

Studies on breeding shorebirds at Medusa Bay, Taimyr, in summer 2002

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**H. Schekkerman
I. Tulp
K. M. Calf
J.J. de Leeuw**

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ABSTRACT

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In the summer of 2002 a combined Dutch-Russian expedition took place to the Willem Barentz field station at Medusa Bay near Dikson in north-western Taimyr, Russia. The expedition was organised by Alterra and the Agricultural Department of the Dutch Embassy in Moscow. Research questions addressed by the Alterra team and basic results obtained during the 2002 season are presented in this report. More elaborate analyses and discussion of the data will be made elsewhere. Where useful, results are compared with data collected in 2000 and 2001. Subjects of study generally concerned breeding biology of arctic breeding shorebirds, especially with respect to timing of breeding.

Keywords: arctic, Taimyr, waders, breeding, reproduction, monitoring, arthropods, predation

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Summary

In the summer of 2002, for the third year in a row, a Dutch-Russian expedition worked at Medusa Bay near Dikson in north-western Taimyr, Russia.. The main aim of the Alterra part of this expedition was to study the consequences of arrival time and arrival mass on reproductive success for long-distance migrant arctic-breeding shorebirds. Many aspects of the breeding biology of waders were studied: arrival date and arrival condition, breeding phenology, clutch size and egg size, nest success, incubation schedules, energy expenditure of adults during incubation and chick-rearing, energy requirements of shorebird chicks, variation of body condition during incubation, insulative properties of nests, and timing and condition at departure on autumn migration. This report summarises the basic data (breeding parameters and biometrics) collected during the 2002 season. It also provides data on weather, snow and predator conditions, and the availability of arthropods as prey for breeding shorebirds and their chicks. More elaborate analyses and discussion of the data collected during the three-year study will be presented in an integrative report and in papers in international refereed journals.

The summer of 2002 was late, moderately cold, clouded, and very wet. Snow cover was still almost complete on 8 June and stayed extensive until about two weeks later than in the previous two years. Arrival and breeding of waders was delayed by about a week, and laying was highly synchronised once the tundra was clear of snow. Although average temperatures were not particularly low, the weather throughout much of the summer was sombre with frequent strong winds, little sunshine, and in comparison to recent years, a remarkable amount of rain.

After two consecutive years with very few lemmings, their numbers increased in 2002, although densities usual in 'lemming peak years' were not reached. Predators such as Snowy Owls and Pomarine and Long-tailed Skuas started nesting, but had problems in finding enough lemmings later in the season. This caused them to shift their search effort partly to waders' nests and chicks. Arctic Foxes were present in the surroundings and visited our study area a few times, leaving behind a trace of empty wader nests. Nevertheless, predation pressure on wader eggs was noticeably less than in 2000 and 2001, and good numbers of chicks hatched. The main hatching period coincided with a spell of warm weather which brought abundant insects to the tundra surface. The later part of the chick period was wet and cold, so that growth conditions were not optimal.

During the season, 231 wader nests plus 34 broods were located, and 300 full-grown shorebirds and 376 chicks were caught and ringed. Trapping efforts during the spring arrival period yielded fewer birds than in 2001 (though more than in 2000). Limited predation pressure made our work on incubating birds easier. Most breeding birds were ringed, and doubly-labelled water experiments, egg temperature studies, a supplemental feeding experiment on Little Stints, and studies of growth rate and energy expenditure of chicks of Little Stints could be made without too many losses. Clap-netting of waders leaving Taimyr on autumn migration in late July and August was much less successful than in 2000 and especially in 2001, mainly because of bad weather which suppressed migration on most days.



Willem Barentsz field station

1 Introduction

1.1 Expedition and participants

In the summer of 2002, for the third year in a row, a combined Dutch-Russian expedition took place to the Willem Barentz field station at Medusa Bay near Dikson in north-western Taimyr, Russia. The expedition was organised by Alterra and five Russian and one Ukrainian biologists from different institutes, supported by the Agricultural Department of the Dutch Embassy in Moscow. The Alterra-part of the expedition was part of a three-year research programme commissioned by the Ministry of Agriculture, Fisheries and Nature Management, entitled 'Modelling of flyway populations of birds'.

This report summarises the research questions, field activities and the basic information collected during the 2002 season by the Alterra part of the expedition. It also provides data on the general conditions and wader breeding success in the 2002 season. More elaborate analyses and discussion of the data collected in 2000-2002 will be presented in an integrative report and in papers in international refereed journals. Research activities of the Russian team members will be reported elsewhere.

Participants of the expedition were: Hans Schekkerman, Ingrid Tulp and Joep de Leeuw (Alterra), Kathleen Calf (University of Cape Town, South Africa), Sergei Kharitonov (senior research biologist, Bird Ringing Centre, Moscow, and expedition coordinator), Mikhail Berezin (entomologist, Moscow Zoo), Andrei Bublichenko (curator of mammalogy, Zoological Museum, St. Petersburg), Tatyana Kirikova (ornithologist, Azov-Black Sea Ornithological station, Ukraine), Tatyana Varlygina and Tatyana Pereladova (botanists, Moscow State University).

The main research topics addressed by the different expedition members were:

<i>Shorebird breeding ecology</i>	Ingrid Tulp, Hans Schekkerman, Joep de Leeuw, Kathleen Calf
<i>Monitoring of breeding birds</i>	Sergei Kharitonov and Tatiana Kirikova
<i>Monitoring of lemming population</i>	Andrei Bublichenko
<i>Breeding of geese, raptors and gulls</i>	Sergei Kharitonov
<i>Monitoring of arthropod abundance</i>	Mikhail Berezin, Hans Schekkerman, Ingrid Tulp
<i>Vegetation mapping</i>	Tatiana Varlygina and Tatiana Pereladova

In the years 1998-2001, territory mapping of breeding birds in 4 km² and 12 km² survey areas was carried by members of the Working Group International Wetland and Waterbird Research (WIWO). In the absence of WIWO-participants, this work was partly adopted by Sergei Kharitonov and Tatiana Kirikova in 2002; it will not be reported here.

1.2 Background and research topics

1.2.1 General framework of the study

The long-term population size of migratory shorebirds is determined by the equilibrium between reproduction on the breeding grounds and mortality on breeding, staging and wintering sites. Many studies have focused on the feeding ecology and migration of shorebirds while present in the European coastal wetlands. Much less is known on the arctic breeding grounds. Yet, it is there that new generations of birds are born to replace those that died on migration or during winter. The arctic summer is short and time available for finding a mate, laying eggs, raising chicks and preparing for migration is hardly more than two months. Even within this period, food abundance shows a seasonal peak and strong weather dependence. Therefore arriving in time and in a condition that allows a quick start of breeding may be paramount for successful reproduction. This is the basic assumption of models of optimal bird migration (Weber *et al.* 1998, 1999). Yet, in contrast to the situation in arctic-breeding geese, to date there is very little published evidence of a relationship between timing and condition at arrival and breeding success in shorebirds.

The main aim of the Alterra team was to study the consequences of arrival time and arrival mass on reproductive success for long-distance migrant and arctic-breeding shorebirds. Both these parameters may be influenced by factors operating in the wintering areas and at migration stopovers (site quality) or during migratory flights (weather), and they may determine whether there is enough time to raise chicks before the end of the short summer, or the number and quality of eggs being produced. This process might thus create a link between events (including human interference) occurring along the migratory route and reproductive output which directly affects population dynamics.



1.2.2 Research topics addressed

The effects of arrival time and condition on the breeding performance can be studied in a direct approach in which shorebirds should be caught upon arrival to determine arrival condition and timing and consecutive breeding performance is followed, and in an indirect approach studying the different selective pressures acting on the timing of breeding. For the direct approach the research topics of interest are:

1. Describe (variation in) arrival date and arrival condition of arctic-breeding shorebirds (results summarised in chapter 6)
2. Study correlations between these variables and a) probability of obtaining a mate and producing a clutch, b) laying date, c) clutch size, d) egg size, e) hatching success, f) chick growth rate and survival, and g) overall reproductive success (results a-b in chapter 7.6, other in separate report integrating results of 3-year study).

These questions can be studied by catching birds upon arrival in the study area to determine arrival date and condition, mark these birds and follow them throughout the season to determine reproductive success. This approach meets with several difficulties in the field, severely limiting its applicability. First of all, it is not easy to catch shorebirds upon arrival in the breeding area. We modified an existing technique used for catching migrant Golden Plovers in The Netherlands (Jukema *et al.* 2001) and used it with variable success in the tundra. The number of birds caught varied between years in relation to weather and timing of snowmelt. Moreover, only a very small proportion of the shorebirds marked during the arrival period settled to breed in the study area, the remainder moving on to presumably breed further north and east on the Taimyr Peninsula. Furthermore, in years with high predation rates as in 2000 and 2001, there is hardly any scope for detecting condition- or arrival date-related effects on reproductive output, because reproduction fails rather indiscriminately.

The indirect approach aims at describing how the breeding schedule is fitted into the seasonal pattern of resource availability, in search of selection pressures on timing of breeding and arrival condition. It involves quantifying seasonal resources (temperature, snow melt, arthropod availability), and quantifying energy requirements of birds during parts of the breeding cycle, to look for possible energetic bottlenecks. This approach involved the following topics in 2002:

3. Seasonal, weather-induced and habitat-related patterns in the abundance of invertebrates as food for breeding shorebirds (see chapter 9).
4. Timing of arrival and breeding in Dunlins *Calidris alpina* that were colour-marked in 2000 and 2001 (chapter 7.6).
5. Timing of breeding of all wader species (chapter 5.4).
6. Growth rate of shorebird chicks in relation to weather conditions and availability of invertebrate food (chapter 8).
7. Time-energy budgets of growing Little Stints *C. minuta* chicks (reported elsewhere).

8. Energy expenditure of incubating and chick-rearing Dunlins, in comparison to similar studies in Little Stints carried out in previous years. In combination with time budget data these studies enable identifying either the incubation or chick-rearing periods as energetically more stressful for parent birds, with possible repercussions for optimal timing of breeding (to be reported elsewhere).
9. Experiments on nest attendance in Little Stints to investigate trade-offs in time allocation between incubation and feeding in relation to food availability and heating and cooling rates of eggs (to be reported elsewhere).
10. Nest dimensions and amount and type of insulative nest materials in relation to body size among wader species, as a follow-up of earlier work on interspecific patterns in energy expenditure of adult shorebirds during incubation (Piersma *et al.* 2003; to be reported elsewhere).
11. Seasonal changes in the depth of the upper surface of the permafrost ice under shorebird nests (to be reported elsewhere).

In addition to questions related to the effect of arrival time and condition on reproduction, we are also interested in the strategies that shorebirds use during the first part of their autumn migration. Especially whether or not they fuel up before departure (intending to make long continuous flights) or make successive short flights is still poorly known. Therefore we applied the same catching technique with clap nets that we used in the arrival period also in autumn to study:

12. Variation in condition parameters of shorebirds upon departure from the arctic breeding grounds in late summer (chapter 6).

Furthermore, we collected samples of preen-gland waxes in adult waders, for a study on the significance of variation of these waxes (Reneerkens *et al.* 2001), and blood samples for identification of blood parasites by Louisa Mendes, NIOZ.

Starting in 1996 and with a more standardised methodology since 1998, volunteers of the Working group on International Wetland and Waterbird Research (WIWO) have conducted yearly monitoring of breeding bird abundance, the general lemming/predator situation, and waterbird breeding success (Tulp *et al.* 1997, Khomenko *et al.* 1999, Willems *et al.* 2002, Klaassen 2002, Peters & Langevoort in prep.). In 2002, no WIWO team joined the expedition. Part of the monitoring programme (territory mapping) was carried out this year by S. Kharitonov and T. Kirikova (to be reported elsewhere). Although the monitoring of breeding bird numbers was not a topic of our studies, our nest searches within the 4 km² intensive plot were sufficiently intensive to allow comparison with results of previous years and give an indication of changes in wader breeding numbers. Also, we present a general description of the abundance of lemmings, lemming predators and geese in chapter 4 of this report. This account is partly based on the census work by Sergei Kharitonov and Andrei Bublichenko.

1.3 Itinerary and outline of the season

Ingrid Tulp and Hans Schekkerman flew from The Netherlands to Moscow on 30 May 2002, where we met up with our Russian and Ukrainian expedition companions and did some shopping. After a 12-hour delay on the airport, Sergei Kharitonov, Andrei Bublichenko, Tatiana Kirikova and we flew to Norilsk on 2 June, where bankruptcy of our airline caused another, two-day delay. The flight to Dickson was made on 6 July, and after staples were bought in the local store, we travelled to Medusa Bay on 8 June, driving by *vezdekhod* (caterpillar vehicle) over the thick coastal ice. We stayed at the Willem Barentz Biological Station 18 km south of Dickson. The station consists of a large building and a few small sheds, providing housing for up to 15 people. On 27 June, Kathy Calf was dropped at the station by helicopter, after having travelled up to Taimyr together with members of the Alterra Brent Goose expedition. Five days later, Joep de Leeuw, Michael Berezin, Tatiana Varlygina and Tatiana Pereladova arrived from Moscow and the expedition crew was complete. Sergei, Andrei and the 'Botanyas' returned to Moscow on 29 July. The rest of us left Medusa Bay on 12 August. We returned to The Netherlands on 17 August.

The summer of 2002 at Medusa bay can be characterised climatically as late, moderately cold, clouded, and very wet. Snow cover was still almost complete upon our arrival and stayed extensive until about two weeks later than in the previous two years. Consequently, arrival and breeding of waders was also delayed by about a week or more, and laying occurred highly synchronised once the tundra was clear of snow. Although average temperatures were not particularly low, the weather throughout much of the summer was sombre with frequent strong winds, little sunshine, and in comparison to recent years, a remarkable amount of rain.

After two consecutive years with very few lemmings, numbers were on the increase in 2002, although densities usual in 'lemming peak years' were not reached. Numbers were high enough however to encourage predators such as Snowy Owls *Nyctea scandiaca* and Pomarine *Stercorarius pomarinus* and Long-tailed Skuas *S. longicaudus* to start nesting, although these species did suffer problems in finding enough lemmings to feed their mates and chicks later in the season. This caused them to shift their search effort partly to waders' nests and chicks. Also, although Arctic Fox *Alopex lagopus* numbers had been much reduced by two years of lemming scarcity, foxes were present in the surroundings and visited our study area a few times, leaving behind a trace of empty wader nests. Nevertheless, predation pressure on breeding waders was noticeably less than in 2000 and 2001, and good numbers of chicks hatched. Exactly around the peak hatching dates, a warm spell occurred which brought abundant insects to the tundra surface (and swept up unprecedented numbers of mosquitoes from the South). The later part of the chick period was wet and cold, so that growth conditions were not optimal.

The extensive snow cover made our efforts to catch recently-arrived waders rather successful in the first few days. Later on, we suffered from a lack of north-easterly winds which make incoming waders fly low over the tundra. The number of birds caught in this period was therefore less than in 2001 (though more than in 2000).

The limited predation pressure made our work on incubating birds easier. Most breeding birds could be ringed, and doubly-labelled water experiments, egg temperature studies and the supplemental feeding experiments on Little Stints were carried out without too many nest losses. Also, it meant that plenty wader chicks were available to study their growth rate. In this work we concentrated on Little Stints, and a successful series of doubly-labelled water measurements was made to describe the energy requirements for growth in the same species. After hatching we collected the lining material from a large number of wader nests and described its amount and composition, to study interspecific patterns in nest insulation.

Clap-netting of waders leaving Taimyr on autumn migration in late July and August was much less successful than in 2000 and especially in 2001. The first reason for this was the weather that suppressed migration on most days in this period. The late start of breeding in waders further meant that reproductive duties also finished later in 2002, causing a delay in the onset of migration. On good weather days, the attracted migrants seemed to be in a hurry and to react less strongly to the tape calls than in the previous years.



2 Study area

The study area is situated 18 km south of Dikson in the west of the Taimyr peninsula at 73°04'N 80°30'E (fig. 2.1). At the north-eastern end of the river Yenissei, near the mouth, Medusa Bay, measuring 1.2 km in diameter, is situated (fig. 2.2). Northeast of Medusa Bay, on a small peninsula a field station was established in 1994. Most of the shorebird breeding biology studies were undertaken in a 4 km² area east of Medusa Bay, defined by natural borders: the Medusa river in the south, the bay and the sea in the north and west and another small river in the north-east (fig. 2.2). However, we also searched for nests and made measurements on nests outside this intensive study area, up to c. 1 km to the north and south.

The study area can be classified as arctic tundra according to Chernov (1985), with some characteristics of typical tundra. The landscape is characterised by a rolling relief. The highest hill in the intensively studied area measures 39 m above sea level (a.s.l.), and the lowest point is at sea level. No lakes or ponds are present. To the east of the study area the relief becomes more distinct, with hilltops reaching as high as 160 m a.s.l. Rock formations are present throughout the area and rocky outcrops are often found on steep slopes. Gravel occurs along rivers, at river mouths and on beaches.

The vegetation consists of lichens, mosses, sedges, grasses, Dwarf Willows *Salix polaris*, and various herbs on the slopes and plateau's on top of hills. In the marshy areas found in valleys, on the lower parts of slopes and sometimes on hilltops, extensive meadows of sedges *Carex spp.* predominate. In the east of the intensive plot, north of the plot and south-east of the plot large polygonal bogs are found. In most of the area well-vegetated tundra predominates, with few areas of frost-boiled tundra with clay-medallions.

Because transportation by helicopter has become increasingly expensive, caterpillar vehicles (*vezdekhods*) are used throughout summer now for transportation in the area, and leave ever-increasing numbers of tracks in the tundra that remain for several decades. In these tracks vegetation cover increases through proliferation of grasses and sedges (Kevan *et al.* 1995). Also tracks cause drainage and creation of micro-relief and new puddles. Besides being a sign of environmental disturbance and degradation, this is also undesirable for the monitoring purposes, where changes in breeding bird numbers are the subject of study.

