all of these activities require permits, there is no centralized documentation of their location or extent. Furthermore, the impacts on Red Knots and other shorebirds is not well known but is thought to be significant.

Threats to Habitat in Brazil

Very little is known about the Red Knots that winter on the coast of Maranhão. They occur along 150 km of highly fragmented shore which is difficult to survey, even from the air, and difficult to access (Baker et al. 2005a). Among the most important threats that can be identified is petroleum exploration in the sea on the continental shelf, as well as iron ore and gold mining, which leads to loss of coastal habitat through the dumping of soil, oil pollution, mercury contamination, and uncontrolled urban spread along the coast. Mangrove clearance has also had a negative impact on Red Knot habitat by altering the deposition of sediments which leads to a reduction in benthic prey.

At the Lagoa do Peixe National Park, the main management activities relate to the controlling of water levels in the lagoon and ameliorating the effects of *Pinus* afforestation. Red Knots feed on snails and other invertebrates around the edges of the lagoon and the abundance and availability of this food supply depends on water levels. Connection between the lagoon and sea occurs naturally mainly during winter and spring when a combination of southerly winds and rainfall opens the sandbar through water pressure. Closure occurs as a result of the deposition of sand in the lagoon mouth during northerly and northeasterly winds. Farmers use pumps to drain water from their lands and this can have a major effect on the level of the lagoon. 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 the periodic exchange of water with the sea that allows

invertebrates to colonize the lagoon and provide a food resource for migratory shorebirds. Although water levels are controlled to some extent by pumping, any factor that interferes with this, such as nearby farmers draining their land, is a threat to the value of this important site for Red Knots.

Another threat to Lagoa do Peixe is the uncontrolled *Pinus* afforestation of land in the vicinity, which probably has the effect of lowering the water table (IBAMA, unpubl. data). In some areas, the plantations appear to help siltation of the lagoon by altering the movement of sand dunes. *Pinus* harvesting leads to the appearance of gullies, which contribute to higher erosion. According to the management plan (IBAMA 1999), studies were to be conducted on the impact of *Pinus* forests, but no results have been published to date.

Threats to Habitat at Migration Stopover Sites Along the Atlantic Coast of Patagonia, Argentina

Oil pollution is a threat in Reserva Provincial de Río Chico para Aves Playeras Migratorias (RPRCAPM) and Reserva Urbana Costera del Río Chico, at Bahía Bustamante (where 15% of Red Knots were polluted with oil in a study in 1979 [Harrington and Morrison 1980]), and at Península Valdés. However, oil pollution has recently decreased significantly along the Patagonian coast (J. L. Estévez, pers. comm.). Development and associated pollution are threatening the RPRCAPM (created in 2001) and Reserva Urbana Costera del Río Chico (created in 2004). This comprises filling in of the tidal flat and marshes for urban use, location of a rubbish dump near shorebird feeding, and roosting sites as well as pollution from urban waste. At the Bahía San Antonio Natural Protected Area (created in 1993) major potential exists for pollution from a soda ash factory which began to operate in 2005 and from port activities which are likely to expand as the factory increases production. In the Bahía Samborombón reserve (created in 1979) threats come from urban and agrosystem expansion and development.

Threat of Oil Pollution and Possibility of Other Unidentified Factors Affecting the Principal *Calidris canutus rufa* Non-breeding Site at Bahía Lomas, Chile

The region of Magellan, Chile, has traditionally been an important producer of oil and natural gas since the first oil discovery was made in 1945 within 10 km from the bayshore in Manantiales. Even though local oil activity has diminished over the last 20 yr and only covers a small percentage of national demand, it is a resource that is still exploited. Oil is extracted by drilling on land and offshore, the latter with no new drillings in the last 8 yr. 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, no incentive exists to continue drilling in the Straits of Magellan. However, on the nearby Atlantic Ocean coast of Argentina, oil drilling has been increasing in the last 10 yr. 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 (48,500 metric tons from the Metula in 1974 and 90 metric tons from the Berge Nice in 2004).

