Survival and behaviour in shorebirds wintering on the Banc d'Arguin, Mauritania

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Contents

SUMMARY AND CONCLUSIONS

This report describes the fieldwork and gives some basic results of a project on the population biology of coastal shorebirds at their most important wintering area along the East Atlantic Flyway, the Banc d'Arguin, Mauritania. The work was carried out in November and/or December 2002, 2003, 2004 and 2005 by members of the shorebird research team of the Royal Netherlands Institute for Sea Research (NIOZ).

The main conclusions are:
a) By using mistnets and a clapnet and by timing the expeditions in the relatively windless period of the year, it appeared to be possible to catch sufficient waders during one new moon period to start a long-term study on survival and behaviour of waders.
b) Red Knots and Sanderlings appeared to be very site-faithful, resulting in high resighting rates during a relatively short observation period. Bar-tailed Godwits, however, appeared to be less site-faithful.
c) After four years (three time steps) it is already possible to give a reliable estimate of the annual survival of Red Knots and Sanderlings. Given the low resighting rate of Bar-tailed Godwits we need a longer research period to estimate survival.
c) The study area appeared to be an ideal location to study the interactions between avian predators and waders.
d) Given the promising results till now, we are determined to try to continue this project for a number of years.

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1 INTRODUCTION

With fishery pressures mounting in coastal areas around the world and with sea level rise and global heating threatening, it is widely recognized that coastal shorebirds could well be the first victims of these changes (e.g. Piersma & Baker 1999, Piersma & Lindström 2004). In fact, evidence is mounting that the populations of some molluscivore specialist shorebirds along the East Atlantic Flyway are declining. For example, the West-African wintering populations of both Red Knots *Calidris canutus* and Bar-tailed Godwits *Limosa lapponica* may have decreased by almost half in the 20 years since they were first counted. To determine the causes of the population declines, over the past few years the shorebird group at the Royal Netherlands Institute for Sea Research (NIOZ) has initiated individual colour-ringing schemes for these two species in order to measure season- and year-specific survival rates. The study will also make it possible to relate individual traits (sex, mass at capture, moult and health status) with subsequent fate. As the birds encountered in the Wadden Sea and the Banc d'Arguin belong the same populations, we need to extend the fieldwork on a regular basis to include the Parc National du Banc d'Arguin. In brief, we aim to establish a study where catching for individual colour ringing in PNBA is combined with detailed essays on the health and vigour of the captured birds. In addition, intensive scanning is required to follow the fate of the individual Red Knots and Bar-tailed Godwits marked in The Netherlands and Mauritania.

Parasites and diseases may have considerable consequences for the population dynamics. For example, Piersma (1997) suggested that the use of particular habitat types by long distant migrant birds could be the result of trade-off between investments in growth, development, functioning of the immunological system and sustained exercise. He argued that some species, particularly the ones living in marine and coastal sites, are restricted to such parasite-poor habitats because small investments in immunomachinery suffice. As such habitats are few and far between and often energetically costly to live in, such species are evolutionarily opting to investment in sustained exercise (flight, thermoregulation) rather than immunocompetence and are thus rather susceptible to parasites and pathogens. In this context we aim to measure the health and parasitism status of shorebirds captured on the Banc d'Arguin, and also assess the extent to which they are able to mount immune responses to fight off any disease problems.

This report describes the fieldwork of this project done in November and/or December 2002, 2003, 2004 and 2005 by members of the shorebird research team of the Royal Netherlands Institute for Sea Research (NIOZ). Some basic results are given. We intend to continue these investigations in the years to come. Some of the results have already been published in scientific journals (Mendes et al. 2005, Leyrer et al. 2005).

2 STUDY AREA AND METHODS

2.1 The study area

Our main study area is the area around the PNBA-station near Iwik: the Iwik-peninsula (19.53.055 N, 16.17.708 W) and the Baie d'Aouatif (Fig. 1). Additional observations were done along the coast between the Ebel Kheaiznaya and the village of Ten-Alloul (sub-area 0) and around the islands Niroumi and Nair (situated west of the north-tip of Tidra, Fig. 1)

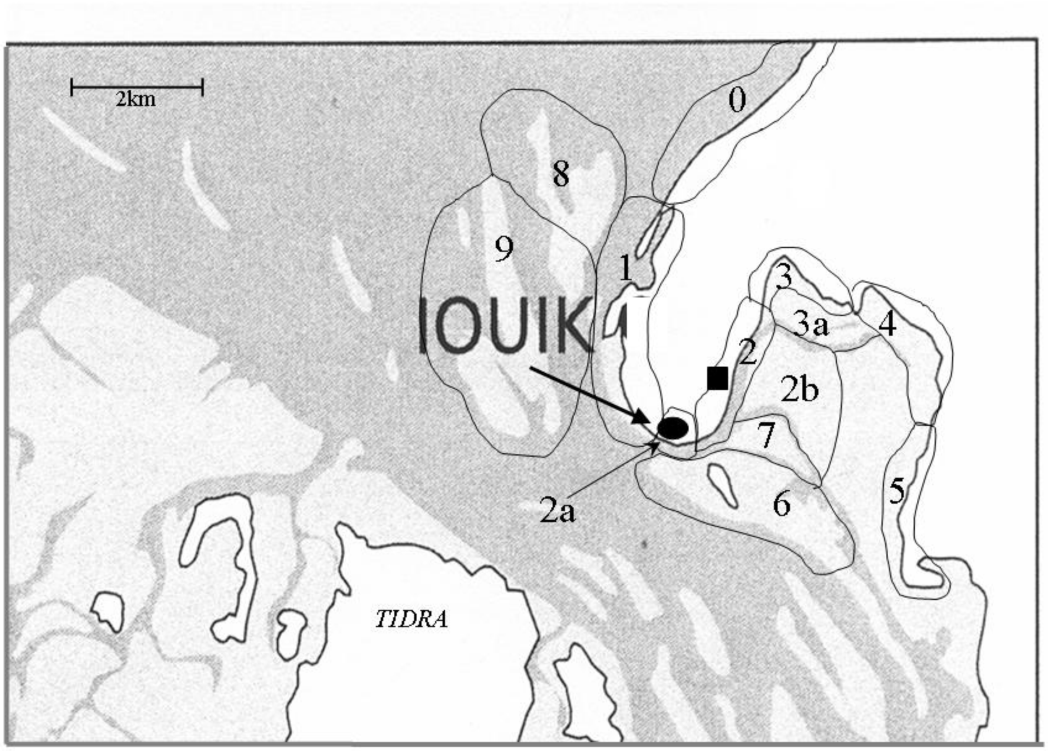


Fig. 1. *Map of the study area. The black square indicates the PNBA-station.*
The sub-areas:

