BTO Research Report No. 351

The migration of Red Knots *Calidris canutus rufa* and Turnstone *Arenaria interpres* passing through Delaware Bay in 2003

Authors

Nigel A. Clark, Phil W. Atkinson, Jacquie Clark,
Simon Gillings and Rob Robinson.

This report was funded by the Delaware Coastal Programs
Pursuant to United States National Oceanic and
Atmospheric Administration Award No. NA170Z1117

February 2004

The British Trust for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU
Registered Charity No. 216652

British Trust for Ornithology

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ISBN: 978-1-908581-11-2

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EXECUTIVE SUMMARY

1. Use of stable isotope signatories enabled an assessment of the size of the *rufa* population from a pilot study. This produced a tentative estimate of forty-eight thousand birds, however, a number of biases were identified which mean that the estimate is likely to be high. Further studies were proposed to obtain better estimates in future years.

2. As in previous years the rate of weight gain varied with date for both Turnstone and Knot. However, for both species the rate of weight gain for any given day was lower than in past years.

3. Few Knots achieved take-off weights before 30 May 2003.

4. Analysis of resighting of individually marked birds within the Delaware shore of Delaware Bay suggested arrivals around 12 May, 15 May and 19 May with birds that arrived early in May leaving the Delaware shore around the time of a major storm on 16 May. Many birds from 19 May arrival were observed remaining in the bay well into June.

5. The pilot work in 2003 resighting individually marked Knot proved the value of this technique. In future, annual samples of birds should be marked with substantial effort made on resighting birds in all areas where they occur within the bay.

Chapter 1. Estimating the size of the *rufa* population of Knot available to migrate through Delaware Bay in Spring 2003

Clark, N.A. & Atkinson, P.W.

1.1 Introduction

In 2001 we produced a value of the size of the *rufa* population passing through Delaware Bay based on mark-recapture models (Atkinson *et al*. 2001) giving an estimate of between 28,000 and 126,000 birds, with a mean of 77,000. This upper estimate was made on the 2001 data, based solely on data collected on the Delaware side of the Bay and may have been biased. Wetlands International gives a population estimate of 60,000 and a declining trend (Wetlands International 2002). Aerial counts, both in Delaware Bay and in the main wintering grounds, have shown declines since 1998 (Baker *et al*. in press).

In 2003 we clipped feathers from a random sample of 90 knot trapped during catching operations, analyzed them for stable isotope ratios and calculated $\delta^{13}C$ and $\delta^{15}N$ values (Atkinson *et al*. submitted). By comparing these with $\delta^{13}C$ and $\delta^{15}N$ values from reference samples of feathers grown in known wintering areas we were able to assign 27 birds to a Florida-type signature, 52 to a Bahia Lomas (Chile) signature 5 to a Rio Grande Argentina) signature and 6 were unclassified.

As counts of the wintering population are available (Morrison *et al.* in press), we can estimate the population size for areas not counted using the proportion of the different populations passing through Delaware Bay. If birds are randomly distributed in Delaware Bay, with respect to wintering origin, and birds from different wintering areas have similar age structures, then these estimates should not be biased. There are very few juveniles in the main wintering sites in Tierra del Fuego so these should not greatly impact the estimates, however it does assume that all second year birds migrate through Delaware and this is unproven. If some second years stay on the wintering grounds rather than migrating to the arctic then the population will be over estimated.

Another source of error is the possibility that some birds moult in the Florida area before moving on to the southern areas to winter. This possibility cannot be ruled out at present and could explain the relatively high estimate for the Florida wintering area. This are may include the whole Caribbean but, even then, the estimates are higher than expected.

Wintering site	Number in random sample	Recent count	Estimate using Argentina and Chile count
Florida	27		14436
Argentina and Chile	57	30475	30475
Unclassified	6		3208
Estimated population size before spring migration			48118

The main conclusion from this analysis is that the population is unlikely to be higher than the 60,000 estimated by Wetlands International and now may be substantially lower. In future we hope to take random samples of feathers from each catch so that better estimates of the population wintering in the areas not censused in winter can be made.

1.2 References

Atkinson, P.W., Henderson, I.G., and Clark, N. A. (2001) *A Preliminary Analysis of the Survival Rates of Red Knots* Calidris canutus rufa *Passing Through the State of Delaware 1997-2001*. BTO Research Report 274, British Trust for Ornithology, Thetford, UK

Baker, A.J, Gonzalez, P.M., Piersma, T. Niles, L.J., Nascimento, I.de L.S., Atkinson, P.W., Clark, N.A., Minton, C.D.T., Peck, M. and Aarts, G. (in press) *Rapid Population Decline in red knots: fitness consequences of decreased refueling rates and late arrival in Delaware Bay* Proc. Roy. Soc. Lon. B.

Morrison, R.I.G, Ross, R.K., and Niles, L.J. (in press) *Declines in the wintering populations of Red Knots in southern South America*. Condor

Wetlands International. (2002) Waterbird Population Estimates – Third Edition. Wetlands International Global Series No 12, Wageningen, The Netherlands

Chapter 2. Weight gain of spring-staging migratory shorebirds on the Delaware shore of Delaware Bay in 2003

Robinson, R.A., Harrington, B., Clark, N.A. & Atkinson, P.W.

2.1 Introduction

Since 1997, an international team of shorebird biologists has been monitoring the migratory patterns of shorebirds staging in Delaware each spring on their northward migration to the arctic breeding grounds. The primary focus has been on the Red Knot *Calidris canutus*, but Ruddy Turnstone *Arenaria interpres* and Sanderling *Calidris alba*, which also use the Bay in large numbers at this time have also been monitored.

