Update to the Status of the Red Knot *Calidris canutus* in the Western Hemisphere, April 2011

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Abstract: There has been a major decline in the population of Red Knots that winters in Tierra del Fuego from 16,260 in 2009/2010 to 9,850 (aerial count) or 11,200 (ground count) in 2010/2011. Numbers wintering in Surinam, French Guyana and part of N Brazil declined from 7,575 in February 2005 to 3,660 in January 2011. Apart from an anomalous high count in 2009, the peak number of knots stopping over in Delaware Bay in May has remained fairly constant over 2003-2010 at about 14,500. Poor conditions for horseshoe crab spawning during the May stopover in Delaware Bay in 2008 resulted in only 14% of Red Knots achieving 180g by 26-28 May, but this figure increased to 31% and 42% in 2009 and 2010 respectively when conditions were better (but not as good as they were in 1998 when 87% were over 180g). Despite a decade of horseshoe crab harvest restrictions instigated by the Atlantic States Marine Fisheries Commission, there is still no evidence of recovery of the horseshoe crab population, either in numbers of spawning females or in all sub-adult age groups including juveniles. Greater restrictions imposed by New Jersey and Delaware to help speed recovery have been undermined by concurrent increases in the harvests made in other states. We discuss the reason for the latest decline in the Tierra del Fuego wintering population in the context of the apparently better feeding conditions in Delaware Bay during the 2010 stopover (which were nevertheless much poorer than in 1998).

INTRODUCTION

The purpose of this report is to provide a draft third 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 Red Knots in the United States. We provided a first update in February 2008, which together with the Status Review itself has since been published in Niles *et al.* (2008). A second update was provided in April 2010 (Niles *et al.* 2010). Further updates will be produced as new information becomes available. This update reflects the state of knowledge as of 1 April 2011. It is assumed that readers of this report are familiar with the contents of the Status Review and the first update. This material has not been peer-reviewed. We offer it in the interest of timely information exchange among researchers, managers and others interested in Red Knot conservation. A final update will be produced in the next two months that will undergo full peer review by all co-authors from the Status Review.

WINTER COUNTS

The January 2011 aerial surveys of the Tierra del Fuego wintering population (Chile and Argentina) showed a significant drop in Red Knot numbers since January 2010, from 16,260 to 9,850. Most of this loss occurred on the main wintering site, Bahia Lomas, Chile, where numbers fell from 15,450 in 2010 to 9,450 in 2011. We carried out a ground count at Bahia Lomas in February 2011 which corroborated the decline shown by the aerial survey; the result showed a total of 11,200; this is 1,750 birds more than the January aerial count but a decline of 4,250 compared with that of January 2010. At Rio Grande, Argentina, both aerial and ground counts showed that wintering knots declined from 1,600 in 2008/9 to 750 in 2009/10 and only 400 in 2010/11. The decrease in Tierra del Fuego follows seven years of stable numbers averaging just under 16,500, although only 14,800 were counted in 2007/8. The increase in the following year suggests either that some birds were overlooked in 2007/8 or there was a real decrease (possibly wholly or partly resulting from a mortality event involving at least 1,300 knots on the coast of Uruguay in April 2007 (Niles *et al.* 2008)) that was offset by good productivity in the 2008 breeding season (evidenced by a large proportion of juveniles in catches in Tierra del Fuego in December 2008).

The decline in Tierra del Fuego might be greater in terms of the adult population than the numbers suggest because more than usual numbers of juveniles were seen in both scans and the single catch made at Rio Grande in 2010/11 (A. Baker pers. comm.). This indicates that there was good breeding productivity in 2010. Therefore if productivity had been only normal or poor, the decline would have been even greater.

Table 1. Counts of Red Knots during the northern winters of 2004/5 to 2010/11 in Tierra del Fuego (Argentina and Chile) by R.I.G. Morrison & R.K. Ross, on the west coast of Florida by L. Niles, A.D. Dey & R.I.G. Morrison, and on Mustang Island, Texas, by A.F. Amos (NC = no count).

Location	2004/5	2005/6	2006/7	2007/8	2008/9	2009/10	2010/11
Tierra del Fuego	17,653	17,211	17,316	14,800	17,800	16,260	9,850
Florida west coast	NC	2,500	1,200	550	1,532	1,378	NC
Texas, Mustang Is.	120		117	121	26	55	13
SE United States *	4,543	NC	NC	NC	NC	NC	3,552

* Data from a sample survey of 129 sites along the SE United States coast between Florida and North Carolina by USGS (concurrent with a survey of wintering Piping Plovers *Charadrius melodus*)

Winter counts along a 300-km stretch of the west coast of Florida show that the number of knots was fairly stable over the four winters from 2006/7 to 2009/10, having dropped from 2,500 in 2005/6 (Table 1). There was no aerial survey of the Florida wintering area in 2011, and no simultaneous ground counts, so the current status of that population is not clear. Independent ground surveys of a portion of the aerial survey study area suggests lower numbers in 2010/11. The International Piping Plover Survey, carried out during the 2010/11 winter, included Red Knots. The 2005 Piping Plover Survey counted 3,020 Red Knots in Florida (east and west coasts) and 1,490 from Georgia north to North Carolina (Niles *et al.* 2006). The results of the 2011 International Piping Plover Survey show a reduction of about 1,000 knots from 4,543 to 3,552. The difficulties of counting birds along the US southeast coast, and the possibility that some birds may move outside the areas surveyed, means that there is some uncertainty as to the trend of this population. Nevertheless, it is clear that it is much less than the 10,000 individuals estimated in the 1980s (Morrison & Harrington 1992).