0) The coast north of Ebel Kheaiznaya till Ten Allul
1) Ebel Kheaiznaya till Iwik
2a) Iwik-village
2b) Mudflats opposite to the station
2) West-shore of Baie d'Aouatif from Iwik till the observation-tower
3) Northwest shore of Baie d'Aouatif
3a) Mudflats in the northwestern part of Baie d'Aouatif
4) Northeast shore of Baie d'Aouatif
5) Southeast shore of Baie d'Aouatif (Tivide)
6) Mudflats around the island of Zira
7) Mudflat Northeast of Zira
8) Outer-mudflats North
9) Outer-mudflats Southwest

The two westernmost islands on the map are Nair and Niroumi

2.2 Catching and processing of the birds

The basis of our investigations is the catching of waders. Mistnets were used as the main catching method. Successful mistnetting is only possible during calm nights (windforce < 4 Bft) and around high tide, when the birds concentrate near the shore. Moreover the nights have to be as dark as possible, preferably without any moon. Therefore the fieldwork-period in all four years was planned during the period around the new moon. From experience we know that hardly any birds are caught with mistnets when wind is stronger than 4 Bft. As Mauritania is situated in the trade-wind zone, it is a “wind-swept” country. December however, is a relatively calm month and therefore the only period of the year suitable for mistnetting.

Mistnet-sections were built on several locations on the higher parts of the mudflats; on the West- and North-side of Baie d’Aouatif as well as at Ebel Kheaiznaya on the West-side of the Iwik-peninsula (Fig. 1). The total length of the sections of mistnets we used per night varied between 120 and 420 meters. After opening the nets, they were checked every half hour. The birds captured were stored in boxes or small tents. At the end of a catching session, the nets were closed and all the birds were transported to the Iwik-station where the processing of the birds was done.

During daytime certain species of waders were caught with a 4 x 10m clap-net. This method works fine for species which can easily be attracted to a certain spot (the catching-sector), for example with food and/or water. In practice we caught mainly Turnstones and Sanderlings in this way.

Captured birds were ringed and biometric measurements as well as a blood-sample were taken. Dutch metal rings from the “vogeltrekstation Arnhem” were used. Bar-tailed Godwits, Red Knots and Sanderlings also got an individual colour-ring combination, making these birds recognisable in the field (see Appendix 2 for the colour-ringing schemes used).

The blood samples are used to determine sex (DNA-analysis, for species without sexual dimorphism) and, especially in 2002, also to measure the parasitism status of individuals for instance. The latter work was done by Luisa Mendes and the results have already been published. See XX for the abstract of this publication. A copy of this paper is added to this report as appendix 7 (Mendes *et al*. 2005).

2.3 The other fieldwork

The following data were collected in the field:

a) Searching for colour-ringed birds by scanning the flocks of waders on the mudflats and high-tide roosts with a telescope. To determine the density of colour-ringed birds, the number of birds that had to be controlled before the first colour-ringed bird was found, was counted.
b) Each year, all the water-birds present in the study area were counted during one high tide period.
c) In 2002 and 2003, daily minimum and maximum temperature were measured at the station. Wind direction was noted 3 times a day (early morning, mid-afternoon and evening) while wind speed was estimated at the same time. For 2004 and 2005 we were allowed to copy the files with weather data collected by the weather-station of the Iwik-station.
d) To get a better insight in the site fidelity within one season, we radio-tagged 20 Knots in 2003 and followed these birds thereafter with 2 automatic receiving stations (one at Ebel Kheaiznay and one on the observation tower in the Northwestern part of Baie d’Aouatif) and with handheld receivers. The results of

this part of our work are already published in the Journal of Ornithology (Leyrer *et al*. 2005). See Appendix 8 for a copy of this paper.

e) Observations on the presence and behaviour of wader-predators (mainly Falcons), including the search for prey-remains. Detailed observations on the impact of avian predators on the behavior of waders and Red Knots in particular, were carried out by P. van den Hout with help of other observers. As part of this work, experiments were done with temporary captive Knots in 2004 to determine possible habitat selection differences in adult and juvenile Knots. See Appendix 1 for a detailed description of this part of our work on the Banc d'Arguin.

2. 4 The time schedule

The dates of the main events during the four expeditions are summarized in table 1.

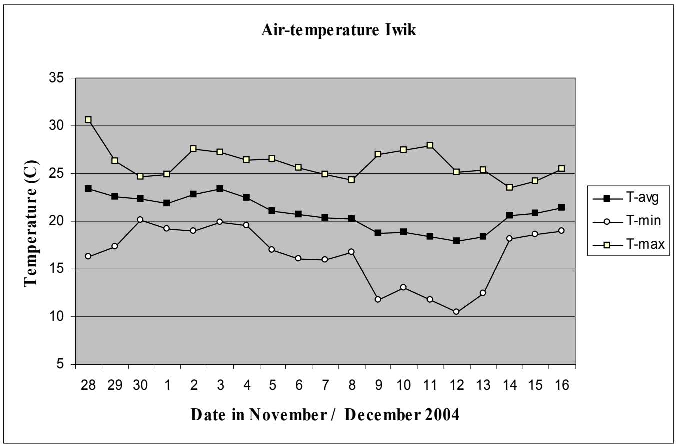
	2002	2003	2004	2005
Flight to Mauritania	22 Nov.	11 Dec.	27 Nov.	15 Nov.
Nouakchott – Iwik	23/24 Nov.	12 Dec.	28 Nov.	16 Nov.
New Moon	4 Dec.	23 Dec.	12 Dec.	1 Dec.
Date of high-tide count	6 Dec.	26 Dec.	14 Dec.	6 Dec.
Iwik – Nouakchott	11/12 Dec.	29 Dec.	17 Dec.	8 Dec.
Flight home	13/14 Dec.	30/31 Dec.	18/19 Dec.	8/9 Dec.

Table 1. *The dates of the main events during the four expeditions.*

3 RESULTS

3.1 Weather conditions

For 2004 and 2005 we have detailed weather data collected by the Iwik-weather-station. The temperatures during our stay in 2004 and 2005 are presented in Fig. 2. For 2004, the daily variation in temperature is shown in Fig. 3. This picture reflects the usual daily trend in temperature. The windspeed during our stay in 2004 and 2005 is plotted in Fig. 4. Though there were windy periods during all four expeditions, on most of the days the wind appeared to be stronger during the afternoon and relatively calm during the evening (Fig. 5). This phenomenon made successful mistnetting possible during most of the evenings. The weather conditions during the 2002 and 2003 expeditions were comparable to those in 2004 and 2005, though it was on average a bit more cloudy, colder and humid during the nights in 2003.