Although the potential threat to the Red Knot population would appear to be significant, no incidents have been reported of Red 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 (A. D. Dey, unpubl. data; L. J. Niles, unpubl. data). However, major declines at Bahía Lomas have not been mirrored at nearby Río Grande (Fig. 50), suggesting a possible problem at Bahía Lomas. If so, 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 *C. c. 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 Red 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 are matters that deserve further investigation.

Oil Pollution Threat and Human Disturbance at the Only Other Major Non-breeding Site at Río Grande, Argentina

Most of the sites used by Red Knots at Río Grande on the Atlantic coast of the Argentinian

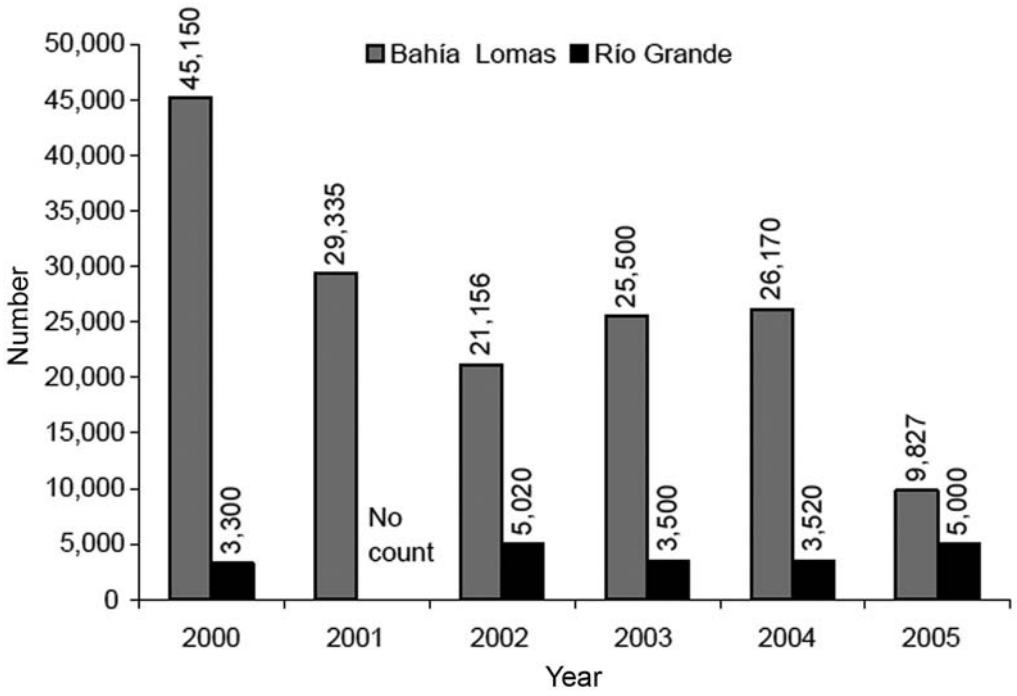

FIGURE 50. Aerial counts of Red Knots (*Calidris canutus rufa*) on major wintering areas in southern South America, January–February 2000–2005—Bahía Lomas and Río Grande, Chile. All sites are in the main wintering area (Morrison et al. 2004).

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, no direct evidence exists of Red Knots having being affected by oil pollution but it remains a threat.

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

Threats to Red Knot Habitat in Canada

The shorebird habitats of the Mingan Islands in the Gulf of St Lawrence, Quebec, are at risk because of the proximity of ships carrying oil, titanium, and iron through the archipelago to the Havre-St-Pierre Harbour. In March 1999, one ship spilled 44 metric tons of crude oil that came ashore in the Mingan area. A similar accident occurring during the July–October stopover could have a serious impact on Red Knot feeding areas.

Over Utilization for Commercial, Recreational, Scientific, or Educational Purposes

In the U.S., no overutilization of the Red Knot for commercial, recreational, or educational purposes has been identified. However, hunting migratory shorebirds for food used to be common among local communities in Maranhão, Northern Brazil. They provided an alternative source of protein and birds with high subcutaneous fat content for long migratory flights were particularly valued (I. Serrano, unpubl. data). According to local people, the most consumed species were Red Knot, Black-bellied Plover (*Pluvialis squatarola*), and Whimbrel (*Numenius phaeopus*), though no data are available as to the number of birds taken. Local people say that although some shorebirds are still hunted, this practice has greatly decreased over the past decade and hunting is not thought to amount to a serious cause of mortality.

