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Seasonal changes in body size and mass of Red Knots *Calidris canutus* during autumn migration through southern Baltic

Säsongsförändringar i storlek och vikt hos kustsnäppor Calidris canutus *under höstflyttning genom södra Östersjön*

WŁODZIMIERZ MEISSNER & PIOTR KAMONT

Abstract

Body size and mass of 1458 juvenile and 558 adult Knots were measured during autumn migration in Puck Bay, Poland, between 1983 and 1999. The measurements fit well with those gathered along the migration route of Siberian Knots *Calidris c. canutus*. All linear measurements of adults, except body mass adjusted for size, were significantly higher than those of juveniles. Shorter wing in juveniles than in adults seems to be a general rule regardless of geographical region. Adult females migrated ahead of males, confirmed by decreasing mean measurements. Juveniles carried larger relative energy stores than adults. Puck Bay may be an emergency feeding place for adult Knots, whereas juveniles may use it as one of many stop-over sites. Juveniles were significantly smaller, but had higher adjusted body mass, in late September than earlier, indicating a behavioural difference between late and early birds during preceding stages of migration. Late juveniles probably follow a time-minimising strategy with larger fuel stores and fewer stop-over sites, whereas birds passing in August migrate with very small energetic reserves, making only short flights and stops.

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Introduction

In autumn, Knots *Calidris c. canutus* appear regularly in the Baltic region during their migration from Siberia to the African wintering grounds (Piersma et al. 1992). There is some evidence that also Icelandic Knots *C. c. islandica* occur in southern Baltic in autumn (Gromadzka 1985, 1992, Nehls 1987, Diershke 1995), but in rather small number.

The number of Knots ringed in Poland exceeds 4000 (Gromadzka 1998, Meissner & Remisiewicz 1998). However, biometrical data have only been published to some extent (Gromadzka 1992, Meissner 1992, 2004). Among other things, there is a lack of analysis concerning energetic reserves carried by adults and juveniles in different periods of autumn migration. Here we present results from an analysis of data collected by WRG KULING with special emphasis on differences of fuel stores in juvenile and adult birds.

Material and methods

Knots were caught between 1983 and 1999 mainly in walk-in traps (Meissner 1998) at three sites along the Puck Bay coast (westernmost part of the Gulf of Gdańsk): Jastarnia, the Reda river mouth, and Rewa (Meissner & Remisiewicz 1998) (Figure 1). Mist-nets were used occasionally. Every year fieldwork started in mid-July and was finished in the end of September. This period covered almost the whole period of Knot migration in the study area (Meissner & Sikora 1995). In total, 1458 juvenile and 558 adult Knots were caught. Data from all sites were combined. Every year the accuracy and the repeatability of the measurements taken by different ringers were checked as described by Busse (2000).

Each Knot was aged (Prater et al. 1977). The following measurements were taken: wing length (Evans 1986), total head length (Green 1980), bill length (Prater et al. 1977), tarsus length (Svensson 1992), and tarsus plus toe length (Piersma 1984). Before 1991, total head length and bill length were

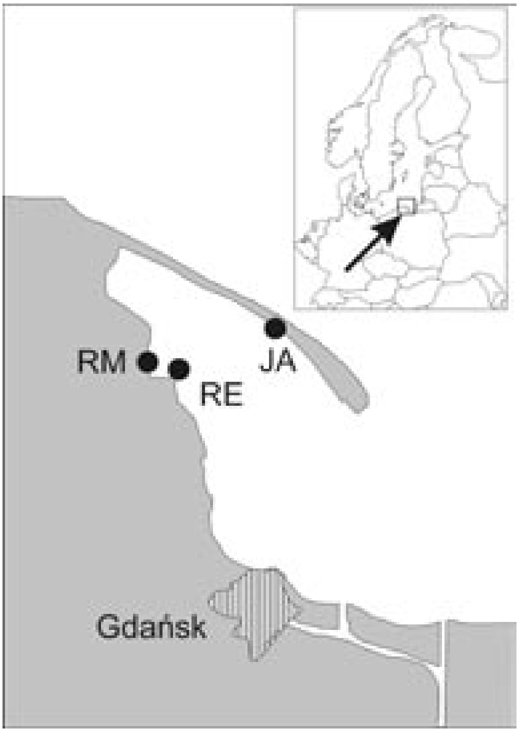

Figure 1. Localisation of the ringing sites of WRG KULING within a study area. RE – Rewa, RM – Reda mouth, JA – Jastarnia.
Ringmärkningsplatserna inom studieområdet: RE – Rewa, RM – Redas mynning, JA – Jastarnia.

