An Investigation of Stopover Ecology of the Red Knot on the Virginia Barrier Islands.

The Center for Conservation Biology
The College of William and Mary

February 2008

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2008
Report

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Cover photo of foraging Red Knots by Barry Truitt, The Nature Conservancy.

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Recommended Citation:

Smith, F.M., A. E. Duerr, B.J. Paxton and B.D. Watts. 2008. An Investigation of Stopover Ecology of the Red Knot on the Virginia Barrier Islands. Center for Conservation Biology Technical Report Series, CCBTR-07-14. College of William and Mary, Williamsburg, VA. 35pp.

Project Funded By:

Virginia Coastal Zone Management Program
(Department of Environmental Quality)

The Center for Conservation Biology
College of William and Mary

This project was funded in part by the Virginia Coastal Zone Management Program at the Department of Environmental Quality through Grant #NA*06NOS4190241* of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, under the Coastal Zone Management Act of 1972, as amended. The views expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Department of Commerce, NOAA, or any of its subagencies.

TABLE OF CONTENTS

Executive Summary..... iii

BACKGROUND..... 1
Context 1
Objectives..... 2

METHODS..... 2
Study Area..... 2
Survey Protocol..... 2
Resight Protocol..... 2
Data Summary and Analysis 4

RESULTS..... 5

DISCUSSION..... 15

ACKNOWLEDGMENTS..... 17

LITERATURE CITED..... 17

APPENDIX I..... 20

APPENDIX II..... 21

APPENDIX III..... 22

EXECUTIVE SUMMARY

The Virginia barrier island chain plays a significant role in the life cycle of many of the most vulnerable shorebird species in North America. The large areas of relatively undisturbed beach and marsh habitat available to shorebirds during the migratory period, along with the strategic geographic position of the region for migrants, combine to make this one of the most important stopover regions in eastern North America.

One of the shorebird species that utilizes the Virginia barrier island system is the Western Hemispheric subspecies of Red Knot (*Calidris canutus rufa*). The *rufa* subspecies migration is one of the longest in the world as they routinely fly over 30,000 km each year (Harrington *et al.*, 1988, Clark *et al*., 1993). Over the past 20 years, the *rufa* population of Red Knot within North America has declined by approximately 80-90% (Piersma and Davidson, 1992, Baker *et al*., 2000, Morrison *et al*., 2004, Niles *et al*., unpublished data). Concern for this species led to an application to the U.S. Fish and Wildlife Service for fast track consideration for federal listing under the Endangered Species Act and a large-scale investigation of conflicts between migrant shorebirds and the Horseshoe Crab (*Limulus polyphemus*) industry (Baker *et al*., 2004, Morrison *et al*., 2004). Most of the conservation efforts to date have focused on the Delaware Bay where the Red Knot is a horseshoe crab egg specialist (Harrington, 1996, Tsipoura and Berger, 1999, Karpanty *et al*., 2006). It is increasing evident that the specialized feeding adaptations of Red Knots using the Delaware Bay, coupled with the lack of adequate horseshoe crab egg density, increases their risk for adult mortality, which is the single most important factor influencing shorebird survival (Davidson and Piersma 1992, Hitchcock and Gratto-Trevor 1997, Baker and Piersma 2000).

In the mid-1990s 3 years of aerial surveys showed that numbers of knots moving through the barrier islands of Virginia between mid-May and the second week of June reach 8,000-10,000 individuals (Watts and Truitt 2000). A single survey on 25 May 2005 showed similar numbers (Watts and Truitt, unpublished data). This compares to approximately 13,000 birds using Delaware Bay in 2006 (Niles *et al*., unpublished data). These findings suggest that the Virginia barrier islands may have more significance to the species than previously believed. Knots using Virginia as a stopover site, unlike the birds staging in Delaware Bay, and similar to knots utilizing other stopover areas (Harrington, 1986, Gonzalez *et al*., 1996), do not depend on horseshoe crabs as a food source (Truitt *et al*., 2001). There are many questions yet to be addressed for knots staging in Virginia that may have broad implications for the future conservation of this species.

A total of 6 barrier islands were intensively surveyed during the 2007 migration season. A total of 60 line transect surveys were conducted between 28 April 2007 and 18 June 2007 on the barrier islands. Transects were positioned to cover the barrier islands with the most Red Knot use. A total of 18,770 Red Knots were detected on surveys, with 12,580 of those knots scanned and resighted, of which 642 were banded. A total of 277 individually marked Red Knots were detected at least once during the spring 2007 migration season.

BACKGROUND

Context

Birds are essential components of natural ecosystems and effective indicators of environmental health. An increased concern for the status of many North American shorebird populations has resulted in an escalation of monitoring and management efforts. Much of this concern has been focused upon the many species of Neotropical migratory shorebirds (species that migrate between breeding grounds in the arctic latitudes of North America and wintering grounds in Central and South America and the Caribbean) that have exhibited substantial population declines in recent decades.

The Virginia barrier island chain plays a significant role in the life cycle of many of the most vulnerable shorebird species in North America. The large areas of relatively undisturbed beach and marsh habitat available to shorebirds during the migratory period, along with the strategic geographic position of the region for migrants, combine to make this one of the most important stopover regions in eastern North America.

One of the shorebird species that utilizes the Virginia barrier island system is the Western Hemispheric subspecies of Red Knot (*Calidris canutus rufa*). The *rufa* subspecies migration is one of the longest in the world as they routinely fly over 30,000 km each year (Harrington *et al.*, 1988, Clark *et al*., 1993). Over the past 20 years, the *rufa* population of Red Knot within North America has declined by approximately 80-90% (Piersma and Davidson, 1992, Baker *et al*., 2000, Morrison *et al*., 2004, Niles *et al*., unpublished data). Concern for this species led to an application to the U.S. Fish and Wildlife Service for fast track consideration for federal listing under the Endangered Species Act and a large-scale investigation of conflicts between migrant shorebirds and the Horseshoe Crab (*Limulus polyphemus*) industry (Baker *et al*., 2004, Morrison *et al*., 2004). Most of the conservation efforts to date have focused on the Delaware Bay where the Red Knot is a horseshoe crab egg specialist (Harrington, 1996, Tsipoura and Berger, 1999, Karpanty *et al*., 2006). It is increasing evident that the specialized feeding adaptations of Red Knots using the Delaware Bay, coupled with the lack of adequate horseshoe crab egg density, increases their risk for adult mortality, which is the single most important factor influencing shorebird survival (Davidson and Piersma 1992, Hitchcock and Gratto-Trevor 1997, Baker and Piersma 2000).

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Objectives

In recent months a consortium of groups including Virginia Tech. University, The Nature Conservancy, the Virginia Department of Game & Inland Fisheries, the U.S. Fish and Wildlife Service, and the Center for Conservation Biology has formed to initiate a research program to answer several of the open questions regarding Red Knots on the seaside of Virginia. Staff from the Center for Conservation Biology, along with volunteers from other organizations, have resighted Red Knots opportunistically during the past few years. These resights revealed that a large number of Red Knots passing through Virginia were banded throughout their entire breeding, migratory, and wintering range. There have been no systematic surveys of the barrier island chain for banded Red Knots up until this point. The primary objectives (from Kalasz, 2006) of this study were:

1) To systematically survey for Red Knots and collect resights from individually marked birds to estimate residency times and local movements.

2) To allow all project partners to collect resight data from Red Knot flocks in a standardized way using established protocols.

3) To build a resight database that will contribute to ongoing flyway and demographic analyses being conducted throughout the species range.

Other objectives of this study were:

4) To look at the temporal distribution of the Red Knot in migration.

5) To look at spatial distribution of the Red Knot on the barrier islands.

METHODS

Study Area

Pared line transect surveys were conducted on 6 islands in Northampton County and on Parramore Island in Accomack County (See Figure 1 for specific locations of transects, see Appendix I for the coordinates for these transects). The Virginia barrier islands consist mainly of sandy beach on the ocean side and tidal marsh on the mainland side.

