Update to the Status of the Red Knot *Calidris canutus* in the Western Hemisphere, February 2008

LAWRENCE J. NILES [1], HUMPHREY P. SITTERS [2], AMANDA D. DEY [3], PHILIP W. ATKINSON [4], ALLAN J. BAKER [5], ROBERTO CARMONA [6], KATHLEEN E. CLARK [3], NIGEL A. CLARK [4], CARMEN ESPOZ [7], PATRICIA M. GONZALEZ [8], BRIAN A. HARRINGTON [9], DANIEL E. HERNANDEZ [10], KEVIN S. KALASZ [11], RICARDO MATUS [12], CLIVE D.T. MINTON [13], R.I. GUY MORRISON [14], MARK K. PECK [5], WILLIAM PITTS [3], ROBERT A. ROBINSON [4] & INÊS L. SERRANO [15]

[1] *Conserve Wildlife Foundation of NJ, 516 Farnsworth Ave. Bordentown, NJ 08505*
[2] *Limosa, Old Ebford Lane, Ebford, Exeter EX3 0QR, UK*
[3] *New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program, PO Box 400, Trenton, NJ 08625*
[4] *British Trust for Ornithology, Thetford, UK*
[5] *Royal Ontario Museum, Toronto, Canada*
[6] *Departamento de Biología Marina, Universidad Autónoma de Baja California Sur, Apartado postal 19-B, CP 23000, La Paz, Baja California Sur, Mexico*
[7] *Departamento de Ciencias Basicas, Universidad Santo Tomas, Santiago, Chile*
[8] *Fundacion Inalafquen, San Antonio Oeste, Argentina*
[9] *Manomet Center for Conservation Sciences, Manomet, MA*
[10] *Richard Stockton College of New Jersey*
[11] *Delaware Division of Fish and Wildlife, Smyrna, DE*
[12] *Natura Patagonia, Punta Arenas, Chile*
[13] *Victoria Wader Studies Group, Melbourne, Australia*
[14] *Environment Canada, National Wildlife Research Centre, Ottawa, Canada*
[15] *Instituto Chico Mendes para Conservação da Biodiversidade, Brazil*

ABSTRACT

New information indicates that the *rufa* subspecies of the Red Knot comprises three biogeographically distinct populations wintering in Tierra del Fuego, Maranhão and Florida, respectively, and that the *roselaari* subspecies is largely or wholly confined to the Pacific coast of the Americas on passage and in winter.

Depending on the subspecific status of large numbers of knots seen in Alaska in 1975-1980, the *roselaari* subspecies might have declined from 100,000+ to <10,000 or it has always had a small population, probably <10,000. In either case the present population is small and vulnerable and deserves protection.

All three wintering populations of *rufa* are now substantially lower than they were stated to be in the recent *Status of the Red Knot,* Calidris canutus rufa, *in the Western Hemisphere* (Niles *et al.* 2007):

- The main wintering population of *rufa* in Tierra del Fuego has declined by 15% from around 17,316 in 2006/7 to 14,800 in 2007/8. This is at least partly the result of mortality of approximately 1,300 birds that occurred during northward migration in April 2007.
- The wintering population of a 300 km stretch of the west coast of Florida was estimated at about 10,000 in the 1980s but declined to 2,500 in 2005/6 and only 550 in 2007/8. The population of the remainder of the SE coast of the US has not been surveyed since 2005 so its recent trend is unknown.
- The population wintering in Maranhão, Brazil, was 7,575 in February 2005, but had dropped to about 3,000 in late 2006.

A new analysis of the weights of Red Knots caught in Delaware Bay during the spring stopover indicates that all but the earliest arrivals (probably about three quarters of the entire stopover population) have suffered significantly reduced rates of mass gain on account of reduced quantities of their main food, horseshoe crab eggs.

The population of horseshoe crabs in Delaware Bay and the densities of their eggs on Bay beaches was stable over 2005-2007 indicating that regulation of the crab harvest to date has been insufficient to achieve the major increase in the crab population needed to sustain the shorebird stopover.

We recommend that the US Fish and Wildlife Service reconsider its decision not to list *rufa* under the Endangered Species Act in view of the fact that all three wintering populations have since shown further significant decline. We also recommend that the Service considers listing *roselaari* in view of the fact that its population is small (probably <10,000) and therefore vulnerable.