In January 2011, Guy Morrison of the Canadian Wildlife Service and David Mizrahi of New Jersey Audubon Society conducted aerial counts of shorebirds in Surinam, French Guyana and along the north coast of Brazil between Belem and Sao Luis. This revealed a wintering population of 3,660 Red Knots, which compares with 8,846 counted in the same area during the 1982-1985 Shorebird Atlas by Guy Morrison and Ken Ross (Morrison and Ross 1989) (Table 1.) and 7,575 in the relatively short section of the coast of Brazil between Baia da Mutuoca and San Luis in February 2005 (Baker *et al.* 2005). Therefore it appears that there has been a substantial (at least 52%) decline in the north Brazil population between 2004/5 and 2010/11.

DELAWARE BAY COUNTS

The peak number of Red Knots counted in the 2010 aerial survey, 14,475, was similar to average count for 2003 to 2008 of 14,355 (Fig.1). In 2009, no aerial count was carried out during peak migration because of mechanical problems with the aircraft and low cloud.

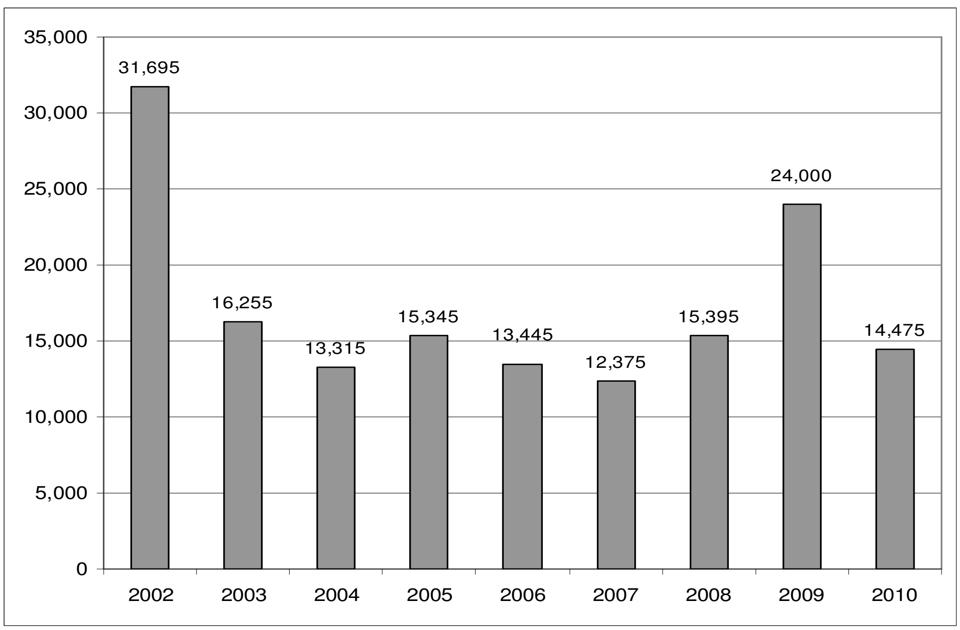

Fig. 1. Peak aerial count of Red Knots in Delaware Bay during spring stopover 2002-2008 and 2010; the figure for 2009 is a peak ground count made on 26 May (See Niles *et al.* 2010).

From 1986 to 2008, shorebirds in Delaware Bay in May and early June were monitored by a weekly aerial count organized by K.E. Clark who retired from this onerous task in 2008. This afforded an appropriate opportunity to reconsider the methodology. Previously, the aerial survey had covered the shoreline of Delaware Bay following the route shown in Fig. 33 of Niles *et al.* (2008), but because the aircraft had flown out and back along the length of the Mispillion Harbor entrance channel, the inner harbor, a high-use area for knots and other shorebirds, was poorly covered. Also, it has recently been realized that in some years varying numbers of knots (from very few up to about 4,000) habitually feed on mussel spat in the Atlantic marshes near Stone Harbor, an area that was not covered by the aerial survey, but flag resightings show that these birds also feed in Delaware Bay. The new survey methods devised for 2009 ensured better coverage of both areas by including a ground count of

Mispillion Harbor and by the flight including the Atlantic coast marshes at Stone Harbor. It was accepted that the results might show an increase that would only reflect more complete survey coverage. It should be noted that small numbers of knots, usually tens to a few hundred, have sometimes been recorded in May farther north along the New Jersey coast (e.g. at Brigantine). These have never been monitored by regular surveys and there are no current plans to include them in future.