Have Scientific Studies Contributed to the Red Knot's Decline?

It is sometimes claimed that the more intrusive forms of avian research, such as catching birds for

banding and examination, has a detrimental effect. The most serious form that overutilization for scientific purposes might take would be if it affected the birds' ability to survive and reproduce and so contributed to the population decline.

Bird banding has been carried out across the world, especially in Europe and North America, for over a century. Virtually all taxa have been banded at one time or another and the practice has come under considerable scrutiny. In most countries, bird banding is highly regulated and limited to trained personnel only. As such, it is considered a valuable and safe research tool. If it led to significant mortality or atypical behavior, it would not be permitted. Moreover, there would be no purpose in doing it because the whole point is to study what birds do naturally. Some bird populations that have been the subject of intensive banding studies have increased while others have decreased. In Europe, for example, the Icelandic race of the Black-tailed Godwit (*Limosa limosa*) has increased, but the western European race has declined, yet both have been banded extensively (Wetlands International 2006).

As to *C. c. rufa*, the banding effort has been fairly constant since intensive studies began in 1997, yet the population has remained stable between some years but declined dramatically between others (Figs. 30 and 32). Moreover the number of birds caught annually (about 1,000 in Delaware Bay plus 300 in South America) is relatively small compared with some of the year-to-year population declines (14,000 from 2004–2005), so most of the birds that disappeared, presumed dead, had never been caught. Therefore, it can be concluded that scientific studies have not been responsible for the major decline of *C. c. rufa*.

Each year, about 50 of the birds caught in Delaware Bay have been the subject of radio-telemetry studies in which a 2-g radio-tag has been glued to their backs. The tags are expected to drop off after 1–2 months through the natural replacement of skin. These birds, like the remainder of Red Knots caught, are also fitted with individually numbered color-flags. Resighting studies in subsequent years show that the annual survival of birds that had been radio tagged was no different to that of birds there had merely been banded (P. W. Atkinson, unpubl. data).

Do Scientific Studies Cause Significant Disturbance to Red Knots?

Harrington (unpubl. data) evaluated the response of Red Knots to disturbance associated with research activities, including cannon-net catches. Observers recorded the frequency of disturbance events and time spent in flight during attempts to catch shorebirds with cannon nets and at the same sites when catch attempts were not conducted. Disturbance events recorded when there was no catching were attributed to sources unrelated to research activities. Results indicate that the mean hourly disturbance rate during catch attempts was 13.0 versus 11.7 when catch attempts were not being conducted; this is not a statistically significant difference (t-test, $P > 0.05$). Harrington also compared the duration of flights by Red Knots that were disturbed by research-related activities ($N = 145$) with that of Red Knots that were disturbed by natural causes, ($N = 179$). About 20% of the Red Knots that were timed flew out of sight, so their flight duration could not be determined. The proportion of Red Knots that flew out of sight during natural disturbance events (21%) was similar to the proportion that flew out of sight during research activities (21%). Of the remaining sample, flights of Red Knots from natural causes tended to be shorter than for Red Knots disturbed by researchers. Harrington also found no statistically significant difference in the mean number of calories used by Red Knots reacting to natural disturbances and Red Knots reacting to the activities of researchers. Analysis of research-related disturbance data for Ruddy Turnstones produced results similar to those for Red Knot, i.e., tests did not detect statistically significant differences between natural and research-related disturbances.

Steps to Minimize Disturbance by Research Activities

In recent years, especially since 2003, considerable care has been taken to minimize disturbance caused to shorebirds in Delaware Bay by researchers. Catching, in particular, has been limited in terms of total numbers caught, frequency, and catch size consistent with the twin aims of monitoring annual survival and weight gain. Moreover most close observation (e.g., to read inscribed color flags) has been carried out, when possible, from well-concealed sites including blinds.