We recommend further reductions in the harvest of adult horseshoe crabs until such time as there is unequivocal evidence that the crab population is undergoing strong recovery towards the levels of the early 1990s.

INTRODUCTION

The purpose of this report is to provide an update of *Status of the Red Knot,* Calidris canutus rufa, *in the Western Hemisphere* (Niles *et al.* 2007; "the Status Review") for the benefit of those organizations and individuals concerned with the conservation of the Red Knot in the United States. Further versions of this report will be produced as new information becomes available. This second version reflects the state of knowledge as of 1 February 2008. It is assumed that readers of this report are familiar with the contents of the Status Review.

The Status Review was principally concerned with the *rufa* subspecies of the Red Knot which breeds in the central Canadian Arctic and has its main wintering area in Tierra del Fuego at the southern tip of South America. However, recent information suggests that the population of the *roselaari* subspecies, which breeds in Alaska and on Wrangel Island

and migrates along the American Pacific coast, may be even more threatened than *rufa*. Therefore in this and future updates we will give equal emphasis to both subspecies.

TAXONOMIC STATUS

According to the Status Review, the knots wintering in Tierra del Fuego are *rufa*, but the subspecific status of those wintering in Florida and in Maranhão (Brazil) is uncertain and either or both could be partly or wholly *rufa* or *roselaari*.

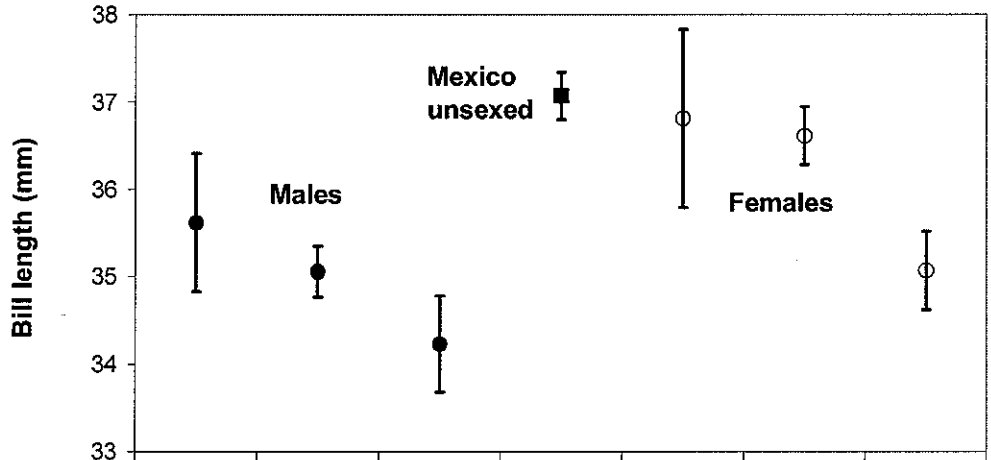
The Status Review includes the following statement which has been misinterpreted as meaning that the wintering populations of Florida and Tierra del Fuego are genetically distinct:

> "Despite the lack of fixed genetic differences among subspecies, the population divergence time of the Red Knots that winter in the southeast of the United States (presumed to be *C. c. roselaari*) and those that winter in Tierra del Fuego (*C. c. rufa*) is estimated to be about 1,200 years ago (Buehler and Baker 2005). Therefore these populations have not been exchanging a significant number of individuals per generation for a long time, and clearly are independent units for conservation."

This statement was made on the assumption that the knots that winter in the southeast of the United States <u>are</u> *roselaari*. Therefore the genetic distinction refers to that between known *roselaari* from Alaska and known *rufa* from Tierra del Fuego. To date there is no evidence of any genetic distinction between knots from the wintering populations of the southeast US, Maranhão and Tierra del Fuego. There is, however, considerable evidence that there is little or no interchange between these populations, that they have distinct migrations and ecological scheduling, and behave as distinct biogeographic populations.

In October 2007, a knot was seen at Guerrero Negro, Baja California, Mexico that had been marked as a breeding adult on Wrangel Island, Russia, during the summer of 2007 (P.S. Tomkovich, B.A. Harrington & R. Carmona, pers. comm.) and two knots were seen at Guerrero Negro that had been marked on migration through the Yukon-Kuskokwim Delta, Alaska, in May 2006 (P.S. Tomkovich, B.A. Harrington, N.A. Clark & H.P. Sitters pers. comm.). These observations confirm that the knots found on the Pacific coast of North America are of the *roselaari* subspecies which breeds in Alaska and on Wrangel Island (Tomkovich 1992).