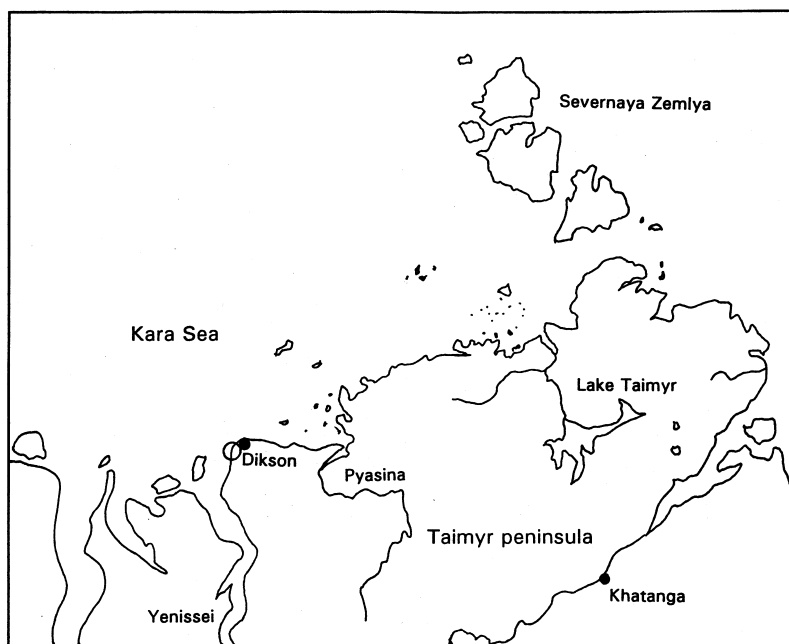


Figure 2.1. Location of the study area (circle near Dikson) on the Taimyr Peninsula

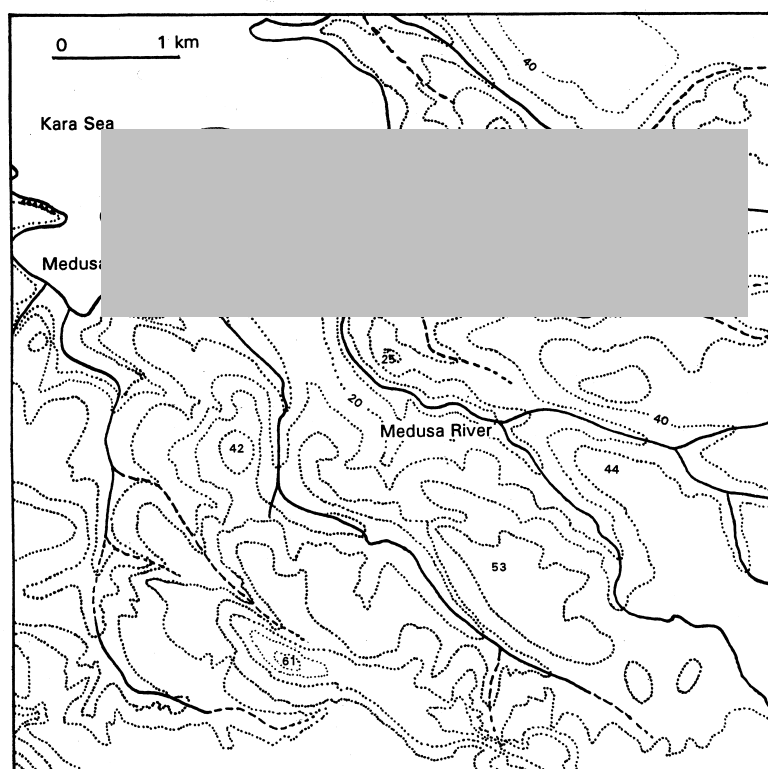


Figure 2.2 The 30 km² study area surveyed for the monitoring scheme, with the 4 km² intensive area (shaded). The dot indicates the location of the field station

3 Weather and snow conditions in summer 2002

3.1 Weather

Weather data were collected in the camp. A small weather station consisting of three temperature probes and devices measuring rain, air pressure, wind speed and direction with wireless connections to the central receiver was installed in the station. Additionally air temperature (T_a) and black sphere temperature (operative temperature T_o , integrating air temperature and solar radiation) were measured every 15 minutes using TinyTag data loggers, mounted in the shade near the station at 1 m height (T_a) and in an unshaded place in the tundra near the station (T_o). To enable comparison with the previous years the data collected using the data loggers are presented here, complemented with precipitation and wind data from the weather station.



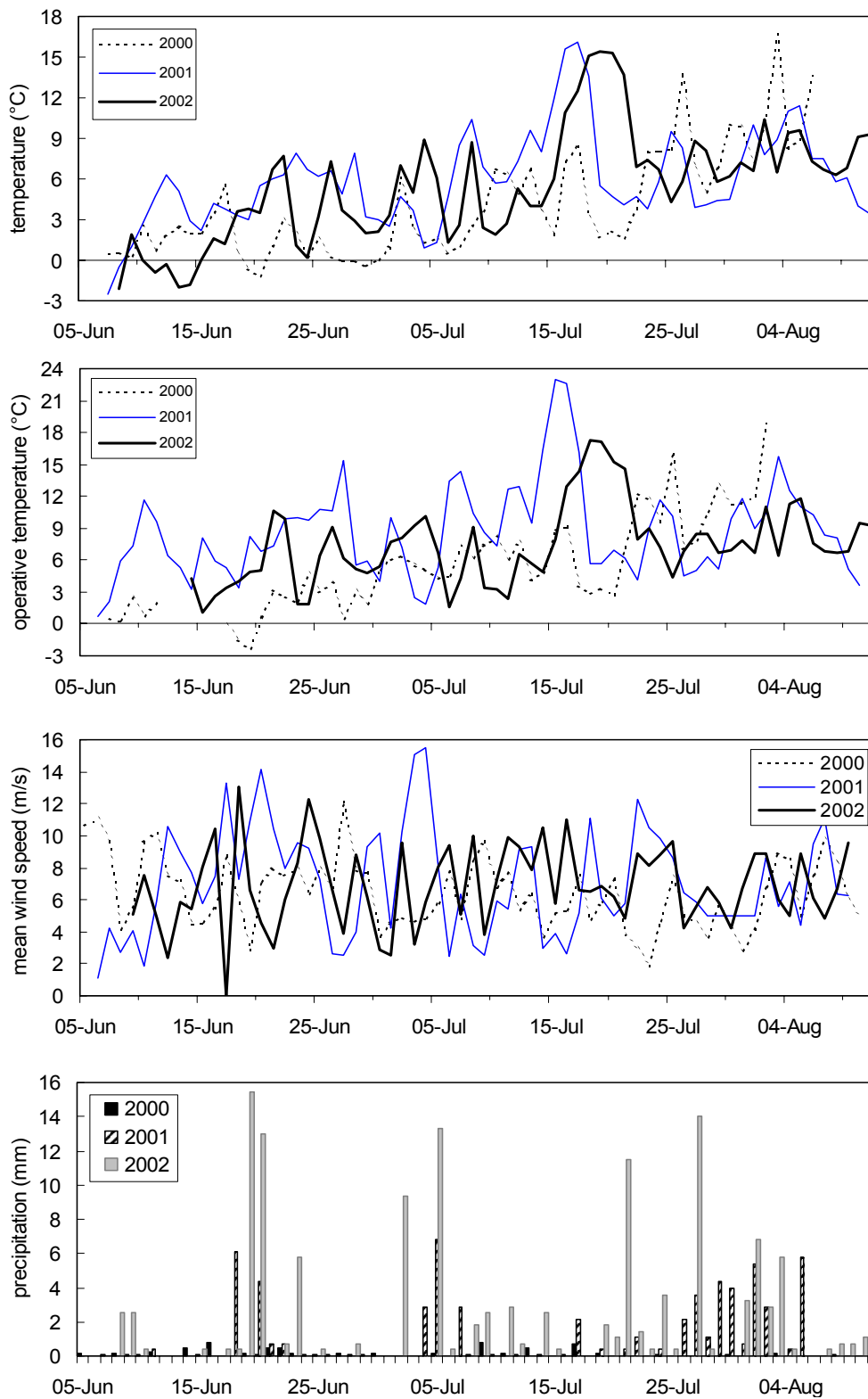


Figure 3.1. From top to bottom: daily mean air temperature (T_a) and operative temperature (T_e), daily mean wind speed and daily precipitation in the camp in the field periods in 2001 compared to 2000 and 2001

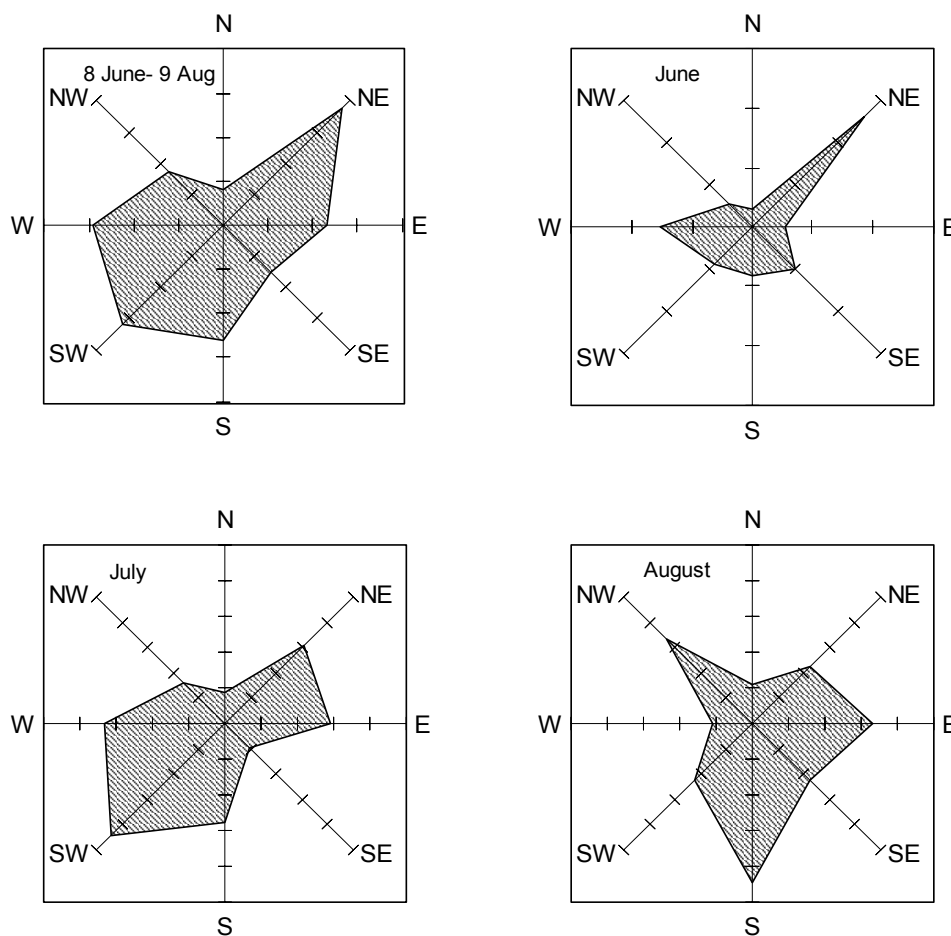


Figure 3.2. Frequency of wind directions in the entire study period (upper left), and in June (upper right), July (lower left) and August (lower right)

The summer of 2002 was on average slightly colder than that of 2001, though not as cold as 2000. Apart from a colder start (average June temperature in 2000 1.2 °C, 2001 4.0 °C, and 2002 2.0 °C), the general pattern in air temperature was similar to that in 2001, although peak temperatures were reached a few days later (fig. 3.1).

However, 2002 was distinctly less sunny, as illustrated by operative temperatures being clearly lower than in 2001, though not as low as in 2000. The most remarkable feature of summer 2002 was its wetness: between 6 June and 9 August no less than 132 mm of precipitation was recorded, compared to 59 mm in 2001 and a mere 7 mm in 2000. Nearly all of this fell in the form of rain; the only significant snowfall occurred on 6 July, but the tundra stayed white for a few hours only. Both the number of days (39, i.e. 60% of all days) with rain and the amount of rain falling on rainy days were larger than in previous years. Heavy rains were usually associated with warm fronts, and in a few cases in July also wind thunderstorms. Overall, wind speeds did not differ much from those in the previous years, although July was a bit windier than usual. Compared to previous years however, there was a high incidence

of southwesterly and southerly winds (fig. 3.2); it was these that brought most of the rain.

Another remarkable feature of the 2002 summer was the number of blood-sucking mosquitoes. In the previous years, mosquito activity was confined to a few of the warmest days; Medusa Bay is situated north of the main belt of mosquito abundance. This year, the first warm spell in mid-July brought very large numbers of them, and thereafter mosquitoes became an annoying presence whenever the weather turned favourable. On the worst days it was hard to do fieldwork, something that we hadn't experienced before in this area.

3.2 Snow, ice and permafrost depth

Upon our arrival on 8 June 2002, almost the whole study area was still covered by snow. Only at west-exposed hilltops and ridges small windblown patches of tundra were snow-free. Because temperatures remained low in early and mid-June, the snow melted away much slower than in the previous two years (Fig. 3.3). On 19 and 20 June snow cover was much reduced by heavy rains, which also set the Medusa river flowing. This first flowing date was late compared to 1997 (17 June, Khomenko *et al.* 1999), and 2000 (12 June), but not to 1994 (21 June, Hertzler & Günther 1994), 1996 (25 June, Tulp *et al.* 1997), 1998 (21 June) and 1999 (21 June, Willems *et al.* 2002.). Snow cover dropped below 50% on 20 June in 2002, nine days later than in 2001 and 15 days later than in 2000.

When emerging from under the snow, the tundra surface is usually completely frozen, but as air temperatures remain above zero it subsequently thaws out. The boundary between the soft thawed clay and the still frozen soil is sharp and can be easily located by inserting a pin into the tundra until it is stopped by the ice. Throughout the 2002 season, we measured this 'permafrost depth' at locations of wader nests (to the nearest cm). At many nests, more than one measurement was taken on different dates. The distance between nest floor and permafrost is a determinant of heat loss from wader nests (Reid *et al.* 2002) and we will use these measurements to analyse differences in nest placement and nest design between wader species (to be reported elsewhere). Here we only present how permafrost depth increases throughout the summer.

There were slight differences in average permafrost depth between nest sites of different species, but the temporal development of permafrost depth was the same at all species' nests (figure 3.4). In the course of the nesting period of shorebirds, permafrost depth increased from 5-10 cm to 25-35 cm, with a further increase to 40-45 cm in early August. Shorebirds may be expected to place their nests at sites which reduce clutch heat loss, and thus at sites with a deeper-than-average permafrost, so our measurements may be in the upper range of permafrost depths present in the study area at any time. We have no data from 2000 or 2001 to compare between years.

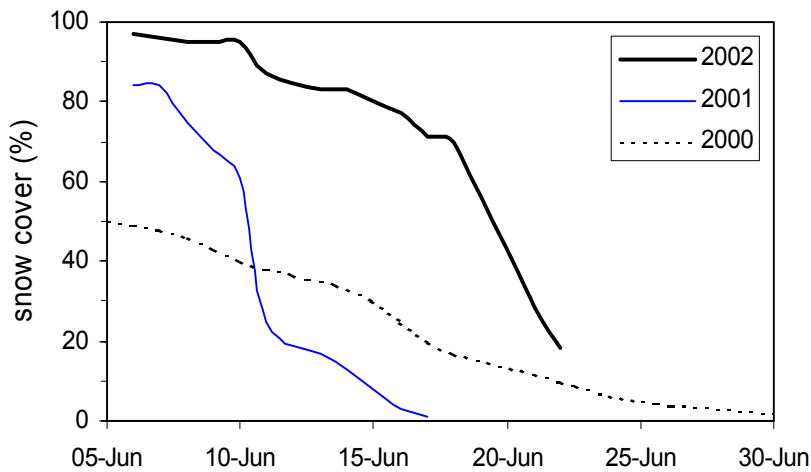


Figure 3.3 Development of snow cover along a 4 km long transect in the intensive study area in 2002 compared to 2000 and 2001

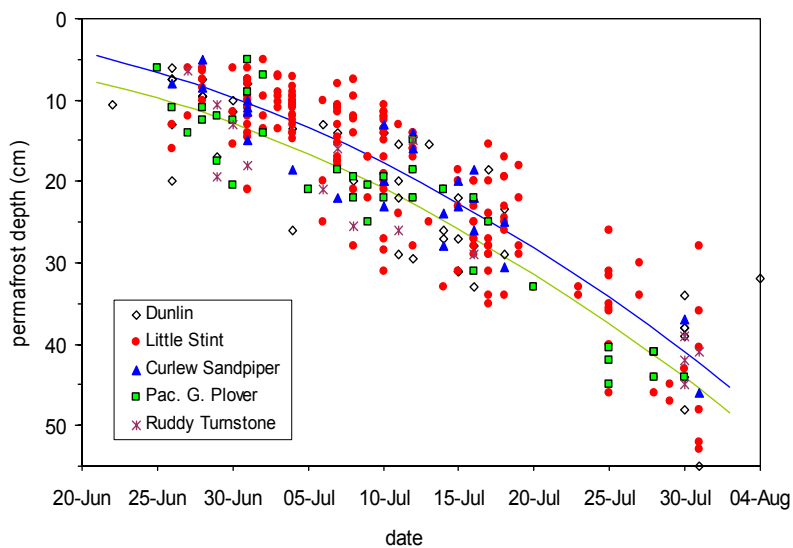
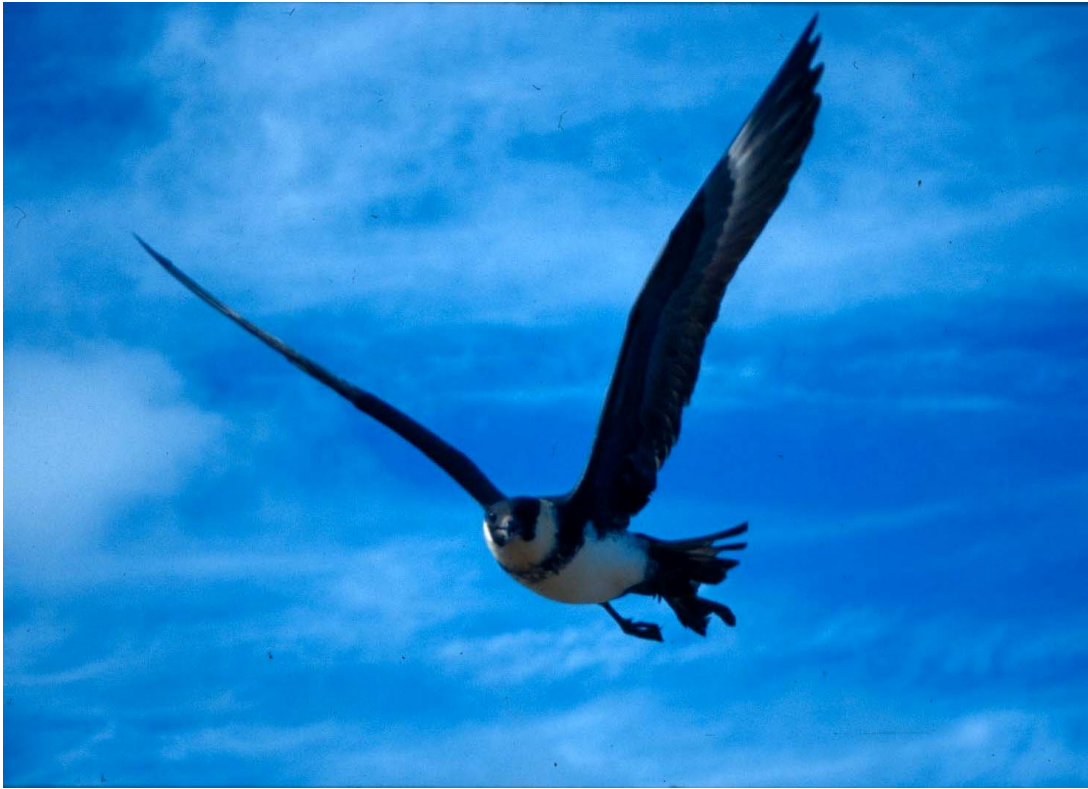


Figure 3.4. Development of the distance between tundra surface and permafrost layer near at wader nest sites in the course of the summer. The two lines give the (quadratic) regression lines for the species with the smallest (Little Stint) and the greatest (Pacific Golden Plover) average permafrost depth. The tundra surface is at the top of the graph



4 Lemmings, predators and geese

Lemming densities were studied by Andrei Bublichenko, by live-trapping in three standard census plots. In addition, we recorded all lemmings observed while we were in the field. By dividing the number of animals recorded by the time in the field and averaging over observers, an index of lemming activity was obtained which illustrates within and between-year patterns in abundance and activity (Fig. 4.1). (Observations of lemmings belonging to a family group living under the boardwalks surrounding the Willem Barentz Station were not included in this index.) The season average-value of the lemming index was 1.3 lemmings seen per 10h in the field (sd=2.1, n=65 days). After two years with extremely low lemming abundance (index 2000: 0.13; 2001: 0.002) this constituted a clear increase, but 2002 cannot be considered a year of very high lemming abundance in absolute terms. The standardised live-trapping revealed a seasonal average density of 10-12 lemmings per hectare, compared to 20-25 in the peak year 1999 (A. Bublichenko). Although our impression was that 2002 was an 'intermediate' year and that the lemming population would continue to grow and peak in 2003, fieldwork at Medusa Bay in 2003 revealed very low lemming numbers and an absence of breeding Snowy Owls and Pomarine Skuas (F. Willems and P. de Nobel *pers. comm.*). Thus the three-year cycle in lemming abundance that has been apparent in W. Taimyr for several decades was maintained, though 2002 formed an unusually poor 'peak'. The main irregularity in this cyclic pattern in recent decades has been the 2-year interval between the peaks of 1994 and 1996, with a subsequent return to three-year intervals. Around this time however, the cycles seem to shifted out of phase in the western and eastern parts of Taimyr (e.g. Tomkovich & Zharikov 1998).