In this report, we update the results of previous reports (*e.g.* Robinson *et al*. 2003) with observations and measurements from the 2003 field season and draw comparisons with other years for this season. Fewer birds were present in 2003 than in previous years (see elsewhere in this report), in particular, Sanderling numbers were very low and few were caught, so here we present just data on Red Knot and Ruddy Turnstone. Data from the 1980s on weights of Red Knot caught in Delaware Bay by a team lead by one of the authors (BH) are also presented to provide an historical comparison.

2.2 Methods

Catches of primarily feeding shorebirds on the beaches of Delaware were made using cannon-nets. Birds were caught during May, the period of peak migration; for convenience the few catches made in the first few days of June in some years were treated as having been in May (June 1 = May 32 *etc*.). After capture, birds were quickly extracted from the net into keeping cages where they awaited processing. All birds were banded with individually numbered rings and most also had colour bands, indicating site and year of capture, applied. Virtually all birds were weighed using an electronic balance and most also had a number of other size and plumage biometrics taken, though these will not be considered here. All birds were processed and released within four hours of capture.

Because birds are arriving from multiple wintering areas it seems likely, though not inevitable, that this will be reflected in arrival dates in Delaware Bay. Such groups can be identified by an examination of the overall weight frequency data and looking for evidence of overlapping normal frequency distributions. The methods used to do this are given in more detail in (Robinson *et al*. 2003) and we used the software package FiSAT (Gayanilo *et al*. 1996) to perform the analyses.

Weight gain between capture occasions of individual birds was modeled using General Linear Models with an identity link function and normal errors. All such models were fitted using SAS PROC GENMOD and significance of individual terms was assessed using Type 3 statistics (SAS Institute 1997).

2.3 Results

Weight gains for the 1070 Red Knot and 1217 Ruddy Turnstone weighed on capture are presented in Table 2.1. The overall pattern of weight gain amongst Red Knot in 2003 was significantly different to other years (Fig. 2.1). Although birds apparently arrived at a similar weight (around 120g) as in previous years, there were many birds at this weight until quite late on in the month. It was not until the end of the month that significant numbers of heavier weight birds were recorded. In contrast, Ruddy Turnstone weight gain, measured by the pattern of overall weights was broadly in line with the pattern from previous years for the early part of the season (Fig. 2.2). However, the weights of birds caught after May 25 were noticeably lower than might be expected from catches in previous years.

Analysis of the rates of weight gain showed that the pattern of weight gain by individual birds was similar to that in other years (Fig. 2.3). Rate of weight gain varied with date of first capture (which is likely to be a proxy for arrival date), birds present earlier in the month put on weight at a lower rate than those which arrive later and rate of weight gain decreases as birds become heavier. However, for a given day and weight, the rate of weight gain in 2003 was lower than in previous years, by around 2g day^{-1}. Similar results were obtained for Ruddy Turnstone, the overall pattern of weight gain was similar to that in previous years, but the absolute rate of weight gain was lower.

Annual catches were made during May in six years of the eight years 1980-87 (Fig. 2.4a). In most years the distribution of catch weights centers around the overall logistic weight curve observed during the late 1990s, suggesting the rate of weight gain was similar during the two periods. The notable exception to this was a catch in 1986 on May 15, which was well above the 'expected' weight, possibly signifying the presence of an earlier arriving cohort that had already achieved significant weight gains. Examining the distributions in more detail show a population of lightweight birds (with weights typical of birds just having arrived) on May 19/20 (Fig. 2.4b). The heavier cohorts broadly fall on the logistic curve observed in recent years.

2.4 Discussion

During their stay in Delaware Bay, Knot are potentially time-stressed in their need to put on sufficient fat for their onward northward migration, however, equally, there are costs to carrying fat, particularly when birds are migrating long distances. Thus the amount of weight gained by birds represents a delicate balance of a number of factors. The results from 2003 further support the general pattern weight gain, but the year was anomalous in a number of respects, which had consequences for the rate of weight gain.

The weather during May 2003 was atypical in many regards. An initial period of bad weather along the East coast appeared to delay the arrival of many birds and a major storm on the 16 greatly reduced the number of feeding opportunities for at least a couple of days. Furthermore, sea surface temperatures were abnormally low. Consequently, spawning activity by the horseshoe crabs, which is known to be temperature dependent (Webber pers. comm.), was unusually low, and late. This is likely to account for the generally low intake rates achieved by the Knot in 2003. However, there was reasonable spawning towards the end of month, at least in the Mispillion, and birds that congregated here (and from where most of the data reported here were derived in 2003) appeared to gain weight rapidly during this period.

2.5 References

Gayanilo, F.C., Sparre, P. & Pauly, D. (1995) The FAO-ICLARM Stock Assessment Tools (FiSAT) user's guide. *FAO Computerised Information Series (Fisheries)*. FAO, Rome.

Robinson, R.A., Atkinson, P.W. & Clark, N.A. (2003) *Arrival and weight gain of Red Knot* Calidris canutus*, Ruddy Turnstone* Arenaria interpres *and Sanderling* Calidris alba *staging in Delaware Bay in spring.* British Trust for Ornithology, Thetford, UK.

SAS Institute (1997) *SAS/STAT software: changes and enhancements through release 6.12.* SAS Institute, Cary, C.

Table 2.1. Growth parameters for (a) Red Knot and (b) RuddyTurnstone in Delaware Bay. Weight (*W*) is modeled as a logistic function of time (day, *x*): $W = W_a + W_g / (1+\exp(a-b.x))$. Parameter estimates are given ± 1 std error. F tests whether the rate of growth (characterised by a, b) in each year is different from that over all years.