In October 2006, 162 Red Knots were caught and measured at Guerrero Negro (R. Carmona, unpublished information). These birds, which have not yet been sexed, had longer bill-lengths than males from the winter populations of Maranhão, Florida and Tierra del Fuego, and also longer than Tierra del Fuego females (Fig. 1). So, unless most or all of the Mexican birds were females (which would seem unlikely), it would appear that *roselaari* are larger than the knots wintering in Florida, Maranhão and Tierra del Fuego and therefore larger than *rufa*.



	Maranhão	Florida	Bahia Lomas	Mexico	Maranhão	Florida	Bahia Lomas
● Males	35.62	35.06	34.23				
○ Females					36.81	36.61	35.07
■ Mexico				37.07			

Fig. 1. Bill-lengths of male and female Red Knots from the wintering populations of Maranhão (Brazil), Florida and Bahia Lomas (Tierra del Fuego) compared with the bill-lengths of unsexed knots caught at Guerrero Negro, Baja California, Mexico in October 2006 (mean ± 95% confidence intervals; data are from Baker *et al.* 2005a, Niles *et al.* 2006, & R. Carmona, unpublished information) .

Current scientific opinion, as expressed in a paper submitted to *Bioscience* on 23 December 2007 by L.J. Niles and 19 other authors (including most of the authors of the Status Review) is that the Florida and Maranhão populations are "believed to be *rufa*" (as well as the population of Tierra del Fuego). However, the three wintering populations do show morphological, particularly size, differences, with Tierra del Fuego birds being significantly smaller than those from Maranhão or Florida (Fig. 1). This may suggest that they have discrete breeding areas. However, as yet there is no proof of this (despite unsuccessful efforts by LJN, ADD and others to determine the status of the knots that breed on Victoria Island during summer 2007). While breeding areas may not currently be clearly delineated, it is important to recognize that the three populations are biogeographically distinct.

POPULATION STATUS OF *ROSELAARI*

According to the *US Shorebird Conservation Plan* (Brown *et al.* 2001), the *roselaari* population was about 150,000 in 2001. This estimate, however, was based on information for 1975-1980 and was therefore out of date when the conservation plan was written. Moreover all attempts to assess the size of the *roselaari* population have been bedeviled by uncertainty as to which passage or wintering population belongs to which subspecies.

Roselaari breeds in west Alaska and on Wrangel Island (Tomkovich 1992) and several population estimates are based on numbers counted in May on Alaskan estuaries, just before the birds disperse to the breeding grounds. These include 110,000 on the Yukon-Kuskokwim Delta (on the west coast of Alaska) in May 1980 and 40,000 on the Copper River Delta (on the south coast) in May 1975 where up to 100,000 have been thought to occur (Morrison *et al.* 2006). There is no record of such large numbers before 1975-1980 or since or of similar numbers in the passage/winter sites of *roselaari* further south along the Pacific coast. Morrison *et al.* (2006) therefore suggest that at least some of the large numbers seen in Alaska are likely to have been *rogersi* which breeds in E Siberia (more or less due south of Wrangel Island) and winters in E Australia and New Zealand and has recently been estimated at about 90,000 (C.D.T. Minton, unpublished information). Precisely why *rogersi* would migrate from Australasia to Siberia via Alaska in 1975-1980 and why they do not appear to do so now (or do so less) is not clear but the possibility cannot be rejected.

The only recent evidence that moderately large numbers may still pass through Alaska is an unpublished report by Pavel Tomkovich and Maksim Dementyev on observations they made in May 2006 on the Tutakoke River in the Yukon-Kuskokwim Delta (Tomkovich & Dementyev 2006). Most of the knots they saw arrived daily from the south and departed northwards. The sum of their counts – 5,780 – was therefore considered to give a reasonably accurate measure of numbers passing through the area. Since they were unable to cover the entire estuary, they were "quite sure that not less than 10,000 knots come through the lower Tutakoke River area". Bearing in mind that the Tutakoke River is only one site among several on the Yukon-Kuskokwim Delta, the total passage population could still be quite large.

Evidence of numbers farther south along the American Pacific coast is fragmentary and difficult to interpret but suggests that the population that has never exceeded about 10,000. Page *et al.* (1999) present summed maximum counts for all sites on the US Pacific coast (except Alaska) for 1988-1995: fall: 7,981; winter: 4,813; spring: 9,035. However, as these are summed peak counts without reference to date, it is highly likely that many individual birds were counted several times over.