Of the 135 lemmings observed in total, only 21 were identified to species: 19 Siberian Lemmings *Lemmus sibiricus*, and two Collared Lemmings *Dicrostonyx torquatus*. There was much variation in the abundance/activity of lemmings over the course of the season (Fig. 4.1). During the first week of our fieldwork, not a single lemming was seen. In winter, lemmings live in burrow systems in and under the snow, and these are found mainly at lower-elevation sites with a deep snow cover over relatively lush vegetation, i.e. sedge meadows in depressions and river valleys. Lemmings become visible on the surface only when snow melt reaches these sites, after the more exposed ridges and watersheds have become snow-free. This can be seen clearly in Fig. 4.1; lemmings were seen regularly only after snow cover dropped below 50% in the study area. Then there was a period of 10-15 days in which the animals were seen frequently, but thereafter numbers dropped markedly and remained low until a slight upsurge occurred late in the summer. The peak in lemming observations is caused by lemmings being driven out of their winter sites by snow melt and flooding, while summer burrows in the exposed parts of the tundra were still either frozen shut or flooded with melt water. Only after the soil thawed out could the animals move underground.

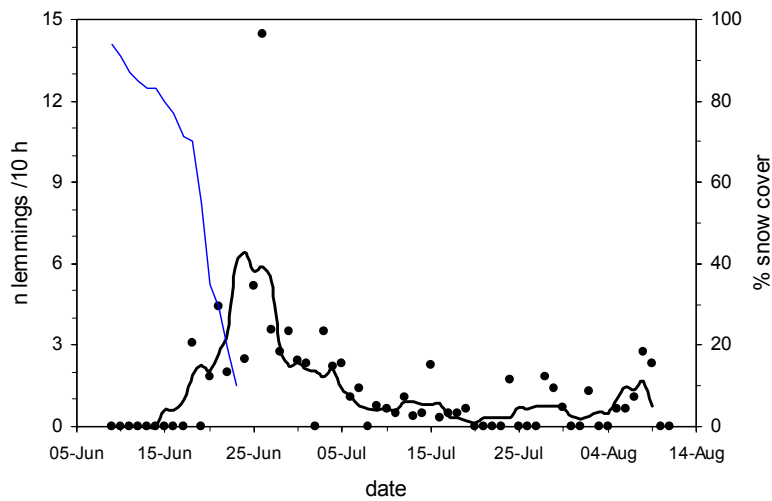


Figure 4.1. Development of the Lemming index (number observed per 10 h field day) in summer 2002 ($n = 135$ lemmings in 982 field hours). Dots: daily means of 2-3 observers; thick line: 5-day running average. Thin line shows development of snow cover for comparison

It was clear that lemmings suffered a lack of hiding places in this period; when animals on the surface were pursued, they did not find a place to hide and eventually threw themselves on their back and tried to scare the 'predator' off with a loud squeak and outstretched legs.

Predators took advantage of this phase of high lemming vulnerability. Pomarine Skuas *Stercorarium pomarinus* started digging lemmings from under the snow even before their winter burrows had fully melted, and their territorial and sexual display activity coincided with the period of high lemming indices. After two years in which Pomarine Skuas had not established territories in the area, there were now six nests within the 4 km² plot. In the extensive sedge meadows surrounding the plot, breeding density was even slightly higher, approximately two pairs per km². We found 15 clutches containing two eggs and two containing one. Long-tailed Skuas *S. longicaudus* also nested, with three pairs inside the 4 km² plot, but this constituted less of a contrast with previous years, when at least two territories (and in 2001 a nest) were present. All four clutches found contained two eggs.

Rough-legged Buzzards *Buteo lagopus* did not breed within the 4 km² plot in 2002, but several pairs were present in the surroundings (20 active nests in approximately 275 km² surveyed, S. Kharitonov). Also, nine pairs of Snowy Owl *Nyctea scandiaca* bred in this area, of which three in the 30 km² and one within the 4 km² plot. It was the first time that Snowy Owls bred since 1999, but clutch sizes of 4-6 eggs indicated that the owls did not experience the availability of lemmings to be optimal. In real lemming peak years, mean clutch size can be as high as 8-11 eggs (Summers *et al.* 1994, Willems *et al.* 2002). In contrast to our experience in such years, none of the Snowy Owl pairs were aggressive when their nest was approached; males just sat calling to the intruder at c. 100 m distance.



Collared Lemming

Could it be that the motivation of owls to make risky attacks on potential predators depends on the perceived value of the clutch (indicated by clutch size)? The cautious investment of owls in reproduction proved justified: when the chicks were born, owls clearly had difficulty in providing enough food. While in lemming peak years it is normal to find several (up to 42, Willems *et al.* 2002) dead lemmings on the nest edge waiting to be consumed by the satiated chicks, in 2000 dead lemmings were not always present and if there were, usually one or two only. Chicks grew poorly and disappeared one by one. None of the owl pairs under observation managed to produce fledged young.

Arctic Foxes *Alopex lagopus* were scarcer than in the previous two years. It took several weeks before the first fox tracks were seen in the snow in the intensive study area. However, fox tracks were seen more regularly near river mouths at some

distance from the main study area. Eventually, no fox took up permanent residency in our intensive study plot, although passing individuals visited it several times. The nearest active fox den was at the Varikova stream, about 6 km North of the intensive study area.

Stoats *Mustela erminea* were not seen in the study area in 2002. During our study, we observed this species only in 2000. A very remarkable observation was a (presumably subadult) Brown Bear *Ursus arctos*, seen by Sergei Kharitonov some 5 km South of the intensive study area on 1 July. This animal was a few hundred kilometres North of its normal range.

Geese and ducks bred in larger numbers than in the two previous years, with several Brent Goose *Branta bernicla* colonies around Snowy Owl nests (64 nests in four colonies and two single nests near owls), as well as scattered solitary pairs (21 nests found). A total of 85 Brent Goose and nine White-fronted Goose *Anser albifrons* nests was found by Sergei Kharitonov in approximately 275 km² of inland tundra, and another 35 Brent Goose nests on the offshore islands. In addition, at least one each of Long-tailed Duck *Clangula hyemalis*, Steller's Eider *Polysticta stelleri* and King Eider *Somateria spectabilis* bred in the 4 km² intensive study area



5 Shorebird breeding parameters

This chapter summarises breeding parameters of shorebirds: number and distribution of nests, phenology, nest success and predation. For shorebirds egg float curves are based on combined data of 2000-2002 and these are used to reconstruct the breeding phenology. In Appendix 2 data on egg size and start of incubation for each nest are presented for all wader species. Some data on other bird species such as passerines, Ptarmigan *Lagopus mutus* and Rough-legged Buzzard are also given here.

5.1 Methods

Throughout the breeding season, we searched for nests by looking for nest-indicative behaviour of the attendant birds. Depending on the species, the incubating bird alarms (Ruddy Turnstone, Dunlin, Ringed Plover, Pacific Golden Plover; see table 5.1 for scientific names), walks or flies off the nest at a large distance (Pacific Golden Plover, Curlew Sandpiper, Ringed Plover) or flushes off when approached closely (Little Stint, Temminck's Stint, Dunlin). Nest positions were recorded with a hand-held Global Positioning System (GPS) with an accuracy of c. 3 m, and most nests were marked inconspicuously with a stone or a small stick at 10 m distance.

Nest search effort was concentrated within the 4 km² intensive study area. Here, we tried to find as many as possible of the wader nests present (except in Pacific Golden Plover and Ringed Plover in 2001-2002). Of course we did not find all nests, however. Since we caught and (colour)marked the great majority of the incubating adults on successful nests, the number of broods that we later encountered accompanied by unmarked adults gives an indication of how many nests we did not find. We also located nests outside the borders of the 4 km² plot, but without the intention of completeness. This was done to increase sample sizes for some species that were scarce within the intensive plot (e.g. Ruddy Turnstone, Red Phalarope), but also to locate nests suitable for experiments. In 2002, this applied especially to Dunlin, in which we measured energy expenditure of incubating adults, and to Little Stints, in which we measured nest attendance of supplementary fed adults and energy expenditure of chicks. Data of these nests outside the intensive study area were used in our analyses of breeding phenology, clutch size and nest success presented below.

Of each nest found, eggs were measured and floated to determine incubation stage (see par. 5.3) and breeding phenology (5.4). Nests were checked regularly to monitor their fate, but mostly at intervals longer than three days, to reduce the risk of predation. At each visit the status of the nest was recorded. If a nest was found empty after the potential hatching date, it was considered to have hatched only if small eggshell fragments were found in the nest cup; if these were absent it was considered predated. Nests considered predated were checked for Arctic Fox scent-marks or droppings, or other signs that could indicate the identity of the predator.

5.2 Numbers and distribution of nests

Numbers of nests and broods found inside and outside the 4 km² intensive study area in 2002 are given in tables 5.1 (waders) and 5.2 (other species), together with those in the previous years of this study. Comparisons between years should be made on the basis of nests found within the 4 km² plot, because there we aimed for complete coverage.

However, we did not try to find all nests of Ringed Plover in 2001-02, in contrast to 2000. Also in Pacific Golden Plover we did not locate all nests, though in this case we suspect that the lower number of nests found in 2002 does reflect a lower number of breeding pairs. This might be connected to the cold weather and late arrival of birds in the spring of 2002, although this does not seem to have led to markedly lower breeding numbers in the other species present. Especially in the Little Stint, numbers found were remarkably similar in the three years, in view of the total lack of breeding site fidelity in this species. In the site-faithful Dunlin, the number of nests found in 2000 is inflated by a relatively high number of replacement clutches compared to the other two years.

Pectoral Sandpipers bred in the study area for the second year in a row. The influx of this species in 2001, after seven years with no breeding records, was attributed to the warm spring weather with easterly winds, but in 2002 again a number of males and some females appeared even though the spring was cold and winds mainly westerly. No birds were colour-marked in 2001 however, so we do not know whether the same individuals were involved. Red Phalaropes also returned to breed, in even larger numbers than in 2001. Figures 5.1-5.2 show the distribution of wader nests found in 2002.

Table 5.1. Numbers of shorebird nests and broods of which nests were not found, inside and outside the 4km² intensive study area in 2002 (Apart from the species listed, single nests of Grey Plover and Red-necked Phalarope and a single brood of Red Knot were found outside the 4km² area in 2002). The last three columns compare the total numbers of nests+broods found inside the 4km² area in 2000-2002

species	inside 4 km ²		outside 4 km ²		nests+broods		
	2002		2002		in 4 km ²		
	nests	broods	nests	broods	2000	2001	2002
Little Stint <i>Calidris minuta</i>	82	17	56	11	110	94	99
Dunlin <i>C. alpina</i>	18	2	9	-	31	18	20
Pac. Golden Plover <i>Pluvialis fulva</i>	17	-	6	-	27	26	17
Curlew Sandpiper <i>C. ferruginea</i>	10	3	3	-	13	19	10
Ringed Plover <i>Charadrius hiaticula</i>	6	-	1	-	10	2	6
Ruddy Turnstone <i>Arenaria interpres</i>	4	-	6	-	3	2	4
Red Phalarope <i>Phalaropus fulicarius</i>	3	-	5	-	-	2	3
Pectoral Sandpiper <i>C. melanotos</i>	2	-	-	-	-	7	2
Temminck's Stint <i>C. teminckii</i>	1	-	-	-	1	2	1
Ruff <i>Philomachus pugnax</i>	-	-	2	1	-	1	-
Dotterel <i>Ch. morinellus</i>	-	-	1	-	-	2	-

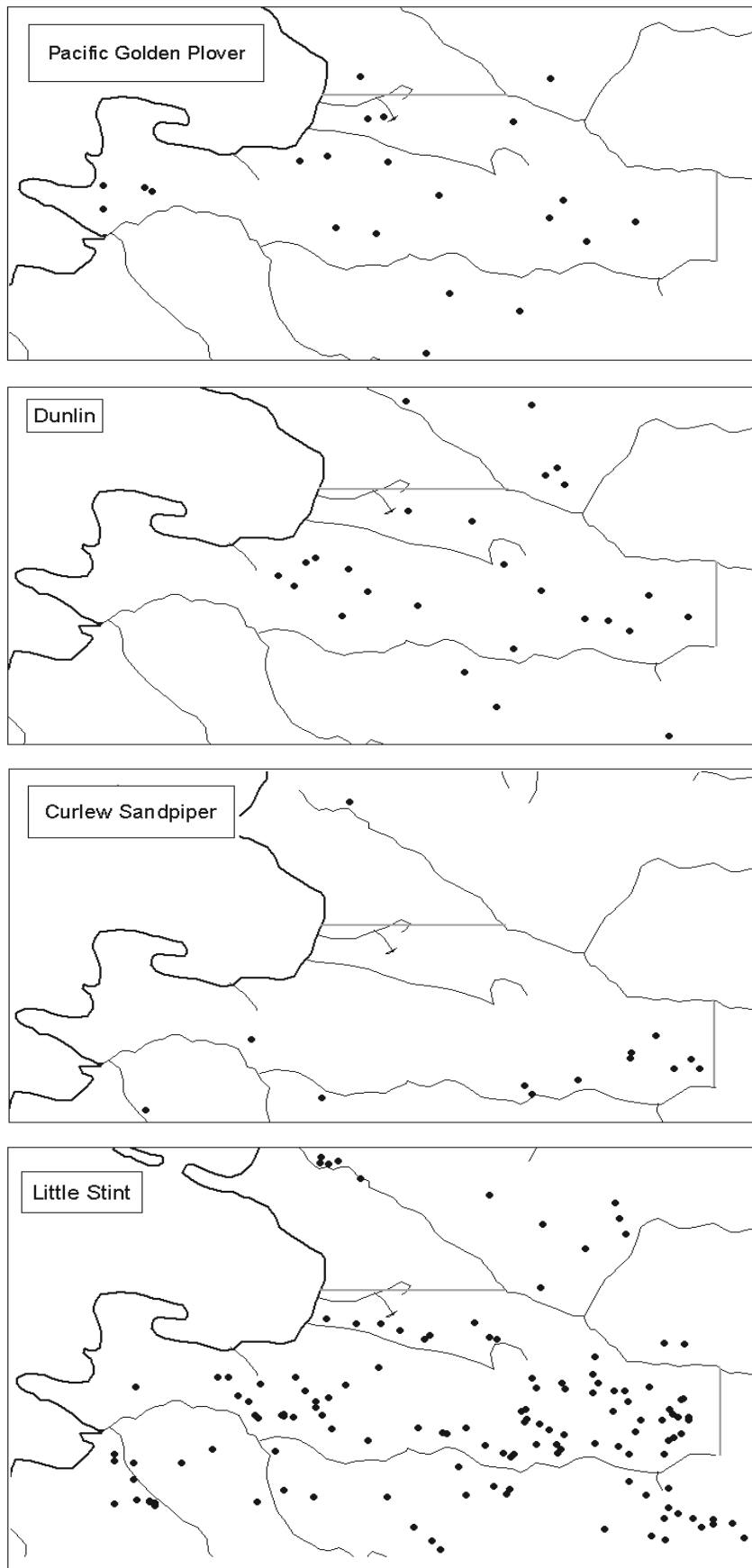


Figure 5.1. Distribution of nests of Pacific Golden Plover, Dunlin, Curlew Sandpiper and Little Stint in 2002. Boundary of 4 km² study area formed by coastline, Medusa river and two straight grey lines

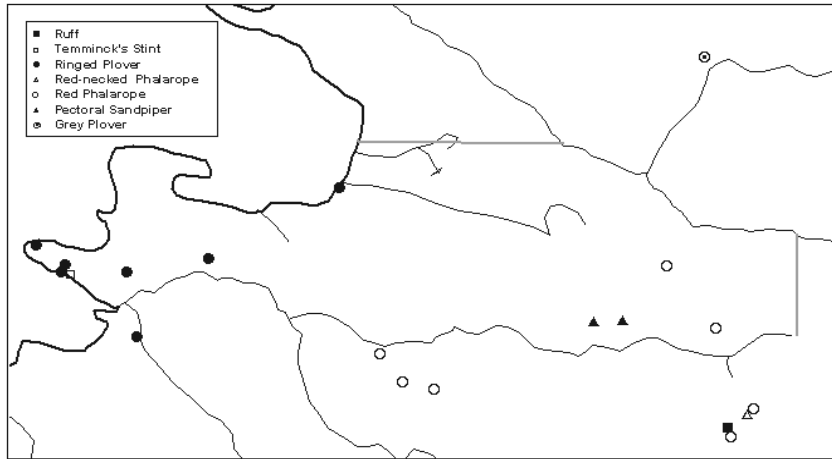


Figure 5.2. Distribution of nests of scarce shorebird species in 2002. The boundary of 4 km² intensive study area is formed by coastline, Medusa river and two straight grey lines

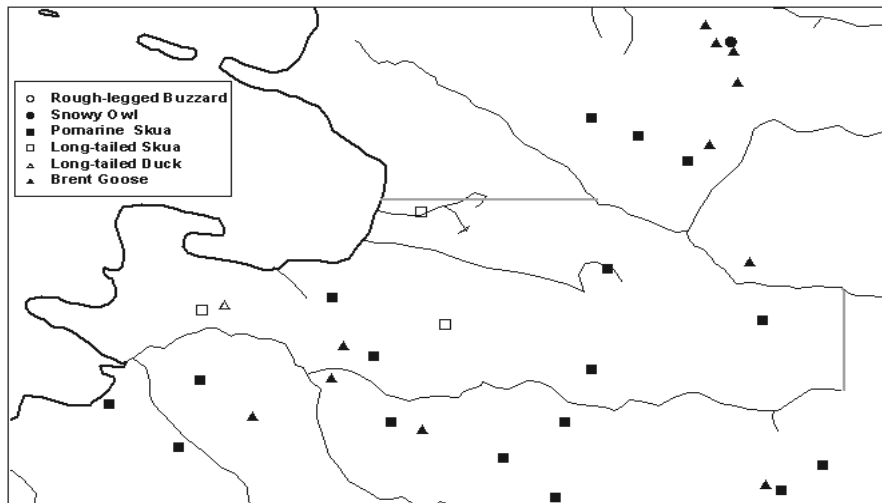


Figure 5.3. Distribution of nests of selected non-wader species in 2002. Boundary of 4 km² intensive study area formed by coastline, Medusa river and two straight grey lines

Table 5.2 gives numbers and figure 5.3 distributions of located nests of non-wader species. We did not strive for completeness in these species, so numbers do not necessarily reflect abundance. Geese, ducks and skuas however bred in clearly larger numbers than in previous years, in response to the increase in lemming numbers and scarcity of arctic foxes. Note that Snowy Owl, Buzzard and goose numbers include only nests in our own database, and not the nests found further afield by Sergei Kharitonov (several additional Snowy Owls of which some with associated colonies of Brent Goose).