Disease or Predation

In Europe and North America, the study of shorebirds over most of the past 30 yr 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-World War

II levels in temperate North America. Butler et al. (2003) 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.

In the Arctic, 3–4 yr 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 *C. c. rufa* population. However, unsuccessful breeding seasons have contributed to at least some recent reductions in the population.

Potential predators of shorebirds, especially Peregrine Falcons, red foxes (*Vulpes vulpes*), and feral cats (*Felis catus*), are possibly more of a threat to Red Knots in Delaware Bay as sources of disturbance than as agents of mortality. Over the past decade, Peregrine Falcons in North America have largely recovered from reduced numbers in the mid 20th century caused by persecution and pesticide poisoning. Now, several pairs nest close to both shores of Delaware Bay. However, they are almost all using artificial nest sites and it is likely that without these Peregrine Falcons would be largely absent, as they probably were before their numbers crashed. The disturbance they cause to Red Knots in Delaware Bay has not been properly evaluated. This should be done and, if it is found to be significant, steps taken to reduce its impact by removal or relocation of the nesting towers.

An epizootic disease resulting in large-scale mortality of Red Knots reported from the west coast of Florida in December 1973 and November 1974 was caused by a protozoan parasite, most likely an undescribed sporozoan species (Harrington 2001). Further reports on Red Knot mortality in Florida in 1981 were due to *Plasmodium hermani* (Harrington 2001). In 1981, Harrington (2001) reported an adventitious molt in Red Knots caused by a mallophagan parasite (Mallophaga, Menoponidae) in feather shafts. On 7 April 1997, 26 Red Knots, 10 White-rumped Sandpipers, and three Sanderlings were found dead or dying along 10 km of beach at Lagoa do Peixe, southern Brazil. The following day, another 13 dead or sick Red 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 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 stable isotope analysis. In the course of these studies in February 2005, all of a sample of 38 Red Knots caught in Maranhão was found to be heavily infected with ectoparasites. The birds were much less than the usual fat-free mass of Red 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, it cannot be known whether this observation is typical of Red Knots wintering in that area or peculiar to one winter, or whether such infestation leads to significant mortality, or 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 if it is shown that ectoparasite infection leads to a loss of fitness. 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 Red Knots caught there (C. D. T. Minton and L. J. Niles, unpubl. data). This is a factor worthy of further investigation.

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 Red Knots, and equine encephalite virus in another (Araújo et al. 2003).

The Inadequacy of Existing Regulatory Mechanisms

Several regulatory issues have negatively influenced the protection of Red Knots. Most have arisen because Red Knots 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 (Fig. 50). 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 (Figs. 51 and 52).

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 (Fig. 53). In April 2007, the Committee on the Status of Endangered Wildlife in Canada determined that *C. c. 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 *C. c. 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 (http://www.cms.int). The U.S., Canada, and Brazil are among the minority of countries that are not yet parties to the convention.

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 its 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, loggerhead turtle (*Caretta caretta*). 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. 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 U.S., the MBTA provides no authority for protection of habitat or food

FIGURE 51. Important *Calidris canutus rufa* breeding, stopover, and wintering areas in the Western Hemisphere

resources. Human disturbance is cited as one of the major threats to Red Knots throughout its migratory range within the U.S. 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