	N	Wa	Wg	a	b	F
(a) Knot						
1997	947	126.3 ± 3.2	57.0 ± 4.1	30.7 ± 4.2	1.35 ± 0.18	1.96
1998	1237	114.0 ± 1.5	89.0 ± 4.4	6.69 ± 0.60	0.32 ± 0.03	1.98
1999	2485	122.9 ± 1.0	47.7 ± 1.2	29.2 ± 4.6	1.72 ± 0.27	2.40*
2000	1256	95.9 ± 13.0	78.4 ± 15.5	3.74 ± 1.11	0.25 ± 0.06	0.60
2001	2327	122.1 ± 2.0	65.7 ± 3.2	7.36 ± 0.65	0.34 ± 0.03	1.20
2002	1441	76.2 ± 69.7	102.0 ± 87.8	1.58 ± 2.27	0.11 ± 0.09	0.05
2003	1070	119.2 ± 1.0	67.7 ± 5.7	14.9 ± 1.6	0.50 ± 0.06	14.72**
All	10763	109.7 ± 2.5	71.1 ± 4.0	4.00 ± 0.36	0.21 ± 0.02	
(b) Turnstone						
1997	723	97.6 ± 2.0	37.3 ± 2.7	14.05 ± 3.22	0.65 ± 0.15	0.36
1998	1690	96.6 ± 1.1	54.4 ± 2.2	8.38 ± 0.92	0.40 ± 0.04	1.68
1999	1924	99.2 ± 1.7	57.3 ± 3.8	4.87 ± 0.58	0.22 ± 0.03	0.42
2000	1529	97.6 ± 2.5	59.5 ± 4.0	6.12 ± 0.80	0.29 ± 0.04	0.90
2001	2683	99.8 ± 0.7	62.1 ± 2.6	8.48 ± 0.58	0.34 ± 0.02	4.23**
2002	1557	98.5 ± 1.7	79.0 ± 7.5	5.73 ± 0.56	0.22 ±0.02	1.10
2003	1217	(97.2)[1]	43.6 ± 3.0	4.80 ± 0.38	0.22 ±0.02	1.25
All	11325	97.2 ± 0.6	61.3 ± 1.6	5.93 ± 0.23	0.26 ±0.01	

Figure 2.1. Weight gain of Red Knot in Delaware Bay during May 2003. Symbols represent group means (± 1 std deviation) identified by decomposition of the overall distribution. Lines connect trapping instances of individual birds. The dashed curve represents the overall schedule across years.

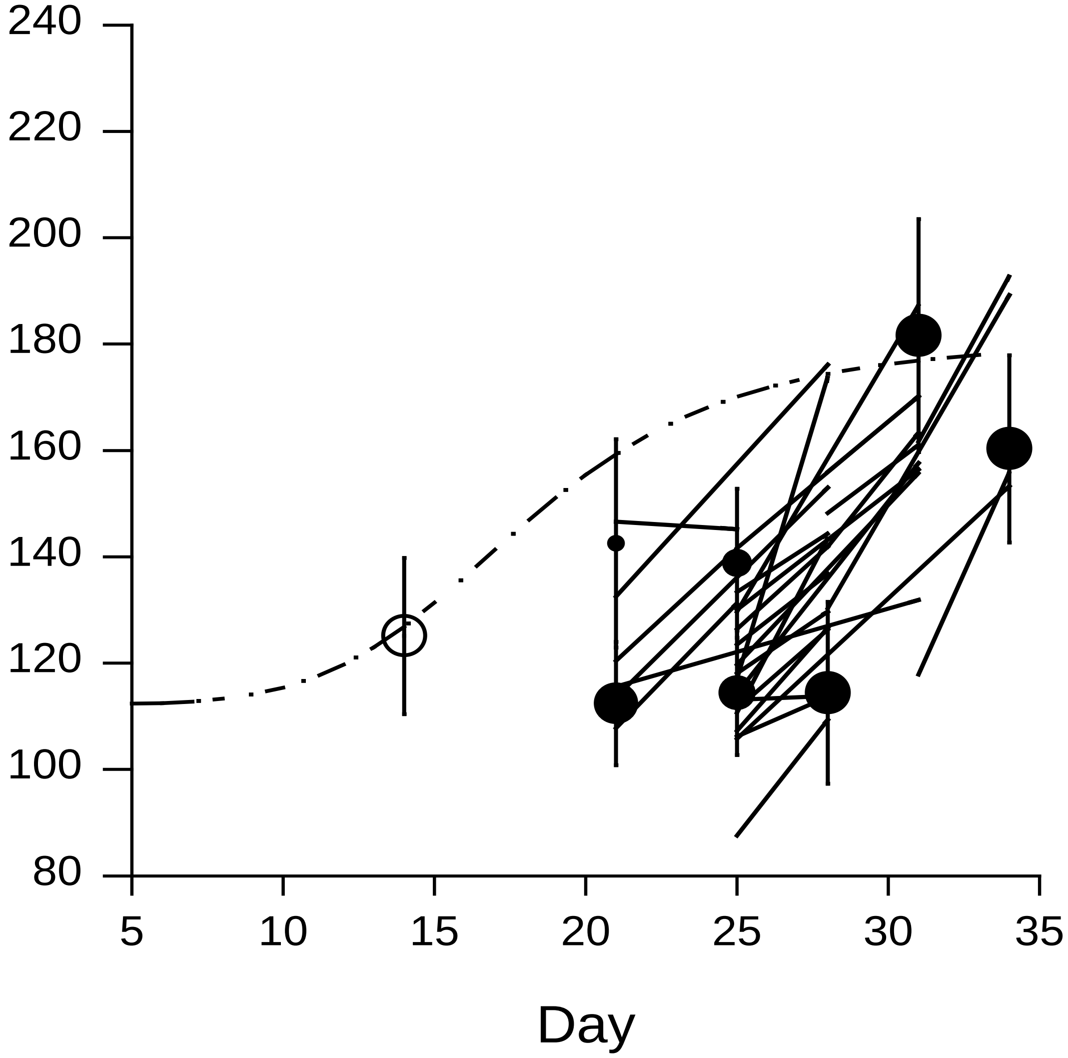


Figure 2.2. Weight gain of Ruddy Turnstone in Delaware Bay during May 2003. Symbols represent group means (± 1 std deviation) identified by decomposition of the overall distribution. Lines connect trapping instances of individual birds. The dashed curve represents the overall schedule across years.