Although no aerial count of the peak stopover population could be carried out in 2009, on 26 May 2009 there was a ground count of 27,187; of these by far the majority was in Mispillion Harbor, Delaware, with only a few hundred elsewhere in Delaware and 900 in New Jersey. Because most of the birds were in Mispillion Harbor and it was believed that past aerial counts had underestimated numbers in that key location, we considered that a more appropriate figure to put alongside data for earlier years was 24,000, as explained in Niles *et al.* (2010). The much lower aerial count of 2010 appears to throw some doubt on the high 2009 ground count. However, most single-day counts underestimate the total number of knots stopping in Delaware Bay because of turnover (Gillings *et al.* 2009). In 2009 the extraordinarily high ground count might have occurred in the probably unusual circumstance that almost all birds had arrived and few had departed. One reason for believing that this may have been the case is that the day after the high ground count, 27 May, the first mass departures of Red Knots took place. Therefore the large numbers seen in Mispillion Harbor may have been a pre-departure "staging event", similar to those observed in Delaware Bay in earlier years. Moreover, this count is not inconsistent with abundances observed in the flyway as a whole (Table 3). Whatever the reason for the high count of 26 May 2009, surveys in the wintering areas before and after May 2009 do not indicate that a substantial increase in the Red Knot population took place (Table 1).

DELAWARE BAY STOPOVER FEEDING CONDITIONS

Although it has long been assumed that the availability of horseshoe crab eggs is the key determinant of whether knots achieve an adequate mass to support their flight to the Arctic by the time of their target departure date (e.g. Niles *et al.* 2008), the lack of a sufficiently long run of egg data has hitherto precluded us from demonstrating this relationship. Only since 2005 have eggs in the top 5 cm of sand been sampled using the same methods on both sides of the bay. Therefore in an attempt to investigate the relationship between the proportion of knots in cannon-net catches during 26-28 May that have achieved at least 180g and egg densities, we have plotted these two parameters using the median of the New Jersey and Delaware egg densities for 14-27 May 2005-2010. This shows a positive and significant relationship (Fig. 2). Therefore we can be confident that conservation action to increase the densities of horseshoe crab eggs on the Delaware Bay beaches will be of real benefit to the knots in enabling them to achieve adequate departure mass by the time they need to leave for the Arctic.

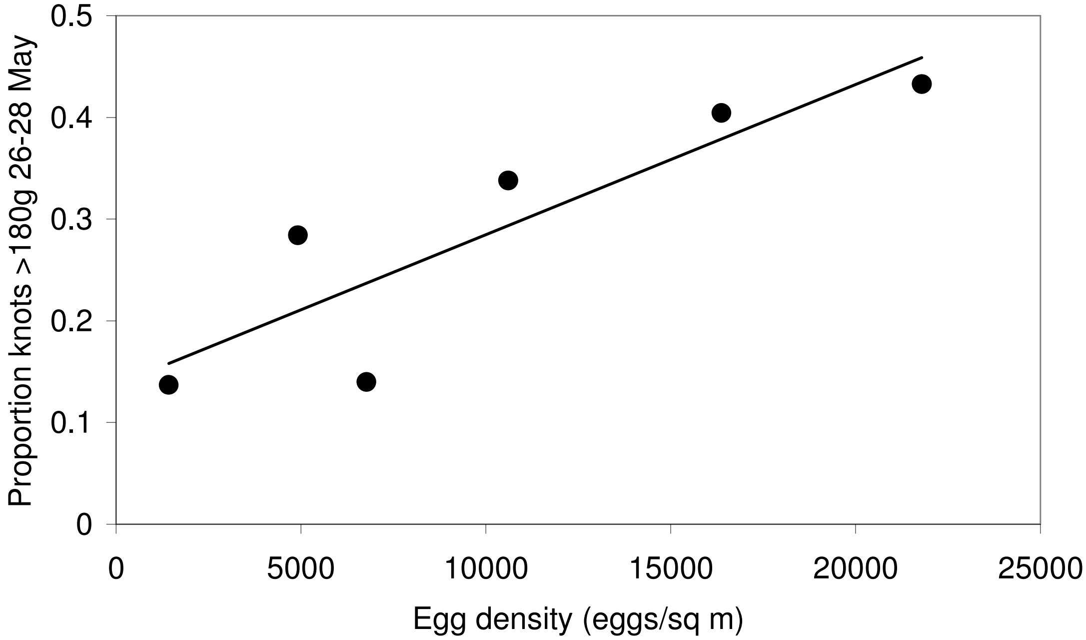

Fig. 2. Proportion of Red Knots in the >180 g body-mass category in Delaware Bay during 26-28 May plotted against the median horseshoe crab egg density during 14-27 May 2005-2010 for Delaware (excluding Mispillion Harbor) and New Jersey ($R_s = 0.94$, $p = 0.021$).