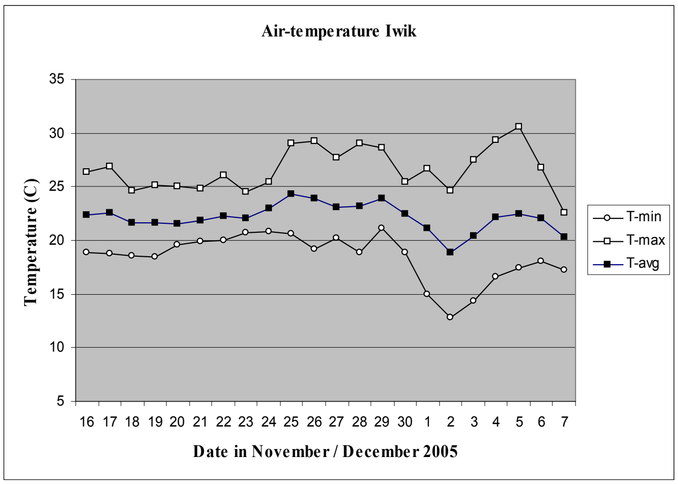


Fig. 2. *The minimum (T-min), maximum (T-max) en average daily temperature(T-avg) in ^{o}C in Iwik between 28 November and 16 December 2004 (upper graph) and from 16 November till 7 December 2005 (lower graph).*

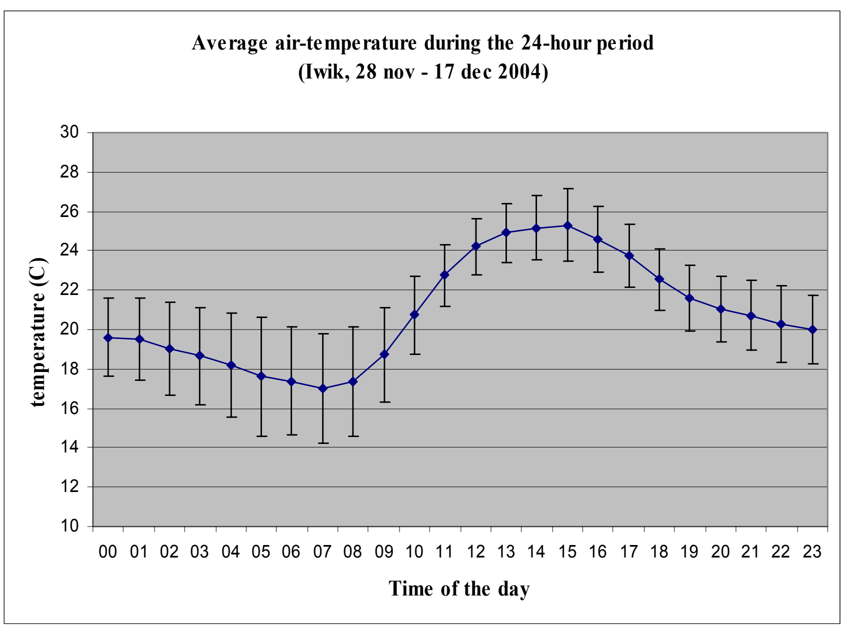


Fig. 3. *The average temperature during the 24-hour period ± SD, Iwik, 28 November till 17 December 2004.*

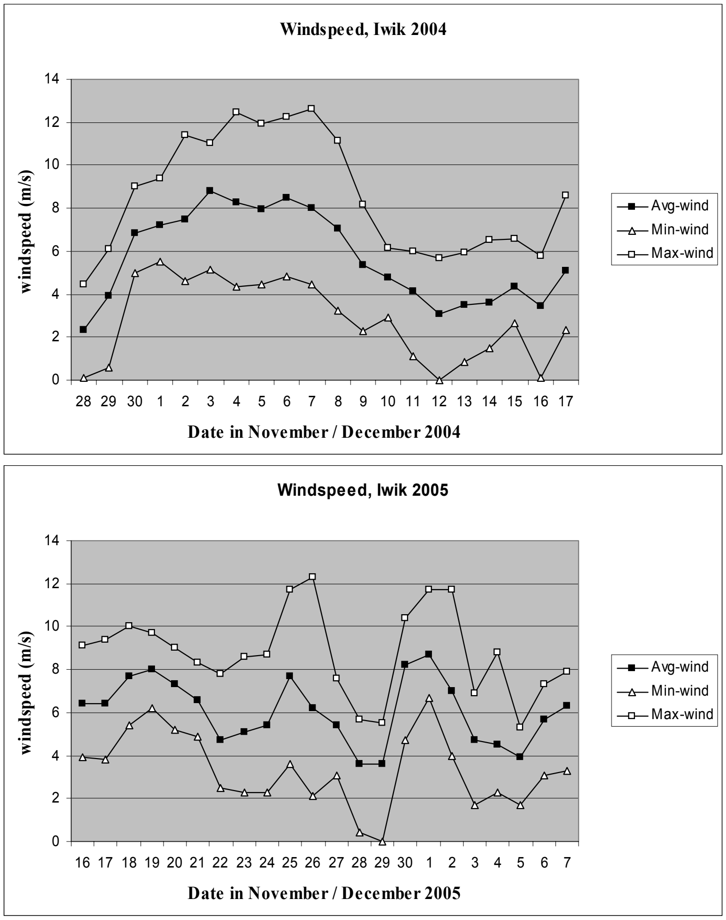


Fig. 4. *Maximum, minimum and average windspeed (m/sec) per day in Iwik between 28 November and 16 December 2004 (upper graph) and between 16 November and 7 December 2005 (lower graph).*

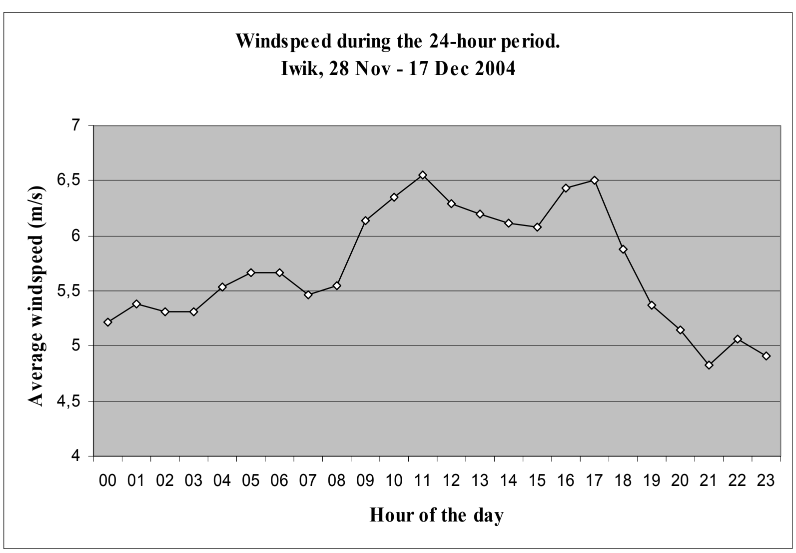


Fig. 5. *Average windspeed (m/sec) during the 24-hour period in Iwik between 28 November and 16 December 2004.*

3.2 The catching results

Almost 4000 waders of 15 different species were caught during the four expeditions (Table 2). The most successful period for mistnetting was from 1 week before till 2 days after the new moon (Fig. 6).