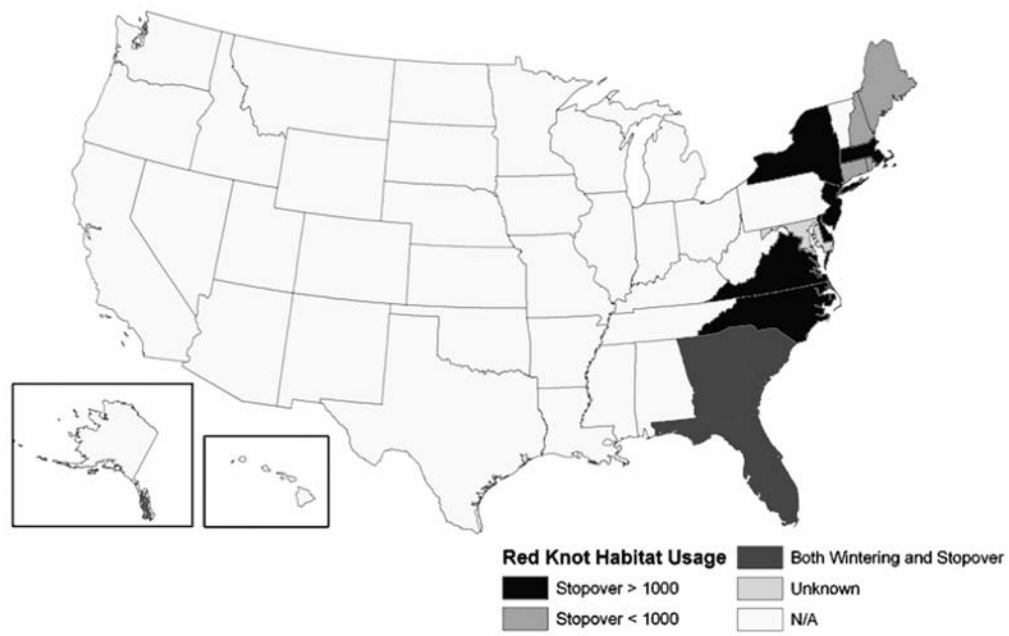

FIGURE 52. Important *Calidris canutus rufa* stopover and wintering areas in the United States.

FIGURE 53. Red Knot state legal status in each state in the U.S.

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.

Inadequacies of Regulatory Systems in Individual States

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. NJDFW 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. 2007). 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. 2007). 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, no legal basis exists for preventing disturbance (Fig. 53). The need to protect Red Knots from repeated disturbance on beaches also applies during southward migration in autumn as shown by recent studies (D. Mizrahi, pers. comm.).

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. No regulatory mechanisms protect the habitat of Delaware state-listed species or to permit regulation of 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.

Curtailment of Habitat Use from Disturbance by People and Dogs

Human disturbance can have an adverse effect on shorebird foraging and this depends on the degree of disturbance and the availability of other suitable feeding areas. Disturbance compels birds to pay the energetic cost of flying to a new area, it may reduce the amount of time that the birds are able to feed, and can prevent them from feeding in the most preferred sites. Any overall reduction in energy intake as a result of these responses is the net impact of disturbance on energy budgets (Davidson and Rothwell 1993). Disturbance, however, may have little impact on birds if there are suitable foraging areas nearby in which they can feed.

In Delaware Bay the spectacle of shorebirds and spawning horseshoe crabs draws hundreds of bird watchers to 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 that a beach was disturbed during any hour of the day dropped from 32.9 min in 1982 to 3.2 min in 2002. This was the direct result of increased management efforts by the NJDFW. Though the period 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 disrupted by people and did not return within 10 min. 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 2003, 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 the weekend on the Atlantic coast in the vicinity of Stone Harbor (H. P. Sitters, unpubl. data).

An additional source of disturbance is that caused by off road vehicle (ORV) use. Although not quantified, areas along the Delaware shore are occasionally used by ORVs. The frequency and duration of this type of disturbance varies but can have a major impact if ORVs remain at a specific location for an extended period of time. An ORV driving along a beach without stopping may have a relatively insignificant effect. However, when they are used with great frequency or for long periods (such as when they are used for recreation as opposed to transportation), ORVs probably cause shorebirds to leave and not return.

Disturbance by people is not limited to direct use of Delaware Bay beaches. Low-energy beaches, particularly those along the mouths of tidal creeks and rivers have been identified as optimum horseshoe crab spawning habitat. Where these have high levels of boat traffic, such as at Mispillion Harbor, disturbance due to the presence, noise, speed, or wake of boats is likely to be considerable (B. A. Harrington, unpubl. data). Preliminary results indicate that boat traffic in Mispillion Harbor represents a significant source of disturbance to feeding shorebirds, particularly when boats travel at high speed (B. A. Harrington, unpubl. data).