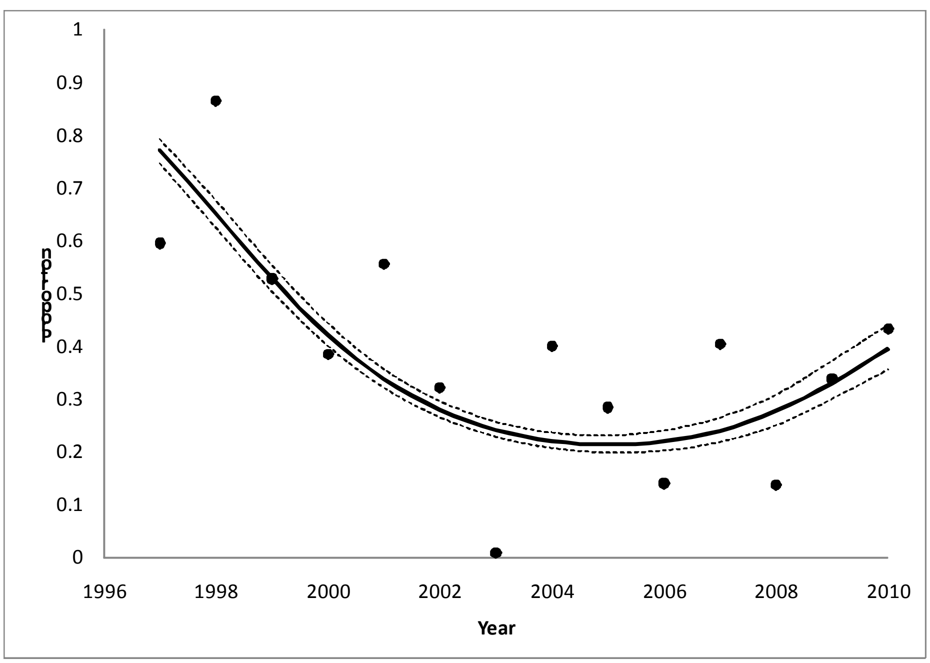

Fig. 3. Proportion of Red Knots in the >180 g body-mass category in Delaware Bay near the usual departure time each year (26-28 May) over 1997–2010. The line shows a significant quadratic trend over 1997-2010 (the trend line (±95% confidence intervals in respect of the line, not the variation in the data) was fitted using binary logistic regression of body mass >180g (1 = yes, 0 = no) on year (negative, $p<0.001$) and year^2 (positive, $p<0.001$)). The strength of the quadratic trend owes much to the very low proportion recorded in 2003, but it is still significant if the 2003 data are omitted.

The proportion of birds in cannon-net catches reaching 180g by 26-28 May, the assumed target mass and target departure dates of the stopover (Niles *et al.* 2009), increased in 2009 and 2010 indicating better feeding conditions compared with several recent years (Fig. 3). The 2009 and 2010 horseshoe crab breeding seasons were remarkable for their lack of significant bad-weather events thus allowing crabs to breed throughout the month of May and on a wider range of bay beaches because of a lower prevalence of strong onshore winds. This was in contrast with 2008 when a strong north-easterly storm on 12 May altered spawning habitat and lower water temperatures led to reduced spawning activity throughout May (Michels *et al.* 2009) and lowered egg densities (Table 2). In that year only 14% of knots caught had achieved 180 g by 26-28 May, but in 2009 the figure had climbed to 31% and in 2010 it was 42%, the highest since 2001 (Fig. 3). This increase must be considered with some caution because in 2001 the food supply was supporting over twice the number of shorebirds on Delaware Bay. Nevertheless the year-on-year trend in the proportion of knots caught at ≥180g during 26-28 May has now changed from a linear decline to a quadratic relationship resulting from the recovery in recent years. Much of the strength of the quadratic can be attributed to the exceptionally low proportion of birds over 180g in 2003, but it is still significant if the 2003 data are omitted (Fig. 3). In some years Red Knots can be seen departing from Delaware Bay as early as 25 May, while in others the first departures are not recorded until 28 May or later. Therefore the proportion of the whole stopover population that is present in the bay and available to be caught during 26-28 May varies from year to year and cannot take account of those birds that achieve an adequate mass and depart early. Therefore data on the proportion of birds caught at ≥180 g during 26-28 May should be treated with caution. Nevertheless it is a metric that shows a significant positive correlation with the availability of horseshoe crab eggs during 14-27 May, which gives it credibility as a measure of the bird's success in obtaining the resources they need at the time those resources are required (Fig. 2).