measured to the nearest 1 mm with a ruler with a stop, later on with callipers to the nearest 0.1 mm. To combine these less and more precise measurements, the latter were rounded to the nearest 1 mm. The birds were also weighed with an accuracy of 1 g.

The body mass of each bird was adjusted for body size. A principal component analysis (PCA) was conducted for juveniles and adults separately. Wing length, total head length, and tarsus length were put into the model to obtain a single value representing the overall size of the bird. These three measurements were taken simultaneously in 850 juvenile and 224 adult birds. The equations for calculating this overall size factor were as follows:

$SF=0.433THL+0.422TL+0.382WL$, $R^2=0.63$ (juveniles)
$SF=0.450THL+0.444TL+0.398WL$, $R^2=0.60$ (adults)

In the equations, SF=body size factor, WL= wing length, THL=total head length, TL= tarsus length. Subsequently, the observed body mass (BM) was regressed against the calculated body size factor. The following linear regression equations were obtained:

$BM=2.33SF-128.55$, $R^2=0.10$, $p<0.0001$ (juveniles)
$BM=1.37SF-38.93$, $R^2=0.11$, $p<0.0001$ (adults)

The slopes of these equations were applied for calculating the size-adjusted body mass (BMA):

$BMA=BM+4.27(103.22-SF)$ (juveniles)
$BMA=BM+1.37(110.93-SF)$ (adults)

Table 1. Comparison of mean measurements of adult and juvenile Knots caught in Puck Bay region during autumn migration.
Jämförelse av medelvärden för adulta och juvenila kustsnäppor fångade i Puck Bay under höstflyttningen.

Measurement	Adults			Juveniles			t-test or	p	Difference	
	Mean	SD	N	Mean	SD	N	t'-test		absolute	relative
Total head length *Total huvudlängd*	63.6	2.02	528	61.8	2.18	1427	t'=16.4	p<0.01	1.8	2.9%
Bill length *Näbblängd*	34.5	1.83	530	32.8	1.99	1424	t'=17.9	p<0.01	1.7	5.2%
Tarsus length *Tarslängd*	32.35	1.38	288	31.61	1.47	923	t=7.6	p<0.01	0.7	2.3%
Tarsus + toe length *Tars + tålängd*	58.6	2.03	181	57.7	2.15	396	t=4.9	p<0.01	0.9	1.6%
Wing length *Vinglängd*	169.7	4.22	421	165.0	3.69	1419	t'=20.9	p<0.01	4.7	2.8%
Body mass *Kroppsmassa*	109.9	12.03	482	110.4	17.97	1362	t'=0.8	p>0.05	-0.5	-0.5%
Adjusted body mass *Justerad kroppsmassa*	108.2	9.42	224	111.9	16.7	850	t'=4.4	p<0.01	-3.7	-3.3%