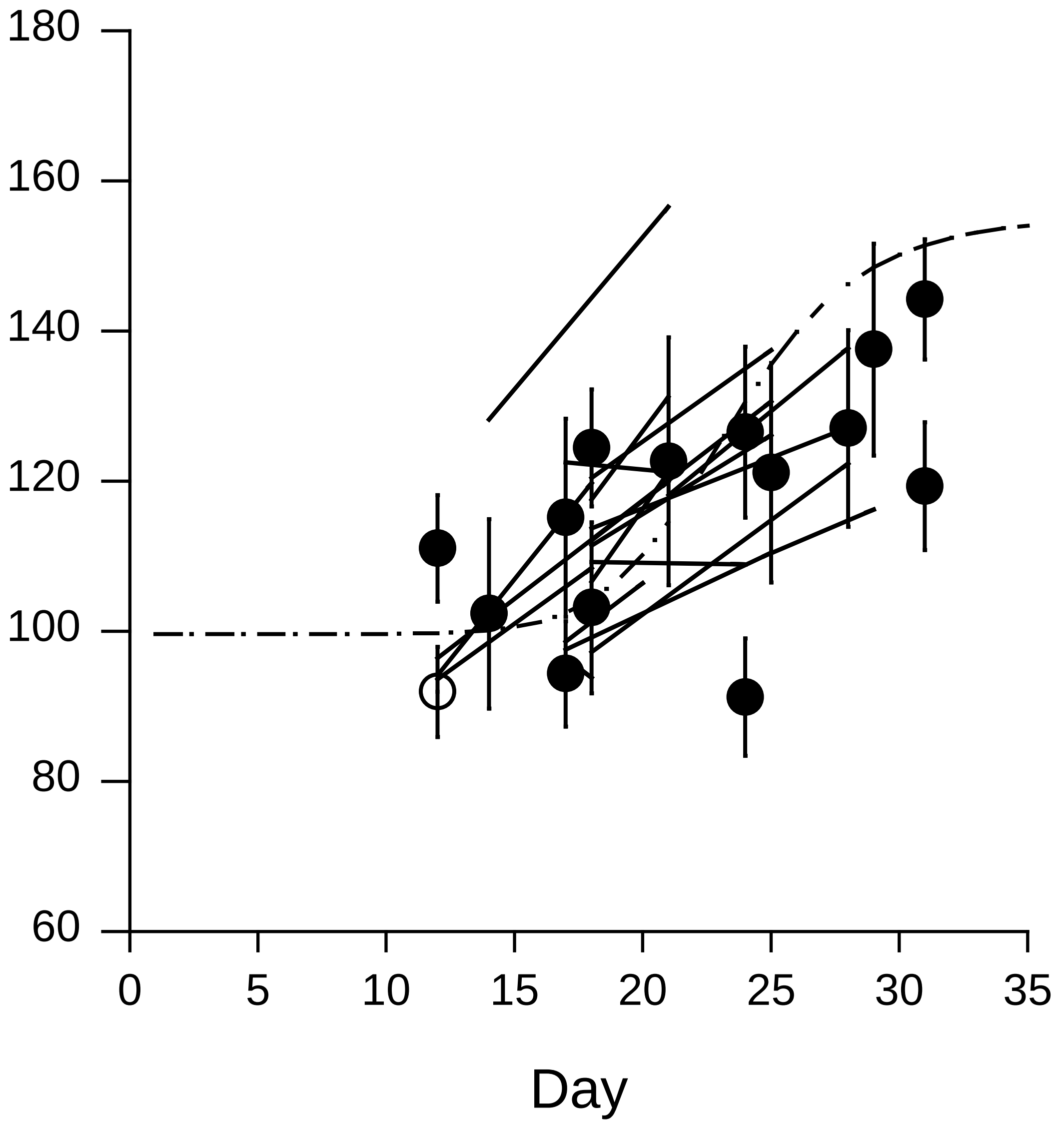


Figure 2.3. Pattern of weight gain for Knot in relation to date of first capture (a proxy for arrival date) and weight at that time, from individual recapture histories. Contours indicate average daily rate of weight gain between day of capture and May 31.