This improvement in birds reaching sufficient departure weight was a direct effect of increasing egg densities in both New Jersey and Delaware (Fig. 2, Table 2). New Jersey egg densities in 2009 and 2010 were only marginally lower than those recorded in 2005, the benchmark year for the egg density index and the first year eggs were counted on both sides of the bay using the same method. During 2005-2010, egg densities in Delaware were invariably higher on average than in New Jersey and were far higher if Mispillion Harbor is included with the rest of the Delaware data (Fig. 4). Densities in Mispillion Harbor averaged 769,000/m^2 in 2010. Excluding this one site brought Delaware's average down to 33,006/m^2, which is similar to that of 2005. Here we treat egg densities in Mispillion Harbor separately from the remainder of the Delaware shore in order to accurately reflect foraging conditions for shorebirds along the bayshore as a whole, while understanding that the egg resources in Mispillion Harbor likely has a very positive effect on Red Knots gaining weight. The knot population that the bay can support might be much lower if it were not for the extremely high egg densities in Mispillion Harbor.

The egg density indices presented here (Table 2) show a recovery in 2009 and 2010 after the all-time low figures for 2008; however, in both New Jersey and Delaware the index is still no higher than it was 2005 when the first baywide surveys were conducted. Mean egg densities, exclusive of Mispillion Harbor, were 33,006/eggs m^2 in Delaware and 5,008/eggs m^2 in New Jersey. These are much lower than the 50,000 eggs/m^2 over 50% of suitable spawning beaches recommended by Niles *et al.* (2009) as a minimum management target to begin recovering the Red Knot population.

The increase in egg densities cannot be attributed to greater abundance of horseshoe crabs. There are three main surveys for horseshoe crabs, two carried out in Delaware Bay during the spawning season (the Delaware 30-foot Trawl Survey and Delaware Bay Spawning Crab Survey) and one carried out in the Atlantic Ocean in the fall after crabs move out of Delaware Bay onto the Atlantic continental shelf (the Virginia Tech Benthic Trawl). The Delaware Bay Spawning Crab Survey shows that there has been no significant trend in the density of breeding females during 1999-2009, but males have shown a significant year-on-year increase and in 2009 outnumbered females by 4.7 to 1 (Table 2) (Michels *et al.* 2010). However, the increase in spawning males only occurred on the New Jersey beaches, and there was no such trend in Delaware (S. Michels, pers. comm.).

Fig. 4a.

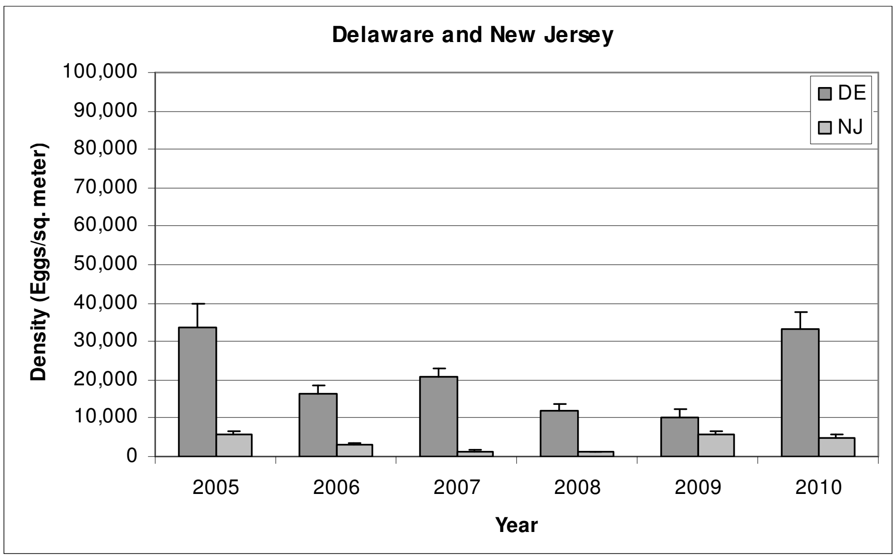

Fig. 4b.

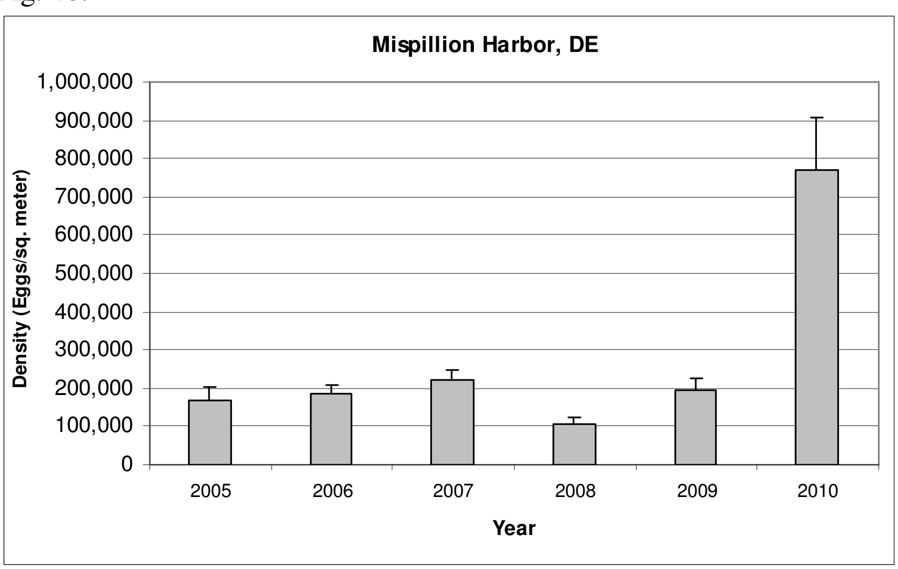

Fig. 4. Density of horseshoe crab eggs in the top 5 cm of sand of Delaware Bay beaches during May and early June 2005-2010: (a) the bay beaches of Delaware and New Jersey, (b)

Mispillion Harbor; note difference in scale (Source: Delaware Division of Fish and Wildlife and the New Jersey Division of Fish and Wildlife).