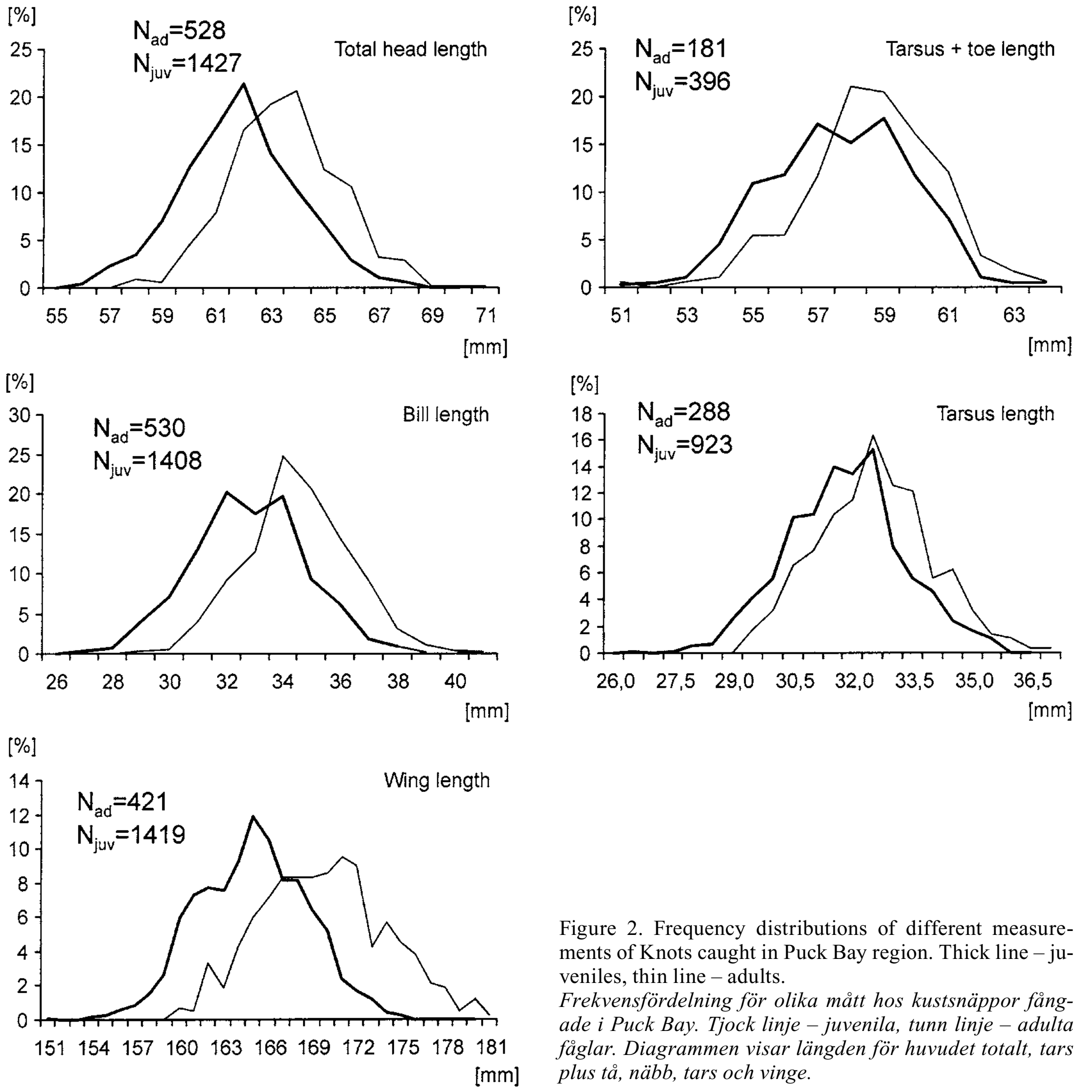

Figure 2. Frequency distributions of different measurements of Knots caught in Puck Bay region. Thick line – juveniles, thin line – adults.
Frekvensfördelning för olika mått hos kustsnäppor fångade i Puck Bay. Tjock linje – juvenila, tunn linje – adulta fåglar. Diagrammen visar längden för huvudet totalt, tars plus tå, näbb, tars och vinge.

Here, 103.22 and 110.93 are the mean size factors calculated for all of 850 juvenile and 224 adult Knots, respectively. All other statistical methods used in this study followed Zar (1996). The analyses were done in STATISTICA 6.0 software (StatSoft 2001).

Results

There was no apparent bimodality in the distribution of any measurement (Figure 2). All linear measurements were significantly larger in adults than in juveniles, and the greatest relative difference was found for bill length (Table 1). The mean body mass was almost the same in both age classes, but juveniles had significantly higher body mass after adjustment for size (Table 1).