Table 5.2. Numbers of nests of other bird species than shorebirds found in 2002, inside and outside the 4 km² intensive study area, and a comparison of total numbers of nests found in 2000-2002.

species	inside 4 km ²	outside 4 km ²	nests in & outside 4 km ²		
			2000	2001	2002
Brent Goose <i>Branta bernicla</i>	2	10	-	1	12
White-fronted Goose <i>Anser albifrons</i>	-	-	-	1	
Long-tailed Duck <i>Clangula hyemalis</i>	1	-	-	-	1
Steller's Eider <i>Polysticta stelleri</i>	-	1	-	-	1
King Eider <i>Somateria spectabilis</i> (brood)	-	1	-	-	1
Ptarmigan <i>Lagopus mutus</i>	2	-	4	4	5
Long-tailed Skua <i>Stercorarius longicaudus</i>	3	1	-	3	4
Pomarine Skua <i>S. pomarinus</i>	6	12	-	-	18
Snowy Owl <i>Nyctea scandiaca</i>	-	2	-	-	2
Rough-legged Buzzard <i>Buteo lagopus</i>	-	1	1	-	-
Shorelark <i>Eremophila alpestris</i>	5	2	6	14	7
Red-throated Pipit <i>Anthus cervinus</i>	1	-	2	6	1
White Wagtail <i>Motacilla alba</i>	-	-	1	1	-
Northern Wheatear <i>Oenanthe oenanthe</i>	1	-	-	1	1
Common Redpoll <i>Carduelis flammea</i>	1	-	-	-	1
Lapland Bunting <i>Calcarinus lapponicus</i>	7	3	18	15	10
Snow Bunting <i>Plectrophenax nivalis</i>	5	1	23	9	6

5.3 Estimation of hatching and clutch completion dates

The developmental stage of eggs was determined by floating them in water. When immersed in water, an undeveloped egg lies on the bottom with the longitudinal axis pointing *c.* 20° upwards. With progressing development of the embryo, the air sac at the blunt end of the egg increases in size and egg mass decreases. At first the angle of the longitudinal axis of the egg with the bottom increases until the egg balances on its tip. Then the egg starts floating and eventually the blunt end is lifted out of the water. Using angle measurements and measurements of the distance between the tip of the egg and the water surface of eggs with a known laying or hatching date, and with knowledge of the duration of the incubation period, the stage of incubation can be estimated (van Paassen *et al.* 1984).

Upon finding a nest, we immersed two of the eggs in water in a rectangular transparent plastic jar with an angular scale drawn on two sides (van Paassen *et al.* 1984). For eggs sinking to the bottom, we estimated the angle between the horizontal plane and the longitudinal axis of the egg (accurate to 5-10°); in floating eggs we estimated the distance between the tip of the egg and the water surface (in mm), by looking through the transparent sides of the jar. If the two eggs differed much in their float characters, we immersed a third or fourth egg to avoid that abnormally developing eggs affected our estimates. Clearly deviating eggs were excluded and averages calculated for the other eggs.

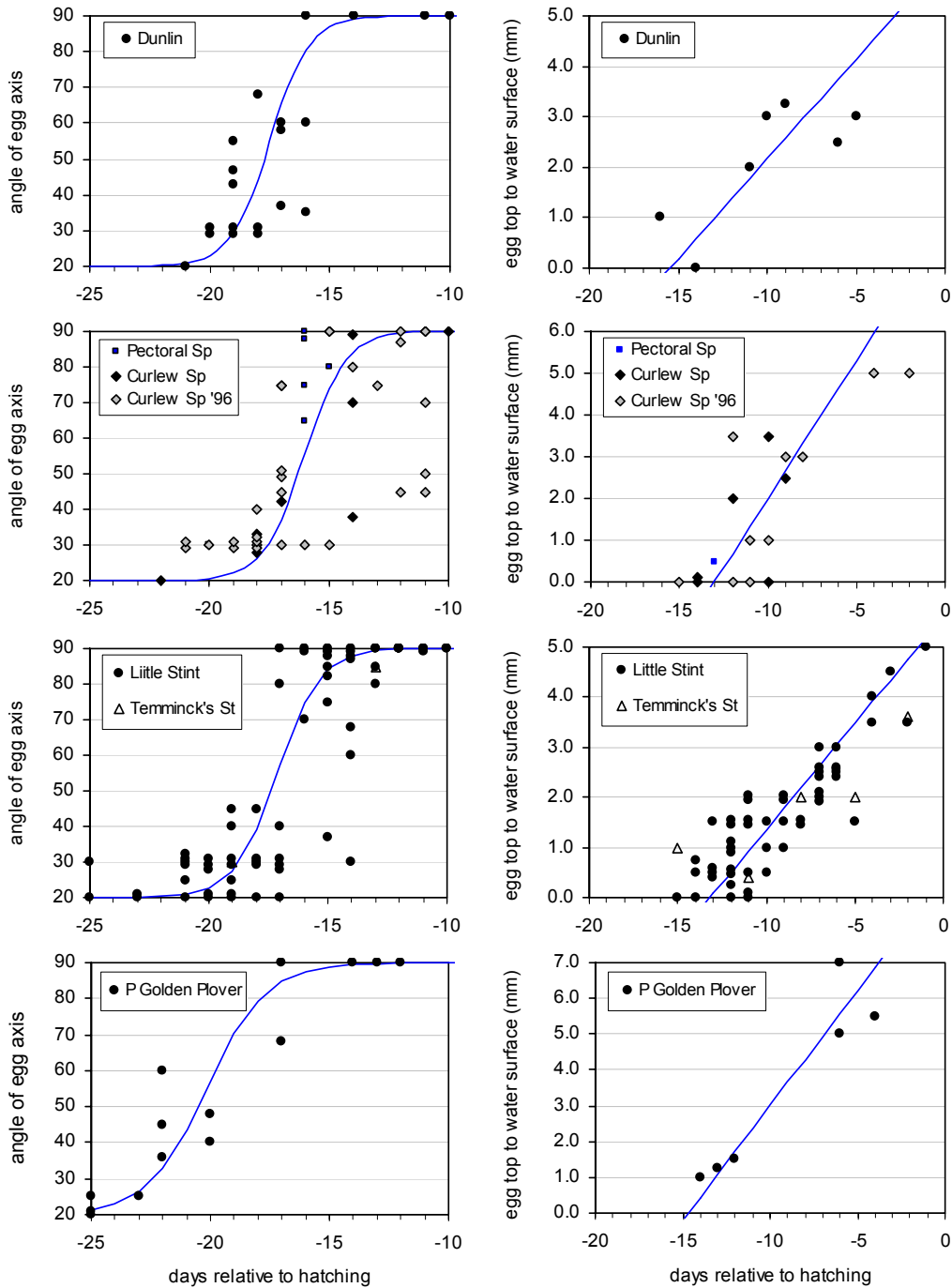


Figure 5.4. Development of incubated eggs and fitted float curves for estimation of hatching dates in (top to bottom) Dunlin, Curlew Sandpiper & Pectoral Sandpiper, Little & Temminck's Stints, and Pacific Golden Plover. Left panels: angle between longitudinal axis of submerged egg and the horizontal; right panels: distance between top of floating egg and water surface. Tables from which the incubation day can be read directly are given in appendix 1

For Pacific Golden Plover, Curlew Sandpiper and Pectoral Sandpiper, Dunlin, and Little and Temminck's Stints, data from 2002 were combined with data obtained at Medusa Bay in 1996 and 2000-2001. Because relatively many clutches hatched in 2002, this year provided a significant improvement to the float curves presented in previous reports. As we are interested in predicting incubation day from the float measurements rather than describing the development of eggs, curves were fitted through these data by linear regression with the incubation day (relative to hatching) as the dependent variable and float characteristics as the independent variable. The angular measurements were first transformed to a proportional angle (P) by giving an angle of 20° the value 0 and 90° the value 1, and interpolating, and then transformed to logits ($\text{logit } P = \ln(P/[1-P])$) to capture the sigmoid shape of the relationship. The resulting float curves are shown in figure 5.4, with statistics in appendix 1. Appendix 1 also includes a table by which incubation day can be estimated directly from the float measurements in the field. As eggs develop in a similar fashion in all species, estimates for different species with intermediate egg size and incubation periods can be derived by interpolation from these data.

As can be seen from the scatter of data points in fig. 5.4, estimation of incubation day from egg floats involves errors of up to several days. The effect of these errors on the prediction of hatching dates is summarised in figure 5.5, which shows the difference between observed hatching dates and those predicted from egg floats for nests found in 2002. Errors ranged up to -8 and +9 days in extreme cases, but in 95% of all 108 cases the true hatching date differed at most 3 days from the prediction in either direction. Predictions were accurate to ± 1 day in 75% of all nests, with a tendency to be slightly less accurate for Little Stints than for other species (73% vs. 78% within 1 day from the prediction, n=66 and 42). We found relatively many nests within the first week of incubation, when the predictive power of the flotation method is relatively poor (fig. 5.4). By re-floating eggs in such nests after a week or so, the predictions could have been further improved.

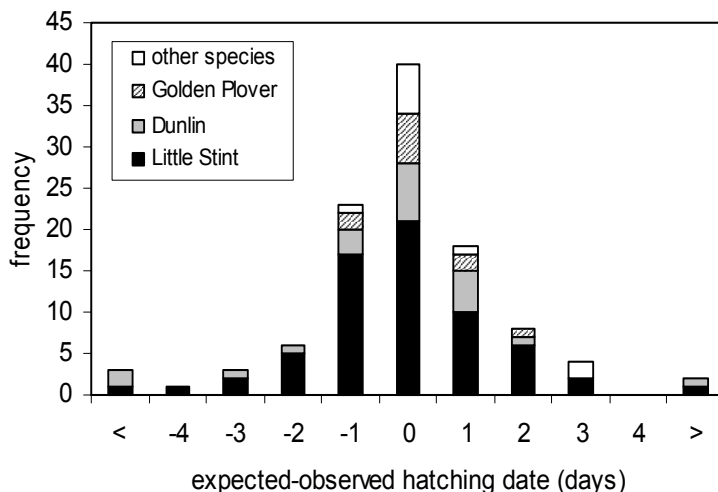


Figure 5.5. Differences between observed hatching dates of shorebird clutches in 2002 and those predicted from float curves in Fig. 5.4

Float curves were used to estimate both the expected hatching date and the date on which incubation started (clutch completion date). For the length of the incubation period we used: Pacific Golden Plover 25 days, Ringed Plover 23 days, Ruddy Turnstone 22 days, Dunlin/Curlew Sandpiper/Pectoral Sandpiper 21 days, Little Stint, Temminck's Stint and phalaropes 20 days (Cramp & Simmons 1983). Measurements of chicks were used to estimate hatching and laying dates for those broods encountered after hatching and accompanied by an unmarked adult. Chicks encountered were measured and weighed, and their age was estimated using growth curves from Schekkerman *et al.* 1998b (Curlew Sandpiper), Schekkerman *et al.* 1998a (Little Stint) and Tulp *et al.* 1998 (Ruddy Turnstone). For Dunlin the growth curve of Curlew Sandpiper was used with the mean mass of juvenile Dunlins caught on autumn migration as the asymptote. Errors in age estimation of chicks were assumed to be of similar magnitude as those involved in egg flotation. These errors were taken into account in the composition of distributions of clutch completion dates. Instead of assigning a single date per nest, the probability of starting on a certain date was spread over five days, with the presumed date given a weight of 0.3, the neighbouring dates given a weight of 0.25 and the first and fifth date a weight of 0.1. Only for nests of which either the starting or hatching date was exactly known from observations, the full weight was given to that date.

5.4 Breeding phenology

Figure 5.6 presents distributions of clutch completion dates for wader clutches in 2000-2002. These distributions are summarised in table 5.3. Overall, it is clear that in 2002 nesting commenced significantly later than in 2000 and 2001, years with a very similar phenology of breeding. Median clutch completion dates were 2-9 days, and on average about a week, later in 2002, except in the Pacific Golden Plover for which there was no difference. The difference was even larger when completion dates of the earliest clutches are compared; these were 5-13 days (average 9 days) later in 2002 than in the two previous years, with a difference also in the Pacific Golden Plover (5-7 days). These differences in earliest dates were larger in species that usually start nesting early (Dunlin, Curlew Sandpiper and Ruddy Turnstone, difference on average 12 days) than in species that usually breed later (Pacific Golden Plover, Little Stint, Pectoral Sandpiper and Red Phalarope; mean difference 7 days).

Table 5.3. Completion dates of shorebird clutches in 2002 (median, 25% and 75% percentiles, and earliest and latest observations) in comparison with median dates in 2000 and 2001

Species	N	2002 clutch completion dates					2000	2001
		median	25%	75%	earliest	latest	median	median
Pacific Golden Plover	23	26/6	25/6	28/6	24/6	8/7	26/6	24/6
Ringed Plover	7	29/6	24/6	5/7	23/6	6/7	23/6	20/6
Little Stint	163	1/7	28/6	3/7	23/6	14/7	29/6	25/6
Curlew Sandpiper	13	25/6	24/6	30/6	23/6	4/7	18/6	17/6
Pectoral Sandpiper	2	30/6	27/6	2/7	27/6	2/7		24/6
Dunlin	29	24/6	23/6	25/6	23/6	13/7	19/6	17/6
Red Phalarope	8	29/6	26/6	4/7	25/6	8/7		23/6
Ruddy Turnstone	10	25/6	23/6	26/6	22/6	28/6	16/6	16/6

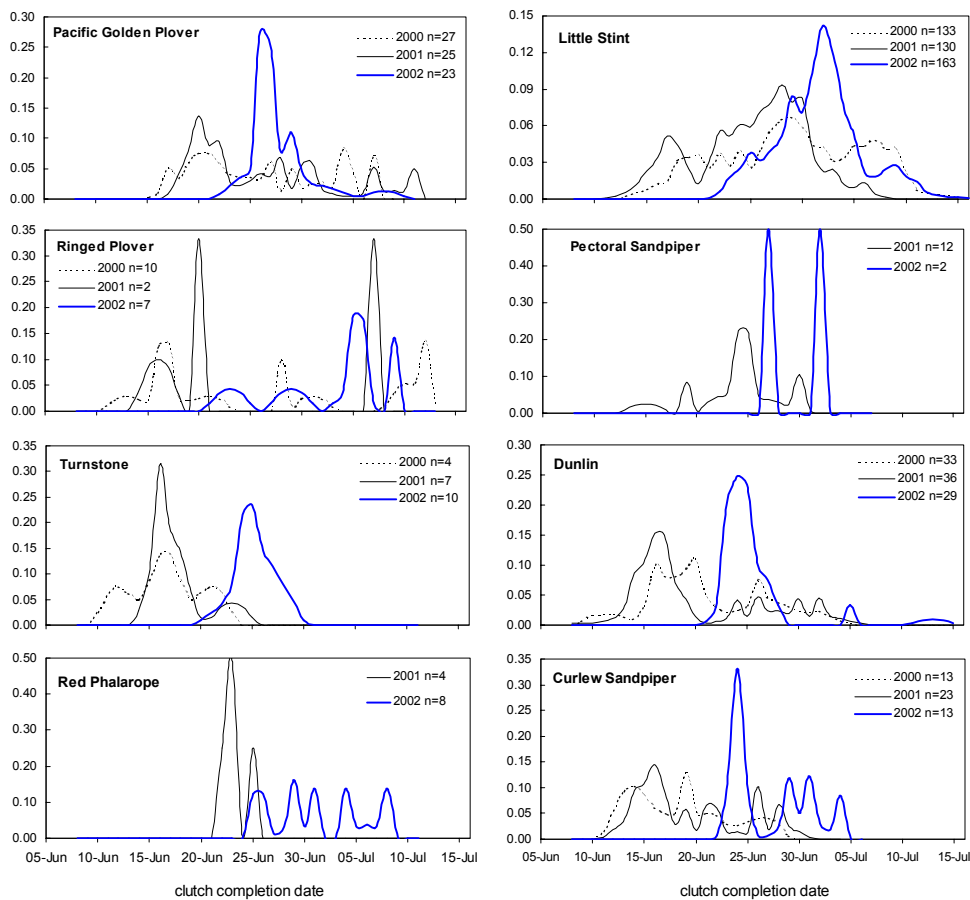


Figure 5.6. Probability distributions of clutch completion dates of waders in 2000-2002. Dates were observed directly (incomplete or hatching clutches), or estimated from egg flotation or chick biometrics. Distributions appear smoothed because 1-2 day errors in estimation errors were taken into account (see text)

Besides being later, laying was also markedly compressed in 2002. For species with at least 10 nests found, the average time between the 25% and 75% percentiles of the laying distributions was 4.8 days (sd=2.6, n=5); for 2000-01 this was 10.0 days (sd=3.6, n=9). The most synchronised laying was observed in Dunlin (50% of clutches completed within 3 days), Pacific Golden Plover and Turnstone (50% within 4 days), but even in the double-clutching Little Stint, half of the clutches were laid within 5 days in 2002.

The late and compressed laying period of 2002 coincided with a late snowmelt: 50% snow cover was reached 11-15 days later in 2002 than in 2000-01. The central ridge of the 4 km² plot, where most Dunlin and Pacific Golden Plovers nest, became exposed between 18 and 21 June. The first nests of these species were initiated on 20 and 21 June respectively, but the majority between 20-23 and 22-25 June. Moist slopes and sedge meadows in the eastern part of the plot, which are the main haunts of Little Stints, mostly became snow-free between 21 and 26 June, while most stints laid their first egg between 25 June and 1 July. Thus it seems that most waders did not start laying as soon as their nesting site had become snow-free but 2-5 days after.

We found one golden plover nest with three eggs at 1.5 m from the receding snow line though; the first egg must have been laid right on the snow edge.

Despite the late snowmelt, resightings of colour-marked Dunlins indicate that their late laying did not result from a longer time between arrival and laying (see chapter 7.5). Instead, the marked local Dunlins arrived about a week later in 2002. Times between arrival, pairing, and laying of the first egg did not differ between 2001 and 2002. This suggests that the late breeding in 2002 could as well be caused by a late arrival of the birds (possibly after a slow progression in the final stages of the journey in response to extensive snow cover), as by a direct constraint on nesting posed by the snow.

Table 5.4 Mean (and standard deviation) clutch size in shorebirds at Medusa Bay by year

Species	2000			2001			2002		
	mean	sd	n	mean	sd	n	mean	sd	n
Grey Plover	4.00	-	1	-	-	-	4.00	-	1
Pacific Golden Plover	3.90	0.40	30	3.90	0.45	23	3.96	0.21	23
Dotterel	-	-	-	3.00	0.00	2	3.00	-	1
Ringed Plover	3.88	0.35	10	3.67	0.58	3	3.67	0.52	6
Red Knot	-	-	-	4.00	-	1	-	-	-
Little Stint	3.86	0.48	107	4.00	0.16	89	3.99	0.12	137
Temminck's Stint	4.00	0.00	3	4.00	0.00	2	4.00	0.00	1
Dunlin	4.00	0.00	29	3.95	0.21	24	3.93	0.27	27
Curlew Sandpiper	3.89	0.33	10	3.81	0.54	17	4.00	0.00	13
Pectoral Sandpiper	-	-	-	4.00	0.00	12	4.00	0.00	2
Ruff	-	-	-	4.00	0.00	2	4.00	0.00	2
Red Phalarope	-	-	-	4.00	0.00	4	3.75	0.46	8
Red-necked Phalarope	-	-	-	-	-	-	4.00	-	1
Ruddy Turnstone	4.00	0.00	3	4.00	0.00	7	4.00	0.5	9

Table 5.5 Mean egg size within shorebird clutches at Medusa Bay. Mean length (mm), width (mm) and volume (cm³) are given for the pooled data from 2000-2002; mean volume is also given by year for the most numerous species

spec	N	2000-2002 pooled						mean volume by year		
		length	sd	width	sd	volume	sd	2000	2001	2002
Grey Plover	2	52.0	1.3	36.3	0.5	34.20	1.87			
Pac. Golden Plover	73	47.6	1.3	32.8	0.7	25.69	1.49	25.4	25.9	25.8
Dotterel	3	41.7	1.1	28.7	0.3	17.13	0.60			
Ringed Plover	15	34.3	1.1	25.0	0.4	10.71	0.60			
Knot	1	44.2		31.8		22.30				
Little Stint	310	28.8	1.0	20.6	0.6	6.12	0.51	6.1	6.2	6.1
Temminck's Stint	4	28.2	0.8	21.0	0.3	6.22	0.18			
Dunlin	80	35.3	1.0	24.9	0.6	10.99	0.75	11.1	10.9	11.0
Curlew Sandpiper	40	36.6	0.8	25.9	0.5	12.32	0.51	12.4	12.4	12.2
Pectoral Sandpiper	14	37.0	1.6	26.4	0.8	12.88	1.16			
Ruff	4	44.2	1.0	30.1	0.8	20.01	1.11			
Red Phalarope	11	31.9	1.0	22.7	0.5	8.22	0.42			
Red-necked Phal.	1	29.6		20.7		6.35				
Ruddy Turnstone	17	39.9	1.0	28.1	1.3	15.84	1.47	15.2	15.8	16.0

5.5 Clutch size and egg size

Mean clutch size for waders in the three years of this study is given in table 5.4. While most sandpipers showed the typical clutch size of four, plovers laid three eggs more often. In Dotterel, three-egg clutches are the rule. In 2002 we found one Turnstone nest containing five eggs (no colour differences between eggs indicative of laying by two females). This clutch failed due to predation. Some studies of arctic waders have found reductions in clutch size in cold and late springs (Nol *et al.* 1997, Meltofte 2000). Although the spring was later and colder at Medusa Bay in 2002 than in the previous two years, no indications were found for a reduction in clutch size in any species. The same can be concluded for egg dimensions (table 5.5).