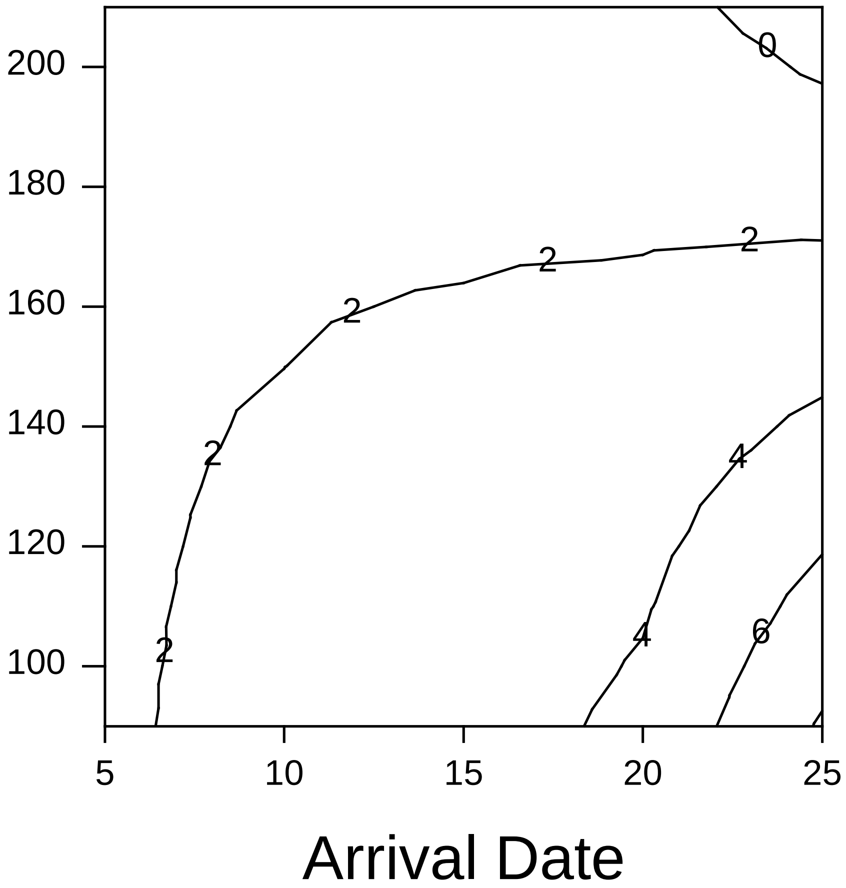
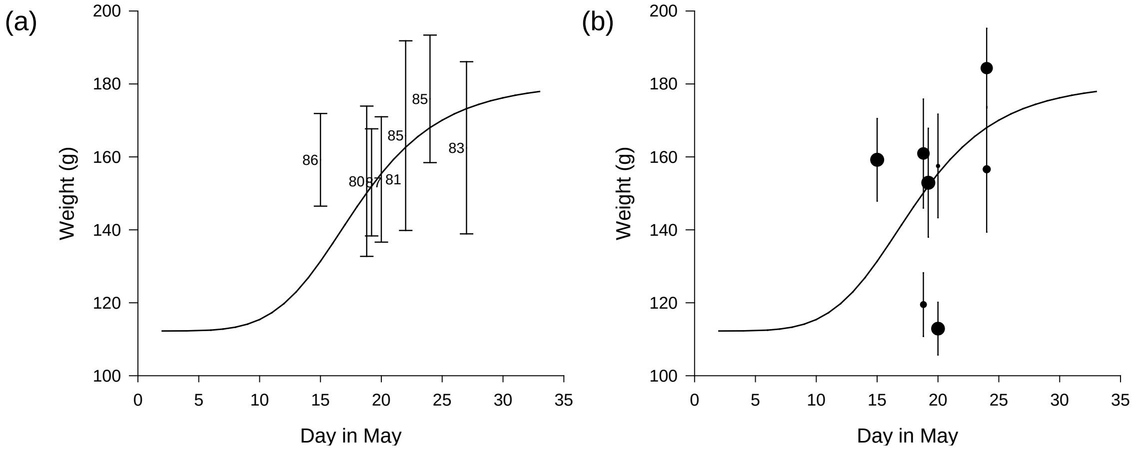


Figure 2.4. Weights of Red Knot caught in Delaware Bay in the 1980s. (a) Simple means (± 1 std deviation) for each catch; symbols identify the year of each catch and are offset for clarity. The overall logistic growth curve from the period 1997-2003 is included to facilitate comparison. (b) Groups identified from decomposition of the overall distribution (means ± 1 std deviation).



Chapter 3. A preliminary analysis of resightings of Red Knot Calidris canutus bearing individually inscribed darvic leg flags on the Delaware shore or Delaware Bay.

Gillings, S., Atkinson, P.W. & Clark, N.A.

3.1 Introduction

Since the early 1990s Red Knot *Calidris canutus* staging in Delaware Bay, USA, have been fitted with color bands to denote year and site cohorts in addition to unique metal bands. Because these bands can be seen easily in the field and potentially large number of resightings can be accrued they offer the potential to provide more information on survival than conventional metal rings for which recapture rates are low. However, estimates of survival based on resightings of cohorts' color bands are very imprecise and using individually inscribed flags has been recommended for the future (Atkinson *et al*. 2003).

Colored flags bearing inscriptions that can be read in the field offer the potential to track individuals and increase the precision of survival estimates. They also offer the potential to look at individual movements, arrival times and stopover duration. This information is very valuable as it can be used alongside information on rates of weight gain to assess whether birds are arriving and departing early or late and help to ascertain where bottlenecks in the system might be arising.

This report describes catching, banding and resighting efforts on the Delaware shore of Delaware Bay in May-June 2003 and illustrates the use of the information collated in assessing stopover duration. Finally we make some recommendations for how banding and resighting could be improved in subsequent years.

3.2 Methods

3.2.1 Banding and resighting

During May-June 2003 catches of Red Knot were made where large concentrations were present. On each catch all or a random sample of individuals were fitted with a unique metal band, an orange color band, and a lime colored flag bearing a two character (letter or number) inscription. A similar banding scheme was employed on the New Jersey shore of Delaware Bay but with a green band in place of orange. Efforts were made to catch and band throughout the migration period to ensure some degree of coverage of different arrival times. Subsequently observers visited all sites on the Delaware shore of Delaware Bay and checked any knot flocks for the presence of lime-flagged birds. Observers also noted any birds bearing New Jersey 2002 individual combinations (color bands), the New Jersey 2003 individual combinations (lime flag plus green color band) and any uniquely colored or uniquely inscribed South American individuals.