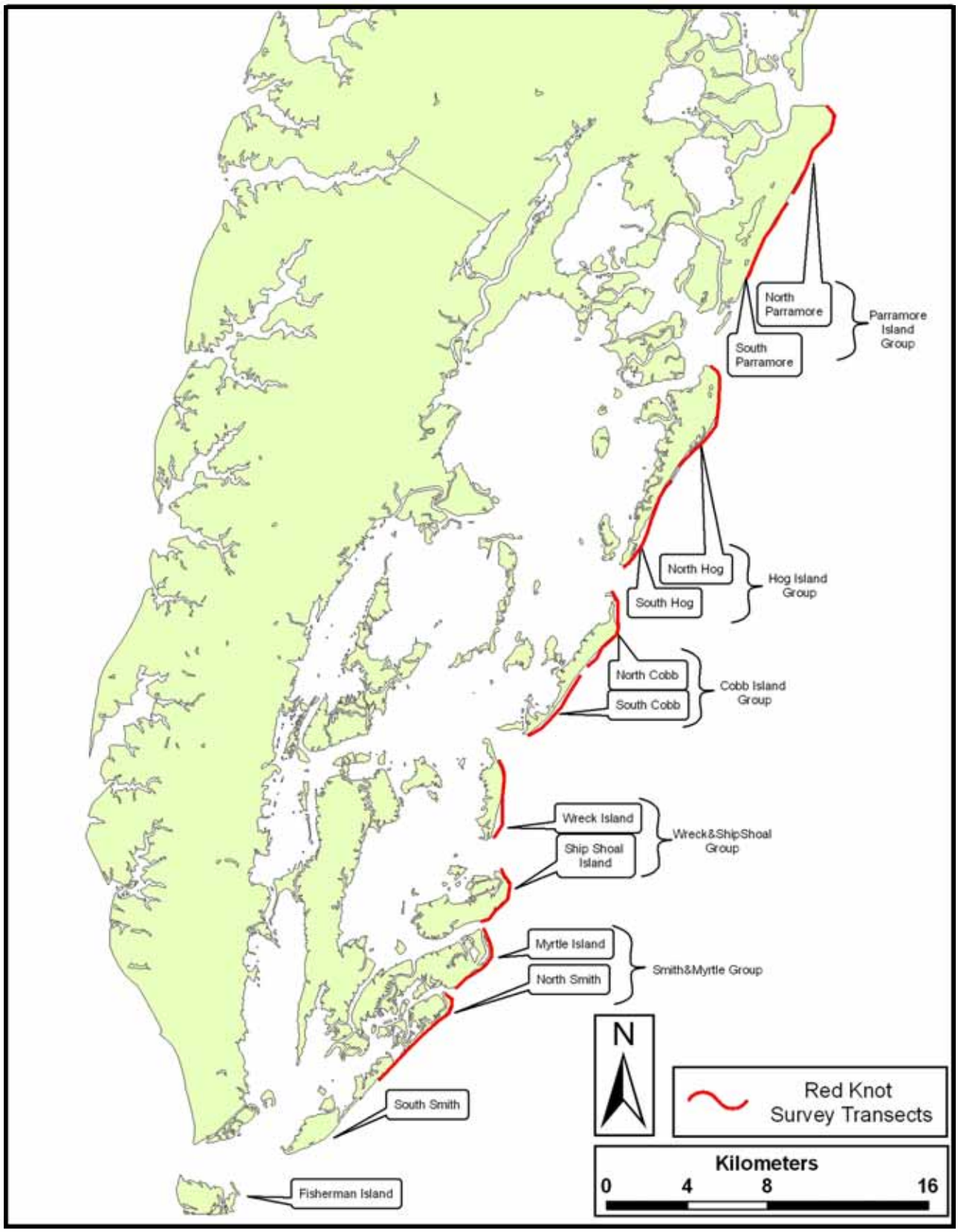

Figure 1. Map of study area within the Virginia barrier island chain. Line transects are denoted by red lines.

A portion of islands surveyed have exposed peat banks during low tides. There is little to no accessibility to the islands by humans which decreases the amount of disturbance to migrant shorebirds.

Transects were selected for highest use by Red Knots based on previous years aerial survey data (Watts and Truitt 2000, Watts and Truitt, unpublished data), and were subject to change based on concurrent aerial survey data (Watts and Truitt, unpublished data).

Survey Protocol

Surveyors used Leica Televid 77 APO scopes with a 20-60 zoom eyepiece to observe Red Knot flocks and bands. All surveys were conducted approximately 1.5 hours before low tide to 1.5 hours after low tide to encounter Red Knots during the peak foraging period (Alerstam *et al*. 1992). All islands were systematically surveyed 1-2 times per week between 28 April 2007 and 18 June 2007 except for Cobb Island, which was dropped from the survey schedule after two rounds due to low numbers of knots detected. All line transect surveys covered the entire length of the island except for the Smith Island transect, which covered the northern section of the island. Data recorded include the time of encounter with the Red Knot flock, date of encounter, the GPS coordinates of the encounter, total flock size, band combination, and total number of banded vs. unbanded birds within the flock. Project partners collected resights opportunistically. Other bird species encountered during the survey transect were counted and recorded (see Appendix II for a list of all species encountered).

Resight Protocol

Established resight protocols (Kalasz, 2006) were used for the 2007 season. The surveyor, upon encountering a group of Red Knots, scanned through the flock until finding a marked bird. The total number of unbanded birds scanned before finding a knot with a color band was recorded when possible. Probable cohort birds were recorded along with individually marked birds. Color combinations were recorded from left to right and top to bottom.

Data Summary and Analysis

Band combinations were filtered to separate probable cohort banded birds from individually marked birds. These unique band combinations were then used to investigate patterns of Red Knot stopover along the Virginia barrier islands. All birds from Chile, Brazil, and the Arctic were considered individually marked birds. Birds with dark green or lime green flags were considered as individually marked if the flag had an alpha-numeric combination or if the bird had 5 or more color bands. Birds with an orange flag were all recorded as individuals. We encountered several band combinations that were considered unique that did not have flags associated with them (see Appendix III for a list of all individually banded knots encountered in 2006 and 2007). Probable cohort combinations were recorded in the field but were not used for mark-recapture analysis.

Survey data were summarized to determine the overall number of Red Knots encountered, the overall number of Red Knots scanned, and the overall number of Red Knots resighted. The proportion of banded Red Knots was also analyzed temporally. The temporal shift in the numbers of Red Knots and the spatial use of Red Knots is presented in the results.

RESULTS

A total of 6 barrier islands were intensively surveyed during the 2007 migration season. A total of 60 line transect surveys were conducted between 28 April 2007 and 18 June 2007 on the barrier islands. Transects were positioned to cover the barrier islands with the most Red Knot use. During the 2007 season, Cobb Island had too few Red Knots to justify intensive resighting effort and was dropped from the survey schedule.

A total of 18,770 Red Knots were detected on surveys, with 12,580 of those knots scanned and resighted, of which 642 were banded (See Tables 1-3 for cumulative resight summaries). A total of 277 individually marked Red Knots were detected at least once during the spring 2007 migration season.

The numbers of knots using the barrier islands as a stopover site changed temporally and differed spatially in the study. The peak number of knots detected, scanned, and resighted coincided with the peak number of knots detected in aerial surveys (Watts and Truitt, unpublished data). During the 3 week peak of migration, 90% of total Red Knot detections were recorded.

Table 1. The temporal shift in the number of knots detected per week, the total number of knots scanned per week, and the total number of bands recorded per week. Also included is the total percentage of knots scanned per week and the proportion of banded knots within the population per week.

Survey Round	Total # of Knots Detected	Total # and % Scanned	Total # and % Banded
1 (4-28 to 5-5-2007)	197	191(97.1%)	9 (4.7%)
2 (5-9 to 5-14-2007)	1488	1179 (79.2%)	65 (5.5%)
3 (5-15 to 5-24-2007)	5451	3225 (59.2%)	131 (4.1%)
4 (5-25 to 5-31-2007)	7550	4912 (65.1%)	271 (5.5%)
5 (6-1 to 6-9-2007)	3894	2933 (75.3%)	155 (5.3%)
6 (6-10 to 6-18-2007)	190	140 (73.7%)	11 (7.9%)
Totals	**18,770**	**12,580 (67.0%)**	**642 (5.1%)**

Table 2. The spatial distribution of the number of knots detected by island, the total number of knots scanned by island, and the total number of bands recorded by island. Also included is the total percentage of knots scanned and the proportion of banded knots within the population by island.

Location	Total # of Knots Detected	Total # and % Scanned	Total # and % Banded
Parramore Island	3,228	2,543 (78.8%)	127 (5.0%)
Hog Island	11,874	7743 (65.2%)	364 (4.7%)
Cobb Island	5	5 (100%)	1 (20%)
Wreck Island	736	574 (78.0%)	29 (5.1%)
Ship Shoal Island	307	252 (82.1%)	13 (5.2%)
Myrtle Island	1,148	690 (60.1%)	31 (4.5%)
Smith Island	835	442 (5.3%)	35 (4.2%)
Fisherman Island	637	332 (52.1%)	42 (12.7%)
Totals	**18,770**	**12,580 (67.0%)**	**642 (5.1%)**

Table 3. Total density of knots detected per island and the total density of resights per island.

Location	Knots/km	Resights/km
Parramore Island	53.80	2.12
Hog Island	107.95	3.31
Cobb Island	0.42	0.08
Wreck Island	30.67	1.21
Ship Shoal Island	14.62	0.62
Myrtle Island	63.78	1.72
Smith Island	34.79	1.46
Mean ± SD	**43.7 ± 35.6 SD**	**1.5 ± 1.0 SD**

We analyzed data of observations of individually marked knots using a mark-recapture framework (Cormack-Jolly-Seber modeling of recaptures) using Program MARK (White and Burnham, 1999). This analysis framework requires initial marking of Red Knots and subsequent observations (resights). Initial marking of knots occurred when they were first observed. Using these definitions, individual knots could enter the marked population at any time during the field season (5 May to 12 June 2007; see Fig. 2).