Species	2002	2003	2004	2005	Total
Bar-tailed Godwit	19	50	29	49	**147**
Curlew	-	4	-	-	**4**
Whimbrel	1	4	8	5	**18**
Redshank	39	41	43	20	**143**
Greenshank	1	1	1	-	**3**
Oystercatcher	2	3	6	7	**18**
Grey Plover	9	12	6	9	**36**
Ringed Plover	7	24	25	3	**59**
Kentish Plover	1	5	5	-	**11**
Turnstone	58	6	67	155	**286**
Red Knot	286	212	213	164	**875**
Curlew Sandpiper	57	30	106	16	**209**
Dunlin	294	387	409	251	**1341**
Sanderling	147	26	200	199	**572**
Little stint	22	29	19	20	**90**
Slender-billed Gull	2	-	-	-	**2**
Common Tern	-	1	-	3	**4**
Spoonbill				1	**1**
Total					**3819**

Table 2. *Total number of birds caught and ringed around IWIK during the three expeditions.*

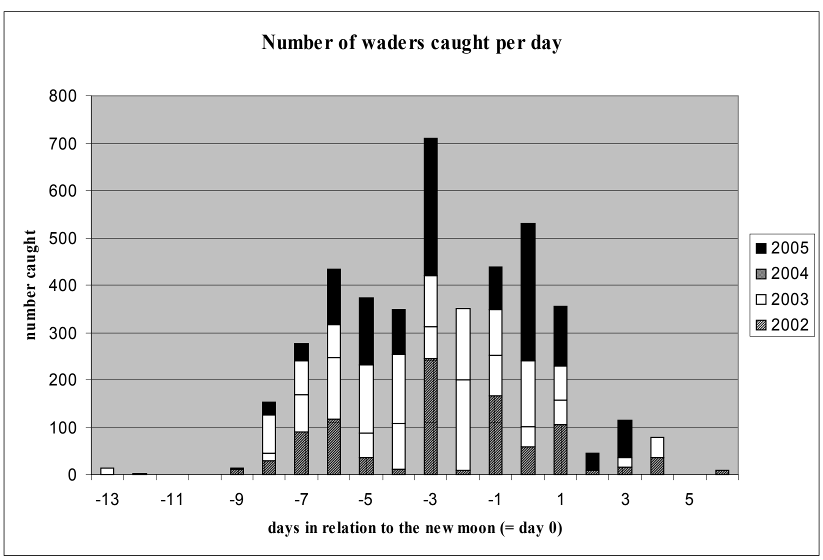


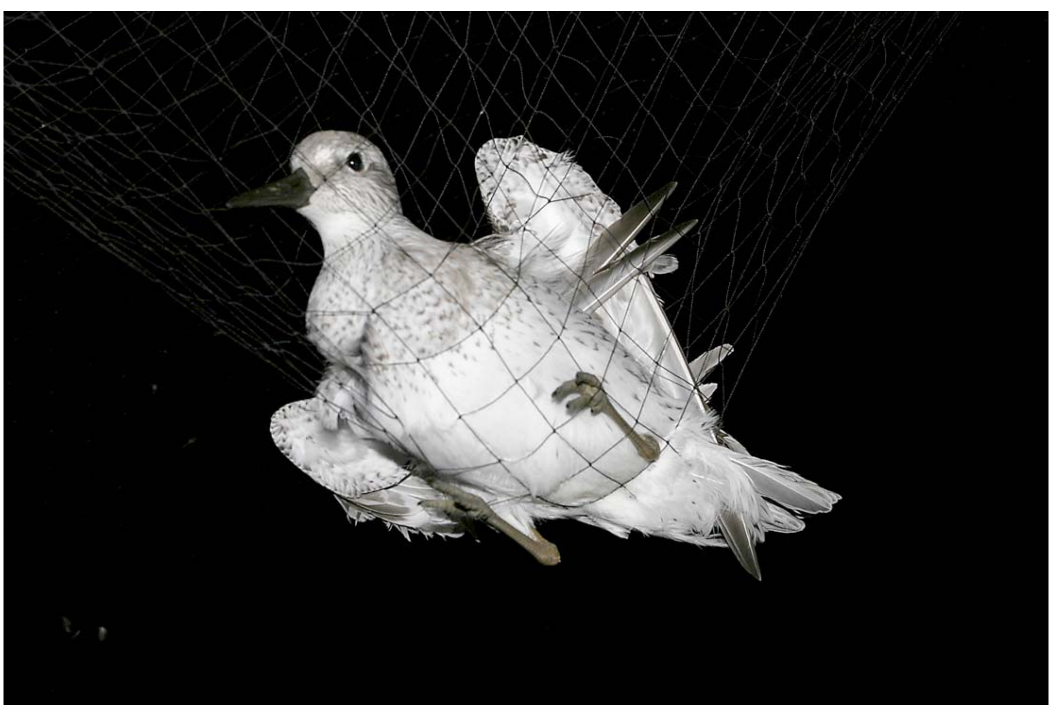
Fig. 6. *The total number of waders caught per day during the three expeditions. The numbers are plotted against the days before and after the new moon.*

The total number of birds that were individually colour-ringed per year is given in table 3. Note that we did not colour-ring Sanderlings in 2003.

Species	Year	Number
Bar-tailed Godwit *Limosa lapponica*	2002	**19**
	2003	**50**
	2004	**29**
	2005	**49**
Red Knot *Calidris Canutus*	2002	**286**
	2003	**214**
	2004	**210**
	2005	**162**
Sanderling *Calidris alba*	2002	**147**
	2003	**0**
	2004	**104**
	2005	**199**

Table 3. *Number of waders individually marked with colour-rings in the area around Iwik.*

Some of the biometrics, the average wing-length and mass per age-class, of the waders we caught during the four expeditions (2002 – 2005) are given in Table 4. A small fraction of the birds were in the last stage of primary-moult where the 10th primary was not yet full grown. Therefore we could not measure wing-length and those birds are excluded from the averages presented in Table 4.