5.6 Nest survival

Nest survival data for 2002 are summarised in table 5.5 and survival is compared between the three years of the study in table 5.6. The increase in lemming numbers and scarcity of Arctic Foxes resulted in better hatching success in 2002 than in the two previous years when very few lemmings were available as food for predators. The overall probability for a wader nest to survive a three-week incubation period (calculated according to Mayfield 1975) was 59%, compared with 3% in 2000 and 19% in 2001. Nevertheless, predation accounted for 60 of the 67 recorded nest losses. Other observed causes were desertion (6) and trampling (1).

In only a few cases did we obtain indications about the species that preyed on nests, but skuas and Arctic Foxes were the most likely candidates. Given the few observations of foxes or fox tracks, many clutches may have been taken by skuas, although when we did find fox tracks in the study area (7 July), several clutches in the vicinity disappeared simultaneously. We conclude that both skuas and foxes were responsible for nest predation.

It was remarkable that breeding geese suffered higher losses to predation than waders and that skuas with their aggressive nest-defence did not do better than waders. S. Kharitonov (pers. comm) found that while eight out of nine White-fronted Goose nests hatched, only 29% of 85 mainland nests of Brent Goose did. Even some Brent Goose colonies in the vicinity of occupied Snowy Owl nests were raided by a fox. Only Brent Geese breeding on the offshore islands escaped predation. This creates the impression that in this year of intermediate lemming abundance, foxes were interested in large (and relatively easily found) eggs, but comparatively less so in (well-hidden) wader clutches that yield much less energy. Possibly, searching for large eggs was more profitable than searching for lemmings, while searching for smaller wader eggs was less profitable.

Table 5.5. Nest survival and predation on bird nests in 2002. Given are the time exposure period for successful nests (L, days), sample size in terms of nest-days and nests, total number of nest losses (N_{lost}) and losses due to predation (N_{pred}) and desertion (N_{des}), daily survival rate (with 95% confidence limits) and overall survival rate

species	L	N	N	N	N	N	Daily Survival rate		Overall survival	
							P	conf lim	H=P ^L	conf lim
Dunlin	21	393	27	6	6	0	0.985	0.974- 0.993	0.73	0.57- 0.87
Curlew Sandpiper	21	154	12	3	3	0	0.981	0.960- 0.995	0.67	0.43- 0.89
Little Stint	20	1434	126	35	28	6	0.976	0.969- 0.982	0.62	0.53- 0.70
phalaropes	20	75	10	2	2	0	0.974	0.939- 0.995	0.59	0.28- 0.91
Pac. Golden Plover	25	377	23	9	9	0	0.977	0.963- 0.988	0.55	0.39- 0.73
Ringed Plover	23	70	7	4	4	0	0.946	0.897- 0.981	0.28	0.08- 0.64
Ruddy Turnstone	22	82	9	6	6	0	0.932	0.883- 0.970	0.21	0.06- 0.51
all waders (L=21)	21	2628	218	67	60	6	0.975	0.970- 0.980	0.59	0.53- 0.65
Ptarmigan	21	33	2	0	0	0	1.000		1.00	0.00- 0.00
skuas	24	192	17	4	4	0	0.980	0.961- 0.993	0.61	0.38- 0.84
Brent Goose, ducks	25	62	10	7	7	0	0.899	0.833- 0.951	0.07	0.01- 0.28
passerines	20	139	12	3	2	1	0.979	0.956- 0.994	0.65	0.41- 0.89

Table 5.6. Daily survival rate and nest success in wader nests in 2000-2001

Species	Nest days			Daily survival rate P			Nest success H=P ^L		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
Dunlin	159	245	393	0.843	0.935	0.985	0.03	0.24	0.73
Curlew Sandpiper	31	118	154	0.677	0.889	0.981	0.00	0.09	0.67
Little Stint	349	723	1434	0.765	0.918	0.976	0.01	0.18	0.62
P. Golden Plover	277	200	377	0.921	0.905	0.977	0.13	0.08	0.55
Ringed Plover	100	85	70	0.930	0.988	0.946	0.19	0.76	0.28
Ruddy Turnstone	23	49	82	0.870	0.877	0.932	0.05	0.06	0.21
all waders (L=21)	979	1622	2628	0.846	0.923	0.975	0.03	0.19	0.59

Figure 5.7 shows that the probability of predation on wader nests was not constant during the summer of 2002, but showed a general increase. Daily predation probability was calculated by dividing the number of nests predated on a date by the total number of nests present on that date. During the first ten days that nests were present in the study area, only two were predated. Predation started when lemmings, which had been relatively common on the tundra surface for a number of days after their winter haunts in the snow had melted, had moved into the thawed-out summer burrows and became much less available to predators. Predation rate increased markedly when the index of lemming abundance dropped below 2 /10h in the first week of July, then declined but showed a second upsurge when lemming activity dropped further in mid-July (fig. 5.7). These observations are in line with the notion that wader clutches are essentially an alternative prey for predators that normally take lemmings as long as they are available. Thus they support on a smaller time scale the 'prey switching hypothesis', which explains interannual variation in breeding success of tundra birds by a switch made by predators from feeding on lemmings to feeding on birds' eggs and young when the former, which form their normal staple food, are scarce (Roselaar 1979, Summers 1986, Dhont 1987).

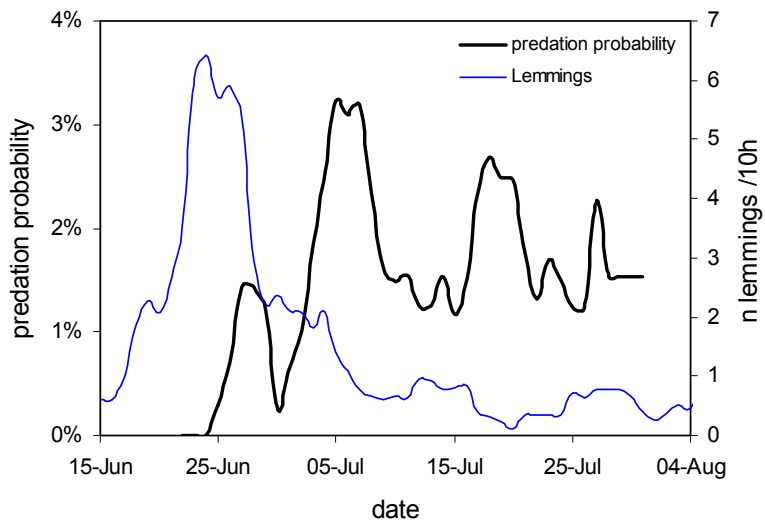
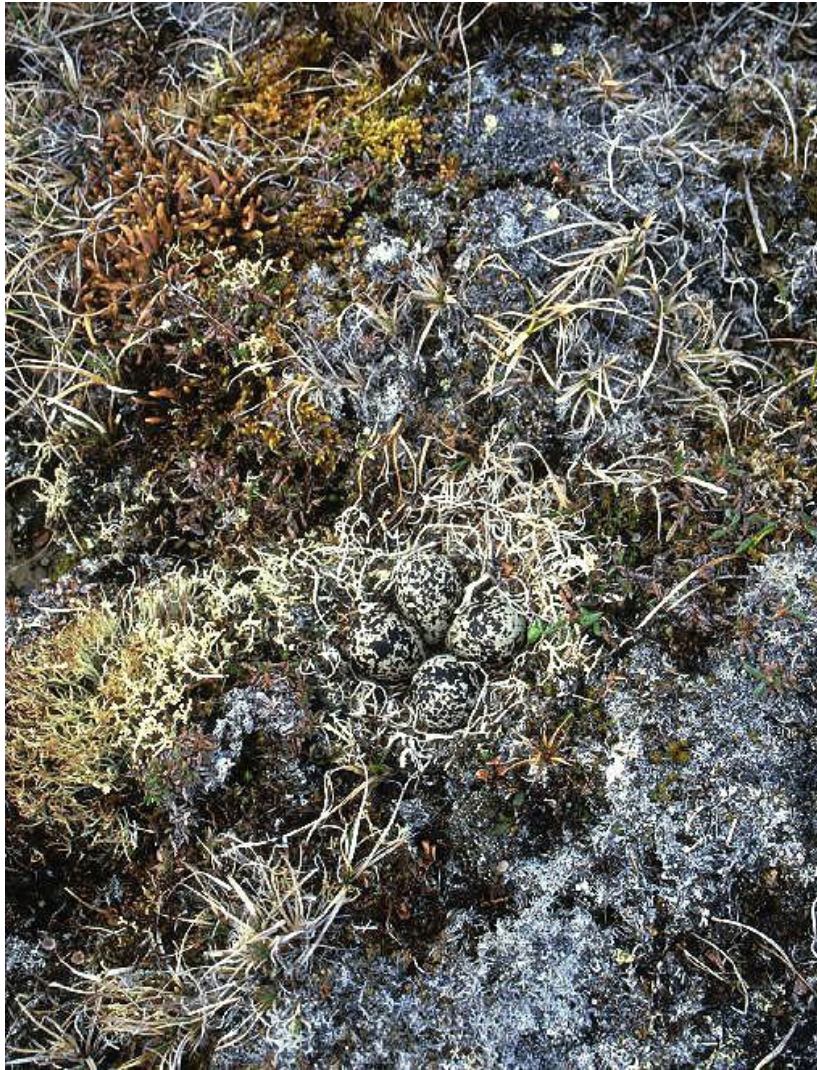


Fig. 5.7. Development of predation probability (nests predated / nests under observation on each date) for wader nests in the summer of 2002, in comparison to development of the number of lemmings observed per 10h in the field. Five-day running means are shown for both predation rate and lemming index



6 Biometrics of adult shorebirds

In this chapter, we present an overview of the biometric data collected on shorebirds trapped for (colour) ringing during the three years of the study, 2000-2002. Data are presented without discussion, mainly as a source for researchers interested in morphometrics of shorebirds from known breeding areas. However we have included a discussion on molecular sexing of waders. We used blood samples to determine sex by analysis of DNA, in order to check our morphometric sex determinations made in the field, and to determine sexes in species that show no reliable sexual dimorphism in their field characters, like the Little Stint. In a forthcoming integrative report, the body mass data will be discussed in more detail.

6.1 Field methods

During the first two weeks of the season (8-20 June) we tried to catch shorebirds that had just arrived to the breeding grounds. A clap net measuring 10x1.5 m was used (see Appendix 4 for a description). Birds were lured to the net by decoys and sound recordings of displaying and calling waders. The same method was used to capture birds on autumn migration in late July and August. With the tapes, actively migrating birds can be 'pulled down' from the air, sometimes from considerable altitudes.

In the pre-laying period, Red Phalaropes foraging in small pools were caught in mist nets held between two observers approaching the birds downwind. Phalaropes swam away until they reached the end of the pool and then either stood undecided what to do until the net was put on top of them, or they flew up into the wind and could be caught by flipping the net upwards.

Nesting birds were caught using small clap nets that were set up over the nest and released by the bird itself when it returned to sit on the eggs. To avoid nest desertion, this was done from the second week of incubation onwards. Birds with chicks were captured with the same clap net, using a small cage to keep the chicks and attract the parent to the trap. Also, a mist net could be held down between two people close to the chicks and either their calls or an imitation of it by the catcher would lure the parent bird to the net. The net was then put on top of the standing bird, or and flipped upwards, catching the adult while flying low over the chicks or around the catchers.

Captured birds were ringed with metal rings (Moscow ringing centre) and adult Little Stints, Curlew Sandpipers, Dunlins and Pacific Golden Plovers were fitted with an individual colour code. The scheme marker for all species was pink over metal on the right tarsus, with two colour rings on the left tarsus and one ring on the left and right tibia constituting the individual code. Birds were aged mostly on primary wear criteria and sexed on plumage characters or morphometrics as described in Prater *et al.* 1977.

Table 6.1. Numbers of shorebirds ringed (or recaptured from previous years) at Medusa Bay in 2002, by age class. Numbers of adults are divided by period: spring arrival and pre-laying, incubation, brood-rearing and autumn departure

Species	adults				total	juveniles	chicks	Grand Total
	spring	nest	brood	autumn		autumn		
Pac. Golden Plover <i>Pluvialis fulva</i>	-	6	9	-	15	-	29	44
Dotterel <i>Charadrius morinellus</i>	4	1	-	-	5	-	-	5
Red Knot <i>Calidris canutus</i>	2	-	1	-	3	-	2	7
Little Stint <i>C. minuta</i>	3	107	16	16	142	17	237	396
Temminck's Stint <i>C. temminckii</i>	-	1	-	-	1	-	-	1
Curlew Sandpiper <i>C. ferruginea</i>	6	12	1	3	22	3	22	47
Pectoral Sandpiper <i>C. melanotos</i>	-	2	-	-	2	-	3	5
Dunlin <i>C. alpina</i>	20	21	3	9	53	1	62	116
Purple Sandpiper <i>C. maritima</i>	2	-	-	-	2	-	-	2
Ruff <i>Philomachus pugnax</i>	1	-	-	-	1	-	1	2
Red Phalarope <i>Phalaropus fulicarius</i>	16	5	-	-	21	1	14	36
Red-necked Phalarope <i>P. lobatus</i>	-	-	-	-	-	-	4	4
Ruddy Turnstone <i>Arenaria interpres</i>	6	1	-	-	7	4	2	13
Total	60	156	30	28	274	26	376	676

In Little Stints we made provisional sex determinations based on plumage, with birds with saturated warm-brown to reddish colours on head (cheeks), breast and back called males and paler birds called females, while also taking into account wing length differences. Bill length, total head length and tarsus length were measured to the nearest 0.1 mm using callipers. Wing length (maximum chord, 1 mm) and tarsus + toe (1 mm) were measured with a stopped ruler. Pesola spring balances were used to measure body mass (to 1 g in Pacific Golden Plover, to 0.1 g in other species). Fat was scored on the belly, abdomen and furculum using a three point scale (0= no fat, 1=little to moderate fat, 2= much fat). Primary moult was scored using the five-point scale of Ginn & Melville (1983).

Contour feather moult was scored separately on the belly (including breast), back and head, using a four point system: 0= no moult, 1= light moult, 2= moderate moult, 3= heavy moult. In total, 300 full-grown shorebirds (including controls) and 376 chicks were trapped and ringed in 2002 (table 6.1).

6.2 DNA sex determinations

From most of the adult shorebirds trapped in 2002, a small blood sample was taken for identification of DNA of blood parasites by Luisa Mendes at the Royal Netherlands Institute of Sea Research (NIOZ). On the same blood samples, DNA-based sex determinations were made by Anneke Bol at NIOZ. DNA sexing was done to check on the accuracy of the sex determinations that we made in the field on the basis of plumage characters and morphometrics, and to identify sexes in species in which sexing is difficult in the field (notably Little Stint).

Table 6.2. Percentage agreement (with no. of birds) between sex determinations made in the field and based on DNA analysis, for adult waders ringed in 2002, separated by stage in the breeding cycle when the birds were caught. Not included in the table are single males of Knot and Ruff which were sexed correctly by both methods

species	caught on nest	with brood	arrival/migration	total
Curlew Sandpiper	100% (9)	100% (1)	100% (6)	100% (16)
Turnstone	100% (1)	-	100% (3)	100% (4)
Pectoral Sandpiper	100% (2)	-	-	100% (2)
Dunlin	100% (17)	100% (2)	93% (13)	97% (32)
Red Phalarope	100% (3)	-	94% (16)	95% (19)
Little Stint	65% (72)	60% (10)	91% (11)	68% (93)
Pacific Golden Plover	53% (15)	-	-	53% (15)
Dotterel	-	-	50% (4)	50% (4)

The DNA sex determinations were made according to the method described by Griffiths *et al.* (1998), based on two CHD genes located on the sex chromosomes of all birds, with the possible exception of ostriches and allies. Among shorebirds, the method has been verified in Red Knots (Baker *et al.* 1999).

In total, 186 adult shorebirds were sexed both in the field and on the basis of their DNA. Table 6.2 gives the proportion of cases in which the bird was assigned to the same sex in the field and on DNA. For Curlew Sandpiper, Ruddy Turnstone and Pectoral Sandpiper, as well as in the single Knot and Ruff processed, there was full agreement between field and DNA determinations. Both the single (female) Dunlin and (male) Red Phalarope in which there was a mismatch were probably assigned the wrong sex in the field: measurements were intermediate between those of other males and females. Our field determinations of sex in Little Stint were tentative and this proved justified: almost a third of the Little Stints was sexed incorrectly. In all these species, molecular sex determinations were consistent with known sex roles during different phases of the breeding cycle: only female Curlew Sandpipers and Pectoral Sandpipers and only male Red Phalaropes were found breeding, and all Dunlin and the single Knot that were caught while tending a brood were males. In Little Stints, molecular sexing provided a reasonably good separation of males and females by wing and (to a lesser extent) bill length (see paragraph 6.4). These findings support the accuracy of the DNA sex determinations.

A special case is provided by the Pacific Golden Plover. According to DNA analysis, almost half of our sex determinations in the field (on plumage, as size dimorphism is absent in this species) should be incorrect. However, the DNA analysis identified only males among the 15 Pacific Golden Plovers, and all seven 'incorrectly sexed' birds were trapped together with their (male) mates on the nest containing hatching eggs or newborn chicks, so we are confident that they were females. For some reason the P2/P8 primers used for molecular sexing do not seem to work in Pacific Golden Plovers. Given these results, those for the other plover species, the Dotterel, should be viewed with caution. The DNA analysis identified all four sampled birds as males, though two had been sexed as females on plumage. We found sexing the birds in the hand difficult and are not too confident about our accuracy, but it remains possible that the errors apparent in golden plovers also occurred in Dotterel. Studies using

this technique on new species should validate DNA sex determinations on a sample of known-sex birds before wide-scale application.

6.3 Sex ratio and breeding system of Little Stints

Our primary interest in using the DNA sexing technique was for identifying the sex of incubating parents in the Little Stint. This species' breeding system is described as 'double clutching', with each female laying two clutches in (fairly) rapid succession, the first of which is usually incubated by the male and the second by the female (Hilden 1978, 1988). With the exception of the work by Chylarecki & Kania (1992) however, the mating system of Little Stints has not been extensively studied in their main Siberian breeding range. In agreement with the published data, we observed in the previous years that all Little Stint nests were incubated by a single bird, and that the mean wing length of incubating stints increased with the laying date of the clutch, suggesting that later clutches were more often incubated by the slightly larger females. But we could not estimate the exact proportions of early and late nests incubated by males and females. With the DNA sex determinations, we can.

Figure 6.1 shows the bill and wing lengths of sexed Little Stints. Females have both longer wings and bills than males, but there is a fairly large zone of overlap making sexing based on biometrics alone unreliable. Figure 6.2 shows the distribution of first egg dates of Little Stint clutches in 2002, separated by sex of the incubating bird.

The sex ratio for each laying date was extrapolated from sex ratios among birds captured on nests initiated in a 3-day period around that date. A logistic regression analysis showed that the probability that a clutch was incubated by a male decreased with laying date ($X^2_{89}=5.88$, $P=0.015$), from 60-75% in the earliest to less than 10% in the latest clutches. Our data thus agree with the double clutching scenario, though not in an absolute sense: about one third of the earliest clutches was incubated by females.