Adults caught in subsequent half-month periods differed significantly in total head length (ANOVA, $F_{3,522}=4.53$, $p=0.004$), bill length (ANOVA, $F_{3,524}=5.25$, $p=0.001$), wing length (ANOVA, $F_{3,416}=7.72$, $p=0.0001$), and adjusted body mass (ANOVA, $F_{3,220}=2.79$, $p=0.04$), but not in tarsus plus toe length (ANOVA, $F_{3,175}=0.74$, $p=0.53$) and in tarsus length (ANOVA, $F_{3,284}$=2.38, p=0.07). Birds migrating in the second half of July had linear measurements significantly higher than those from the second half of August (Newman-Keulis post-hoc test, p<0.05). Adjusted body mass of adults from the first half of September (the latest migrants of this age class) was higher than in birds at the beginning of the migration period (the second half of July) (Newman-Keulis post-hoc test, p<0.05).

Differences between the early and latest juvenile migrants were detected in all linear measurements (total head length: ANOVA, $F_{2,1398}$=7.58, p=0.0005, bill length: ANOVA, $F_{2,1395}$=3.67, p=0.03, tarsus length ANOVA, $F_{2,904}$=18.27, p<0.0001, tarsus plus toe length: ANOVA, $F_{2,379}$=9.39, p=0.0001 and wing length: ANOVA, $F_{2,1390}$=4.75, p=0.009). Birds migrating in the second half of September had lower mean values of every measurement than those from the second half of August and first half of September (Newman-Keulis post-hoc test, p<0.05). Juveniles migrating in the second half of August had much lower adjusted body mass (102.8 g) than birds caught in the next half-month periods (116.2 g and 117.2 g respectively). This difference is highly significant (ANOVA, $F_{2,831}$=68.90, p<0.0001 and Newman-Keulis post-hoc test, p<0.05). The earliest arriving juveniles caught in the first half of August were omitted in the statistical analysis due to small sample size (N=16), but the mean adjusted body mass of these birds was even lower (mean=99.0, SD=8.66).

Discussion

In Knots, males are smaller than females (Cramp & Simmons 1986). Quite conspicuous between-year variability in the measurements of juvenile Knots (Meissner 2004) and the possibility of even a small occurrence of Icelandic Knots among the birds caught in the Puck Bay region (Gromadzka 1992, 1985) might be responsible for the absence of an expected binominal distribution in both age classes. On the other hand, the obtained result might be caused by overlap of two unimodal distributions with means lying not far from each other. The difference between mean bill length of males and females of Siberian Knots caught during spring migration is only 0.9 mm, and for wing length only 1.0 mm (Prokosch 1988). Larger differences were revealed in birds sexed during the breeding season in Taimyr: 2.1 mm and 4.2 mm, respectively, but the sample size, especially for females, was rather small (Tomkovich & Soloviev 1996). Within adult Knots caught in the Puck Bay region, 238 males and 164 females were recognised according to the formula given by Tomkovich & Soloviev (1996). The occurrence of a sex-bias in this sample may also have contributed to the lack of bimodality in linear measurement distributions.

Although adults had worn primaries, the average wing length of juveniles, which migrated in fresh plumage, was significantly shorter. Similar results were obtained in France (Fournier & Spitz 1970), in Dutch Wadden Sea (Koopman 2002), in Vistula mouth, Poland (Gromadzka 1992), and in Australia (Barter et al. 1988). Thus, it seems that relatively short wing length may be a general rule in juvenile Knots regardless of geographical region. Shorter wings in juveniles than in adults were found in autumn also in Turnstone *Arenaria interpres* and in Grey Plover *Pluvialis squatarola* (Meissner & Koziróg 2001, Krupa & Krupa 2002). Shorter bill in juvenile waders caught during autumn migration is probably caused by a not finished growth (Meissner 1997, Meissner & Ściborski 2002, Meissner & Górecki in press). Juveniles in Puck Bay had shorter tarsus and tarsus plus toe than adults despite of transitory higher content of cartilage in joints of young birds (Cymborski & Szulc-Olechowa 1967, Meissner 1997, Meissner & Górecki in press). This indicates that the growth of leg bones in juveniles has not been finished yet.

In this study, adult females migrated ahead of adult males, which was confirmed by decreasing mean size measurements as time proceeded. This is a general rule in this species, where the females leave the breeding grounds before the males, which are involved in brood rearing (Cramp & Simmons 1986). Sexual segregation of migration periods in juveniles cannot be expected. However, smaller juveniles were found during the latest phase of the passage. Recently, Meissner (2004) showed considerable between-year variation in linear measurements of juvenile Knots caught during autumn migration. However, the data in the present study were pooled over many years, and annual differences should then be smoothed out. Small, late migrating juveniles may come from late broods, which did not have enough time to reach final dimensions before bad weather forced them to depart from the breeding grounds.