The Delaware 30-foot Trawl Survey showed lower numbers of adult horseshoe crabs in Delaware Bay in 2010 than in 2009 but so significant trend over 2004-2010. The 2010 average of 0.75 crabs/tow is far lower than that of 1989 when it was >7 crabs/tow.

The Virginia Tech Benthic Trawl shows no significant change in the number of mature or newly mature males or females over 2001-2010 (Fig. 5). The ratio of mature males to mature females in this survey in 2009 was 2.19:1. The ratio of males to females increased in 2010 to approximately 2.9:1. This is an important parameter because ratios of 3 to 1 or higher trigger harvests of males in the new Adaptive Resource Management (ARM) Model. It is worth noting that the sex ratio of juvenile crabs is close to 1:1; the ratio of males to females increases in newly mature crabs, and the difference is greatest in mature crabs. This indicates that despite reductions in the number of females allowed in harvests, the current harvests are depressing the female population which has shown no sign of recovery during the nine years of this survey. While numbers of juveniles had been increasing from 2005 to 2009; in 2010, juvenile abundance declined.

There is no evidence of a significant increase in the mature horseshoe crab population in the Delaware Bay Spawning Crab Survey, the Delaware 30-foot Trawl Survey or the Virginia Tech Benthic Trawl Survey. Therefore, it seems likely that the improved feeding conditions for Red Knots in 2009 and 2010 arose largely because of a closer match between the timing of crab spawning and the birds' stopover resulting from the unusually settled weather in both years.

Table 2. Population parameters of horseshoe crabs in Delaware Bay for 2004-2010.

	2004	2005	2006	2007	2008	2009	2010[4]	Trend	Source
Spawning females (index)	0.77	0.82	0.99	0.89	0.68	1.00	Not available	None [3]	Michels *et al.* 2010
Spawning males (index)	2.93	3.23	3.99	4.22	2.30	4.67	Not available	Increase[3]	Michels *et al.* 2010
Egg density New Jersey (index) [1]	55	100	50	27	23	96	87	None	NJDFW per D. Hernandez
Egg density Delaware (index) [1]	No survey	100	73	123	52	85	272	Increase	DEDFW per K. Kalasz
Egg density Delaware exc Mispillion (index) [1]	No survey	100	49	62	35	30	98	None	DEDFW per K. Kalasz
Delaware Trawl Survey (geo-mean) [2]	0.06	0.20	1.37	1.72	0.77	1.06	0.75	None [3]	S.F. Michels pers. comm.

[1] In top 5 cm of sand, 2005 = 100
[2] Data relate to trawls during April-July
[3] Trend relates to 1999-2009
[4] No data from the horseshoe crab spawning survey were available when this version of the report was prepared in March 2011; such data will be added later.