In Washington, passage numbers have declined from a few thousand in the 1980s to peaks of 248 in spring 2006 and 446 in spring 2007 (Buchanan 2006, Buchanan 2007).

In Baja California, 1,053 were counted at Guerrero Negro in Jan 1994 (Page *et al.* 1997), but it was not until recently that relatively larger numbers were recorded there. Carmona *et al.* (2006) working in the Guerrero Negro area counted 2,907 knots in the ESSA saltworks alone in Oct 2005. Subsequently 6,458 were counted in the saltworks and the adjoining Guerrero Negro and Ojo de Liebre lagoons in Sept 2006, 4,595 in Dec 2006 and 4,647 in April 2007 (R. Carmona, unpublished information). Whether the recent observations represent a real increase in the population is not clear. It is a remote area and this population could have been overlooked in the past.

In summary:

- *Roselaari* MIGHT have declined from 100,000+ to <10,000 if the large numbers reported in Alaska in 1975-1980 were *roselaari* and did not include substantial numbers of *rogersi*.
- Alternatively, *roselaari* has always had a small population, probably <10,000, and has shown no clear long-term trend. Nevertheless, as a small population (probably less than half that of *rufa*), it is vulnerable and deserves protection.

POPULATION STATUS OF *RUFA*

All three of the main wintering populations of *rufa* have shown substantial declines compared with the numbers reported in the Status Review (Table 1). From 2004/5 to 2007/8, counts were conducted each winter in Tierra del Fuego, Maranhão and on the west coast of Florida, apart from 2005/6 and 2007/8 in Maranhão and 2004/5 in Florida. If the previous year's count is used for the missing counts in Maranhão and the succeeding year's count is used for the missing count in Florida (which is the most conservative approach in terms of estimating the scale of the decline), the total wintering population declined from 27,728 to 18,350 (33% or 11% per annum) over the four winters. However, since these wintering groups behave as separate populations, it would be more appropriate from the conservation point of view to consider their status individually.

Table 1. Counts of Red Knots during the northern winters of 2004/5 to 2007/8 in Tierra del Fuego (Argentina and Chile), Maranhão (Brazil) and on the west coast of Florida (NC = no count). Where there was no count, the totals row uses the previous year's count in respect of Maranhão and the succeeding year's count in respect of Florida (see text). Numbers reported in the Status Review are indicated with an asterisk (*).

	2004/5	2005/6	2006/7	2007/8	Observers
Tierra del Fuego	17,653*	17,211*	17,316	14,800	R.I.G. Morrison & R.K. Ross
Maranhão	7,575*	NC	3,000	NC	I. Serrano
Florida west coast	NC	2,500*	1,200	550	L. Niles, A.D. Dey & R.I.G. Morrison
Total	27,728	26,286	21,516	18,350	

Tierra del Fuego population

In April 2007, very approximately 1,300 dead knots were found on the coast of Uruguay, as described in the following report posted on BirdLife International's website:

> Recent unexplained Red Knot die-offs have highlighted further the need for research into the variety of threats afflicting the already declining *rufa* population. In April 2007, 312 dead *C. c. rufa* were discovered by a park guard at Playa La Coronilla in southeastern Uruguay and the same day over 1,000 birds were found

> dead at a second site nearby. Of the events Joaquín Aldabe, IBA coordinator at Aves Uruguay (BirdLife in Uruguay) commented: 'It seems possible that harmful algal blooms could be related to it, although additional studies are required in order to fully understand this unexpected event.' Aves Uruguay, in connection with other national and international organizations, is already working in the area to establish the possible causes of the casualties and the role of Uruguay as stopover for the species. 'The death of more than 1,300 Red Knots in Uruguay is of particular concern given the low overall population size,' said Rob Clay, Conservation Manager of BirdLife's Americas Secretariat. 'This number represents over 6% of the [*rufa*] population, all of which winter in southern South America. The discovery underlines the need to better understand factors which may be affecting the species during migration and on its wintering grounds.'

Subsequently, PMG and AB interviewed the people who had found the dead knots and it was established that the count of 312 was accurate but the statement that "over 1,000 were found dead at a second site" was only a very rough estimate. Therefore there is some doubt as to the total number of birds affected. However, whatever the number seen, it is likely that more died and were lost (e.g. in the sea or to scavengers).