Body mass of adult Knots caught in autumn in southern Baltic is one of the lowest noted in the subspecies *C. c. canutus* (Piersma et al. 1992), and it was confirmed in this study. This suggests that this area is an emergency feeding place rather than

Table 2. Comparison of the average wing and bill length of adult Knots measured alive or freshly collected in different localities within the range of *Calidris c. canutus*.
Jämförelse mellan genomsnittlig ving- och näbblängd hos adulta kustsnäppor som mätts levande eller nyligen insamlade på olika lokaler inom området för Calidris c. canutus

Area	Juveniles		Adults		Source
Område	Wing length *Ving-längd*	Bill length *Näbb-längd*	Wing length *Ving-längd*	Bill length *Näbb-längd*	*Källa*
Taimyr			170.2	34.3	Tomkovich & Soloviev (1996)[1]
Puck Bay	165.0	32.8	169.7	34.5	This study
Vistula mouth	164.1	32.8	170.4	34.3	Gromadzka (1992) [2]
Langenwerder	165.5	33.3	170.6	34.2	Nehls (1987)
The Netherlands	164.1	33.2	170.8	34.4	Koopman (2002) [3]
Mauritania	163.8	35.6	169.6	35.1	Wymenga et al. (1990)

[1] Means recalculated from table 8. *Medelvärden omräknade från tabell 8.*
[2] Means recalculated from tables 5, 6 and 7. *Medelvärden omräknade från tabellerna 5, 6 och 7.*
[3] Only non-moulting adults were taken into account. *Endast icke ruggande adulter medtagna.*

a regular stop-over site on the route between Siberia and Africa. Adult males, passing the study area at the end of the migration period, accumulated larger energetic reserves than birds arriving earlier. It might be a kind of insurance against deteriorating weather and thus feeding condition. Greater energetic reserves could also allow them to make longer flight to the next destination.

In general, juveniles had significantly higher adjusted body mass than adults. It means that they carried larger relative energetic stores than adults. Autumn ringing recoveries of juvenile Knots are dispersed along the migration route, not concentrated around traditional stop-over sites of this species (Gromadzka 1992, Dierschke 1995). Probably, inexperienced juveniles migrate by small steps, not by long distance flights as adults. Thus, Puck Bay may be an emergency feeding place for adult Knots, whereas juveniles may use this place as one of many stop-over sites along their migration route.

The earliest migrating juveniles arriving in the Puck Bay region in August had adjusted body mass about 15% lower than birds making a stop in September. Thus it seems that early and late migrants may behave in different ways during the preceding stages of their migration. Fuel stores of juvenile waders before departure from Arctic breeding grounds are very low (Lindström 1998, Lindström et al. 2002). The first part of their migration is probably carried out in short flights. Time-minimisers are expected to carry larger fuel stores between fewer stop-over sites along the migration route (Gudmundsson et al. 1991, Lindström et al. 2002). It might be a case of later migrating juvenile Knots, whereas juveniles passing the study area in August probably migrated all the way with very small energetic reserves making only short flights and short stops.

Icelandic Knots have on average shorter bills and longer wings than Siberian Knots (Cramp & Simmons 1986). The mean measurements of adult Knots obtained in this study correspond to data gathered along the migration route of the subspecies *C. c. canutus* (Table 2). It is worth noticing that due to different migration periods of adult males and females, such samples may be sex biased (Nebel et al. 2000). Thus, only data collected in the period covering the whole time of adult migration were included in Table 2. Icelandic Knots appear in autumn in the Baltic area, but owing to the considerable overlap of the wing and bill length ranges, and between-year variability (Meissner 2004), these measurements are not useful in recognising to which subspecies an individual bird belongs. Even if a few Icelandic Knots were included into the analysed sample, they could not be detected by analysing the distribution of a single measurement. A correlogram of wing and bill length distribution (Figure 3) revealed that the biometrics of some of the birds fit with measurements of Icelandic Knots. However, their number seems to be very low.