3.2.2 Analysis

A matrix was created of all flags used against date in May/June. For each flag inscription we entered the date of initial and subsequent capture, and any resightings. The matrix was extended to include any other known individuals of New Jersey or South American origin. Each bird was then coded to give its recapture/resighting history as a series of ones and zeros for use in Mark-recapture software.

The recapture/resighting histories were analysed to determine stopover duration. One can simply investigate the maximum duration between initial capture and final sighting, but these estimates are shown to widely underestimate true stopover duration. Instead Schaub *et al*. 2001 propose a two-stage method that employs techniques similar to Survival modelling. The stopover duration is conceptually split into the period prior to capture and the period post capture. For the post capture period a basic survival model is used in which departure is analogous to mortality. For the period prior to capture recruitment models are used (Pradel 1996). Both these models can be run in isolation in a programme such as MARK, however, confidence estimates cannot be calculated because the covariance between probabilities of immigration and emigration are neither zero nor unknown (Schaub *et al*. 2001). Instead Schaub *et al*. (2001) recommends a boot-strapping technique and this was applied here. However, before running the SODA programme to boot-strap stopover duration estimates it is first necessary to investigate model selection in MARK (version 2.1). MARK was also used to investigate the effect of date of initial capture and weight at capture on the subsequent duration of stopover. We predict that birds of high weight should remain for shorter periods (low daily survival) and birds caught at late in May should remain for a short period. Equally, one might expect an interaction, since if caught at low weight late in the month the bird may stay longer than a bird of high weight caught late in the month.

3.3 Results

During May-June 2003 inscribed lime colored flags were fitted to 664 Red Knots on the Delaware shore of Delaware Bay. Of the 664 birds banded, 258 (39%) were resighted at least once in the field. A total of 454 resightings were made (mean of 1.8 resightings per bird), The majority of the resightings (417, 92%) were in Mispillion Harbour, because this is where the majority of the birds were present on the Delaware state shore and resighting effort was concentrated where most birds were present. However, frequent surveys were made of other sites to check for Knot flocks and where present, these were also checked for inscribed flags.

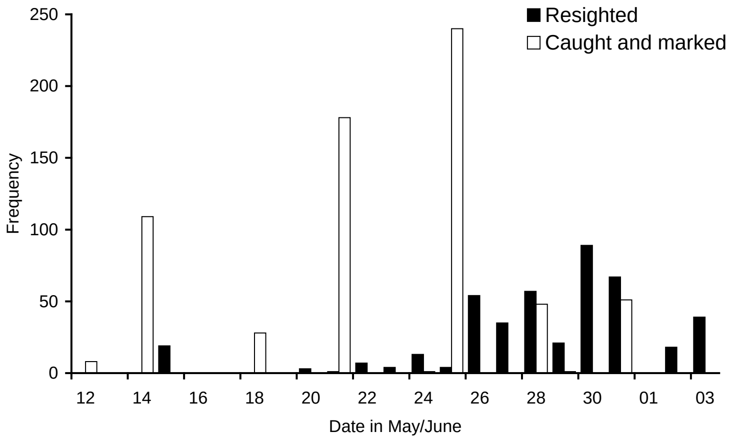


Figure 3.1. Daily number of Red Knot fitted with inscribed lime flags, and number resighted in the field on the Delaware state shore in May 2002

Despite the large catch on May 14 very few birds were resighted until 10 days later (Figure 3.1). Furthermore, of those banded on the initial catch, few were resighted at any time. Shortly after the catch on May 15 a severe storm caused up to 30cm of sand to be deposited on some bay beaches including Mispillion harbour. This effectively made the eggs from large spawning on May 14 inaccessible and many Knot left the area. This coincided with many birds being seen on the Atlantic coast.

The median weight at initial capture of birds resighted during the season was 125.0 (quartiles 113.0-137.3) and the median weight at capture of birds not resighted during the season was 123.6 (quartiles 110.4-139.9) and these weights did not differ significantly (Kruskal-Wallis $\chi^2_1 = 0.005$, $P > 0.9$).

Table 3.1. Resighting rates of different catches.

Date of catch	Resighted	%
12	0 of 8	0%
14	28 of 109	26%
18	8 of 28	29%
21	50 of 178	28%
24	0 of 1	0%
25	134 of 240	56%
28	27 of 48	56%
29	1 of 1	100%
31	9 of 51	18%

3.4 Stopover duration

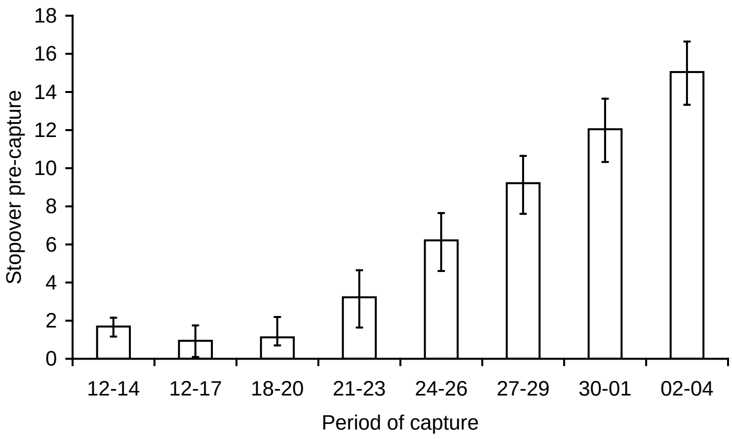
Due to problems of transients and low resighting effort during some periods observations were combined into three day periods for analysis. Preliminary analysis in MARK showed that a fully-time dependent model was best (Table 3.2) and these options were subsequently used in the SODA package. 779 individuals were used in that analysis.