This appears to have been a one-off event but has similarities to a smaller one mentioned in the Status Review that occurred at Lagoa do Peixe in southern Brazil in 1997.

The January 2008 Tierra del Fuego count of 14,800 was 2,516 or 15% lower than the previous year.

Maranhão population

Baker *et al.* (2005) counted 7,575 knots from the air along 150 km of the shore of Maranhão, Brazil, in February 2005. A repeat count in December 2006 could only find 3,000 (I. Serrano, unpublished information).

Florida population

The Status Review made a very tentative estimate of the size of the Florida population as 7,500 and stated that there was no clear evidence of trend. Counts in the winter of 2005/6 showed a minimum population of about 4,000 plus another 1,500 scattered along the coasts of Georgia, N & S Carolina and Virginia (Niles *et al.* 2006). Of the 4,000 in Florida, 2,500 were found along 300 km of the west coast between Anclote Key and Cape Romano where an estimated 10,000 occurred in the 1980s (Morrison & Harrington 1992) indicating a substantial decline in what used to be the main Florida stronghold. Further counts along this coast show that the numbers wintering in this area declined to 1,200 in 2006/7 and only 550 in 2007/8.

Are the counts accurate?

The aerial counting of shorebirds requires skill and rapid assessment. Those involved in the counts reported here are all highly qualified counters, particularly R.I.G. Morrison & R.K. Ross who are probably the most experienced aerial counters of shorebirds in the world. RIGM and RKR have conducted all of the Tierra del Fuego counts, so the data have all been collected in a consistent manner by the same observers, and RIGM took part in the last Florida count. The remaining counts were conducted by people who have very considerable experience of counting shorebirds on the ground as well as some experience of counting from the air.

In Tierra del Fuego, all potential knot habitat consists of simple linear shorelines so there is very little likelihood that any birds will have been overlooked. In comparison, the shores of west Florida and Maranhão are complex and highly fragmented making accurate counting more difficult. To allow for this, aerial coverage in both areas was more extensive and included not only the ocean shore but also a great variety of back bays and channels where knots might possibly occur.

In all three areas, when fewer birds were found than in earlier years, searching was intensified. In some cases, repeat flights were made in case birds had been missed; in others the search was extended to marginal habitats to ensure that all locations where knots might possibly be found were covered. Intensified coverage revealed virtually no additional knots.

It is concluded that all of the counts were of sufficient accuracy that there can be confidence that the trends shown are true and the scale of the declines is correct.

Could the birds have moved elsewhere?

Generally, arctic-breeding shorebirds, including Red Knots, have been found to be highly site-faithful to their wintering grounds. However, changes in wintering site have not infrequently been recorded and have variously been attributed to changes in the availability of food, changes in the risk of predation, loss of habitat, and improved conditions closer to breeding grounds arising from climate change.

We are not aware of any changes to the habitats used by knots in Maranhão or Tierra del Fuego that could have led the birds to winter elsewhere. In Florida, recreational use of the beaches has increased in recent years to such an extent that it could be a factor that has led birds to change site. However, the main sites occupied in 2005/6 are well within or towards the middle of the 300 km of coast surveyed each year. Therefore if the birds have moved elsewhere, they must have moved a considerable distance. It should be noted that the population of the remainder of the SE coast of the US has not been surveyed since 2005 so its recent trend is unknown.

In Tierra del Fuego, all coastlines that have supported knots in the past, and especially the "core" sites supporting the bulk of the population (Bahia Lomas, Bahia San Sebastian and Rio Grande) have been surveyed from the air in January in the years 2000 to 2008. Previously occupied areas on the coast of Patagonia were also surveyed in three separate

years, but were found to support few knots (2% of the wintering count) compared to the 1980s (14%), indicating the population is now found almost entirely in the "core" sites, with few in the more peripheral areas, and with no evidence for any redistribution outside the core region. Moreover, we are in regular contact with shorebird observers in Patagonia and there have been no reports of significant numbers of knots wintering north of Tierra del Fuego in Argentina in 2007/8, again indicating that no significant redistribution has occurred. With consistent declines observed at all migration areas as well, it is considered extremely unlikely that redistribution could account for the declines observed since 2000.