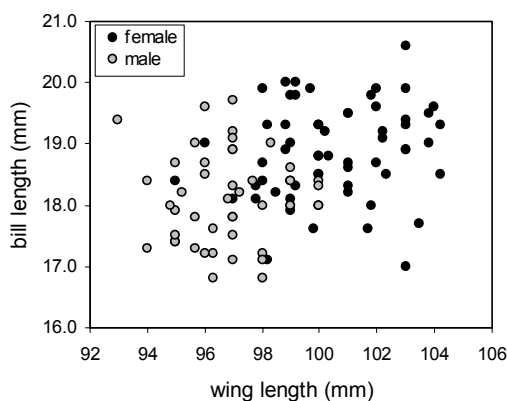


Figure 6.1. Wing and bill lengths of adult Little Stints sexed by their DNA

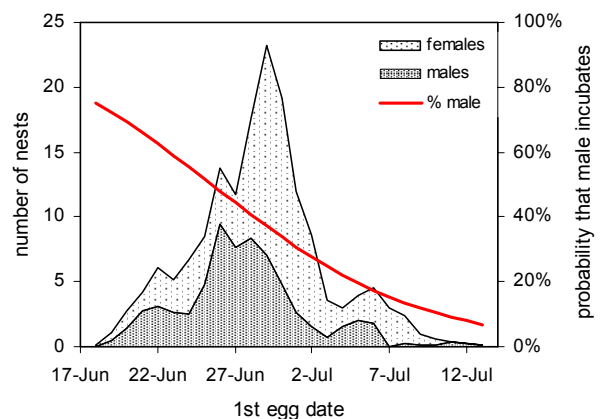


Figure 6.2. First egg dates of Little Stint clutches in 2002, separated by sex of the incubating bird. Sex ratios are based on birds caught on 90 of the 163 nests. The probability that a clutch is incubated by a male (line) declines with laying date

It is possible that in a late breeding season like 2002, females may consider that re-nesting opportunities are smaller than usual and therefore be more willing to incubate their first clutch and forego a second attempt, but it is difficult to test this hypothesis without data on parentage of different clutches in the study area. Because we have no DNA sex determinations available for birds incubating in 2000 and 2001, we can as yet not say whether the proportion of females incubating early clutches was larger in 2002 than in the earlier years.

6.4 Biometrics

Tables 6.3 and 6.4 summarise size measurements and weights of all full-grown waders captured throughout the study in 2000-2002. Age and sex classes are presented separately wherever possible. For Little Stint we present sex-specific data only for the subsample sexed by DNA analysis in 2002. In the other species, field determinations of sex were mostly correct and these are presented as samples sizes are much larger. The sex determinations in Dotterel must be regarded tentative, except those of the incubating males. For linear measurements, we distinguished between local breeding birds and birds trapped during the spring migration/arrival and autumn departure/migration periods, as the latter will include birds that breed North and East of Medusa Bay on Taimyr and could theoretically belong to a different geographical population. When considering body mass this distinction was also made, but further differentiation was made between spring and autumn migration and between the incubation and brood-rearing periods. The reason for the latter is that many arctic shorebirds carry considerable mass stores during incubation, which they lose at/after hatching of the eggs (Soloviev & Tomkovich 1997, Tulp *et al.* 2002). This pattern is visible in our weight measurements from Medusa Bay in almost all the species for which we have data from both periods.

Table 6.3. Mean biometrics (with standard deviation on line below, both in mm) of shorebirds captured at Medusa Bay in 2000-2002. Biometrics are given for combined and separate sex and age classes, and a distinction is made between local breeding birds and birds captured while migrating, that might have bred further N and E on the Taimyr Peninsula. Little Stints and Dotterels were provisionally sexed on plumage differences in the spring arrival and incubation periods only; some errors will have been made. Recaptured birds feature only once in the database

Species	Age	Sex	Status	N	wing	bill	head	tarsus	tars+toe	
Pac. Golden Plover	adult	all	breeding	35	168.5	22.3	56.5	42.9	73.0	
					2.7	1.2	1.6	1.3	1.8	
	adult	female	breeding	15	169.3	22.3	56.0	43.1	72.8	
					2.7	1.2	1.8	1.1	2.4	
	adult	male	breeding	19	167.8	22.3	56.8	42.8	73.2	
					2.8	1.2	1.4	1.4	1.3	
Dotterel	adult	all	all	28	157.1	16.6	50.4	38.0	63.0	
					3.9	0.9	1.2	1.5	2.3	
	adult	'female'	migrating	15	157.4	16.6	50.2	37.9	62.9	
					4.1	0.6	1.1	1.8	2.5	
	adult	'male'	all	13	156.84	16.7	50.6	38.2	63.0	
				3.89	1.2	1.1	1.1	2.1		
	adult	male	breeding	2	153.5	15.7	50.1	37.4	60.5	
					5.0	0.3	0.2	0.3	1.4	
	adult	'male'	migrating	11	157.5	16.9	50.7	38.4	63.5	
					3.6	1.2	1.4	1.1	1.8	
Ringed Plover	adult	all	breeding	5	132.8	13.4	40.1	26.6	46.8	
					3.4	0.4	0.5	2.3	1.6	
	adult	female	breeding	4	133.0	13.3	39.9	26.7	46.5	
					3.9	0.4	0.3	2.7	1.7	
	adult	male	breeding	1	132.0	13.7	40.8	26.4	48.0	
Little Stint	adult	all	all	412	98.7	18.5	39.1	21.7	40.2	
					2.8	1.0	1.2	1.0	1.4	
	adult	all	breeding	280	98.8	18.5	39.1	21.8	40.3	
					2.7	1.0	1.2	1.0	1.5	
	adult	all	migrating	132	98.4	18.6	39.0	21.6	40.1	
					2.9	1.0	1.2	0.9	1.3	
	(DNA-sexed only)	adult	female	all	72	100.2	18.8	39.3	21.9	40.4
						2.5	0.8	0.9	0.9	1.2
	(DNA-sexed only)	adult	female	breeding	57	100.0	18.8	39.3	21.8	40.4
						2.6	0.9	0.9	0.9	1.2
	(DNA-sexed only)	adult	female	migrating	15	100.6	18.9	39.2	22.1	40.7
						1.7	0.7	0.5	0.7	1.0
	(DNA-sexed only)	adult	male	all	51	97.0	18.1	38.5	21.6	39.7
						1.8	0.7	0.9	0.8	1.1
	(DNA-sexed only)	adult	male	breeding	34	96.8	17.9	38.4	21.6	39.7
					1.6	0.6	0.9	0.9	1.2	
(DNA-sexed only)	adult	male	migrating	17	97.4	18.4	38.9	21.6	39.9	
					2.1	0.8	0.9	0.7	0.8	
	juvenile	all	migrating	164	98.9	18.3	38.6	21.9	40.2	
					2.9	0.9	1.1	1.1	1.1	

Table 6.3 (Continued)

Species	Age	Sex	Status	N	wing	bill	head	tarsus	tars+toe
Temminck's Stint	adult	all	all	4	101.0	18.3	37.6	18.2	36.0
					1.2	0.4	0.4	0.3	0.7
	adult	all	breeding	3	101.3	18.4	37.3	18.1	36.0
Red Knot	adult	all	migrating	1	100.0	18.0	38.2	18.6	36.0
					1.2	0.4	0.1	0.3	0.9
	adult	all	all	6	170.7	34.1	63.7	32.5	59.9
Pectoral Sandpiper	adult	female	breeding	9	132.3	27.6	52.1	28.0	54.0
					3.9	1.2	1.8	1.2	2.1
	adult	male	breeding	1	177.0	35.2	64.8	32.1	60.0
Curlew Sandpiper	adult	all	all	118	132.8	39.1	63.7	31.4	54.5
					3.2	2.4	2.5	1.4	2.1
	adult	female	all	98	133.0	39.8	64.4	31.7	54.9
	adult	female	breeding	32	133.5	39.8	64.5	31.8	55.2
					3.3	1.6	1.8	1.6	2.1
	adult	female	migrating	66	132.7	39.8	64.3	31.6	54.7
	adult	male	migrating	20	132.0	35.8	60.4	30.4	52.8
2.4					1.6	1.6	1.1	1.9	
juvenile	all	migrating	21	131.7	36.3	60.4	31.2	53.8	
Dunlin	adult	all	all	130	117.86	34.1	58.4	25.6	47.9
					3.23	2.6	2.8	1.2	1.7
	adult	all	breeding	72	118.8	34.2	58.5	25.5	48.0
	adult	all	migrating	58	116.8	34.0	58.2	25.8	47.7
					3.5	2.6	3.1	1.3	1.9
	adult	female	all	51	120.0	36.6	61.0	26.3	49.0
	adult	female	breeding	35	120.3	36.4	60.7	26.1	48.8
					2.7	1.7	1.7	1.1	1.3
	adult	female	migrating	16	119.5	37.1	61.6	26.7	49.4
	adult	male	all	77	116.4	32.5	56.7	25.2	47.1
					2.4	1.8	2.1	1.1	1.2
	adult	male	breeding	36	117.2	32.3	56.5	25.0	47.3
	adult	male	migrating	41	115.7	32.7	56.8	25.4	47.0
					1.8	1.3	1.5	1.0	1.3
juvenile	all	migrating	10	120.4	31.6	55.6	25.9	48.2	
				3.3	1.6	2.2	1.2	1.8	
					2.5	1.5	1.9	0.7	1.4

Table 6.3 (Continued)

Species	Age	Sex	Status	N	wing	bill	head	tarsus	tars+toe
Purple Sandpiper	adult	all	migrating	2	131.5	29.3	54.9	23.7	50.0
					0.7	0.1	0.1	0.4	0.0
Sanderling	adult	male	migrating	2	127.0	23.7	49.2	25.7	45.3
					1.4	0.1	0.6	0.2	0.4
Red-necked Stint	juvenile	all	migrating	1	109.0	18.5	39.8	19.8	39.0
Red Phalarope	adult	all	all	23	138.0	23.4	47.6	23.1	47.2
					3.5	1.0	1.6	0.8	1.6
	adult	all	migrating	17	139.1	23.8	48.2	22.8	47.0
					3.5	0.8	1.4	0.6	1.6
	adult	female	migrating	12	141.0	24.0	48.7	22.9	47.1
					1.7	0.6	1.0	0.6	1.7
	adult	male	all	11	134.7	22.8	46.4	23.3	47.3
					1.3	1.0	1.2	0.9	1.5
adult	male	breeding	6	135.0	22.4	46.0	23.9	47.6	
				1.1	0.9	1.3	0.7	1.8	
adult	male	migrating	5	134.4	23.3	46.8	22.6	46.9	
				1.5	1.0	1.2	0.6	1.2	
juvenile	all	migrating	2	131.5	20.9	44.8	22.2	46.5	
				0.7	1.0	1.4	0.4	1.4	
Red-n. Phalarope	adult	male	migrating	5	109.4	21.5	43.4	20.3	41.1
					4.6	0.9	1.0	0.6	1.2
Ruff	adult	male	migrating	1	191.0	31.7	59.0	47.1	85.0
Ruddy Turnstone	adult	all	all	23	154.0	21.5	49.5	26.0	51.0
					3.6	1.3	1.5	1.2	1.0
	adult	all	breeding	6	151.7	20.2	48.3	25.7	50.9
					2.3	1.2	1.4	1.5	1.0
	adult	all	migrating	17	154.9	22.0	50.0	26.1	51.1
					3.6	1.0	1.4	0.9	1.0
	adult	female	all	9	154.6	21.9	50.1	26.3	51.3
					3.3	1.3	1.6	1.2	1.4
	adult	female	breeding	2	154.0	21.1	48.7	26.8	50.3
					1.4	1.1	0.5	2.1	1.1
	adult	female	migrating	7	154.7	22.2	50.5	26.2	51.6
					3.8	1.2	1.6	1.0	1.4
	adult	male	all	14	153.7	21.3	49.2	25.8	50.9
3.8					1.3	1.3	1.0	0.6	
adult	male	breeding	4	150.5	19.8	48.1	25.1	51.3	
				1.7	1.1	1.7	1.0	1.0	
adult	male	migrating	10	155.0	21.9	49.6	26.1	50.7	
				3.7	0.8	0.9	0.9	0.4	
juvenile	all	migrating	11	148.6	20.5	48.4	26.1	51.8	
				5.4	1.0	1.4	1.2	2.6	

Table 6.4. Mean body mass of shorebirds caught at Medusa Bay in 2000-2003 (with standard deviation and sample size). Means are given for age and sex classes separately, and for different phases of the breeding cycle: arrival and pre-laying, incubation, brood-rearing and autumn departure periods. Little Stints and Dotterels were sexed provisionally in the arrival and incubation periods only; some errors will have occurred. Recaptured birds are included only once within the same phase

species	cat	sex		phase			all	
				spring	nest	brood	autumn	combined
Pacific Golden Plover	adult	all	mean		132.5	131.5		132.2
			SD		7.6	6.9		7.3
			N		27	11		38
	adult	female	mean		136.4	131.4		134.8
			SD		9.2	8.0		8.9
			N		12	6		18
	adult	male	mean		129.7	131.5		130.2
			SD		4.1	6.3		4.7
			N		14	5		19
Dotterel	adult	all	mean	124.5	110.5			123.5
			SD	7.2	0.7			7.9
			N	26	2			28
	adult	female	mean	124.8				124.8
			SD	6.2				6.2
			N	15				15
		male	mean	124.1	110.5			122.0
			SD	8.8	0.7			9.5
			N	11	2			13
Ringed plover	adult	all	mean		61.5			61.5
			SD		6.1			6.1
			N		5			5
	adult	female	mean		62.4			62.4
			SD		6.7			6.7
			N		4			4
	adult	male	mean		58.0			58.0
			SD		1			1
			N		1			1
Red Knot	adult	all	mean	130.1		124.0		129.1
			SD	8.1				7.7
			N	5		1		6
	adult	male	mean	123.0		124.0		123.5
			SD	-		-		0.7
			N	1		1		2
Sanderling	adult	male	mean	48.5				48.5
			SD	4.9				4.9
			N	2				2
Red-necked Stint	juv	all	mean				33.3	33.3
			N				1	1

Table 6.4 (Continued)

species	cat	sex		phase				all	
				spring	nest	brood	autumn	combined	
Little Stint	adult	all	mean	26.0	29.1	27.2	25.7	27.8	
			SD	3.6	2.6	2.4	2.6	3.0	
			N	22	235	56	112	425	
	<i>(DNA-sexed only)</i>	adult	female	mean	-	29.0	27.5	26.7	28.4
				SD	-	2.1	1.9	2.4	2.7
				N	-	49	8	15	72
	<i>(DNA-sexed only)</i>	adult	male	mean	26.6	28.3	26.0	25.0	27.0
				SD	3.1	2.7	2.7	2.8	3.1
				N	2	30	6	15	53
		juv	all	mean				23.6	23.6
				SD				1.9	1.9
				N				159	159
Temminck's Stint	adult	all	mean	26.5	28.8	28.9		28.4	
			SD		2.9			2.3	
			N	1	3	1		5	
	adult	female	mean	26.5	32.1			29.3	
			N	1	1			2	
	adult	male	mean		27.3			27.3	
			N		1			1	
	Curlew Sandpiper	adult	all	mean	58.4	64.7	58.2	57.1	59.3
				SD	4.0	4.2	5.8	4.4	5.2
N				36	28	4	50	118	
adult		female	mean	60.4	64.7	58.2	57.1	59.9	
			SD	4.5	4.2	5.8	4.4	5.4	
			N	16	28	4	50	98	
adult		male	mean	56.8				56.8	
			SD	2.7				2.7	
			N	20				20	
juv		all	mean				53.1	53.1	
			SD				4.2	4.2	
			N				21	21	
Dunlin	adult	all	mean	48.9	53.3	47.9	48.2	50.9	
			SD	3.9	3.5	3.0	4.6	4.5	
			N	28	81	13	35	157	
	adult	female	mean	51.9	54.9		50.7	53.6	
			SD	3.4	3.3		3.9	3.8	
			N	9	37		11	57	
	adult	male	mean	47.4	51.9	47.9	47.1	49.3	
			SD	3.3	3.2	3.0	4.5	4.2	
			N	19	42	13	24	98	
	juv	all	mean				46.4	46.4	
			SD				2.8	2.8	
			N				10	10	

Table 6.4 (Continued)

species	cat	sex		phase				all
				spring	nest	brood	autumn	combined
Pectoral Sandpiper	adult	female	mean		63.3	55.5		62.5
			SD		4.6			5.0
			N		9	1		10
Purple Sandpiper	adult	all	mean	69.3				69.3
			SD	0.1				0.1
			N	2				2
Ruff	adult	male	mean	180.5				180.5
			N	1				1
Red Phalarope	adult	all	mean	58.3	50.9			56.0
			SD	8.0	6.2			8.1
			N	16	7			23
	adult	female	mean	61.1				61.1
			SD	6.9				6.9
			N	12				12
	adult	male	mean	49.8	51.1			50.6
			SD	4.1	6.8			5.6
			N	4	6			10
	juv	all	mean				37.0	37.0
			SD				8.5	8.5
			N				2	2
Red-necked Phalarope	adult	all	mean				33.2	33.2
			SD				2.4	2.4
			N				5	5
Ruddy Turnstone	adult	all	mean	102.5	101.4	100.5	92.0	101.2
			SD	8.3	5.7	6.8	0.0	7.8
			N	15	3	3	2	23
	adult	female	mean	108.9	108.0	107.5	92.0	106.8
			SD	9.9				9.6
			N	6	1	1	1	9
	adult	male	mean	98.3	98.1	97.0	92.0	97.6
			SD	2.9	0.6	4.2		3.1
			N	9	2	2	1	14
	juv	all	mean				88.0	88.0
			SD				7.7	7.7
			N				11	11

6.5 Ringing recoveries

During the three study years 2000-2002, we ringed a total of 1050 full-grown and 730 chick shorebirds at Medusa Bay. About 500 of the full-grown birds were also individually colour-marked. Up to May 2004, we obtained one ring recovery and five colour-ring readings away from the ringing site. These are listed in table 6.5, together with details of a chick ringed at Medusa Bay in 1996 that was recovered in Spain.

Curlew Sandpipers from Medusa Bay were reported from Britain, Spain, and South Africa, all in autumn. These recoveries confirm that both juvenile and adult Curlew Sandpipers may migrate to their African winter quarters via western Europe, as was shown before by about five recoveries of Taimyr birds (Tomkovich *et al.* 2000). The bird seen in South Africa may however very well have arrived there via a route through eastern Africa.

The recoveries of Little Stints add significantly to our knowledge, as only very few Taimyr Little Stints have been recovered, despite thousands of birds having been ringed both in Taimyr and abroad. A bird ringed in the Persian Gulf in autumn was controlled with chicks in W-Taimyr (Tomkovich *et al.* 2000). Our three recoveries show how much the recovery potential increases by using colour-rings, and suggest that perhaps most Taimyr Stints migrate along a route through or to the Middle East and East Africa, and as far as southern Africa.

In view of the numbers ringed, it is somewhat remarkable that, in contrast to Curlew Sandpiper and Little Stint, no recoveries or resightings of Dunlin were received. This suggest that Durlins from our study area migrate through and winter in areas seldom visited by ringers or observers of shorebirds, rather than towards Europe. The Persian Gulf and the coasts of Pakistan and India might be such areas.