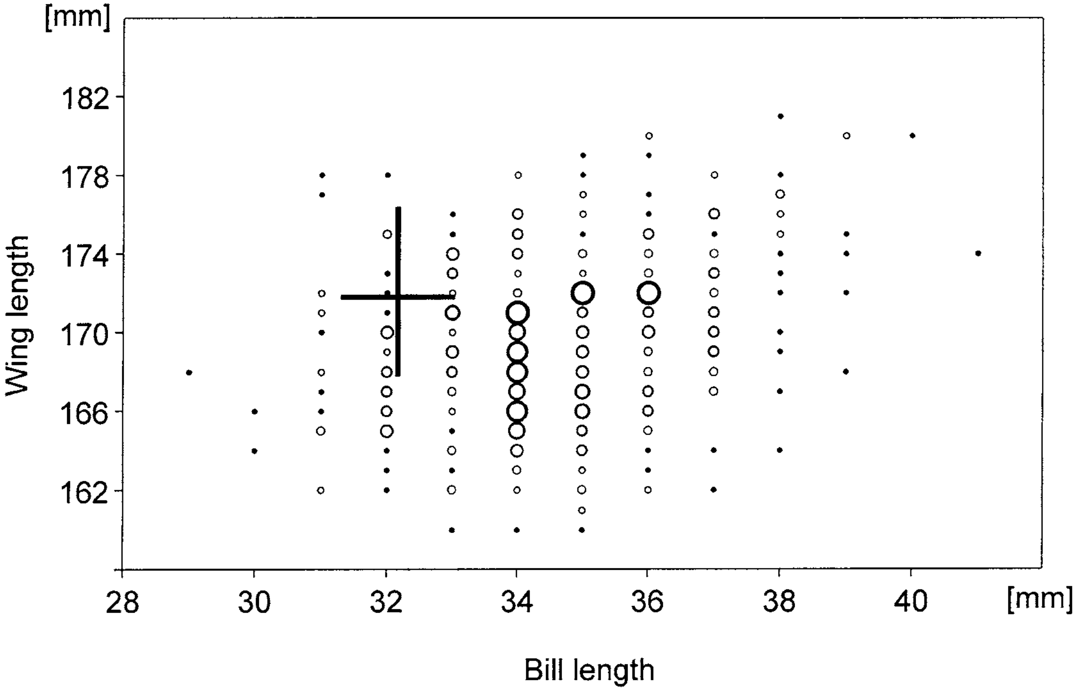

Figure 3. Relationship between bill length and wing length of adult Knots caught in Puck Bay region. Mean values (±SD) for Icelandic Knots wintering in Dutch Delta were indicated by crossed thick lines (according to Schekkerman et al. 1992).
Förhållandet mellan näbblängd och vinglängd hos adulta kustsnäppor fångade i Puck Bay. Medelvärden (±SD) för isländska kustsnäppor som övervintrat i Nederländerna har markerats med tjocka korsade linjer (enligt Schekkerman et al. 1992).

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Sammanfattning

Kustsnäppor från Sibirien (*Calidris canutus canutus*) rastar regelbundet längs södra Östersjöns stränder under höstflyttningen till de afrikanska vinterkvarteren. Enstaka individer av den isländska rasen *C. c. islandica* förekommer också, men i små antal. Trots att det ringmärkts över 4000 kustsnäppor i Polen har biometriska data analyserats i bara begränsad omfattning. Åren 1983–1999 fångades, mättes och vägdes 1458 juvenila och 558 adulta kustsnäppor på tre lokaler i Puckviken (västra delen av Gdańskbukten, Polen; Figur 1). I denna uppsats presenterar vi en analys av detta material med särskild betoning på skillnader i energireserver mellan olika delar av hösten och mellan gamla och unga fåglar.

De mått som togs och de genomsnittliga resultat som erhölls framgår av Tabell 1. Mätvärdenas fördelning visas i Figur 2. Vi gjorde en principalkomponentanalys för unga och gamla fåglar separat med vinglängd, total huvudlängd och tarslängd i modellen för att få ett sammanfattande storleksindex för varje fågel. Regressionen mellan detta index och kroppsvikten beräknades därefter. Regressionens lutning användes därefter för att beräkna en kroppsvikt som var justerad för fågelns storlek. Detaljer och formler finns i den engelska texten.