MASS GAIN IN DELAWARE BAY

At the time the Status Review was written, it was well understood that the decrease in the food supply of Red Knots in Delaware Bay (horseshoe crab *Limulus polyphemus* eggs) was strongly implicated in the decline of the *rufa* population. Baker *et al.* (2004) showed that knots unable to gain adequate weight in Delaware Bay for onward migration to the arctic breeding grounds had significantly lower survival. Morrison et al. (2007) also showed that body stores were important indicators of survival in *islandica* populations of Red Knots breeding in the High Arctic. However, the precise impact of reduced numbers of eggs was not clear. In a study of birds trapped twice during a single spring stopover, Atkinson *et al.* (2006) showed that the earliest arrivals accumulate mass at a relatively low rate (~4 g/day) but later arrivals can catch up lost time and achieve a much higher rate of mass gain (up to 10-15 g/day). New analyses by led by Robert A. Robinson (British Trust for Ornithology, presented to a joint meeting of the Horseshoe Crab and Shorebird Technical Committees of the Atlantic States Marine Fisheries Commission in October 2007) have shown that the earliest arrivals have not suffered reduced rates of mass gain. However, the later arrivals that try to catch up lost time, comprising approximately three quarters of the entire stopover population, have shown a significant year-on-year decline in the rate of mass gain they have achieved over 1998 to 2007. As lower weight birds have lower survival (Baker *et al.* 2004), it can be concluded that the reduced availability of crab eggs in Delaware Bay has been a critical factor in the decline of *rufa* knots.

As reported in the Status Review, there has been a tendency for northward passage of knots to be about a week later at three sites in South America. To date no clear evidence has been found (e.g. from the aerial counts) that this has led to later arrival in Delaware Bay. However, if this does occur, it will merely exacerbate an already bad situation (more birds will be arriving late and trying to gain mass rapidly on inadequate food supplies).

HORSESHOE CRABS AND THEIR EGGS IN DELAWARE BAY

Current evidence suggests that the horseshoe crab population of Delaware Bay has stabilized following the major decline documented in the Status Review.

Table 2. Population parameters of horseshoe crabs in Delaware Bay for 2004-2007.

	2004	2005	2006	2007	Trend	Source
Spawning females (index)	0.77	0.82	0.99	0.89	None [3]	Michels *et al.* 2008
Spawning males (index)	2.93	3.23	3.99	4.22	Increase [3]	Michels *et al.* 2008
Egg density New Jersey (index) [1]	61	100	49	29	None [4]	NJDFW per D. Hernandez
Egg density Delaware (index) [1]	No survey	100	73	76	None	DEDFW Per K. Kalasz
Delaware Trawl Survey (geo-mean) [2]	0.059	0.203	1.372	1.617 [5]	Increase	S.F. Michels pers. comm.
Offshore Trawl core area multiparous females (strat mean catch/tow)	8.2	10.7	24.6	29.1	Increase	Hata (2008)
Offshore Trawl peripheral area multiparous females (strat mean catch/tow)	3.2	2.8	5.5	2.8	None	Hata (2008)

[1] In top 5 cm of sand, 2005 = 100
[2] Data relate to trawls during April-July
[3] Trend relates to 1999-2007
[4] Trend relates to 2000-2007; over 2005-2007, the trend is a decline
[5] The Delaware Trawl figure for 2007 is provisional

From the birds' perspective, the key factor in being able to acquire adequate body reserves for onward migration is the density of available eggs. This has shown no significant change over 2000-2007 (though over 2005-2007 it declined) (Table 2). Similarly, the number of spawning female crabs has shown no significant trend over 1999-2007; however, there has been an increase in the number of breeding males (Table 2). The increase in males might be an indication that the population is on the brink of recovery; however, it is females that lay eggs, so an increase in male crabs is largely irrelevant to the birds. More encouraging, however, is a sharp, 7-10-fold increase in 2006 and 2007 in the number of crabs recorded by the Delaware Division of Fish & Wildlife's trawl survey (Table 2; Michels *et al.* 2008). Presumably the increase relates largely to males and/or immatures because there has not yet been an increase in the number of spawning females. Nevertheless, this might be a welcome indication that the population is starting to recover. However, this evidence should be treated with great caution because the sharp increase recorded by the Delaware trawl in 2006 was not corroborated by the offshore trawl survey conducted by the Horseshoe Crab Research Center (Hata 2008) which recorded a much lower and non-significant increase (x2.5-3.0) (Table 2).

In summary, recovery in the horseshoe crab population might possibly be starting in response to harvest restrictions, but the evidence is far from clear and, even if it is starting

it has not yet led to an increase in the number of spawning female crabs or eggs for the birds.