In Massachusetts disturbance by humans and dogs has been identified as a threat to Red Knots.

In Virginia some of the potential threats Red Knots currently face on the barrier islands include frequent interruptions in foraging and roosting bouts caused by humans and an introduced breeding population of Peregrines Falcons.

Along the coast of North Carolina, threats to migrant and wintering Red Knots include human disturbance, especially at the following key sites:

1. Tubbs Inlet—human disturbance.
2. Bear Island/Bogue Inlet—some human disturbance at inlet and nearby bath house during the spring and summer months but very limited at present.
3. Bird Shoals—human disturbance primarily during the spring and summer months.
4. Cape Lookout National Seashore—human disturbance including beach driving during spring and summer months.
5. Cape Hatteras National Seashore—human disturbance including beach driving during spring-summer months.
6. Pea Island—human disturbance during the spring and summer months.
7. Clam Shoal—this site is fairly inaccessible, but more people have visited it in recent years so possibly human disturbance during the spring and summer months is increasing.

A large area of the South Carolina coast is protected due to public ownership and conservation easements. Few opportunities exist to increase the amount of protected coastal land. The biggest threat to Red Knots is disturbance by boats, humans, and dogs, even in Cape Romain NWR. Presently in South Carolina, only two islands (in Cape Romain NWR) are closed to boat landings that are known to be important Red Knot loafing and foraging areas. Coastal counties are experiencing annual human population growth rates of 2–3%.

In Georgia, human disturbance (pedestrians, dogs, boats, and bicyclists) is the most significant threat to important winter and stopover habitats for Red Knots.

In Florida, it appears that the most immediate and tangible threat to migrant and wintering Red Knots is chronic disturbance (Niles et al. 2006). However, with the exception of a few federally owned sites, most beaches experience very high human disturbance rates which are increasing. While almost all foraging habitat and most

roosting sites are in public ownership, very few locations are managed in any way for winter or passage shorebirds. Seasonal posting in Florida is done primarily for beach-nesting birds during the spring and summer months. Publicly owned lands, if managed at all, are generally under tremendous recreational pressure from a rapidly growing human population. 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.).

In Argentina, human disturbance is a threat on the beaches at Reserva Provincial de Río Chico para Aves Playeras Migratorias and Reserva Urbana Costera del Río Chico (tourism), on Península Valdés (tourism, with dogs a particular problem, and fishermen with cats [L. Bala, pers. comm.]), in the Bahía San Antonio Natural Protected Area (beach tourism), and in Bahía Samborombón (tourism).

Red Knots frequently suffer human disturbance while feeding and roosting around Río Grande city, especially by people using all-terrain vehicles and motor cycles, as well as from walkers, runners, fishermen, and dogs.

Competition from Gulls

Gulls are both competitors for food and potential predators of 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, numbers of two common species, Laughing Gull and Herring Gull (*Larus argentatus*), fluctuated widely but with a no statistically significant long-term trend. However, Greater Black-backed Gulls (*L. marinus*) increased significantly (Table 38). Number of gulls using the New Jersey bayshore for feeding has not changed significantly (Sutton and Dowdell 2002). During 1992–2002, the number of gulls recorded in single-day counts on accessible New Jersey bayshore beaches ranged from 10,000–23,000.

Gull breeding colonies in Delaware are not located as close to the bayshore beaches as in New Jersey. However, immature, non-breeding, large gulls (Greater Black-backed Gull and Herring Gull) and some Laughing Gulls (most likely from New Jersey breeding colonies) do congregate on the Delaware shore during the spring, especially at Mispillion Harbor. Though gull numbers have been recorded along the Delaware bayshore in recent years, there are insufficient long-term data to show populations trends.

Although total gull numbers have shown no significant long-term trend (Table 38), the effect of their competition on the shorebirds may have increased as a result of the decline in the availability of horseshoe crab eggs. Burger et al. (2007) found that gulls are more tolerant of human disturbance than shorebirds. When disturbed by humans, gull numbers returned to pre-disturbance levels within 5 min. Even after 10 min 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 most spend more time watching out for gulls to the detriment of time spent feeding (J. Burger, unpubl. data).