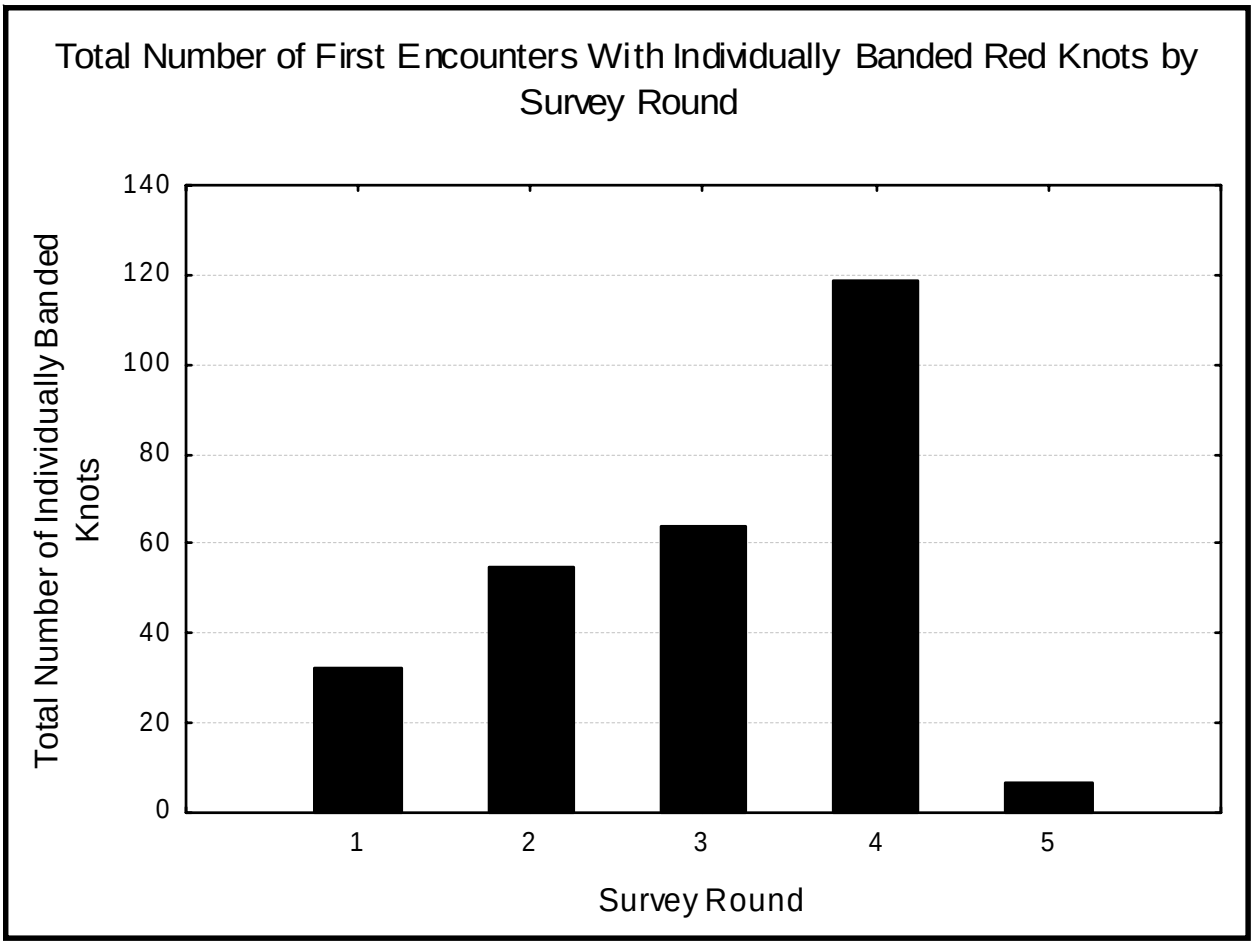

Figure 2. Survey round that individually marked Red Knots were first observed along the Virginia barrier islands in 2007 (Round 1= 5-5 to 5-14, round 2= 5-15 to 5-23, round 3= 5-24 to 5-27, round 4= 5-30 to 6-4, and round 5= 6-5 to 6-12 for all mark-recapture analysis.

Analysis of the mark-resight dataset allows us to estimate apparent survival and resight probabilities. Apparent survival is the joint probability that an individual survives from one day to the next and remains within the study area. For Red Knots that stop along the Virginia barrier islands during migration, our interests lie with emigration from the study area. Because we can assume that mortality within the study area is negligible, apparent survival rates represent probabilities that a knot remains in the study area from one day to the next (i.e., daily fidelity to the stopover area). Resight probability is the probability that an individual

knot will be observed given that it is present in the study area.

Red Knots that arrived at the Virginia barrier islands with unique band codes or combinations were resighted every 3-7 days from 28 April to 18 June 2007. We separated the field season into week long intervals following Cohen et al. (In Review). For purposes of our analysis, we combined weeks at the start and end of the study with data from adjoining weeks to define 5 periods that were approximately 1 week in length. We also dropped the data in which no knots were observed at the beginning and end of the season.

We developed 9 alternative models to explain patterns in fidelity and resight rates. The models included all possible combinations of 3 models for fidelity rates and 3 models for resight probabilities. Fidelity rates were allowed to 1) differ every week, 2) every 2 weeks, or 3) remain constant throughout the study period. Resight rates were allowed to 1) differ among 3 different groups or combinations of groups of observers that searched for banded knots, 2) differ between groups that followed an established resighting protocol compared to those that did not follow the protocol (Kalasz, 2006), or 3) remain constant throughout the study period. We checked for model fit using the median c-hat approach (White, 2002) and corrected for slight overdispersion in the data (c-hat = 1.356).

Data analysis indicates there is not overwhelming support for a single model for estimating fidelity and resight rates (see Table 4). QAICc weights provide the degree of evidence for support for each model in the data. Similarly, effect weights provide the degree of support for each effect in the data. These weights can be interpreted as the proportion of support in the data. We model averaged parameter estimates from all models to obtain best estimates for each parameter (Buckland *et al.,* 1997).

Table 4. Models used to estimate fidelity and resight rates for individually identifiable Red Knots observed along the Virginia barrier islands in 2007.

	Models								
	Fidelity			Resight					
Model Rank	**2 week**	**1 week**	**constant**	**group**	**protocol**	**constant**	**Delta QAICc**	**QAICc Weights**	**No. Param.**
1	1			1			0.000	0.375	8
2		1			1		1.099	0.217	7
3		1		1			2.375	0.114	10
4				1		1	2.398	0.113	6
5	1				1		3.822	0.056	5
6					1	1	3.829	0.055	3
7		1	1				5.145	0.029	6
8	1		1				5.197	0.028	4
9			1			1	6.749	0.013	2
Effect weights	0.459	0.360	0.069	0.603	0.328	0.181			

Model averaged estimates of fidelity rates varied from 0.65 to 0.96 (see Table 5). Fidelity rates were highest during week 1, decreased in week 2, increased in week 3, and decreased through the end of the study. The increase in fidelity during week 3 corresponded with an increase in the number of Red Knots first observed during this week (see Fig. 1). As knots continue to arrive onto the migration stopover site, average fidelity to the site should increase during this and subsequent time periods.

Resight rates varied for each of 3 groups during this study (see Table 6). This does not indicate that certain groups were better at resighting banded Red Knots, but is likely an indication of geographic differences in resight locations. The field technicians from the Center for Conservation Biology covered the largest geographic areas, which also included Hog Island where Red Knots were known to concentrate in recent years. The U.S. Fish and Wildlife Service concentrated their efforts on Fisherman Island, where Red Knot abundance is relatively low. Finally, a biologist with The Nature Conservancy photographed groups of foraging Red Knots on Hog Island and read bands and band codes from these photographs (see Figures X-X for the cumulative resights per island). As expected, when 2 groups recorded resightings on the same days, resight probabilities increased for those days.

Table 5. Fidelity rates for individually banded Red Knots observed along Virginia barrier islands in 2007.

Fidelity rates			
Week	**Estimate**	**SE**	**95% CI**
1	0.962	0.0883	[0.181, 1.000]
2	0.836	0.0584	[0.689, 0.922]
3	0.855	0.0554	[0.711, 0.934]
4	0.829	0.1254	[0.461, 0.965]
5	0.647	0.2169	[0.222, 0.922]

Table 6. Resight rates for individually banded Red Knots observed along Virginia barrier islands in 2007.

Resight rates			
Group	**Estimate**	**SE**	**95% CI**
CCB	0.049	0.0155	[0.026, 0.090]
FWS	0.022	0.0284	[0.002, 0.233]
TNC	0.020	0.0169	[0.004, 0.100]
CCB & FWS	0.053	0.0214	[0.024, 0.114]
CCB & TNC	0.119	0.0755	[0.032, 0.356]

Figure 3. Location of cummulative Red Knot resights on Fisherman Island throughout the 2007 season.

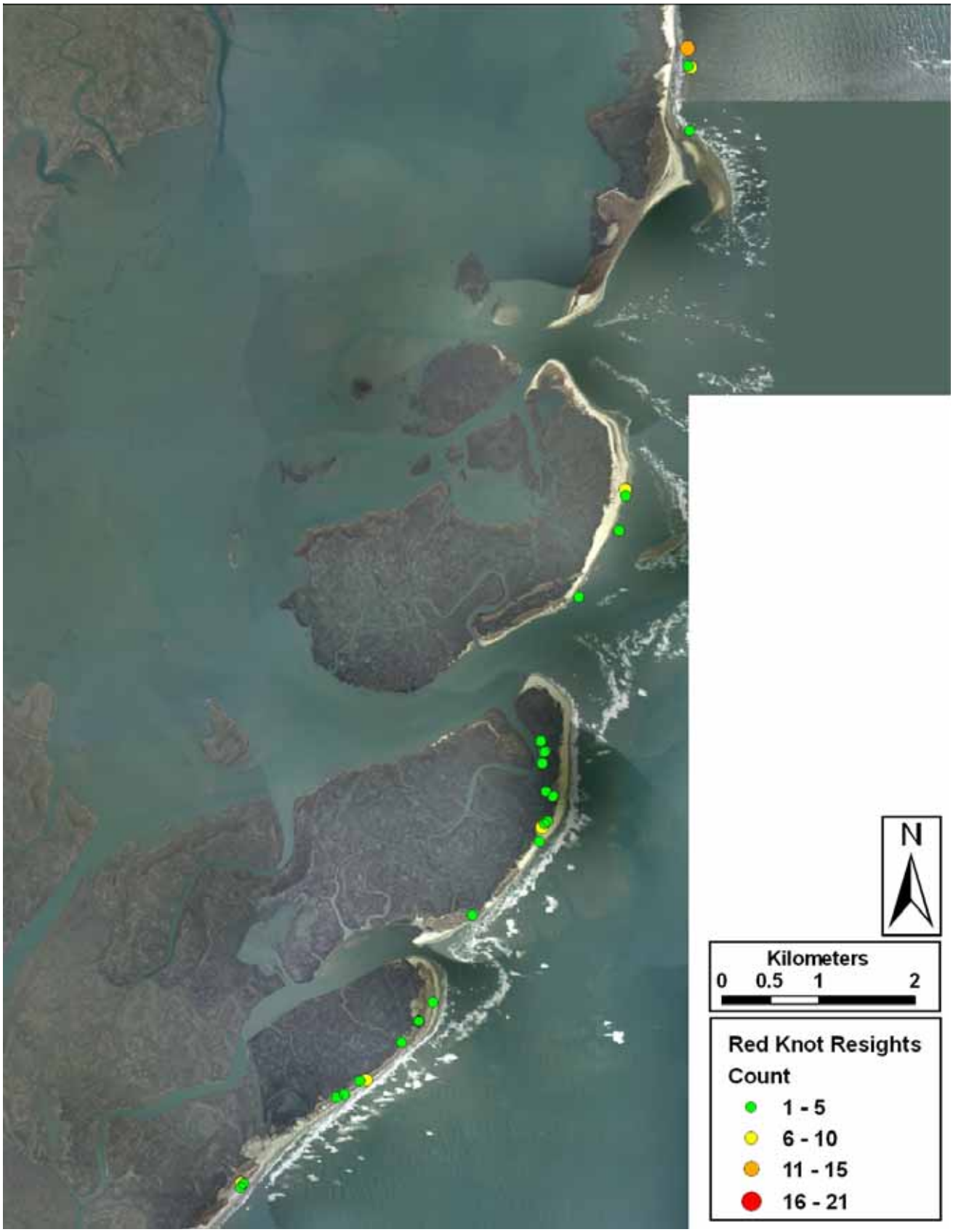

Figure 4. Location of cummulative Red Knot resights on Wreck, Myrtle, Ship Shoal, and Smith Islands throughout the 2007 season.