It is emphasized that the scale of recovery of the horseshoe crab population needed to sustain the Delaware Bay shorebird stopover is an order of magnitude increase to the levels of the early 1990s, not just an improvement in current numbers.

In the course of preparing this report it was realized that over the last three years (2005-2007) surveys of horseshoe crab eggs have shown much higher densities in Delaware than in New Jersey. This is thought to be a sampling problem which does not reflect a systematic difference in egg densities between the two states and is discussed in more detail in the Appendix.

RECOMMENDATIONS

- In 2006, the US Fish and Wildlife Service decided that listing *rufa* as threatened or endangered under the Endangered Species Act was justified but precluded by species with higher conservation priority. That decision was made on the basis of the information contained in the Status Review. Since then all three of the main wintering populations have shown significant further decline. Therefore the priority for listing *rufa* has increased. Accordingly we recommend that the USFWS reconsider listing *rufa*. It may be noted that the *rufa* population of Red Knots has been designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2007).

- Although there may be uncertainties about the status of *roselaari* because of the lack of comprehensive surveys, it is probable that its population is less than 10,000, which is considerably less than current estimates for *rufa*. As a small population it is particularly vulnerable to stochastic events, harmful genetic mutation and habitat loss. Therefore we recommend that the USFWS gives consideration to listing *roselaari* as well as *rufa*.

- The Status Review showed that the Delaware Bay population of horseshoe crabs declined by around 90% between 1990 and 2006 as a result of excessive harvest. This has been shown to be strongly implicated in the decline of *rufa*. This finding is now further reinforced by the demonstration that the majority of knots stopping over in Delaware Bay have suffered reduced rates of mass gain over 1998-2007. The suggestion that the crab population might have started to recover in 2006 as a result of harvest management is therefore welcome. However, the recovery needs to be towards the levels of the early 1990s – an order of magnitude increase – before it can be expected to have a beneficial effect on the survival of the knot population. Therefore we recommend that the Atlantic States Marine Fisheries Commission and the individual states involved further restricts the harvest of adult crabs until such time as there is unequivocal evidence of a strong recovery in the number of spawning crabs and the density of their eggs towards the levels of the early 1990s.

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APPENDIX

Horseshoe crab egg densities in New Jersey and Delaware

In the course of preparing this report it was realized (for the first time) that over the last three years (2005-2007) surveys of horseshoe crab eggs have shown much higher densities in Delaware than in New Jersey, although percentage change from year to year is not dissimilar (Table A; compare with index in Table 2).

Table A. Density of horseshoe crab eggs in the top 5 cm of sand in the beaches of Delaware Bay during May and June 2004-2007 in New Jersey and Delaware (surveys conducted respectively by the New Jersey and Delaware Divisions of Fish and Wildlife).
[1] Data from Michels *et al.* (2008); the index is the mean number of female crabs per sq m per night.

Mean egg density (eggs /sq m, top 5 cm sand) in:	2004	2005	2006	2007
1. New Jersey (no hot-spots)	3,175	5,237	2,551	1,502
2. New Jersey (with hot-spots)	No survey	7,469	3,772	2,006
3. Delaware (all sites)	No survey	49,933	36,687	38,131
4. Delaware (all except Mispillion)	No survey	33,534	16,357	20,664
5. New Jersey index of female crab spawning [1]	0.78	0.99	1.17	0.82
6. Delaware index of female crab spawning [1]	0.76	0.65	0.81	0.96

All egg surveys have shown considerable heterogeneity with especially high densities in protected bays and creek mouths. One New Jersey dataset avoids samples from known hot-spots (Table A, row 1); another includes such sites (row 2); but both show much lower densities than the main Delaware dataset (row 3). The Delaware data include a known hot-spot, Mispillion Harbor; but even if that site is excluded (row 4) the difference in mean density between New Jersey and Delaware is still very large.

In principle, there is no reason why egg densities in New Jersey and Delaware should be very different because the density of spawning females in the same years has been quite similar with even higher numbers in New Jersey than in Delaware in 2005 and 2006 (Table A, rows 5 and 6; Michels *et al.* 2008). It is therefore assumed that there is a systematic difference in habitat quality for spawning crabs between the sites sampled in each state. Discussion is currently under way between the NJ and DE Divisions of Fish and Wildlife with a view to designing a new survey protocol that will facilitate a better comparison of egg densities across Delaware Bay.