Table 3.2. Results of Red Knot daily survival models, based on resightings within May-June 2003 of birds bearing individually inscribed leg flags. The models are ranked by the Akaike Information Criterion (AIC), with the most parsimonious model at the top. Model notation: φ = daily survival, ρ = daily reporting rate. Parameters: . = constant (*i.e.* time independent) parameter, t = time dependent, W = linear function of the weight at capture, D = linear function of the date of capture after May 1. The model number is indicated on the left hand side of the tables and is referred to as such in the text.

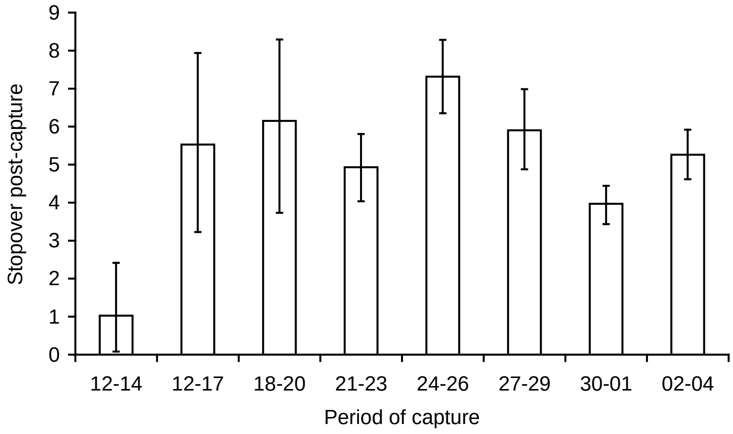
Model	AICc	Δ AICc	AICc Weight	Model Likelihood	N°. Parms	Deviance
1 $\varphi_{(t)}\ \rho_{(t)}$	1665.7	0.0	0.97502	1.0000	12	1641.4
2 $\varphi_{(W+D+DW)}\ \rho_{(t)}$	1674.1	8.4	0.01470	0.0151	10	1653.8
3 $\varphi_{(W+D)}\ \rho_{(t)}$	1675.8	10.1	0.00618	0.0063	9	1657.6
4 $\varphi_{(W*t+D+DW)}\ \rho_{(t)}$	1677.5	11.8	0.00266	0.0027	15	1647.0
5 $\varphi_{(D*t+D*t+DW)}\ \rho_{(t)}$	1679.4	13.8	0.00101	0.0010	14	1651.0
6 $\varphi_{(.)}\ \rho_{(t)}$	1682.8	17.1	0.00019	0.0002	7	1668.7
7 $\varphi_{(W*t)}\ \rho_{(t)}$	1683.1	17.4	0.00016	0.0002	13	1656.7
8 $\varphi_{(W)}\ \rho_{(t)}$	1684.4	18.7	0.00009	0.0001	8	1668.2
9 $\varphi_{(t)}\ \rho_{(.)}$	1708.4	42.7	0.00000	0.0000	7	1694.3
10 $\varphi_{(.)}\ \rho_{(.)}$	1835.0	169.3	0.00000	0.0000	2	1831.0

Thus Figures 3.2A and 3.2B show the predicted duration of stay prior and post each period of capture. For instance, birds caught during the period May 21-23 were estimated to have been present for on average 3.2 days and were estimated to have stayed for a further 4.9 days, giving a total estimated stopover duration of 8.1 days. From Figure 3.2A it is clear that from the period May 18-20 onwards birds during each period had been present for progressively longer prior to capture. This is more apparent in Figure 3.2C in which the pre and post capture durations were respectively subtracted and added to the midpoint of each period of capture. In this way the likely arrival dates and departure dates were estimated and it can be seen that apart from arrivals on around May 11 and 15 all other captures appear to relate to a single arrival on around May 19. Also, the birds present on the Delaware shore during two earliest periods stayed for only very short periods of a few days and this matches field observations. Around May 16 a severe storm resulted in both departure of the birds that were present and severely curtailed resighting observations for 1-2 days.

A. Duration of stopover prior to capture



B. Duration of stopover post capture



C. Estimates residency periods

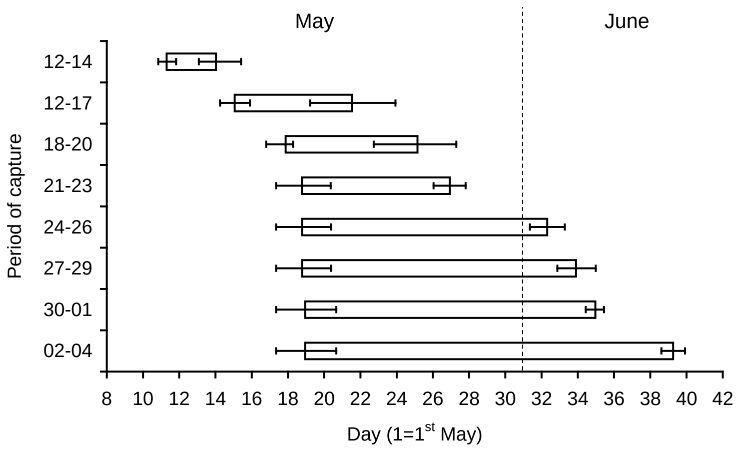


Figure 3.2. Results of stopover duration analysis. A) mean duration of stopover prior to capture for three-day capture periods, B) mean duration of stopover post capture and C) estimated arrival date and departure date forecasted from pre and post stopover duration for each three-day period (error bars are 95% confidence limits throughout).