Figur 2 visar att den sedvanliga tågordningen mellan honor och hanar inte framgår i form av tvåtoppiga kurvor, vilket beror på att så många år slagits samman. Tabell 1 visar att alla linjära mått var signifikant större hos adulta än hos juveniler. Däremot fanns ingen signifikant skillnad för vikten, men efter det att vikten justerats för kroppsstorleken, var adulta signifikant tyngre än juvenila.

Mellan olika delar av flyttningssäsongen fanns signifikanta skillnader för adulta beträffande total huvudlängd, näbblängd, vinglängd och justerad kroppsvikt, men inte för längden av tars eller tars plus tå. Det var de tidiga flyttarna som hade de högre värdena. De adulta fåglarnas justerade kroppsvikt var högre i september än i början av flyttningen.

Hos de juvenila fanns det tidsskillnader för alla linjära mått, och det var de sena flyttarna hade de lägre värdena. För den justerade kroppsvikten gällde att de tidiga flyttarna hade mycket lägre värden än de sena.

De gamla kustsnäpporna flyttade med slitna medan de unga flyttade med nyruggade handpennor. Trots detta hade de unga kortare vingar. Samma sak har man funnit i andra studier och hos vissa andra arter, och detta tycks alltså vara en allmän regel oberoende av varifrån fåglarna kommer. Att unga vadare har kortare näbbar än gamla är också känt och tros bero på att näbbarna ännu inte är färdigvuxna vid första höstflyttningen.

Bland de adulta flyttade honorna före hanarna, vilket framgick av att fåglarnas genomsnittliga storlek successivt minskade. Detta är en allmän regel som beror på att hanarna stannar en tid i häckningsområdet för att ta hand om ungarna. Någon sådan tidsskillnad är inte att vänta bland ungfåglarna. Vi fann dock att de senast passerande ungfåglarna var mindre än de tidigare. Detta kan bero på att de kommer från sena kullar och att de inte hunnit bli fullvuxna innan de tvingades iväg av dåligt väder.

Kroppvikten hos adulta kustsnäppor i södra Östersjön har tidigare visat sig vara bland de lägsta som uppmätts någonstans för den aktuella underarten, något som bekräftades av denna studie. Det antyder att området mera är en rastplats för krislägen än en normal plats för födosök under flyttningen.

Eftersom ungfåglarna hade större kroppsmassa i förhållande till sin storlek än gamla fåglar hade de därmed större relativa energireserver. Återfynden av ungfåglar visar att dessa är spridda längs hela flyttningsvägen och inte koncentrerade till stora traditionella rastlokaler. Sannolikt är det så att de oerfarna ungfåglarna flyttar i små etapper och inte genomför de långdistansflygningar som de gamla fåglarna gör. Södra Östersjön kan således vara en av många normala rastplatser för ungfåglarna.

I augusti hade de anländande ungfåglarna en justerad kroppsmassa som var 15% lägre än fåglarna som kom i september. En förklaring kan vara olika beteende under färden mellan häckningsområdet och rastplatsen. Man vet att ungfåglar har mycket låga energireserver när de lämnar sina arktiska häckningsplatser. De tidiga fåglarna kan ha flyttat korta etapper och lagt upp bara en liten mängd fett på varje plats, medan de senare fåglarna kan ha haft tid att lägga upp en större reserv och sedan flyttat en längre sträcka.

Isländska kustsnäppor har kortare näbbar och längre vingar än de från Sibirien. Data från några olika rastlokaler för rasen *canutus* ges i Tabell 2. Figur 3 visar fördelningen av vinglängd och näbblängd för de adulta kustsnäpporna som fångade i Puckviken. I denna figur har motsvarande mått för isländska kustsnäppor lagts in. Som synes faller många fåglar inom variationen för de isländska men det är ett stort överlapp, vilket innebär att enskilda individer inte med säkerhet kan föras till den ena eller andra rasen. Antalet isländska kustsnäppor i Puckviken är dock troligen mycket lågt.