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 (S. Karpanty, pers. comm.). Burger et al. (2004) found that

Table 38. Aerial survey counts of gulls on the Atlantic coast of New Jersey (D. Jenkins, unpubl. data).

Year	Laughing Gull	Herring Gull	Great Black-backed Gull	All gulls
1979	59,914	5,802	128	65,844
1983	58,267	5,237	260	63,764
1985	54,434	4,720	226	59,380
1989	58,797	7,097	293	66,187
1995	39,085	6,828	781	46,694
2001	80,253	9,814	1,036	91,103
2004	52,765	5,347	795	58,907
Mean	57,645	6,406	503	64,554
Correlation with year (r_s)	–0.29 (P > 0.05)	0.39 (P > 0.05)	0.93 (P = 0.003)	–0.18 (P > 0.05)

gulls out competed all shorebird species including Red Knots for horseshoe crab eggs, and that the influence of gulls increases with repeated disturbance. In contrast to shorebirds, people walking dogs caused gulls to leave but they returned shortly after the disturbance ended.

Red Knot foraging efficiency is also adversely affected by the mere presence of gulls. Hernández (2005) found that the foraging efficiency of Red Knots feeding on horseshoe crab eggs decreased by as much as 40% when feeding close to a gull.

Risks Associated with Small Population Size

The threat to *C. c. 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. Small populations are also at greater risk from the effects of stochastic events. This applies especially those which, like the Red Knot, are highly dependent on a small number of sites.

Weather-Related Threats to Red Knots

Cold and/or wet weather during the brief arctic summer can have a severely adverse effect on the breeding success of shorebirds (van de Kam et al. 2004). Global climate warming may lead to alterations in arctic weather patterns. These may be beneficial to shorebirds if they lead to warmer, longer breeding seasons but this is by no means certain (Rehfisch and Crick 2003).

In the very long term global warming may lead to large-scale habitat changes which will be greatly exacerbated by vegetation responses to increased atmospheric carbon dioxide (Rehfisch and Crick 2003). It has been predicted that this may lead to a 65% decrease in tundra habitat over a large area of the Arctic (Cramer 1997). If so, Red Knot breeding habitat would become so scarce that there is little doubt that this would restrict the size of its population.

SUMMARY OF LAND OWNERSHIP AND EXISTING HABITAT PROTECTION FOR POPULATIONS

Appendix 4 summarizes details of the ownership of all land considered to be important for Red Knots throughout the western Atlantic flyway. This appendix also indicates the approximate percentage of land that is subject to some arrangement for habitat protection. However, it should be noted that the nature of such arrangements varies from place to place and in only a very few cases is the arrangement specifically for the benefit of Red Knots.

PAST AND CURRENT CONSERVATION AND HABITAT MANAGEMENT ACTIVITIES UNDERTAKEN TO BENEFIT THE SPECIES

As part of this assessment, biologists representing each state and country were contacted and were requested to outline management efforts for Red Knots. We found that no management efforts are 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.

The Ramsar Convention on Wetlands

The Convention on Wetlands, signed at 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. Presently the convention has 146 contracting parties with 1,463 wetland sites, totaling 125,400,000 ha, designated for inclusion in the Ramsar List of Wetlands of International Importance.

The mission of the convention agreed at the eighth meeting of the Conference of the Contracting Parties in Valencia in 2002 is to promote 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 (http://www.ramsar.org).

Western Hemisphere Shorebird Reserve Network

The network is a voluntary, non-regulatory coalition of over 160 private and public organizations in seven countries working together to study and conserve shorebirds throughout their habitats. Membership in Western Hemisphere Shorebird Reserve Network (WHSRN) provides the site with international recognition as a major host for shorebirds. The network now includes 46 officially designated sites that are responsible for managing >80,940,000 ha. Member sites are located in Argentina, Brazil, Peru, Suriname, Mexico, U.S., and Canada. Further, almost 150