species	Age	Wing	SD		Mass	SD	N
Bar-tailed Godwit	1	209	6.7		224	34.9	31
	2	220	9.1		205	16.2	3
	3	216	14.6		263	51.8	69
Curlew	1	303	6.2		730	104.9	4
Curlew Sandpiper	1	131	2.7		51	4.2	43
	2	131	1.4		49	3.5	2
	3	132	3.4		55	4.7	150
Dunlin	1	117	3.5		39	3.6	655
	3	117	3.2		412	3.6	662
Greenshank	1	191	1.4		145	4.9	2
	3	195			170		1
Grey Plover	1	198	7.0		191	24.6	17
	3	201	4.6		182	38.1	10
Kentish Plover	1	111	2.7		39	2.8	6
	3	113	3.4		42	2.9	5
Red Knot	1	165	4.3		117	11.9	237
	2	170	4.8		124	10.7	84
	3	172	4.6		127	9.8	481
Little Stint	1	99	4.8		23	2.1	18
	3	99	3.4		23	2.2	65
Oystercatcher	1	245			370		1
	2	247			414		1
	3	243	16.4		515	48.6	3
Redshank	1	159	11.3		114	8.7	58
	3	160	9.6		116	10.6	84
Ringed Plover	1	132	2.3		51	6.6	12
	2	132	2.6		53	5.1	4
	3	132	4.8		49	3.7	33
	4	129	2.2		49	3.5	9
Sanderling	1	126	2.9		47	4.8	307
	3	128	3.3		47	4.2	259
Turnstone	1	155	4.5		99	8.8	164
	3	159	4.4		101	7.1	87
Whimbrel	1	258	9.5		466	41.1	14
	3	255	2.1		443	66.2	3

Table 4. *Average wing-length ± SD (mm) and average mass ± SD (g) per age-class of waders caught around Iwik from 2002 - 2005. Age 1: first cy, 2: second cy, 3: adult, 4: unknown age, N = number of birds.*

3.3 The resightings of Red Knots

As an example of the observation effort within the period of one expedition, the number of resightings per colour-ringed Knot in 2005 is shown in Fig. 7. Only the Knots that have been colour-marked before the 2005 expedition are taken into account here.

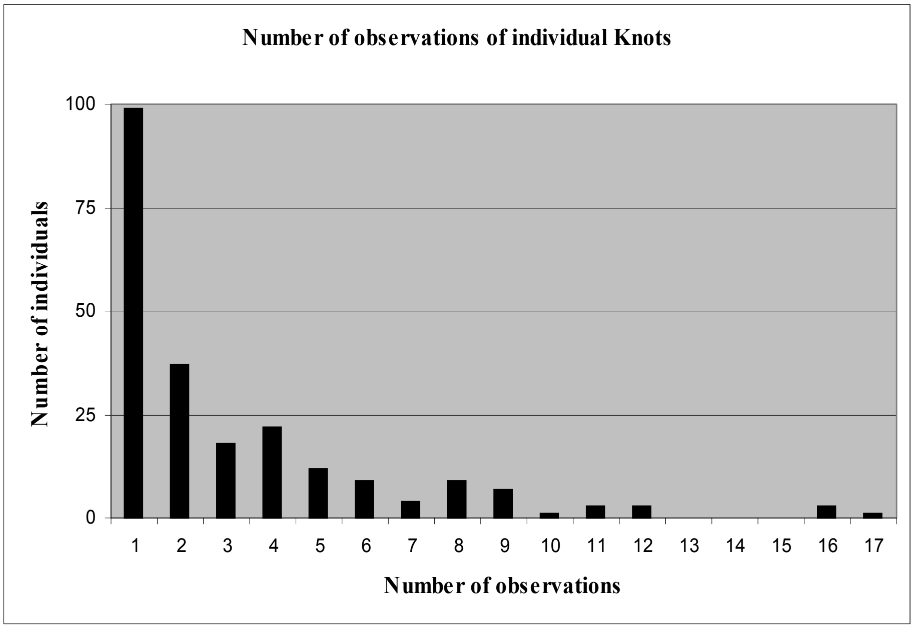


Fig. 7. *The number of observations per colour-ringed Knot during the 2005 expedition. The total number of observed individuals is 228.*

To estimate survival with the software program MARK, the data on marking and resighting have to be summarized in a special way. For every marked individual, a life-history is made on an annual basis where a **1** means alive (caught or observed) and a **0** means not observed in the year concerned. For the Knot these life-histories are presented in Table 5. Birds that were caught as a juvenile are distinguished here from those which were caught as adult.

Year	02	03	04	05	N-juv	N-adult
	0	**0**	**0**	**1**	**23**	**139**
	0	**0**	**1**	**0**	**43**	**87**
	0	**0**	**1**	**1**	**25**	**46**
	0	**1**	**0**	**0**	**22**	**62**
	0	**1**	**0**	**1**	**9**	**13**
	0	**1**	**1**	**0**	**15**	**28**
	0	**1**	**1**	**1**	**17**	**30**
	1	**0**	**0**	**0**	**31**	**93**
	1	**0**	**0**	**1**	**1**	**22**
	1	**0**	**1**	**0**	**5**	**25**
	1	**0**	**1**	**1**	**1**	**11**
	1	**1**	**0**	**0**	**7**	**14**
	1	**1**	**0**	**1**	**3**	**6**
	1	**1**	**1**	**0**	**1**	**10**
	1	**1**	**1**	**1**	**2**	**12**

Table 5. *Life-histories of colour-ringed Knots after 4 encounter occasions (years). An **1** means "alive". The first 1 in a row means "caught" and after that "observed". A **0** means not observed. This table is only based on the observations on the Banc d'Arguin. The fifth column gives the number of individuals with such a life-history caught as juvenile and the sixth column the birds caught as adult. The first row are the birds caught in the last year, 2005.*

3.4 Annual survival of Red Knots

With the life-histories as presented in table 5, it is possible to estimate annual survival and recovery rate (= resighting probability) using the software-program MARK. The results should be seen as "preliminary" because four encounter occasions (= three time-steps) is still a very short period for this kind of analysis. The results are given in table 6.

Parameter	Estimate	Standard Error	95% Confidence Interval Lower	95% Confidence Interval Upper
Phi-juv	0,722	0,061	0,589	0,825
Phi-adult	0,752	0,042	0,660	0,825
P_{2003}	0,307	0,050	0,219	0,412
P_{2004}	0,557	0,054	0,451	0,658
P_{2005}	0,551	0,063	0,428	0,670

Table 6. *Results of Survival analysis in MARK, including correction for c-hat.*
Phi-juv: average annual survival of Knots caught as juvenile
Phi-adult: average annual survival of Knots caught as adult
P_{2003}: resighting probability in 2003
P_{2004}: resighting probability in 2004
P_{2005}: resighting probability in 2005

3.5 Observations in Europe of Red Knots colour-ringed around Iwik.

In total 48 individuals were observed outside the Banc d'Arguin in Europe. Appendix 3 gives an overview of all these observations.

3.6 Resightings of Bar-tailed Godwits

The number of Bar-tailed Godwits colour-ringed around Iwik and their resightings in this area are summarized as life-histories in Table 7 (see also 3.3).