Table 6.5. Foreign recoveries of shorebirds ringed at Medusa Bay, mainly in 2000-2002

Species / Ring no.	Ringing Date	Ringed as	Recovery Date	Recovery Site	Lat/ Long	Remarks
Curlew Sandpiper						
Moskwa KS02684	10-7-1996	pullus	5-8-2002	Marismas del Odiel, Huelva, SPAIN	37.16 N 06.55 W	controlled by ringer
Moskwa KS06356	7-7-2002	adult female nesting	10-8-2003 - 13-8-2003	Cresswell Pond, Northumberland, U.K.	55.14 N 01.34 W	colour-rings read
Moskwa KS06351 / KS06327	4-7-2002 / 10-7-2002	adult female nesting	1-10-2002	Langebaan Lagoon, W.Cape, S. AFRICA		colour-rings read
Little Stint						
Moskwa FS10068	30-6-2000	adult nesting	7-9-2000	Huleh Valley, ISRAEL	33.05 N 35.35 E	colour-rings read
13 candidates	2000 / 2001 / 2002	adult prob. nesting	30-11-2002	Seronera, Serengeti TANZANIA		colour-rings read (incomplete)
Moskwa FS10940	19-7-2001	adult nesting	14-11-2002	Bird Paradise, Walvis Bay, NAMIBIA	22.58 S 14.32 E	found dead (≤1 month old)



7 Colour-marking studies

7.1 Methods

From the first year of this study onwards (2000), locally breeding Little Stints, Curlew Sandpipers, Dunlin, Ruddy Turnstones and Pacific Golden Plovers have been caught and fitted with metal rings plus an individual combination of five plastic colour rings to enable individual recognition in the field. In 2001 and 2002, we have been looking out for colour-marked birds both during the prebreeding and breeding periods. The purpose of these observations was to estimate arrival dates and return rates, giving information on (apparent) survival and site- and mate-fidelity. In addition to visual inspections of birds in the field, most of the Curlew Sandpipers, Little Stints and Dunlin breeding within the 4 km² intensive study plot were trapped on the nest, giving a further opportunity for identification and adding further birds to the marked population. In Pacific Golden Plover and Ruddy Turnstone, the proportion of the population trapped annually was much smaller than in the other species. Besides in the 4 km² intensive plot, we also worked in the surrounding areas c. 1 km both to the south and the north. Although we made no efforts to find all nests in those areas, we visited them regularly, and always looked out for marked birds.

In the Dunlin, the only site-faithful small sandpiper, we made special efforts in the arrival and prebreeding periods to find and identify marked birds as soon as possible so that their arrival date and date of pairing could be determined.

In 2001, we walked a route in the western half of the intensive study plot along the sites where Dunlin territories were present in the previous year about every second day during these periods, checking all birds seen for colour-rings. In 2002, we checked most snow-free areas in the 4 km² plot every afternoon until 20 June (until then snow-free patches were only present in the western half), and thereafter made regular controls of new areas becoming snow-free as well as other known territories.

These data allow calculation of *resighting rates*, defined as the number of previously marked individuals observed in the study area in year t+1, divided by the number of marked birds present in year t (and marked either in that or some previous year). Because birds marked during the pre- and postbreeding migration periods may have originated from breeding sites well outside the study area and because surrounding areas were searched less intensively than the 4 km² plot, only birds marked as breeders in the study area have been used in the calculation. Crude resighting rate may give an underestimate of survival from year to year, due to emigration of birds and the fact that not all birds present may actually be observed in each year. The probability that a marked bird will be seen the next year is the product of the probabilities of (1) surviving between the summer of year t and the summer of year t+1, (2) returning to the study area when alive and (3) being noticed while present in the study area. When resighting data are collected over more than two consecutive years, statistical models can be used to derive estimates of both the *apparent survival rate* (survival x site fidelity) and the *conditional resighting probability*. The first parameter

is called *apparent* survival because birds that permanently emigrate from the study area cannot be distinguished from birds that have died. On the other hand, birds that bred somewhere else for one year and then return to the study area decrease the estimate of resighting probability. These models make use of those individuals that are not resighted in year t+1 but are in year t+2 (so must also have been alive in year t+1, though not necessary in the study area) to estimate the resighting probability. We fitted such models to the data for Dunlin and Pacific Golden Plover, using the program MARK (White & Burnham 1999).

7.2 Crude resighting rates

Of 79 and 79 colour-marked Little Stints breeding in 2000 and 2001, none were resighted or retrapped in the following years. The same applied to the 12 and 12 female colour-ringed Curlew Sandpipers present in the first two years. The total lack of breeding site fidelity in these species is in accordance with earlier findings (Underhill *et al.* 1993, Tomkovich & Soloviev 1994). Of the three and four marked Ruddy Turnstones present in 2000 and 2001, two and two respectively were seen in the next year, giving an overall crude resighting rate of 57%. Of 19 and 20 colour-ringed Pacific Golden Plovers breeding within the intensive study area in the two years, 13 and 12 were seen in the next year, giving an overall resighting rate of 64%. The species with the highest resighting rate (69%) was the Dunlin: 34 and 36 colour-ringed adults bred within the area in 2000 and 2001 respectively, of which 21 and 27 were resighted in the next year. These are crude rates though, not taking into account that returning birds may not all have been resighted. Only for Dunlin and Pacific Golden Plover were sample sizes large enough to allow estimation of apparent survival rates and resighting probabilities using MARK, and look for possible differences between the sexes. For these species, we will also discuss breeding site fidelity and mate fidelity.

7.3 Return rate, mate retention and breeding site fidelity in Dunlin

7.3.1 Return rate

The apparent survival rate of Dunlins marked in 2000-2001 as estimated by MARK was 69%, with a resighting probability of 82% (table 7.1). There was a tendency for males to be resighted more often than females. The MARK analysis suggests that this was more likely due to a higher reporting probability than to a higher survival of males. However, the model with sex-specific reporting probability was not significantly better in explaining the variation in the data than the simplest model, with sex- and time-independent survival and reporting rates (likelihood ratio test, $X^2_1=1.35$, $P=0.24$). With more years of data, a sex-effect may prove significant. Males behave more conspicuously than females (especially during the courtship period) and thus may well be resighted more easily than females.

In some shorebirds, return rates depend on breeding success in the previous year, with successful birds being more likely to return to the breeding site than failed

breeders (e.g. Groen 1993, Jackson 1994). We analysed this for Dunlins on the basis of crude resightings, distinguishing between birds that were known to have hatched young from either a first or a replacement clutch and birds that lost their clutch and were not seen with young in the previous year (a few of these may have hatched young unnoticed from a replacement, but this is unlikely), and between the sexes (Table 7.2). When analysing the whole dataset (2000-2002), we found no significant effects on resighting probability of either sex (logistic regression, $X^2_1=2.41$, $P=0.12$), hatching success ($X^2_1=1.51$, $P=0.22$), or the interaction between the two ($X^2_1=2.36$, $P=0.12$). When analysing the sexes separately however, we found a marginally significant effect that males were resighted more often after they had hatched young in the previous year ($X^2_1=4.21$, $P=0.04$). This effect was absent in females ($X^2_1=0.01$, $P=0.95$).

Table 7.1. Results of MARK analysis of resightings in 2001-2002 of Dunlin ringed inside the 4km² plot in 2000-2001. Models are ordered according to the associated Akaike Information Criterion (AIC); number of estimated parameters, deviance, and estimates for apparent survival (ϕ) and resighting probability (p , with standard error and 95% confidence limits) are given. Models with more than three parameters were not considered

Model	AICc	Delta AICc	# Par	Deviance	parameter	estimate	s.e.	95% c.l.
$\phi(\cdot) p(\cdot)$	128.713	0.00	2	2.955	ϕ	0.69	0.07	0.54 - 0.83
$\phi(\cdot) p(\text{sex})$	129.523	0.81	3	1.603	p	0.82	0.14	0.58 - 0.94
					ϕ	0.70	0.07	0.54 - 0.82
					$p(f)$	0.72	0.14	0.40 - 0.91
					$p(m)$	0.90	0.09	0.55 - 0.98
$\phi(\text{year}) p(\cdot)$	129.921	1.21	3	2.001	$\phi(0-1)$	0.73	0.08	0.54 - 0.87
					$\phi(1-2)$	0.60	0.11	0.38 - 0.79
					p	0.83	0.09	0.59 - 0.95
					$\phi(f)$	0.64	0.09	0.45 - 0.79
$\phi(\text{sex}) p(\cdot)$	129.955	1.24	3	2.035	$\phi(m)$	0.75	0.09	0.54 - 0.88
					p	0.82	0.09	0.58 - 0.94

Table 7.2. (Crude) resighting probability of Dunlin in relation to hatching success in the previous year

Sex	Hatching success year x	Resighted in year $x + 1$			% resighted
		no	yes	total	
Female	no	9	10	19	53%
	yes	6	7	13	54%
Male	no	9	14	23	61%
	yes	1	11	12	92%



7.3.2 Mate fidelity

Twelve fully colour-marked Dunlin pairs were present in the study area at the end of the 2001 breeding season. Table 7.3 tabulates their fates in 2002, together with those of 11 pairs marked in 2000. Overall, only 35% of all pairs reunited in the next year, but most 'break-ups' occurred when one of the partners was not resighted in the study area (83% of all known cases, 86% if wholly disappearing pairs are included). When both partners were seen in the study area in the next year, eight out of ten pairs reunited. Failure of a partner to return thus seems the most important cause of pair break-up. Of the eight pairs that reunited, five hatched young in the previous season and three did not. Of the two divorcing pairs, one had hatched young in the previous year and one had not ($X^2_1=0.1$, $P=0.75$). Though sample size is small, this does not point to previous breeding success as an important factor affecting mate fidelity.

The case of divorce among surviving birds in 2001 commenced in the breeding season of 2000. After losing a first clutch to predation, the female produced a second clutch with a different male almost 2 km away. In 2001, the female, the first and the second male all paired with yet different partners. In the 2002 divorce case, the female paired with a neighbour male (breeding 140 m away in 2001) of which the previous partner was not seen in 2002. The new pair bred in the exact same nest cup that the female had used also in 2001 – the only case of nest re-use observed in our study.

Her previous male was first seen (still unmated) on 24 June, later than the female (that started laying on 20 June) and eventually paired with an unmarked female and hatched eggs as late as 31 July. This opens the possibility that this divorce was a result of the male arriving too late after his previous female and therefore losing the opportunity to remate. In the arctic-breeding Black Turnstone *Arenaria melanocephala*, delayed arrival of one of the partners was a common cause for divorce, and led to reduced fitness as reunited pairs produced on average more young than newly established pairs (Handel & Gill 2000).

Table 7..3. Fates of marked Dunlin pairs from 2000 and 2001 to the next year

partners returned	pair reunited?	2000-01	2001-02	total	%
both partners returned	yes	3	5	8	35%
” ” ”	no	1	1	2	9%
male only returned	no	4	3	7	30%
female only returned	no	1	2	3	13%
neither partner returned	-	2	1	3	13%
Total number of pairs		11	12	23	

7.3.3 Nest site fidelity

Of 15 colour-marked Dunlins the site of the (first) nest was known for both 2001 and 2002, bringing the total of such cases for the whole study to 32. Distances between nests in consecutive years ranged from 0 to 2189 m, the lower extreme being the single case of nest cup re-use described above. Since the distribution of distances was skewed (Fig. 7.3), the geometric mean describes the average distance better than the arithmetic mean, which is more sensitive to extreme values. Median interannual nest distances were very similar for males and females. For each sex separately (otherwise some nests would occur twice in the dataset), we tested whether the interannual nest distance was influenced by whether or not the same partners bred together in both years. There was no such effect in either females (Mann-Whitney $U=9$, $P=0.41$) or males ($U=33$, $P=0.89$). The outcome of the nest in the first year (eggs hatched or not) also had no discernible effect on the distance between the nests (females $U=14$, $P=1.0$, males $U=41.5$, $P=0.38$). Given the small sample sizes, the statistical power of these tests is low, however.

One replacement clutch of colour-marked Dunlins was identified in 2002, bringing the total for the three-year study to eight. Distances between first clutches and replacement clutches within the same season ranged between 79 m and 1900 m, with the upper extreme linked to the above-mentioned case of mate-change between breeding attempts. Excluding that case, replacement clutches by the same pairs were laid 79-410 m away from the first clutch (geometric mean 181 m), which is similar to distances between clutches laid in different years.

Previous studies on nest site fidelity for Dunlins were conducted mainly in temperate populations (*C.a. schinzii*), in the UK, Germany, Sweden and Finland. Soikkeli (1970a) found that in Baltic Dunlins, site fidelity was closely linked to mate fidelity, and 75% of reunited pairs bred within 100 m from the previous nest site (and all within

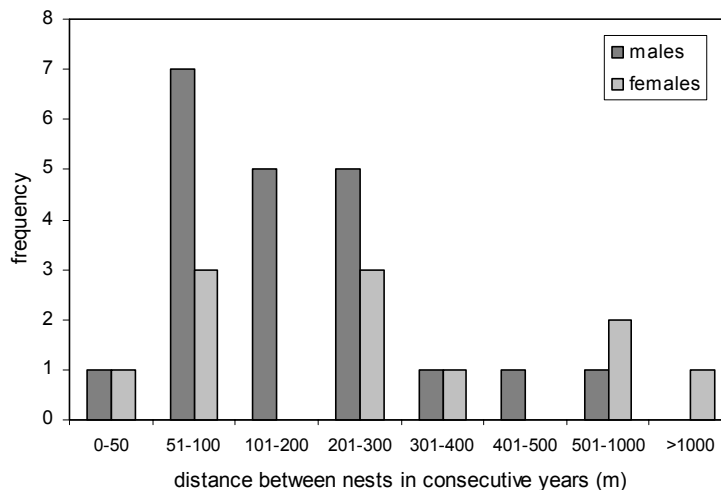


Figure 7.1. Frequency distributions of distances between nests of marked male and female Dunlins in consecutive years

Table 7.4. Geometric mean distances (and range, m) between nests of marked Dunlins in consecutive years, grouped by whether the bird nested with the same partner in both years and whether the nest in the 1st year hatched successfully

Group	Females			Males		
	mean	range	N	mean	range	N
same partner in both years	184	69-895	7	184	69-895	7
different partner in 2 nd year	146	0-2189	4	180	65-417	10
young hatched in 1 st year	91	0-895	4	188	38-895	9
no young hatched in 1 st year	240	69-2189	7	133	63-316	12
totals	161	0-2189	11	155	38-895	21

300 m). Both sexes tended to nest further away when remated with a different partner, but this effect was much stronger in females (18% remained within 100 m) than in males (35% within 100 m). In the Outer Hebrides, 90% of males and 65% of females bred within 100 m of their previous nest-site in the next year (Jackson 1994). In that study also, females proved markedly less site-faithful than males, and this was associated with breeding success: females (but not males) were twice as likely to move more than 100 m after losing their clutch. The non-site-faithful females also moved further than dispersing males: while the largest distance for a male was 450 m, almost half of the dispersing females moved >500 m and the furthest 4 km.

Compared to the above mentioned figures from temperate Dunlin studies, return rate was slightly lower and interannual nest site distances were slightly larger in our arctic study area. This could reflect a somewhat higher propensity for dispersal, perhaps as a result of the near-continuous distribution and vast scale of the tundra breeding habitat.

Another contrast is the lack of a correlation between breeding site fidelity and previous breeding success in our female Dunlins. This could be a result of our small sample sizes, or a genuine difference between the study populations. A lack of correlation between these parameters was also found in Western Sandpipers breeding in arctic Alaska (Sandercock *et al.* 2000). In the Siberian tundras, predation is the major cause of nest failure in waders and highly correlated with cyclic variations in lemming abundance. Hence, temporal variation in risk of nest failure is probably much larger than spatial variation, and thus the balance between benefits and costs may favour returning to the spot irrespective of success: it may well be better next year, and if not it is likely to be bad everywhere; so why not return to the site that you know?

Table 7.5. Literature data on breeding site fidelity in Dunlin.

Subspecies	Site	Area km ²	breeding return rate ¹ (%)				% dispersing <100 m ²			
			♂♂	♀♀	both	N	♂♂	♀♀	both	N
<i>C.a. schinzii</i>	Scotland ³	2-4					90	65	78	243
<i>C.a. schinzii</i>	N-Germany ⁴		57	56	56	223				
<i>C.a. schinzii</i>	S-Sweden ⁵	0.6?	89	77	84	396				
<i>C.a. schinzii</i>	Finland ⁶	0.6	77	72	74	323	70	52	56	142
<i>C.a. pacifica</i>	Alaska ⁷				69	13				
<i>C.a. centralis</i>	Taimyr ⁸	4	75	64	69		38	36	37	32

¹ proportion of birds relocated breeding at the study site; ² of those birds returning to the site; ³ Jackson 1994; ⁴ Heldt 1966; ⁵ Jönsson 1991; ⁶ Soikelli 1970b; ⁷ Holmes in Soikelli 1970a; ⁸ this study.

7.4 Return rate, mate retention and breeding site fidelity in Pacific Golden Plover

The overall MARK estimate of apparent survival rate of Pacific Golden Plovers was 65%. Estimated reporting probability was 1 in all models, so apparently no marked birds that were present in the area were overlooked. These estimates are based on few birds, however. Although the estimates of survival produced by MARK were lower for the second than for the first year, this difference was not significant ($X^2_1=1.21$, $P=0.27$). Neither were there strong indications for a sex difference in apparent survival.

When analysing whether (crude) resighting rate depended on breeding success in the previous year (defined as having hatched young from either a first or a replacement clutch), we found no significant effects on resighting probability of either sex (logistic regression, $X^2_1=0.91$, $P=0.34$), hatching success ($X^2_1=0.25$, $P=0.62$), or the interaction between the two ($X^2_1=0.04$, $P=0.85$) (Table 7.5).

Of the four fully marked pairs present at the end of the summer of 2001, only two birds were seen in 2002, in contrast to 2001 when all members of three pairs marked in 2000 were resighted. Over the three-year study, of the total of seven pairs, neither partner was resighted in the next year in two pairs, only the male or only the female in one each, and both partners in three pairs. Of these, the pair split up in one, stayed together in one and in the third case the situation was not clear (seen together once, but female also once seen with a different male). These limited data hardly allow for generalisations, perhaps except that mate fidelity seemed somewhat less strong in Golden Plovers than in Dunlins.

Over the three years, 12 matches could be made between pairs of nests of colour-marked Pacific Golden Plovers in consecutive years (eight in 2000-01, four in 2001-02). Distances between these nests were 8 - 432 m, with a geometric mean of 101 m.



Table 7.4. Results of MARK analysis of resightings in 2001-2002 of Pacific Golden Plover ringed inside the 4km² plot in 2000-2001. Models are ordered according to the associated Akaike Information Criterion (AIC); number of estimated parameters, deviance, and estimates for apparent survival (ϕ) and resighting probability (p , with standard error and 95% confidence limits) are given

Model	AICc	Delta AICc	# Par	Deviance	parameter	estimate	s.e.	95% c.l.
$\phi(\cdot) p(\cdot)$	56.120	0.00	2	5.093	ϕ	0.65	0.07	0.49 - 0.78
					p	1.00	0.00	1.00 - 1.00
$\phi(t) p(\cdot)$	57.250	1.13	3	3.880	$\phi(0-1)$	0.74	0.10	0.50 - 0.89
					$\phi(1-2)$	0.57	0.11	0.36 - 0.76
					p	1.00	0.00	1.00 - 1.00
$\phi(g) p(\cdot)$	58.422	2.30	3	5.053	$\phi(f)$	0.67	0.11	0.43 - 0.84
					$\phi(m)$	0.64	0.10	0.42 - 0.81
					p	1.00	0.00	1.00 - 1.00

Table 7.5. (Crude) resighting probability of Pacific Golden Plover in relation to hatching success in the previous year

Sex	Hatching success year x	Resighted in year $x + 1$			
		no	yes	total	% resighted
Female	no	3	3	6	50%
	yes	4	3	7	43%
Male	no	2	5	7	71%
	yes	5	7	12	58%

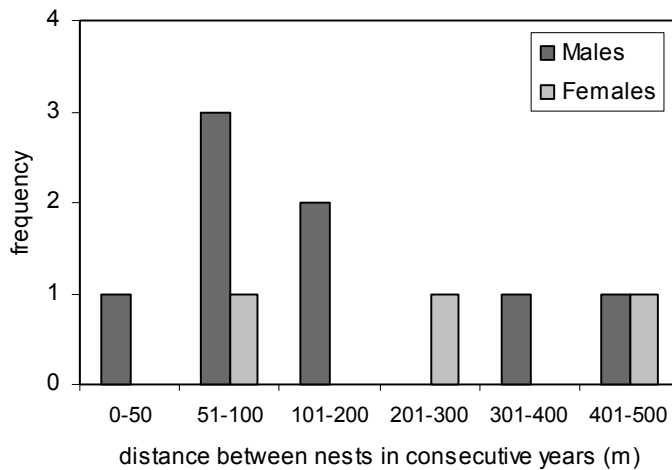


Figure 7.2. Frequency distributions of distances between nests of marked Pacific Golden Plovers in consecutive years

There were too few matches to test for effects on nest site fidelity of sex (means 106 m for males, 92 m for females; Fig. 7.2), stability of pair bond, or previous breeding success. The only pair that was known to have reunited did however show the shortest distance of all matches (8 m). These interannual nest distances are slightly smaller than in the Dunlin. The two replacement nests in 2000 and the single one in 2001 that could be matched to a first clutch of the same pairs, were 66-330 m (mean 178 m) away from the first nest.