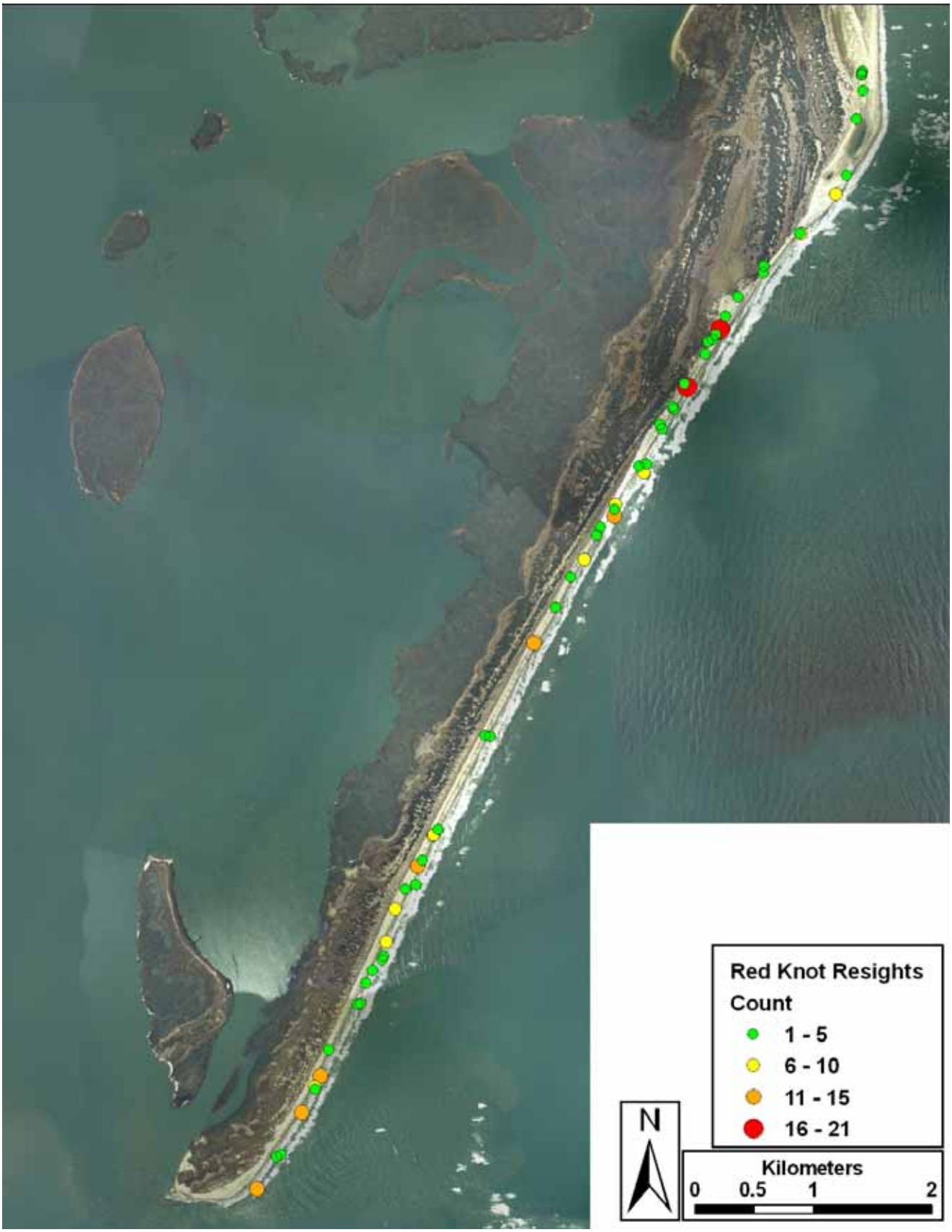

Figure 5. Location of cummulative Red Knot resights on Hog Island throughout the 2007 season.

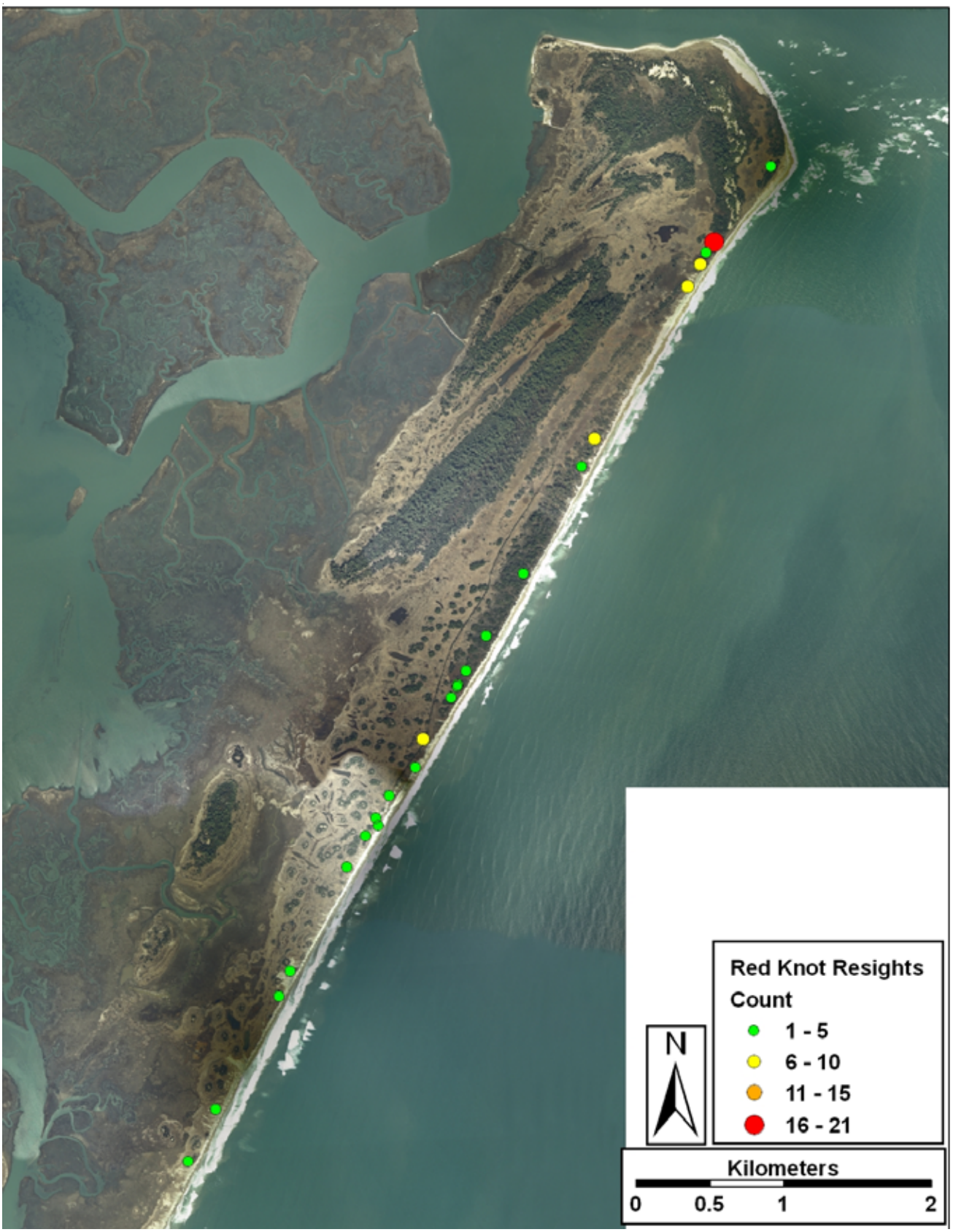

Figure 6. Location of cummulative Red Knot resights on Parramore Island throughout the 2007 season.

DISCUSSION

The results of the study suggest that the Virginia barrier island chain supports a significant population of the *rufa* subspecies of Red Knots during spring migration. This corroborates the findings from past aerial survey data (Watts and Truitt 2000, Watts and Truitt unpublished data). Before this project was initiated, very few resights were recorded in Virginia, and no systematic ground surveys were performed.

Site fidelity rates varied through the season. Knots arriving early in the season were more likely to stay longer than knots arriving later in the season. The lower fidelity rates later in the season could be due to increased availability of bivalves and quicker mass gain in the peak of migration. The preliminary findings of the analysis of stopover fidelity are similar to what Cohen et al. (In Press) found during the 2007 season. More study on the rates of site fidelity in relation to the amount of prey available is warranted.

The density of knots/km was not even across the barrier island chain and differed significantly along the stopover sites (X^2 statistic > 800, P < .01). Islands that held large numbers of Red Knots in previous years such as Cobb Island and Metompkin Island (Watts and Truitt, 2000) had fewer knots/km in 2007 (Watts and Truitt, unpublished data). Our survey effort found the highest concentrations of Red Knots on Hog Island, which has held the largest numbers of migrant knots the past two years (Watts and Truitt, unpublished data). Availability of prey items such as *Donax* and *Mitilus* bivalves, rather than amount of beach habitat available, was likely reason for the differences in densities of knots on the islands. Conversely, the frequency of resights/km did not differ significantly in relation to island length (X^2 statistic < 5, P > .05).

The proportion of knots encountered with color markings remained relatively constant throughout the season. The number of banded knots encountered along the barrier islands hovered near 5% from the beginning of the season until the end. From this it can be inferred that all groups of knots encountered were from the same general population. The percentage of knots banded at each island was also relatively constant at around 5%. Fisherman Island had a higher percentage of resighted knots from the total number of birds scanned, though that was most likely due to the lower numbers of knots using that island as a stopover and higher frequency of scans during the peak of migration.