Year	02	03	04	05	N-ind
	0	**0**	**1**	**0**	**23**
	0	**0**	**1**	**1**	**6**
	0	**1**	**0**	**0**	**42**
	0	**1**	**0**	**1**	**1**
	0	**1**	**1**	**0**	**7**
	1	**0**	**0**	**0**	**13**
	1	**0**	**0**	**1**	**1**
	1	**0**	**1**	**0**	**1**
	1	**0**	**1**	**1**	**1**
	1	**1**	**0**	**0**	**1**
	1	**1**	**1**	**0**	**2**
	0	**0**	**0**	**1**	**49**

Table 7. *Life-histories of colour-ringed Bar-tailed Godwits after 4 years. A **1** means "alive". The first 1 in a row means caught and after that "observed". A **0** means "not observed". This table is only based on the observations on the Banc d'Arguin. The final column gives the number of individuals with such a life-history. The final row concerns the birds caught in 2005.*

As the number of resightings of Bar-tailed Godwits is relatively low, the confidence limits of the survival estimates in MARK are still very large. Therefore the results are not presented here. We need data over a longer period to get reliable results. Despite the fact that colour-ringed Bar-tailed Godwits are far more easily found and read compared to colour-ringed Knots and Sanderlings, we've only seen relatively few birds again after one or more years. This indicates that Bar-tailed Godwits around Iwik are by far not as site-faithful as Knots and Sanderlings are and that is a very interesting result in itself. To illustrate this in a different way, the fraction of the colour-ringed birds that was seen again after one or more years is calculated (Table 8). In the years after ringing, we've resighted almost twice as many Knots as Bar-tailed Godwits and almost 3 times as many Sanderlings. The number of individuals that were colour-ringed in the Netherlands and resighted on the Banc d'Arguin is also shown in Table 8. It is not useful to express this number as a fraction of the total number of birds colour-ringed in the Netherlands because it is often not possible to tell to which subspecies birds, captured in the Netherlands, belong.

	Red Knot	Bar-tailed Godwit	Sanderling
Total number colour-ringed on BDA till 2004	710	98	251
Number seen again after 1 or more years	294	20	139
% seen again	41%	20%	55%
Number of individuals colour-ringed in the Netherlands seen on Banc d'Arguin	62	28	0

Table 8. *Comparison of site-faithfulness between the three colour-ringed species. The last row shows the number of individuals, colour-ringed in Europe and resighted on the Banc d'Arguin.*

3.7 Observations in Europe of Bar-tailed Godwits colour-ringed around Iwik

In total 9 individuals were observed outside the Banc d'Arguin in Europe. In Appendix 4 an overview is given of these observations.

3.8 Resightings of Sanderlings

The number of Sanderlings colour-ringed on the Banc d'Arguin and their resightings in the Iwik-area are summarized as life-histories in Table 9.

Year	02	03	04	05	N-individuals
	1	**0**	**0**	**0**	**56**
	1	**0**	**0**	**1**	**6**
	1	**0**	**1**	**0**	**10**
	1	**0**	**1**	**1**	**4**
	1	**1**	**0**	**0**	**26**
	1	**1**	**1**	**0**	**11**
	1	**1**	**0**	**1**	**3**
	1	**1**	**1**	**1**	**29**
	0	**0**	**1**	**0**	**56**
	0	**0**	**1**	**1**	**50**
	0	**0**	**0**	**1**	**199**

Table 9. *Life-histories of colour-ringed Sanderlings after four years. A* ***1*** *means "alive". The first 1 in a row means caught and after that "observed". A* ***0*** *means not observed. This table is only based on the observations around Iwik on the Banc d'Arguin. The final column gives the number of individuals with such a life-history. The final row are the birds caught in 2005.*

3.9 Annual survival of Sanderlings

Using Table 9, the annual survival and recovery rate was estimated with the MARK-software. Given the short data-set (four years, three time steps), only one average annual survival value (Phi) is estimated and three year dependent resighting-probabilities (P_{year}). The results are given in Table 10.

			95% Confidence Interval	
Parameter	Estimate	Standard Error	Lower	Upper
Phi	0.701	0.034	0.629	0.763
P_{2003}	0.680	0.053	0.569	0.774
P_{2004}	0.758	0.065	0.610	0.863
P_{2005}	0.741	0.071	0.581	0.855

Table 10. *Results of Survival analysis in MARK of the Sanderling captures and resightings.*
Phi: average annual survival of Sanderlings
P_{2003}: resighting probability in 2003
P_{2004}: resighting probability in 2004
P_{2005}: resighting probability in 2005

The very high resighting rates (Table 10) show that Sanderlings are very site-faithful to the study area and also that they are easy to observe.

3.10 Observations in Europe of Sanderlings coulour-ringed around Iwik

As far as we know, only three individual Sanderlings from Iwik were observed in Europe.
Individual **B2GOBG** was caught at Iwik-station on 27 November 2002. It was observed on 7 June 2005 on "de Hors", Texel, Netherlands (53.00 N, 4.44 E) by Bob Loos and again on 23 July 2005 just at the opposite side of the North Sea at Snettisham, Norfolk, UK (52.52 N, 0.27 E) by Chris Kelly.
B2ROYB was caught on 28 November 2003, at Iwik-station. This bird was seen again on 23 July 2005 at Heacham, Norfolk, UK (52.55 N, 0.29 E) by Chris Kelly.
B2RORG was caught on 1 December 2002 near the Observation tower (NW-part of Baie d'Aouatif). It was seen on 6 June 2005 on De Hors, Texel, Netherlands(53.00 N, 4.44 E) by Bob Loos.

3.11 Recaptures of birds that were metal-ringed elsewhere

During the four expeditions we caught in total 34 birds of 8 species that were already ringed elsewhere. In Table 11 these retraps are summarized. We can not present all the original ringing data here because we did not yet receive those data from the national ringing centres for some of these individuals.