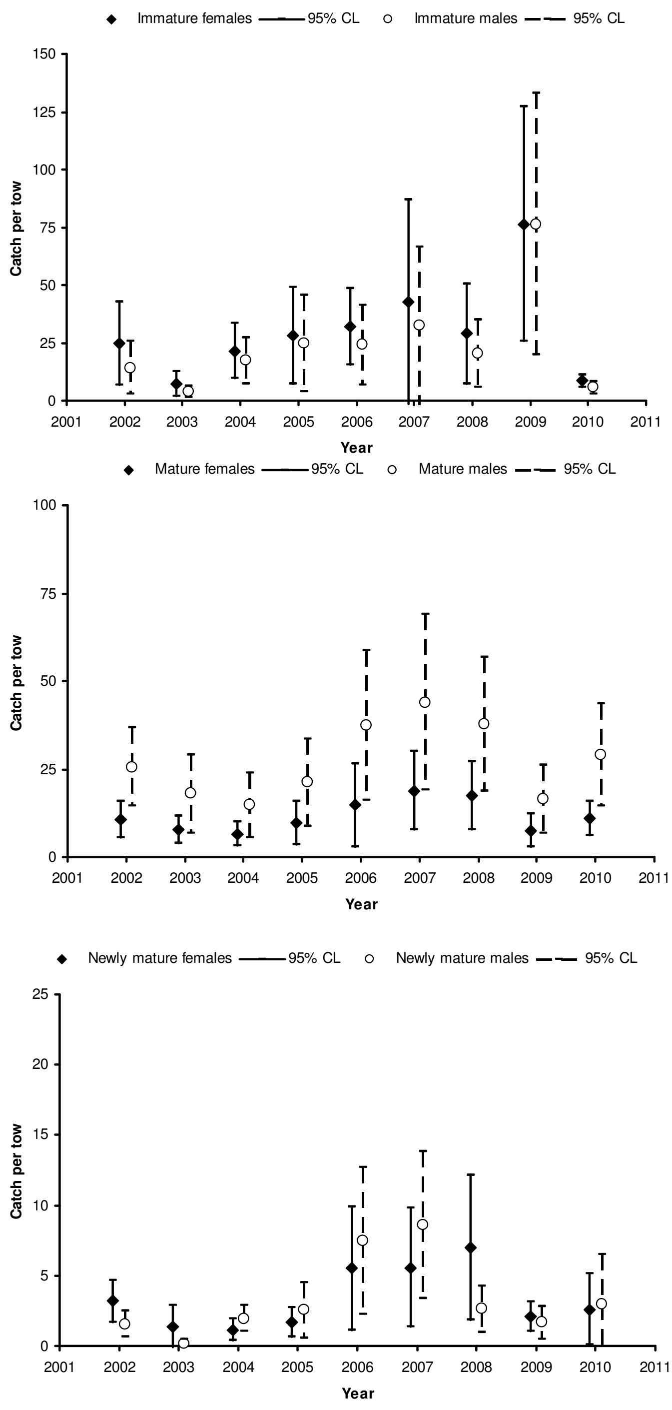

Fig. 5. Plots of stratified (delta distribution) mean catches per tow of horseshoe crabs in the Virginia Tech Delaware Bay Offshore Trawl Survey (Hata & Hallerman pers comm..) by sex and demographic group: (a) immatures, (b) newly mature adults and (c) mature adults by demographic group (± 95% confidence limits). The survey area is within 12 nautical miles of the coast and from 37°40'N to 39°20'N, but excludes Delaware Bay itself. Note different y-axis scales.

After reaching a peak in 1998, management actions by the Atlantic States Marine Fisheries Commission and various states have led to a reduction in the annual harvest of horseshoe crabs taken in the mid-Atlantic region to a mean of 577,895 crabs over 2004-2009 (Fig. 6). In 2006, a full moratorium on horseshoe crab harvesting was imposed in New Jersey and greater harvest restrictions were applied in Delaware in an effort to speed recovery. However, despite these actions the total harvest has not decreased (Fig. 6) indicating that other states have increased their harvest.

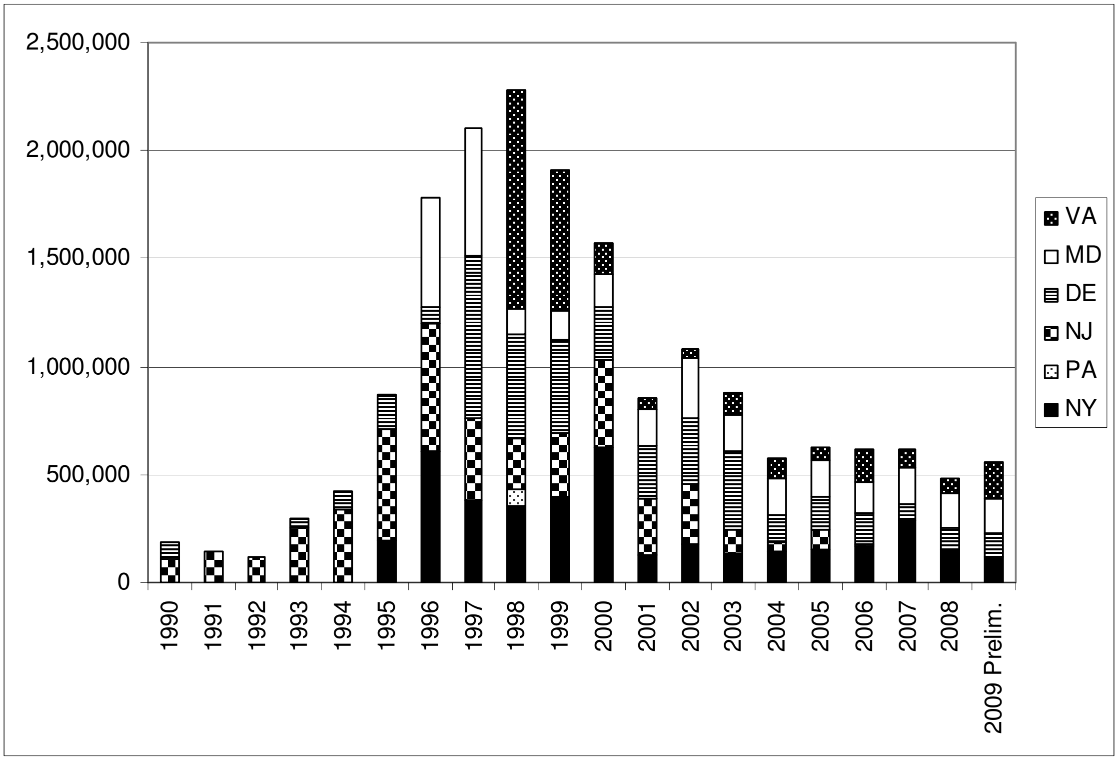

Fig. 6. Reported Atlantic coast horseshoe crab landings 1990-2009 for mid-Atlantic states; note that reporting was not compulsory until 1998 so earlier figures may underestimate the true harvest (NMFS Commercial Fishery Landings Database 2009).