The origin of the birds resighted included the full spectrum of color-flagged knots that one could encounter. Birds were recorded from Argentina, the Canadian Arctic, Brazil, Chile, and the U.S.A (Table 6). Specific banding locations of these individually banded knots were requested from the original banders but are not yet known. Of particular interest to this study would be whether or not these birds were encountered elsewhere in the 2007 migration season (i.e. Delaware Bay), and also locations of resights in previous years.

Table 6. The probable country of origin along with the total number of individually banded knots (IBK's) detected at least once during 2006 and 2007.

Country of Origin	Total # of IBK's, 2006	Total # of IBK's, 2007
U.S.A.	22	143
Argentina	15	94
Chile	2	26
Brazil	2	4
Canadian Arctic	0	5
Unknown	2	5
Totals	**43**	**277**

Based on the amount of resights accumulated from one season of intensive work on the barrier islands, systematic resighting should continue for this critically imperiled species. A significant percentage of Red Knots using Virginia as a stopover site are banded. Many things can be learned from the resighting of these color-marked birds. More detailed analysis of stopover times, within season spatial shifts in island use, within season temporal shifts in island use, year to year use of the barrier islands, year to year survival, use of wintering grounds, and patterns in migration can be determined by accumulating resight data. Future work on this species could be concentrated around the peak of migration. The three week peak movement of knots (15 May 2007 through 9 June 2007) produced 90% of all knots scanned and 86.7% of all resights recorded. Furthermore, Hog and Parramore Islands produced 76.2% of all resights, so future effort should be made to concentrate resighting efforts on the islands most utilized by knots.

ACKNOWLEDGMENTS

This project would not have been possible without the efforts of many people. We appreciate Carlton Adams, Mike Ludwick, Renee Peace, Cheryl Pope, Mark Roberts, and Gloria Sciole for providing important administrative support from the College of William and Mary. Laura McKay of the Coastal Zone Management Program provided administrative oversight. Financial support was provided by the Coastal Zone Management Program and The Center for Conservation Biology, College of William and Mary. Leif Burhans and Beth Wright performed all systematic surveys, and Barry Truitt, Alex Wilke, and Adam Dinouvo of The Nature Conservancy and Sue Rice, Pam Denmon, Amanda Hackney, and Carolyn Sternberg of the Eastern Shore of Virginia National Wildlife Refuge provided resight data. The Nature Conservancy and Dot Field of The Department of Conservation and Recreation Natural Heritage Program allowed access to the barrier islands for research.

LITERATURE CITED

Alerstam, T., G. A. Gudmundsson and K. Johannesson. 1992. Resources for long distance migration—intertidal exploitation of *Littorina* and *Mytilus* by knots *Calidris canutus* in Iceland. Oikos 65:179–189.

Baker, A.J., P.M. Gonzalez, C.D.T. Minton, D.B. Carter, L.J. Niles, I.L.S. Nascimento, and T. Piersma. 2001. Hemispheric problems in the conservation of Red Knots (*Calidrus canutus rufa*), p. 21-28. In F. Zern [ED.], Proceedings of the VI Neotropical Ornithological Congress International Shorebird Symposium, Monterrey, Mexico, October 1999. Western Hemishphere Shorebird Reserve Network, Manomet Center for Conservatin Sciences, Manomet, MA.

Baker, A.J., P.M. Gonzalez, T. Piersma, L.J. Niles, I.L.S. Nascimento, P.W. Atkinson, N.A. Clark, C.D.T. Minton, M. Peck, and G. Asarts. 2004. Rapid population decline in Red Knots: fitness consequenses of decreased refuelling rates and late arrival in Delaware Bay. *Proceedings of the Royal Society, Series B*, 271:875-882.

Baker, A.J., and T. Piersma. 2000. Life history characteristics and the conservation of migratory shorebirds, p. 105-124. *In* L.M. Gosling and W.J. Sutherland [EDS.], Behaviour and conservation. Cambridge University Press, Cambridge, UK.

Buckland,S.T., Burnham,K.P., Augustin,N.H., 1997. Model selection: An integral part of inference. Biometrics 53:603-618.

Clark, K.E., L. J. Niles, and J. Burger. 1993. Abundance and distribution of migrant shorebirds in Delaware Bay. Condor 95:694–705.

Cohen, J.B., Karpanty, S.M., Fraser, J.D., Watts, B.D., Clark, K.E., Niles, L.J., Dey, A.D., 2008. Size and Daily Site Fidelity of Red Knot Populations during Migratory Stopovers. Journal of Wildlife Management (In Review).

Davidson, N., and T. Piersma. 1992. The migration of knots: conservation needs and implications. Wader Study Group Bulletin (Supplement) 64:198-209.

González, P. M., T. Piersma and Y. Verkuil. 1996. Food, feeding and refueling of Red Knots *Calidris canutus rufa* during northward migration at San Antonio Oeste, Rio Negro, Argentina. J. Field Ornithol. 67:575–591.

Harrington, B. A., P. de T. Z. Antas and F. Silva. 1986. Northward shorebird migration on the Atlantic coast of southern Brazil. Vida Silvestre Neotropical 1: 45–54.

Harrington, B.A., J.M. Hagan, and L.E. Leddy. 1988. Site fidelity and survival differences between two groups of New World Red Knots *Calidris canutus*. Auk 105:439-445.

Harrington, B. A. 1996. The flight of the Red Knot. W. W. Norton and Co., New York.

Hitchcock, C.L., and C. Gratto-Trevor. 1997. Diagnosing a shorebird local population decline with a stage-structured population model. Ecology 78:522-534.

Kalasz, K., 2006. Resighting Individually Marked Red Knots of Delaware Beaches. Protocol from the Delaware Fish and Wildlife Shorebird Project.

Karpanty, S.M., J.D. Fraser, J. Berkson, L.J. Niles, A.Dey, and E.P. Smith. 2006. Horseshoe crab eggs determine red knot distribution in Delaware Bay. Journal of Wildlife Management 70:1704-1710.

Morrison, R. I. G., R. K. Ross, and L.J. Niles. 2004. Declines in wintering populations of red knots in southern South America. Condor 106:60-70.

Piersma, T., and N.C. Davidson. 1992. The migrations and annual cycles of five subspecies of knots in perspective. Wader Study Group Bull. Suppl. 64:52-63.

Tsipoura, N., and J. Burger. 1999. Shorebird diet during spring migration stopover on Delaware Bay. Condor 101:635-644.

Truitt B. R., B.D. Watts, B.L. Brown, and W. Dunstan. 2001. Red knot densities and invertebrate prey densities on the Virginia barrier islands. Wader Study Group Bulletin 95:12.

Watts, B.D., and B.R. Truitt. 2000. Abundance of shorebirds along the Virginia Barrier Islands during spring migration. Raven 71:33-39.

White,G.C., 2002. Discussion comments on: the use of Auxiliary Variables in Capture-recapture modelling. An overview. Journal of Applied Statistics 29:103-106.

White,G.C., Burnham,K.P., 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46:120-138.

Appendix I. Transect ID's and coordinates of start and end points.

Transect ID	Geographic Position of Point	X Coordinate	Y Coordinate
Parramore Island North	North	37.57604	-75.60197
Parramore Island North	South	37.53877	-75.62380
Parramore Island South	North	37.53786	-75.62464
Parramore Island South	South	37.49919	-75.65357
Hog Island North	North	37.46020	-75.66038
Hog Island North	South	37.41403	-75.68875
Hog Island South	North	37.41269	-75.68952
Hog Island South	South	37.36852	-75.72565
Cobb Island North	North	37.36049	-75.72783
Cobb Island North	South	37.32929	-75.73985
Cobb Island South	North	37.32413	-75.74529
Cobb Island South	South	37.30013	-75.77810
Wreck Island	North	37.27130	-75.79653
Wreck Island	South	37.24076	-75.81132
Ship Shoal Island	North	37.23742	-75.81238
Ship Shoal Island	South	37.21128	-75.82109
Myrtle Island	North	37.20784	-75.81534
Myrtle Island	South	37.18347	-75.82993
Smith Island	North	37.18200	-75.83007
Smith Island	South	37.14361	-75.86950

Appendix II. Total list of all birds encountered during line transect surveys in 2007 by common name, AOU code, Genus species, and migratory status.