Species	Date of retrap			Metal ring from:	Date of ringing	Place of ringing (Country)
Bar-tailed Godwit	2005	11	26	France		
Common Tern	2003	12	22	Netherlands	25/07/2003	Netherlands
Curlew Sandpiper	2003	12	17	Germany	18/07/1997	Germany
Curlew Sandpiper	2003	12	23	Italy		
Curlew Sandpiper	2004	12	8	Norway	01/09/98	Norway
Dunlin	2002	11	28	UK	02/08/96	England
Dunlin	2002	11	29	UK	05/09/2002	England
Dunlin	2003	12	17	Spain	07/05/1998	Spain
Dunlin	2003	12	22	Danmark	07/06/1991	Danmark
Dunlin	2003	12	26	UK	06/05/2000	Scotland
Dunlin	2004	12	5	UK	August 1996	England
Dunlin	2004	12	7	Norway	22/08/2004	Norway
Dunlin	2004	12	8	Portugal	28/04/2002	Portugal
Dunlin	2004	12	8	Portugal	02/05/1995	Portugal
Dunlin	2004	12	8	Spain	06/08/2000	Spain
Dunlin	2004	12	8	Portugal	29/08/2004	Portugal
Dunlin	2004	12	11	UK	May 2003	Scotland
Dunlin	2004	12	11	Portugal	26/09/2001	Portugal
Dunlin	2005	11	25	Spain	03/08/2003	Spain
Dunlin	2005	11	28	UK	September 2004	England
Dunlin*	2005	12	2	Portugal	02/05/1995	Portugal
Dunlin	2005	12	2	Spain		
Knot	2002	12	1	Netherlands	06/08/2002	Netherlands
Knot	2003	12	22	France		
Knot	2004	12	6	Ghana	12/10/1991	Ghana
Knot	2004	12	10	Norway	12/09/2004	Norway
Knot	2004	12	16	Germany	04/06/2004	Germany
Knot	2005	11	26	Netherlands	29/07/2003	Netherlands
Little Stint	2005	11	25	Italy		
Redshank	2004	12	7	Netherlands	25/07/2001	Netherlands
Redshank	2005	11	26	Germany	19/08/1988	Germany
Turnstone	2004	12	12	Belgium	25/01/2004	Senegal (!)
Turnstone	2005	12	4	France		
Turnstone	2005	12	4	Sweden	04/08/2005	Sweden

Table 11. *Overview of all the recaptures that were done around Iwik.*
* second recapture, was also caught by us on 8/12/2004.

3.12 The Annual total bird-counts in the study area

In Table 1 the dates of our high-tide counts are given. When we did our first high-tide count on 6 December 2002, only the sub-areas 1, 2, 3 and 4 were counted. In 2003, we added area 5 to get a total picture of the whole Baie d'Aouatif. Unfortunately, the island of Zira was counted 2 days later. Due to differences in tidal hight, the actual number of birds on the high tide roosts on Zira can vary considerably. Therefore the numbers counted on 28 December 2002 on Zira may not simply be added to the numbers counted in the rest of the area on 26 December. In 2004 and 2005 all the sub-areas were counted during the one high tide period. The results of these counts are summarized in appendix 5.

In appendix 6, all the bird-species observed during the Nioz-expeditions are listed.

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Progress Report on the study of wader-predator interactions on the Banc d'Arguin, March 2006

How coastal shorebirds adjust foraging and phenotype to predation danger

Piet van den Hout

Introduction

So far, most studies on feeding ecology of wintering waders on the Banc d'Arguin focussed on the relationship of shorebirds with their benthic prey (e.g. Homeward Bound, special edition of Ardea 78 (1/2) 1990). These predator-prey relationships may in turn be affected by a few relatively rare top-predators, such as large falcons (see Bijlsma 1990). These influences may be largely indirect, touching upon distribution, behaviour and phenotype of targeted prey.

Generally, in the context of a starvation-predation trade-off, shorebirds are predicted to strongly minimize predation risk, because, in short, one or more decisions leading to missing a few meals is less harmful to fitness than a single mistake causing death by predation (see Lima & Dill 1990 for a review). In this project we aim to quantify the indirect effects of these predators on shorebirds that utilise the intertidal flats of the Banc d'Arguin. We focus on red knot, a preferred species by large falcons, building on the wealth of knowledge about foraging and migration patterns of this species.

Assessment of predation risk

In 2002, we kicked off by roaming the area from prey remains resulting from raptor attack. At the same time we collected as many observations of raptor hunting events as possible. On the Banc d'Arguin, Lanner Falcon *Falco biarmicus*, Peregrine Falcon *Falco peregrinus* and Barbary Falcon *Falco peregrinus pelegrinoides* were responsible for the majority of attacks. In this year we found a few hundred remains, mostly waders. A comparison of the numbers of victims with the composition of the local wader population revealed that medium-sized waders, particularly red knots, were most vulnerable to raptor predation. Furthermore, these victims consisted mostly of juveniles. In the years 2003-2005, medium-sized juvenile birds were also most vulnerable to attack, but these data await more detailed analyses.

Determinants of vulnerability

What determines vulnerability of shorebirds to predation, or in other terms, what factors constitute prey preference exhibited by raptors? Optimal foraging theory predicts that for prey to be profitable raptors balance the effort needed to catch prey and the energy value gained from it. Yet, this idea may have to be modified by detection chance affected by crypsis (Zwart & Wanink 1983). The effort needed to catch prey is expected to be influenced by anti-predator behaviours, like patch choice, flocking and vigilance.

Patch choice. Although the find-spot of a victim does not tell us much about the location where it was caught, repeated observations of juvenile red knots foraging close to the dune-bordered shoreline gave us reason to think that these juveniles, more than adults - which mainly seemed to forage further from shore on seagrass - were rather vulnerable to surprise attack by raptors. Indeed, we were able to quantify (and confirm) this age segregation in foraging sites. These large flocks of supposedly 'seagrass knots' (see below) only approached the shore when the tide came in, leaving only nearshore seagrass fields available. Juvenile habitat choice may thus explain the large fraction of juveniles among the prey remains.

Flocking and vigilance. Juvenile red knots not only visited foraging patches close to cover, they also foraged in significantly smaller flocks than adults did. Small flocks may be more vulnerable to attack as they contain fewer eyes to scan for predators, and it may require predators less effort to single out prey.

Energy-safety trade-offs

Several studies have shown that the energetic state (the quantity of reserves) of the bird determines to what extent the individual will allocate its activities to energy gain or safety from predators (e.g. Abrahams & Dill 1989). Yet, also foraging skills may affect this decision. Based on the observation that most adults fed on seagrass, whereas juveniles chose dangerous sandy shore habitat for foraging, we hypothesised the existence of phenotype-limited foraging strategies (Parker 1982). In order to find out whether such a phenotype-limited distribution indeed exists we capitalised on our colour-marking project, by trying to get as many repeatable observations of individuals as possible. Although we still need many observations to get a reliable picture, it seems that most individuals are faithful to their micro-habitat, which would support the idea that separate foraging strategies exist. At least, as measured in 2005, juvenile gizzards were larger than those of adults, supporting the idea of an age-related diet (see below). To answer the question whether the sandy shore, though more dangerous, provides more food, we compared intake rates between micro-habitats. Complementary to intake rate recordings, we collected knot droppings and benthos samples. In the laboratory at NIOZ we were able to reconstruct the diet of red knots from these droppings. At least for 2003, this revealed a difference in diet between these respective micro-habitats (other years have not yet been analysed). Red knots on seagrass had higher item intake rates, yet smaller prey items, than conspecifics on sandy habitat. In addition, the small seagrass prey was of better quality than sandy shore prey ('quality' refers to the ratio of flesh over shell mass; knots swallow shell whole, so incur extra digestive costs because they have to process the shell waste). The fact that, as mentioned earlier, juveniles in catches had larger gizzards than adults suggests that indeed juveniles experienced lower quality food than adults. In short, it seems that sandy shore foragers, though having lower *item* intake rates, had higher *energy* intake rates, at the expense of a need for a larger gizzard, due to lower food quality. Comparison with other years must reveal whether this is a general pattern.