The most parsimonious model was fully-time dependent and this is the model that was subsequently used in the SODA package. However, incorporating covariates for Weight, Date and Weight×Date interaction yielded a model (model 2) that was only slightly poorer than the fully time dependent model, and was significantly better (Likelihood ratio $\chi^2_3 = 14.9$, $P < 0.002$) than the constant survival model (model 6). The resulting daily survival probabilities of this model are shown in Figure 3 plotted against variation in day of capture and weight at capture. In this case high daily survival is analogous to high probability of being resighted the following day. High resighting probabilities are associated with either late capture at low weight, or early capture at high weight. Low resighting probabilities are associated with either low weight early capture or high weight late capture.

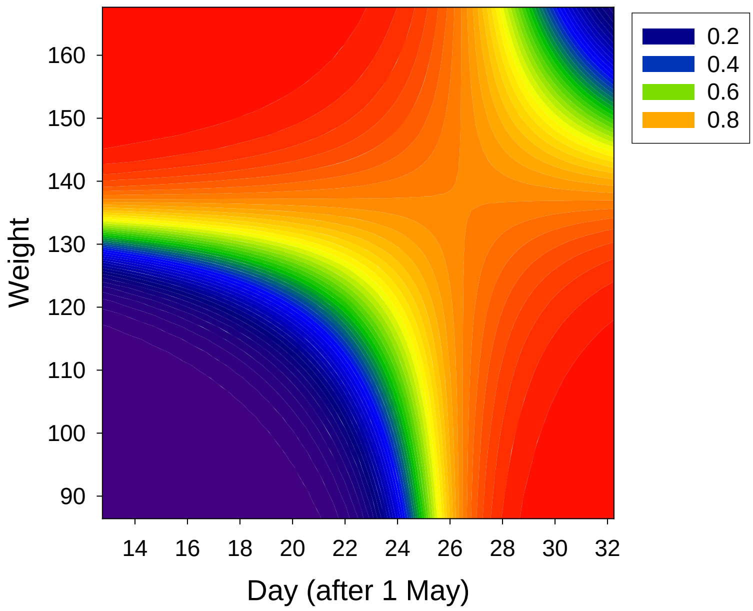


Figure 3.3. Predicted daily survival probabilities across a range of dates and weights of capture.

3.5 Discussion

The new inscribed flags were very effective and relatively easy to read in the field as evidenced by the high reporting rate. Forty percent of individuals were resighted, on average almost twice in addition to their initial capture. This level of information was achieved by spending a minimum of 4 person hours per day scanning for leg flags.

With only one year of data on the new inscribed flags it is not possible to assess survival but resightings in spring 2004 offer the potential to assess survival one year on. Nonetheless the data from the first year were useful in a preliminary analysis of stopover duration. Weather conditions in May 2003 mean that these are perhaps slightly atypical patterns with respect to the rapid departure of birds present early in May. That meaningful relationships can be found between residency, weight and date of capture is encouraging though the pattern of mass departure in the first half of the month is atypical.

The most striking feature is the pronounced arrival of birds on approximately May 19. Intriguingly this is exactly the time that inspection of histograms of weights suggests to be a major period of arrival owing to the sudden appearance of a large number of light weight birds in catches. This lends support to the argument that there is a staggered arrival of knot throughout May. Whether these different birds originate from different wintering areas or represent different migration strategies has yet to be ascertained.

3.6 Recommendations

Resightings in future years have two aims. First, they must ensure adequate reporting of birds from previous years, and second they must adequately monitor residency of birds flagged in that year.

3.6.1 How many flags to fit per year?

Atkinson *et al*. (2003) suggested 1000 birds should be flagged per year for survival estimation. The main aim should be to ensure that a sample of birds are flagged throughout the month, rather than fitting a high proportion on one catch. This should aid analysis of stopover duration and will prevent bias resulting from only banding one part of the population. Banding late arriving birds will be especially informative.

3.6.2 How much resighting effort?

Atkinson *et al*. (2003) suggested scanning through 15,000-20,000 birds and this should be treated as a minimum effort. Resightings should aim for a minimum of 25 birds resighted per day. Ideally this should be 25 of a 'cohort' or 'year-class' (in terms of catching, not age). The SODA package struggled with some parts of the analysis (*e.g*. resightings had to be aggregated into three day periods). For this reason, 50 individuals/cohort ought to be a minimum. Resighting observation should be evenly distributed throughout the staging period and without major gaps (ideally daily/every two days).

3.6.3 Concentration of effort into different areas.

In 2003 the majority of resightings were made on the Delaware shore of Delaware Bay. Movements from one side of the bay to the other occur over a matter of days, and certainly consecutive years can see large numbers of birds originally banded on one shore staging on the opposite. Therefore, in order to get accurate information on survival and staging an equal resighting effort should be maintained on both Delaware and New Jersey bay shores at all sites where significant numbers occur. Frequent checks of Stone Harbour and other Atlantic coast sites may be rewarding as is evident from movements of radio-tagged birds in 2003 (H. Sitters pers. comm.).

Observations in May 2003 suggested that individual knots were faithful to certain sections of beach. Thus in a site as small as Mispillion Harbour, where discrete beach sections are a maximum of 500 m apart, certain individual birds were only ever recorded on certain beaches. This warrants further study, but also suggests that resighting efforts should be randomised, or observations attempted on all flocks located, not simply the largest to ensure no systematic bias in recording.

3.7 References

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Acknowledgements

This work was funded by the Division of Soil and Water, Delaware Department of Natural Resources and Environmental Control.

Vehicles were kindly loaned for use during the fieldwork by the US Fish and Wildlife Service.

Thanks are due to all the volunteers who helped on the catches and resighting work during the season.

We would particularly like to thank Dave Carter and Kimberley Cole for the support that we received during our stay. They and the other members of DENREC staff who helped make the field season extremely enjoyable, and solved many of our problems.

Alan Baker and Patricia Gonzalez kindly provided details of previously ringed birds.