Common name	AOU Code	Genus	Species	Migratory Status
Canada Goose	CAGO	*Branta*	*canadensis*	Resident
American Black Duck	ABDU	*Anas*	*rubripes*	Temperate Migrant
Common Merganser	COME	*Mergus*	*merganser*	Temperate Migrant
Red-breasted Merganser	RBME	*Mergus*	*serrator*	Temperate Migrant
Unidentified Duck	UIDU	Duck	sp.	Temperate Migrant
Common Loon	COLO	*Gavia*	*immer*	Temperate Migrant
Brown Pelican	BRPE	*Pelecanus*	*occidentalis*	Resident
Double-crested Cormorant	DCCO	*Phalacrocorax*	*auritus*	Resident
Great Blue Heron	GBHE	*Ardea*	*herodias*	Resident
Great Egret	GREG	*Ardea*	*alba*	Temperate Migrant
Snowy Egret	SNEG	*Egretta*	*thula*	Temperate Migrant
Little Blue Heron	LBHE	*Egretta*	*caerulea*	Temperate Migrant
Tricolored Heron	TRHE	*Egretta*	*tricolor*	Temperate Migrant
White Ibis	WHIB	*Eudocimus*	*albus*	Temperate Migrant
Glossy Ibis	GLIB	*Plegadis*	*falcinellus*	Temperate Migrant
Black Vulture	BLVU	*Coragyps*	*atratus*	Temperate Migrant
Osprey	OSPR	*Pandion*	*haliaetus*	Neotropical Migrant
Bald Eagle	BAEA	*Haliaeetus*	*leucocephalus*	Resident
Merlin	MERL	*Falco*	*columbarius*	Neotropical Migrant
Peregrine Falcon	PEFA	*Falco*	*peregrinus*	Neotropical Migrant
Unidentified Falcon	UIFA	*Falco*	*sp.*	Neotropical Migrant
Clapper Rail	CLRA	*Rallus*	*longirostris*	Neotropical Migrant
Black-bellied Plover	BBPL	*Pluvialis*	*squatarola*	Neotropical Migrant
Semipalmated Plover	SEPL	*Charadrius*	*semipalmatus*	Neotropical Migrant
Piping Plover	PIPL	*Charadrius*	*melodus*	Neotropical Migrant
American Oystercatcher	AMOY	*Haematopus*	*palliatus*	Resident
Greater Yellowlegs	GRYE	*Tringa*	*melanoleuca*	Neotropical Migrant
Willet	WILL	*Catoptrophorus*	*semipalmatus*	Neotropical Migrant
Whimbrel	WHIM	*Numenius*	*phaeopus*	Neotropical Migrant
Ruddy Turnstone	RUTU	*Arenaria*	*interpres*	Neotropical Migrant
Red Knot	REKN	*Calidris*	*canutus rufa*	Neotropical Migrant
Sanderling	SAND	*Calidris*	*alba*	Neotropical Migrant
Semipalmated Sandpiper	SESA	*Calidris*	*pusilla*	Neotropical Migrant
Unidentified Peep	UIPE	*Calidris*	*sp.*	Neotropical Migrant
Dunlin	DUNL	*Calidris*	*alpina*	Neotropical Migrant
Short-billed Dowitcher	SBDO	*Limnodromus*	*griseus*	Neotropical Migrant
Laughing Gull	LAGU	*Larus*	*atricilla*	Neotropical Migrant
Ring-billed Gull	RBGU	*Larus*	*delawarensis*	Temperate Migrant
Unidentified Gull	UIGU	Gull	sp.	
Herring Gull	HERG	*Larus*	*argentatus*	Temperate Migrant
Great Black-backed Gull	GBBG	*Larus*	*marinus*	Resident
Gull-billed Tern	GBTE	*Sterna*	*nilotica*	Neotropical Migrant
Caspian Tern	CATE	*Sterna*	*caspia*	Neotropical Migrant
Royal Tern	ROYT	*Sterna*	*maxima*	Neotropical Migrant
Sandwich Tern	SATE	*Sterna*	*sandvicensis*	Neotropical Migrant
Forster's Tern	FOTE	*Sterna*	*forsteri*	Temperate Migrant
Common Tern	COTE	*Sterna*	*hirundo*	Neotropical Migrant
Least Tern	LETE	*Sterna*	*antillarum*	Neotropical Migrant
Unidentified Tern	UTER	Tern	sp.	Neotropical Migrant
Black Skimmer	BLSK	*Rynchops*	*niger*	Neotropical Migrant
Fish Crow	FICR	*Corvus*	*ossifragus*	Temperate Migrant
Barn Swallow	BARS	*Hirundo*	*rustica*	Neotropical Migrant
Seaside Sparrow	SESP	*Ammodramus*	*maritimus*	Temperate Migrant
Song Sparrow	SOSP	*Melospiza*	*melodia*	Temperate Migrant
Red-winged Blackbird	RWBL	*Agelaius*	*phoeniceus*	Temperate Migrant
Eastern Meadowlark	EAME	*Sturnella*	*magna*	Temperate Migrant
Boat-tailed Grackle	BTGR	*Quiscalus*	*major*	Temperate Migrant

Appendix III. All individually marked Red Knot band combinations, the date and location of first resight, and their probable origin.

Date	Band Combination	Location of Resight	Probable Band Origin
5/20/2007	-/- : FW/G	Hog Island	Arctic
5/20/2007	FW/- : O/MR	Hog Island	Arctic
5/23/2007	M/- : FW/-	Wreck Island	Arctic
5/30/2007	M/- : FW/O	Hog Island	Arctic
5/30/2007	M/- : FW/Y	Hog Island	Arctic
5/31/2007	-/FO : M/RYW	Myrtle Island	Argentina
6/1/2007	-/RFO(B13)R : M/YO	Parramore Island	Argentina
5/23/2006	-/RO : FO/OR	Hog Island	Argentina
5/12/2007	-/WFOR : -/YG	Ship Shoal Island	Argentina
6/6/2007	FO(?VT)/? : ?/?	Hog Island	Argentina
6/2/2007	FO(A12)/Y : M/R	Hog Island	Argentina
5/30/2007	FO(AB)/- : M/-	Hog Island	Argentina
5/19/2007	FO(ACN)/- : M/B	Hog Island	Argentina
6/1/2007	FO(ADI)/- : M/B	Parramore Island	Argentina
5/27/2007	FO(ADJ)/- : M/B	Wreck Island	Argentina
5/23/2006	FO(AIP)/- : M/B	Hog Island	Argentina
6/2/2007	FO(AJU)/- : M/N	Hog Island	Argentina
5/17/2007	FO(AM)/Y : M/R	Hog Island	Argentina
5/25/2007	FO(AOK)/- : M/N	Parramore Island	Argentina
5/17/2007	FO(AON)/- : M/B	Hog Island	Argentina
5/26/2007	FO(APD)/- : M/B	Hog Island	Argentina
5/31/2007	FO(APX)/- : M/B	Smith Island	Argentina
5/23/2006	FO(AUM)/- : M/B	Hog Island	Argentina
5/30/2007	FO(AUU)/- : M/B	Hog Island	Argentina
5/14/2007	FO(AXT)/- : M/O	Smith Island	Argentina
5/17/2007	FO(AY)/OWR : M/O	Hog Island	Argentina
6/1/2007	FO(AZN)/- : M/B	Parramore Island	Argentina
5/17/2007	FO(B55)/Y : M/R	Hog Island	Argentina
6/1/2007	FO(CAE)/- : M/B	Parramore Island	Argentina
5/30/2007	FO(CAH)/- : M/B	Hog Island	Argentina
5/30/2007	FO(CAJ)/- : M/U	Hog Island	Argentina
5/20/2007	FO(CAN)/W : -/-	Hog Island	Argentina
5/20/2007	FO(CCK)/- : M/?	Hog Island	Argentina
5/20/2007	FO(CCM)/- : ?/M	Hog Island	Argentina
5/23/2006	FO(CJU)/- : M/-	Hog Island	Argentina
5/24/2006	FO(COK)/- : M/B	Hog Island	Argentina
6/1/2007	FO(CON)/X : M/X	Parramore Island	Argentina
5/23/2006	FO(D8)/G : M/-	Hog Island	Argentina
5/17/2006	FO(D8)/OG : M/YO	Hog Island	Argentina
5/5/2007	FO(DT)/- : M/O	Hog Island	Argentina
5/24/2007	FO(EAV)/W : M/-	Myrtle Island	Argentina
5/15/2007	FO(ECJ)/Y : M/-	Parramore Island	Argentina

Appendix III (cont...). All individually marked Red Knot band combinations, the date and location of first resight, and their probable origin.

Date	Band Combination	Location of Resight	Probable Band Origin
5/30/2007	FO(ECL)/Y : M/-	Hog Island	Argentina
5/26/2007	FO(EEA)/- : M/Y	Hog Island	Argentina
5/30/2007	FO(EJN)/W : M/-	Hog Island	Argentina
6/1/2007	FO(EJP)/W : M/-	Parramore Island	Argentina
5/31/2007	FO(EP)/W : M/-	Smith Island	Argentina
5/30/2007	FO(HO)/GR : M/WR	Hog Island	Argentina
5/27/2007	FO(HX)/YY : M/YR	Wreck Island	Argentina
5/24/2007	FO(JD)/R : M/YRG	Smith Island	Argentina
5/30/2007	FO(JD)/R : M/YRG	Hog Island	Argentina
6/1/2007	FO(JJ)/- : M/O	Parramore Island	Argentina
5/23/2006	FO(K8)/G : M/-	Hog Island	Argentina
6/6/2007	FO(KT?)/- : ?/B	Hog Island	Argentina
6/2/2007	FO(LC)/G : M/-	Hog Island	Argentina
5/15/2007	FO(LCU)/W : M/-	Parramore Island	Argentina
5/26/2007	FO(LHJ)/W : M/-	Hog Island	Argentina
5/24/2007	FO(LHU)/Y : M/-	Myrtle Island	Argentina
6/1/2007	FO(LJJ)/W : M/-	Parramore Island	Argentina
5/30/2007	FO(LLC)/W : M/-	Hog Island	Argentina
5/26/2007	FO(LLM)/W : M/-	Hog Island	Argentina
5/20/2007	FO(LLN)/W : M/W	Hog Island	Argentina
5/17/2007	FO(LMH)/W : M/-	Hog Island	Argentina
6/1/2007	FO(LPA)/W : M/-	Parramore Island	Argentina
5/30/2007	FO(LTC)/Y : M/-	Hog Island	Argentina
5/25/2007	FO(LUM)/Y : M/-	Parramore Island	Argentina
5/25/2007	FO(LVL)/W : M/-	Parramore Island	Argentina
5/31/2007	FO(LXA)/Y : M/-	Smith Island	Argentina
6/1/2007	FO(LXX)/W : M/-	Parramore Island	Argentina
5/30/2007	FO(LYP)/W : M/-	Hog Island	Argentina
6/2/2007	FO(MAN)/W : M/-	Hog Island	Argentina
5/30/2007	FO(MAY)/? : M/?	Hog Island	Argentina
6/1/2007	FO(MO)/G : M/-	Parramore Island	Argentina
5/23/2007	FO(OAH)/- : M/B	Ship Shoal Island	Argentina
6/1/2007	FO(P3)/G : M/-	Parramore Island	Argentina
5/27/2007	FO(PT)/G : M/-	Wreck Island	Argentina
5/23/2006	FO(SY)/G : M/-	Hog Island	Argentina
5/24/2007	FO(T2)/G : M/-	Myrtle Island	Argentina
5/26/2007	FO(TB)/GG : M/-	Hog Island	Argentina
5/24/2006	FO(U7)/G : M/-	Hog Island	Argentina
6/1/2007	FO(UPA)/W : M/-	Parramore Island	Argentina
5/31/2007	FO(US)/G : M/-	Myrtle Island	Argentina
5/5/2007	FO(XE)/R : M/-	Hog Island	Argentina
5/23/2007	FO(XY)/G : M/-	Fisherman Island	Argentina

Appendix III (cont...). All individually marked Red Knot band combinations, the date and location of first resight, and their probable origin.