In the proposed phenotype-limited distribution juvenile red knot would be energy-maximisers and adults risk-minimisers, like Cresswell showed for redshanks foraging in a Scottish estuary (Cresswell 1994). Yet, why would these juveniles decide for the risky strategy? We can think of several solutions: (1) juveniles were forced to rich and dangerous foraging because of a low energetic state, (2) juveniles were constrained by inferior foraging skills, barring them from seagrass. (3) juvenile were competitively excluded from seagrass by adults.

(1) *Energetic state?* Corrected for their smaller size juveniles in general weighted less than adults. Yet, we don't have information yet on energetic states of shoreline foraging juveniles in particular (see below: *future plans*).
(2) *Foraging skills?* In 2004 we performed an experiment, comparing foraging skills of adult and juvenile birds, on sandy and seagrass habitat respectively. At a patch were sandy habitat meets seagrass we put an observation tent, in which various combinations of locally caught individuals were allowed to forage. This should give an answer to the question whether age-related foraging skills exist. Unfortunately, birds did not seem very comfortable in this cage, and thus may not have behaved in a natural fashion. These data have not yet been analysed.
(3) *Competitive exclusion?* Competitive exclusion may be an additive factor explaining habitat segregation. If so, then one would expect excluded birds to move in as soon as dominants leave the patch. We did not see such a pattern in the course of the tidal cycle. Yet, in the time window of ontogeny, judging from the majority of red knots foraging on seagrass beds, in some life stage birds must move from sand to seagrass, unless none of the sandy habitat birds survive. In the long run, demographic studies, performed by NIOZ colleagues (Bernard Spaans & Jutta Leyrer) may yield an answer to the latter question. Following, for now, the assumption that many juvenile sand foragers do survive, the period that juveniles start exploiting seagrass habitat is expected to coincide with the departure of the adults to the breeding grounds (first year birds stay on the winter ground for another year). To test this idea we visited the area in spring 2005 and recorded age-distribution from the first week of April until the first week of May (by that time most of the adults had left the area). A quick scan on the data shows that a number of juveniles may indeed have shifted from sandy habitat to seagrass in this period, but more detailed analyses have to be performed to present a reliable result.

Risk management

Waders are not expected to resign in being possible target. They can affect chances of being killed. One possible behavioural mechanism to manage risk is by scanning more often in dangerous situations, like close to shore, where surprise attacks occur. This is indeed what we observed. The closer to shore red knots foraged, the more head-ups were recorded. In fact, at the same time the increased vigilance may have been a compensation for the relatively small flocks shoreline foragers engaged in, that is the few eyes that were available for scanning. Vigilance and flocking refer to detection of predators, yet, if it comes to an attack escape performance comes into play. Carrying fat reserves goes at the expense of flight manoeuvrability. Experiencing predictable food conditions, and relatively high ambient temperatures, red knots on the Banc d'Arguin carry few fat reserves. In addition to body mass, flight muscle size and wing surface determine flight output. Interestingly, ultrasound measurements on mist-netted birds revealed that juvenile red knots had a higher pectoral muscle to body mass ratio. Although we cannot be sure that all measured juveniles were indeed sandy shore foragers, this result may reflect three - possibly overlapping – adjustments to predation risk:

1. *A compensation for the high predation danger close to shore*.

2. *A compensation for extra gut (gizzard + intestine) mass*. The larger gut needed for a diet on sandy habitat adds to body mass, limiting escape performance from predators. As juveniles on the Banc d'Arguin can hardly economise on body mass, as they store only about 2-3 g of fat (Piersma & van Brederode 1990), compensation in terms of relatively large pectoral muscle may be logical
3. *Advanced growth of the pectoral muscle*. As mist-netted juvenile red knots had shorter wings and smaller tarsus than adults, it may be that the former were not yet fully grown (see Rising & Somers 1989). Considering this, the relatively larger pectoral muscle may reflect an anti-predator adaptation in – inexperienced - juvenile birds, the same way as relatively large legs in precocials serve for locomotion and relatively large guts in altricials for receiving food loads. Yet, the adaptive significance would be hard to prove.

Plumage characteristics and bird quality

The numbers of sandy shore juvenile red knot were low relative to the flocks observed on seagrass. Likewise, the observed juvenile proportion seemed not to be reflected in the age-distribution found in mist-net catches. This triggered the question: is the described juvenile behaviour representative for the majority of that age-class? Could it be that, seeing variability in juvenile plumage, the sandy shore juveniles were in fact the ones with a delayed pattern of body moult (clearly showing juvenile plumage characteristics), perhaps due to low condition and/or late arrival? Have the other juveniles moulted in such a manner that they lost recognisable juvenile feathers, thus becoming lost in the crowd of adults? In that case it would be only a subsample of the juveniles that engage in this habitat choice. By studying juvenile moulting pattern in captive birds at NIOZ, combined with more field observations (e.g. tracking moult patterns in colour-marked birds) we try to get a better grip on this problem (see below: *future plans)*.

In any case, intermediate plumage patterns found in mist-netted red knots, showed corresponding biometric features, including wing, tarsus and body mass, suggesting plumage variability is more than just variance.

Future plans

In addition to catching up with the analyses of collected field data, we are currently preparing an expedition for autumn of 2006. Preceding our regular expedition in December, a small group of researchers will make a supplementary visit to the Banc d'Arguin in September and October, with the following commission:

1. Catching juvenile birds on shoreline sandy habitat, assessing biometrics, measuring gizzard and pectoral muscle with ultrasonography and setting them free with radio-transmitters attached. As the birds will be colour-marked, we can track them down by a receiver and subsequently observe micro-habitat use and plumage development through telescope. The transmitters will have a 4-month recording capacity, allowing use to resume observations in December.
2. Extending our 'routine' observations on: (a) raptor hunting, (b) age- and plumage-related micro-habitat use, particularly on colour-marked birds, (c) intake rates, (d) vigilance, (e) age-composition and (f) flocking characteristics.

Based on our plumage studies in the field and in the lab, we are currently developing a novel plumage score scheme, in order to track possible correlations between plumage and age and state of the bird.

If, indeed, bird condition would be reflected in plumage characteristics, it is interesting to know whether predators do capitalise on these quality differences. What preference rules do raptor use? Are hunting decisions merely guided by habitat characteristic (e.g. opportunities for surprise attacks), or does (visible) bird condition play a role? If indeed predators would be able to select prey in this subtle fashion, birds in delayed plumage would be particularly vulnerable.

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