All three measures of horseshoe crab numbers have shown no significant signs of increase and the improvement of Red Knot weights in 2009 and 2010 is most likely a result of the unusually settled weather of those two years. More usual, poorer weather could produce dramatically different outcomes for the birds. Moreover the hopeful sign of increasing numbers of juvenile horseshoe crabs in the offshore survey evaporated with a virtual absence of juveniles in the 2010 survey. No survey shows an increase in mature and newly mature females - the most important demographic groups in terms of producing eggs for the birds.

The management of horseshoe crab harvests has only been enough to stop the population from declining further after the major losses resulting from the uncontrolled over-harvest of the late 1990s. However, harvest restrictions have been insufficient to allow the recovery of the population; moreover it is now clear that they will continue to be insufficient unless the harvest is further reduced. Even if there is an immediate substantial reduction, in view of the fact that horseshoe crabs take nine years to reach maturity, the population is unlikely to show significant recovery for some time.

US EAST COAST COUNT OF RED KNOTS IN MAY

Since 2006, A.D. Dey has coordinated a count of Red Knots along the whole US east coast from Florida to Delaware Bay during two days in the period 20-24 May when it is thought that peak numbers normally occur along the coast as a whole (though not necessarily in any one locality). Coverage has been patchy, but was fairly comprehensive in 2009 & 2010 apart from limitations caused by foul weather in the southeast in 2009 that precluded a survey in Georgia and made conditions difficult in South Carolina and Florida (Table 3). All states were covered in 2010 producing a total estimate of 25,328 birds. Over 2006-2010 there has been no change in numbers that cannot be attributed to varying coverage.

Table 3. Counts of Red Knots along the US east coast from Florida to Delaware Bay carried out over two consecutive days during 20-24 May in each year from 2006 to 2010.

State	2006	2007	2008	2009*	2010
New Jersey	7,860	4,445	10,045		8,945
Delaware	820	2,950	5,350	16,229	5,530
Maryland	ns	ns	663	78	5
Virginia	5,783	5,939	7,802	3,261	8,214
North Carolina	235	304	1,137	1,466	1,113
South Carolina	ns	125	180	10	1,220
Georgia	796	2,155	1,487	ns	260
Florida	ns	ns	868	800	41
Total	**15,494**	**15,918**	**27,532**	**21,844**	**25,328**

*2009 Delaware Bay (NJ + DE) count calibrated by ground counts

Making allowance for those parts of the coast that were not covered and the likelihood that most or all juveniles of the South American wintering populations do not migrate northwards, the 2010 east coast count suggests a flyway population of probably just under 30,000. This is at least 6,000 more than the sum of known wintering populations in 2009/2010 and suggests that there may be significant undiscovered wintering sites. In view of the most recent decline in numbers wintering in Tierra del Fuego, the total population of *rufa* is now unlikely to be more than about 25,000.

REASON FOR THE LATEST DECLINE IN THE TIERRA DEL FUEGO WINTERING POPULATION

In view of the relatively good feeding conditions in Delaware Bay in May 2010 (see above), it would seem possible that the reason for the steep decline in the Tierra del Fuego wintering population recorded in January 2011 lies elsewhere. We have no direct evidence of the explanation, though survival analyses might eventually identify the season in which higher-than-usual mortality took place.

Several largely inexplicable mortality events have been reported to affect presumed Tierra del Fuego winterers during migration along the coast of South America, especially in Uruguay and S Brazil (Niles *et al.* 2008, Buehler *et al.* 2010); and we have just received a report from Carmem Fedrizzi of yet another in Rio Grande do Sul, Brazil, in April 2011 when 40 knot corpses were collected for analysis. However, we have no evidence that such an event took place between January 2010 and January 2011 that might have accounted for the steep decline in numbers recorded in Tierra del Fuego.

Greater than usual mortality might also occur during migration if large numbers of birds are driven off course by storms while crossing the Atlantic Ocean. Knots fitted with geolocators were apparently diverted considerable distances across the ocean by adverse weather during southward migration in 2009 (Niles *et al.* 2010). This must result in considerable additional energy expenditure, which on some occasions might lead to mortality. There is evidence that the frequency and severity of tropical storms in the North Atlantic has increased in recent decades and may continue to do so as a consequence of climate change (Pew Center on Global Climate Change 2011). This could possibly explain some recent losses in the *rufa* population and might become an important factor causing mortality in future.

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