Date	Band Combination	Location of Resight	Probable Band Origin
5/24/2006	FO(Z3)/G : M/-	Hog Island	Argentina
5/17/2006	G/FO : M/RYW	Hog Island	Argentina
5/30/2007	M/- : -/RFO	Hog Island	Argentina
5/24/2007	M/- : FO(CJE)/-	Smith Island	Argentina
5/26/2007	M/- : FO(CJL)/-	Hog Island	Argentina
5/25/2007	M/- : FO(CKE)/-	Parramore Island	Argentina
5/30/2007	M/- : FO(CLN)/-	Hog Island	Argentina
5/30/2007	M/- : FO(CLT)/-	Hog Island	Argentina
5/30/2007	M/- : FO(CSN)/-	Hog Island	Argentina
5/24/2007	M/- : FO(CSU)/-	Fisherman Island	Argentina
5/26/2007	M/B : FO(APD)/-	Hog Island	Argentina
5/30/2007	M/BG : FO(T1)/YG	Hog Island	Argentina
5/24/2007	M/BR : FO/-	Fisherman Island	Argentina
5/17/2006	M/BW : FO/Y	Hog Island	Argentina
5/23/2007	M/BY : FO(MCJ)/GY	Wreck Island	Argentina
6/2/2007	M/FO : -/YW	Hog Island	Argentina
5/14/2007	M/G : FO(MMA)/-	Myrtle Island	Argentina
5/26/2007	M/G : FO(MME)/-	Hog Island	Argentina
5/30/2007	M/G : FO(MNE)/-	Hog Island	Argentina
5/30/2007	M/GR : FO(WX)/YY	Hog Island	Argentina
5/30/2007	M/GR : FO(WY)/GR	Hog Island	Argentina
5/26/2007	M/GY : FO(???)/Y	Hog Island	Argentina
5/30/2007	M/GYG : FO(?)/Y	Hog Island	Argentina
5/15/2007	M/GYW : FO(CGH)/G	Parramore Island	Argentina
5/26/2007	M/RG : FO(WY):RG	Hog Island	Argentina
5/23/2006	M/ROG : -/YFO	Hog Island	Argentina
5/26/2007	M/S : FO/-	Hog Island	Argentina
5/17/2007	M/W : -/FOW	Hog Island	Argentina
5/23/2006	M/WY : -/GFOG	Hog Island	Argentina
6/1/2007	M/Y : FO(CEL)/W	Parramore Island	Argentina
5/23/2007	FB(BC)/R : M/BRO	Fisherman Island	Brazil
5/26/2007	FB/W : M/-	Hog Island	Brazil
5/24/2007	FB/Y : M/-	Smith Island	Brazil
5/26/2007	FB/YW : M/-	Hog Island	Brazil
5/23/2006	M/- : FB/W	Hog Island	Brazil
5/23/2006	M/- : FB/Y	Hog Island	Brazil
5/17/2007	-/W : M/OFR	Hog Island	Chile
5/27/2007	FR(75)/- : -/M	Wreck Island	Chile
5/23/2007	FR(JJ)/- : -/M	Wreck Island	Chile
5/30/2007	FR(KI)/- : -/M	Hog Island	Chile
6/1/2007	FR(LX)/- : -/-	Parramore Island	Chile
5/30/2007	FR(OA)/- : -/M	Hog Island	Chile

Appendix III (cont...). All individually marked Red Knot band combinations, the date and location of first resight, and their probable origin.

Date	Band Combination	Location of Resight	Probable Band Origin
5/31/2007	FR(OX)/W : -/M	Smith Island	Chile
5/31/2007	FR(OX)/W : -/M	Smith Island	Chile
6/1/2007	FR(SM)/- : M/-	Parramore Island	Chile
5/31/2007	FR(UY)/- : -/M	Smith Island	Chile
5/30/2007	FR(WD)/- : -/M	Hog Island	Chile
6/2/2007	FR(WW)/- : -/M	Hog Island	Chile
5/26/2007	FR(YS)/- : -/M	Hog Island	Chile
5/24/2006	M/- : FR(11)/-	Hog Island	Chile
5/17/2007	M/- : FR(CP)/G	Hog Island	Chile
5/30/2007	M/- : FR(EU)/G	Hog Island	Chile
5/23/2007	M/- : FR(OW)/G	Fisherman Island	Chile
6/1/2007	M/- : W/WFR	Parramore Island	Chile
5/26/2007	M/- : W/YFR	Hog Island	Chile
5/30/2007	M/- : Y/OFR	Hog Island	Chile
5/23/2007	M/GR : -/GFR	Ship Shoal Island	Chile
5/26/2007	M/OFR : W/-	Hog Island	Chile
5/23/2007	M/S : -/FR	Ship Shoal Island	Chile
5/15/2007	M/YGR : -/GFR	Parramore Island	Chile
5/24/2007	M/YR : -/GFR	Myrtle Island	Chile
6/1/2007	M/YR : FR/GR	Parramore Island	Chile
5/23/2006	W/- : M/OFR	Hog Island	Chile
6/2/2007	Y/- : M/OFR	Hog Island	Chile
5/19/2007	-/- : FG(UL4)/M	Hog Island	U.S.A.
5/5/2007	-/- : FL(HU5)/M	Myrtle Island	U.S.A.
5/9/2007	-/- : FL(TT5)/M	Fisherman Island	U.S.A.
5/27/2007	-/- : FL(VX4)/M	Wreck Island	U.S.A.
5/10/2007	-/- : FL(Y4)/M	Hog Island	U.S.A.
5/23/2007	?/? : FL(YM4)/?	Wreck Island	U.S.A.
5/27/2007	B/- : FL(VHM)/M	Ship Shoal Island	U.S.A.
5/24/2007	B/- : FL(VHN)/M	Myrtle Island	U.S.A.
5/10/2007	B/- : FL(VMP)/M	Hog Island	U.S.A.
5/23/2006	B/- : FL(VNY)/M	Hog Island	U.S.A.
5/9/2007	B/- : FL(VUL)/M	Fisherman Island	U.S.A.
5/24/2006	FG(NA)/- : O/M	Hog Island	U.S.A.
5/25/2007	FG/B : M/GW	Parramore Island	U.S.A.
5/15/2007	FG/B : M/GY	Parramore Island	U.S.A.
5/10/2007	FG/GO : M/GR	Hog Island	U.S.A.
5/17/2006	FG/GY : M/GR	Hog Island	U.S.A.
5/10/2007	FG/O : M/GR	Hog Island	U.S.A.
5/23/2007	FG/RO : M/GR	Wreck Island	U.S.A.
5/15/2007	FG/X : M/NOY	Parramore Island	U.S.A.
5/23/2007	FG/YR : M/G	Fisherman Island	U.S.A.

Appendix III (cont...). All individually marked Red Knot band combinations, the date and location of first resight, and their probable origin.

Date	Band Combination	Location of Resight	Probable Band Origin
5/24/2007	FL(17)/- : O/M	Smith Island	U.S.A.
6/1/2007	FL(4U)/- : G/M	Parramore Island	U.S.A.
5/10/2007	FL(7N)/- : O/M	Hog Island	U.S.A.
5/5/2007	FL(AA5)/- : M/O	Hog Island	U.S.A.
5/30/2007	FL(AAH)/- : M/-	Hog Island	U.S.A.
5/17/2007	FL(AET)/- : M/-	Hog Island	U.S.A.
5/30/2007	FL(AKM)/- : M/-	Hog Island	U.S.A.
6/2/2007	FL(BE1)/- : G/M	Hog Island	U.S.A.
5/23/2006	FL(CE)/- : G/M	Hog Island	U.S.A.
6/1/2007	FL(CEE)/- : M/-	Parramore Island	U.S.A.
5/30/2007	FL(CEL)/- : M/-	Hog Island	U.S.A.
5/20/2007	FL(CHL)/? : ?/?	Hog Island	U.S.A.
5/31/2007	FL(CJT)/- : M/-	Smith Island	U.S.A.
5/23/2006	FL(CVC)/- : M/-	Hog Island	U.S.A.
6/1/2007	FL(CYN)/- : M/-	Parramore Island	U.S.A.
5/24/2007	FL(DB)/- : -/R	Fisherman Island	U.S.A.
6/1/2007	FL(EAS)/- : O/-	Parramore Island	U.S.A.
5/30/2007	FL(EAY)/- : M/-	Hog Island	U.S.A.
6/1/2007	FL(EEO)/Y : M/-	Parramore Island	U.S.A.
5/10/2007	FL(EHA)/- : W/M	Hog Island	U.S.A.
5/30/2007	FL(EHP)/- : M/-	Hog Island	U.S.A.
5/26/2007	FL(HAT)/- : W/X	Hog Island	U.S.A.
5/27/2007	FL(HMP)/M : W/-	Wreck Island	U.S.A.
5/30/2007	FL(HMT)/- : W/M	Hog Island	U.S.A.
5/30/2007	FL(HT)/- : G/M	Hog Island	U.S.A.
5/14/2007	FL(HTV)/- : L/M	Smith Island	U.S.A.
6/2/2007	FL(HUT)/- : L/M	Hog Island	U.S.A.
6/1/2007	FL(J9)/- : O/-	Parramore Island	U.S.A.
5/17/2007	FL(JAO)/- : L/U	Hog Island	U.S.A.
5/17/2007	FL(JCU)/- : W/M	Hog Island	U.S.A.
5/10/2007	FL(JVH)/- : L/M	Hog Island	U.S.A.
5/30/2007	FL(JVI)/- : L/M	Hog Island	U.S.A.
5/17/2007	FL(JVM)/- : L/M	Hog Island	U.S.A.
5/10/2007	FL(KCK)/- : L/M	Fisherman Island	U.S.A.
5/10/2007	FL(KEJ)/- : L/-	Hog Island	U.S.A.
5/30/2007	FL(KEM)/- : L/M	Hog Island	U.S.A.
5/30/2007	FL(KHU)/- : L/M	Hog Island	U.S.A.
5/26/2007	FL(KLY)/- : L/-	Hog Island	U.S.A.
5/23/2007	FL(KPH)/- : L/-	Ship Shoal Island	U.S.A.
5/20/2007	FL(KTO)/- : W/M	Hog Island	U.S.A.
5/30/2007	FL(KVC)/- : L/M	Hog Island	U.S.A.
5/24/2007	FL(KYH)/- : L	Fisherman Island	U.S.A.

Appendix III (cont...). All individually marked Red Knot band combinations, the date and location of first resight, and their probable origin.

Date	Band Combination	Location of Resight	Probable Band Origin
5/24/2007	FL(KYK) : L/M	Fisherman Island	U.S.A.
5/10/2007	FL(KYO)/- : L/M	Hog Island	U.S.A.
6/2/2007	FL(LAS)/- : O/M	Hog Island	U.S.A.
5/5/2007	FL(LKZ)/- : L/M	Myrtle Island	U.S.A.
5/14/2007	FL(LNJ)/- : R/M	Myrtle Island	U.S.A.
5/17/2007	FL(LTN)/- : M/R	Hog Island	U.S.A.
5/26/2007	FL(LVI)/- : L/M	Hog Island	U.S.A.
6/2/2007	FL(LXO)/- : L/M	Hog Island	U.S.A.
6/2/2007	FL(LYO)/- : L/M	Hog Island	U.S.A.
5/26/2007	FL(MA5)/- : O/M	Hog Island	U.S.A.
5/31/2007	FL(MAY)/- : R/M	Smith Island	U.S.A.
5/30/2007	FL(MJP)/- : -/M	Hog Island	U.S.A.
5/30/2007	FL(MML)/- : -/M	Hog Island	U.S.A.
5/26/2007	FL(MTC)/- : M/R	Hog Island	U.S.A.
6/2/2007	FL(MVA)/- : R/M	Hog Island	U.S.A.
5/30/2007	FL(NCK)/- : R/M	Hog Island	U.S.A.
6/11/2007	FL(NCS)/- : O/M	Hog Island	U.S.A.
5/30/2007	FL(NHN)/M : Y/-	Hog Island	U.S.A.
5/24/2007	FL(NY)/- : G/M	Fisherman Island	U.S.A.
5/27/2007	FL(O4)/- : G/U	Wreck Island	U.S.A.
5/26/2007	FL(OB)/- : G/M	Hog Island	U.S.A.
5/14/2007	FL(OW)/- : G/M	Myrtle Island	U.S.A.
5/25/2007	FL(OXJ)/- : M/-	Parramore Island	U.S.A.
5/26/2007	FL(PCE)/- : Y/M	Hog Island	U.S.A.
5/30/2007	FL(PEO)/- : L/M	Hog Island	U.S.A.
5/10/2007	FL(PHH)/- : Y/M	Hog Island	U.S.A.
5/23/2007	FL(PKC)/- : Y/M	Fisherman Island	U.S.A.
6/2/2007	FL(PLL)/- : Y/M	Hog Island	U.S.A.
5/30/2007	FL(PTK)/- : O/M	Hog Island	U.S.A.
5/17/2006	FL(T6)/- : O/M	Hog Island	U.S.A.
6/2/2007	FL(TA5)/- : O/M	Hog Island	U.S.A.
5/30/2007	FL(TC)/- : O/M	Hog Island	U.S.A.
5/26/2007	FL(TCV)/M : Y/-	Hog Island	U.S.A.
5/31/2007	FL(TEN)/- : L/M	Smith Island	U.S.A.
5/26/2007	FL(TGV)/- : Y/M	Hog Island	U.S.A.
6/1/2007	FL(TPY)/- : O/M	Parramore Island	U.S.A.
6/2/2007	FL(TTA)/- : O/-	Hog Island	U.S.A.
6/1/2007	FL(TTE)/- : O/M	Parramore Island	U.S.A.
5/27/2007	FL(TTL)/- : O/M	Wreck Island	U.S.A.
6/9/2007	FL(TVA)/- : O/M	Hog Island	U.S.A.
5/30/2007	FL(TVE)/- : O/M	Hog Island	U.S.A.
6/1/2007	FL(TVK)/- : L/M	Parramore Island	U.S.A.

Appendix III (cont...). All individually marked Red Knot band combinations, the date and location of first resight, and their probable origin.

Date	Band Combination	Location of Resight	Probable Band Origin
5/30/2007	FL(TX)/- : G/M	Hog Island	U.S.A.
6/2/2007	FL(TXJ)/- : O/M	Hog Island	U.S.A.
5/30/2007	FL(TXX)/- : O/M	Hog Island	U.S.A.
6/2/2007	FL(TXY)/- : O/M	Hog Island	U.S.A.
5/20/2007	FL(ULL)/- : W/M	Hog Island	U.S.A.
5/23/2007	FL(ULN)/- : Y/M	Ship Shoal Island	U.S.A.
5/17/2007	FL(UMK)/- : Y/M	Hog Island	U.S.A.
5/17/2007	FL(UNK)/- : Y/M	Hog Island	U.S.A.
6/2/2007	FL(URO)/- : L/M	Hog Island	U.S.A.
5/10/2007	FL(UVV)/- : L/M	Hog Island	U.S.A.
5/5/2007	FL(UYV)/- : L/M	Myrtle Island	U.S.A.
5/23/2006	FL(VCV)/- : B/M	Hog Island	U.S.A.
6/6/2007	FL(VV7)/- : L/M	Hog Island	U.S.A.
5/30/2007	FL(VYC)/- : L/M	Hog Island	U.S.A.
6/2/2007	FL(XCA)/- : ?	Hog Island	U.S.A.
5/14/2007	FL(XTY)/R : M/B	Smith Island	U.S.A.
5/20/2007	FL(XUM)/- : L/M	Hog Island	U.S.A.
5/14/2007	FL(XUN)/- : L/M	Myrtle Island	U.S.A.
5/24/2006	FL(XVK)/- : L/M	Hog Island	U.S.A.
5/24/2006	FL(XVT)/- : L/M	Hog Island	U.S.A.
5/31/2007	FL(XXN)/- : L/-	Smith Island	U.S.A.
6/1/2007	FL(XXT)/- : L/M	Parramore Island	U.S.A.
5/24/2007	FL(XXX)/- : L/M	Smith Island	U.S.A.
5/30/2007	FL(XXY)/- : L/M	Hog Island	U.S.A.
6/2/2007	FL(XY)/M : G/-	Hog Island	U.S.A.
6/2/2007	FL(XY)/M : G/-	Hog Island	U.S.A.
5/5/2007	FL(XYA)/- : L/M	Myrtle Island	U.S.A.
5/24/2007	FL(XYE)/- : L/M	Smith Island	U.S.A.
5/10/2007	FL(XYH)/- : L/M	Hog Island	U.S.A.
5/14/2007	FL(XYJ)/- : L/M	Myrtle Island	U.S.A.
5/24/2006	FL(YAA)/- : L/M	Hog Island	U.S.A.
5/23/2006	FL(YAH)/- : L/M	Hog Island	U.S.A.
5/17/2007	FL(YAN)/- : L/M	Hog Island	U.S.A.
5/24/2006	FL(YAP)/- : L/M	Hog Island	U.S.A.
5/23/2006	FL(YAT)/- : L/M	Hog Island	U.S.A.
5/26/2007	FL(YAV)/- : Y/-	Hog Island	U.S.A.
5/15/2007	FL(YCE)/M : L/-	Parramore Island	U.S.A.
5/23/2006	FL(YCJ)/- : L/-	Hog Island	U.S.A.
5/27/2007	FL(YCN)/- : L/M	Wreck Island	U.S.A.
6/11/2007	FL(YCS)/- : O/M	Hog Island	U.S.A.
5/17/2007	FL(YCV)/- : L/M	Hog Island	U.S.A.
5/23/2006	FL(YCX)/- : ML/-	Hog Island	U.S.A.

Appendix III (cont...). All individually marked Red Knot band combinations, the date and location of first resight, and their probable origin.

Date	Band Combination	Location of Resight	Probable Band Origin
6/2/2007	FL(YEL)/- : L/M	Hog Island	U.S.A.
6/13/2007	FL(YH8)/- : L/M	Hog Island	U.S.A.
5/30/2007	FL(YHT)/- : L/M	Hog Island	U.S.A.
6/2/2007	FL(YPT)/- : L/M	Hog Island	U.S.A.
5/31/2007	FL(YYO)/- : L/M	Smith Island	U.S.A.
5/27/2007	FP(CJT)/- : Y/M	Fisherman Island	U.S.A.
5/27/2007	FP(PKC)/- : Y/M	Fisherman Island	U.S.A.
5/19/2007	L/M : FL(KLN)/-	Hog Island	U.S.A.
5/5/2007	L/M : FL(YAL)/-	Myrtle Island	U.S.A.
5/20/2007	M/- : FG(AA5)/-	Hog Island	U.S.A.
5/23/2006	M/- : FP/Y	Hog Island	U.S.A.
5/19/2007	W/- : FL(???)/M	Hog Island	U.S.A.
5/19/2007	W/W : M/FL	Hog Island	U.S.A.
5/14/2006	FL(TKM)/- : Y/M	Ship Shoal Island	U.S.A.
5/14/2006	FL(TLN)/- : ?/?	Ship Shoal Island	U.S.A.
5/14/2006	B/? : FL(VCP)/-	Ship Shoal Island	U.S.A.
5/14/2006	B/- : FL(VAN)/M	Ship Shoal Island	U.S.A.
5/14/2006	B/- : FL(UNP)/M	Ship Shoal Island	U.S.A.
5/14/2006	FL(JMM)/- : W/M	Ship Shoal Island	U.S.A.
5/24/2007	-/- : M/Ys	Fisherman Island	Unknown (yellow spiral)
6/2/2007	-/MY : S/YW	Hog Island	Unknown
5/23/2006	-/RO : M/GY	Hog Island	Unknown
5/27/2007	FY(?)/ - : O/-	Fisherman Island	Unknown
5/23/2006	M/W : -/S	Hog Island	Unknown
5/24/2007	S/SW : -/S	Smith Island	Unknown
6/1/2007	X/GR : O/R	Parramore Island	Unknown