The only comparable data on survival and site fidelity in Pacific Golden Plovers are from birds breeding in Alaska and wintering in Hawaii. On breeding grounds near Nome in 1988-2000, 12 out of 16 males but only two of 12 banded females were seen in the study area in a later season, with return rates of 77% and 25% respectively (Johnson *et al.* 2001). On the basis of birds returning from year to year to established wintering territories in Hawaii, adult annual survival was estimated at 80% for both sexes (Johnson *et al.* 2001), so males seemed to be almost totally site-faithful while females were clearly not. With a somewhat smaller sample of birds, we did not find such a clear sex difference in breeding site fidelity in our Taimyr study site, and a return rate that was slightly lower for males, but distinctly higher for females.

Distances between Pacific Golden Plover nests in consecutive years in Alaska ranged between 20 and 280 m (when longer time intervals are included, 0-370 m, including three cases of nest-cup re-use; Johnson *et al.* 2001). This is similar to our results.

7.5 Arrival, pairing and laying dates in marked Dunlin

Because we searched the study area intensively for marked birds in the arrival period in 2001 and 2002, the first observations of marked birds are likely to be an indication of their arrival date. We cannot be sure of this however: a marked Dunlin could have been present in the study area for some time without being noticed. This may be more likely in females than males, as the latter commence conspicuous song-flights shortly after arrival. However, once females are paired with a male, they are no less easy observed, as the pair tends to stay close together during the pre-laying period (mate-guarding). The likelihood of missing the true arrival date of a marked bird may be higher for birds that did not settle as breeding birds in the study area in the given season, but only paid a visit. Therefore the following analysis of arrival dates is restricted to birds that were found breeding within the 4 km² study area.

A check on the accuracy of the estimated arrival date for these birds can be made by comparing the date of first sighting by the date on which the first egg was laid, back-calculated from egg flotation. Obviously, both parents must have arrived –and paired up– before laying. Of 36 marked breeding Dunlins observed in 2001 and 2002, six (17%) were observed for the first time only on or after the estimated first egg date. These birds were excluded from analyses involving the estimated date of arrival.

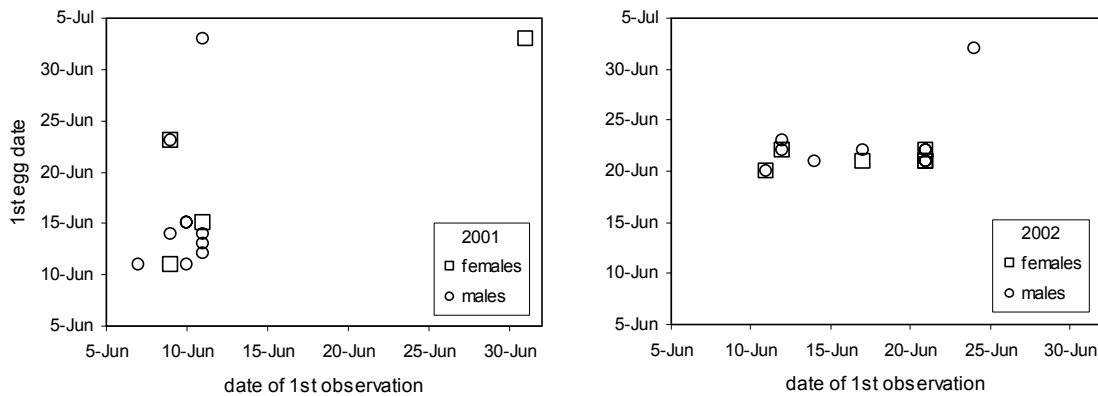


Figure 7.3. Relationships between the date of first observation and date of laying of the first egg in previously colour-marked male and female Dunlins that bred in the study area in 2001 and 2002

The relationship between dates of first observation and laying of the first egg is shown in figure 7.3. There was no significant difference between the sexes in the estimated arrival date in either 2001 (Mann-Whitney $U_{4,10}=18$, $P=0.83$) or 2002 ($U_{6,10}=28$, $P=0.88$), despite the very late first date of one female in 2001 (her male was seen 19 days earlier, but she laid very late; it cannot be excluded that this pair lost an earlier clutch unnoticed). Estimated arrival dates were earlier in 2001 than in 2002, by six days on average (eight if the late female in 2001 is excluded, $U_{14,16}=21$, $P<0.001$). Laying dates of these marked birds were also later in 2002, by seven days ($U_{14,16}=41.5$, $P=0.002$). The number of days between arrival and laying of the first egg did however not differ significantly between the years (average 2001 6.0 d, 2002 4.8 d; $U_{14,16}=96.5$, $P=0.52$). Dunlins were first seen to be paired 0-6 days after arrival (average 1.8 d); 17 out of 27 birds (63%) were already paired when observed for the first time, with no difference between the two years ($U_{13,14}=72$, $P=0.38$). Consequently, the interval between estimated date of pairing and laying (0-14 days, average 3.3 d) did not differ between the years either ($U_{14,16}=88$, $P=0.91$).

If birds reach the breeding area in a single flight from a distant stopover site and laying date is limited by the availability of snow-free habitat, one would expect that arrival date would not be affected by a late snow melt, but the interval between arrival and laying would be. Delayed laying in 2002 did coincide with a delayed snow melt, but the colour-mark resightings indicate that this did not result in a longer time between arrival and laying. Instead, the birds arrived later and events developed similarly thereafter. This suggests that Dunlins do not fly to their previous year's breeding site directly but make one or more stops short of their final destination, adjusting their progress across the tundra to local snow conditions.

That such a scenario indeed occurs is also indicated by transect counts made in the snow-free areas of the study plot during the first weeks of the season in 2002. Numbers of Dunlin counted along the transect were high in the first week but initially very few marked birds were seen among them (figure 7.4), indicating that the majority were not local breeding birds (of which at least 50% were colour-marked in 2001). In the first week, the western part of our 4 km² plot was one of the few areas with substantial snow-free patches in the wider surroundings. When snowmelt accelerated around 16-20 June, the unmarked birds disappeared from the area and the proportion of marked Dunlin rose quickly. In other species, the presence of lingering transients was clear from numbers observed in the first week, which exceeded the number consequently found breeding: Red Knot (maximum counted 50, breeding 2), Ruddy Turnstone (13 resp. 8), Purple Sandpiper (6, 0). Of these three species, the majority of the population breeds further North(east) on Taimyr than Medusa Bay.

A prudent final approach to the breeding site is a sensible strategy given that birds may easily starve if they have to wait too long for food becoming available in thawed-out tundra. But it also means that 'arrival date' and 'arrival condition' in the sense used in migration models like that of Weber *et al.* (1998) have a rather wide geographic definition (perhaps up to a few 100 km of latitude), and are therefore difficult to measure in the field, where observations are by default site-specific.

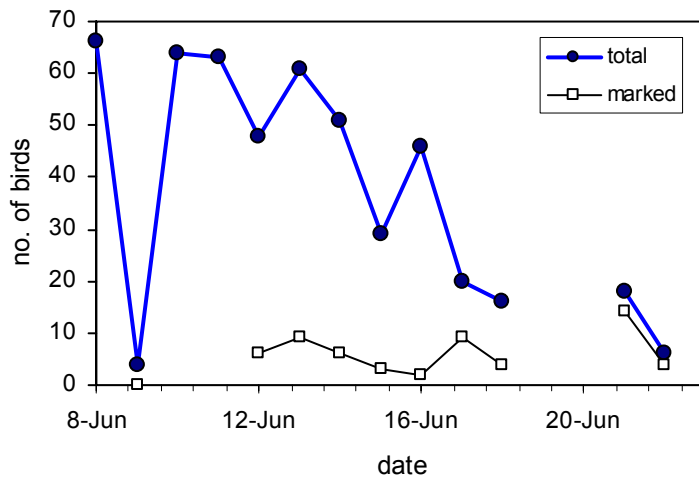


Figure 7.4. Total numbers and numbers of colour-marked Dunlins counted in the snow-free, western part of the study area during the first two weeks of the 2002 season



8 Arthropod abundance

8.1 Introduction and methods

Arthropods are the major food for arctic breeding shorebirds. Adult birds have an alternative food source in soil arthropods such as worms and larvae, but chicks rely entirely on surface-dwelling and flying arthropods. Upon arrival, adults largely feed on buried prey and on collembolas along the edges of snow fields. During the first weeks of their stay, when very few insects have started to emerge, they rely on this food source. Around the end of June, they are first seen taking insects from the vegetation and depending on weather and food availability alternate this with probing for buried prey. As investigating the abundance of buried prey is extremely time consuming due to their aggregated distribution, low overall densities and the tough substrate structure, we were not able to fit a thorough investigation of buried fauna into our research scheme. Measuring food abundance for chicks that rely solely on surface-dwelling arthropods, is however relatively simple and less time-consuming.

Arthropod abundance was sampled for two different purposes. Therefore two different methods were applied. As part of a long term monitoring scheme, running since 1998, seven lines of ten 500 ml (\varnothing 11 cm) pitfalls each were placed in permanent positions. The aim of this scheme is to investigate differences in composition of arthropod communities between different habitats, between-year fluctuations in numbers and coarse-scale seasonal patterns. This scheme was run by Dr. Mikhail Berezin and pitfalls were emptied once a week, between 10 June and 31 July.

Starting in 2000, two of the seven pitfall lines were additionally used to analyse variation in arthropod abundance related to season and weather. These lines were situated close to camp and emptied daily between 22:00 and 24:00 from 16 June to 9 August. Pitfalls could not be dug in earlier because of the permafrost. One line (dry) was situated on top of a hill close to the station in relatively dry, frost-heaved tundra. The other (wet) line was placed in a depression, where snowmelt was late, in a marshy area with sedges and grass. The wet line was installed on 23 June, because only then was the area free of snow and ice. Each day the samples were collected and sorted to family level in the station and the length of each individual was estimated to the nearest 0.5 mm (arthropods < 5 mm) or 1 mm (> 5 mm). Dry mass of arthropods was calculated using the length-dry mass relationships given for different orders in Rogers *et al.* (1977) and Schekkerman (1997). Log-linear regressions were used to analyse effects of season and weather on numbers and biomass caught.

8.2 Results and discussion

Due to the long period of cold weather in early spring, number of arthropods caught hardly showed an increase in June (Fig. 8.1).

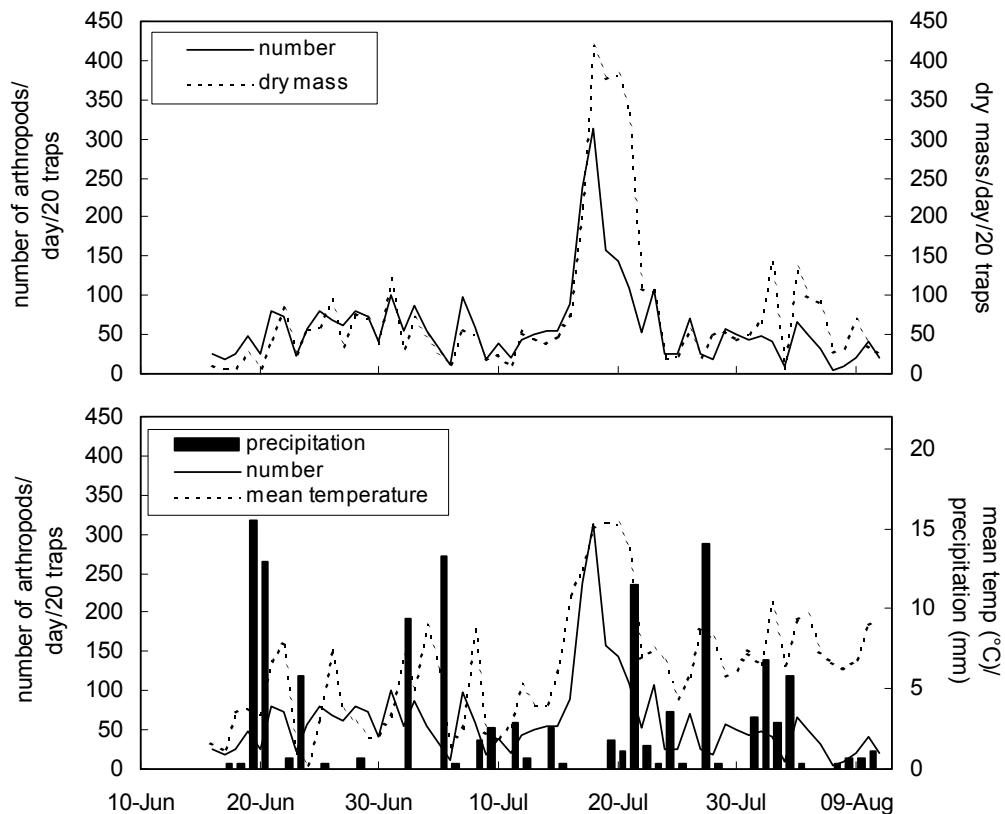


Figure 8.1. Seasonal pattern in total number and dry mass of arthropods (upper) and mean temperature, precipitation and total number of arthropods (lower)

Daily numbers (and dry mass) caught showed very little variation, until mid July when temperatures rose and a short peak, lasting only one week, was observed in arthropod abundance. This maximum is even more pronounced than in total numbers, indicating that in this period not only the number, but also the mean size of arthropods caught was larger than earlier and later in the season. Thereafter temperatures and numbers caught decreased to the level of June. The data from the three consecutive recent years show totally different patterns (Fig. 8.2). In 2000 numbers only increased very slowly until July, but kept increasing up to the last day of our sampling period. The next year showed a clearcut peak in abundance around the second week of July, with decreasing numbers in late July and August.

As found previously (Maclean & Pitelka 1971, Tulp *et al.* 1997, 1998, 2000, Tulp & Schekkerman 2001) numbers were strongly correlated with temperature. Contrary to other years no clear effect of precipitation (rain in most cases) on daily arthropod abundance was found (Fig. 8.1). The season was extremely wet compared to other years (see chapter 3), with rain on 60% of the days, which might explain the lack of an effect.

In a loglinear regression analysis investigating seasonal and weather effects on the dry mass of arthropods, cumulative mean temperature and its quadratic term, mean operative temperature, date and date² were significant predictors (table x.1). Wind speed and precipitation were tested, but did not significantly contribute to the model. As seasonal effects and weather effects are highly correlated it is difficult to distinguish between them. After correction for season, the remaining variation can partly be explained by weather variables and vice versa. However, cumulative temperature incorporates both the temperature and the speed at which it increases over the season. Therefore it is a better predictor (in combination with date) than the combination of temperature and date alone. The model describing variation in dry mass indicated a peak on 17 July, 10 days later than in 2001.

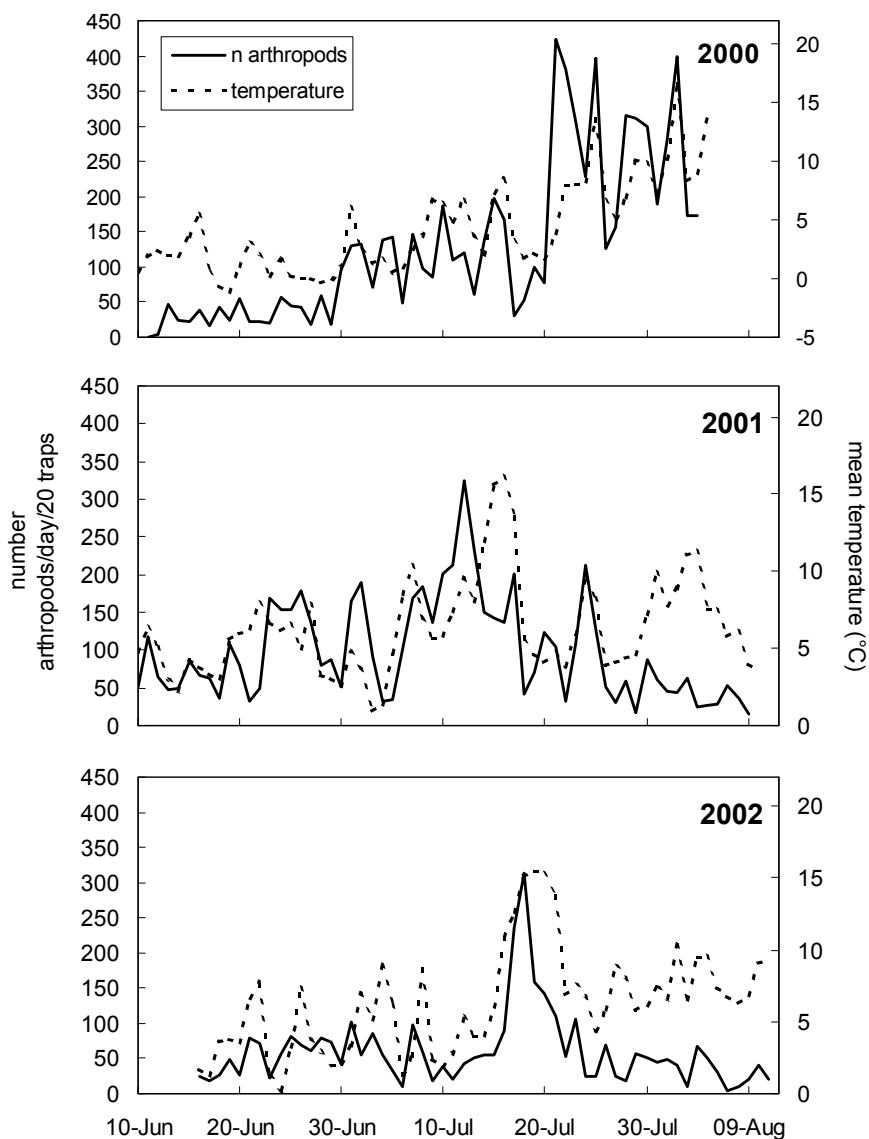


Figure 8.2. Seasonal pattern in total number of arthropods in 2000, 2001 and 2003

Table 8.1. Analysis of seasonal trend in total dry mass of arthropods (per 20 traps per day) including weather variables at Medusa Bay in 2002. The null model includes the constant only, the final model includes all significant parameters shown. First *cummeantemp* (+quadratic term) was added to the empty model and significance of all other weather parameters was tested by dropping them one at a time from the maximum model, using the change in deviance (likelihood ratio test). Date and *date*² were entered last. The parameters tested included: *date*, *date*² (together describing a parabolic curve), mean operative temperature (*temp* in °C), mean cumulative temperature since 1 June, mean wind speed (*wind* in $m \bullet s^{-1}$) plus quadratic terms and

model	change in deviance	df	P	coefficient	se
null model	4159	54			
final model	3467	5			
<i>cummeantemp</i>	204	1	<0.001	-0.0057	0.0112
<i>cummeantemp</i> ²	981	1	<0.001	0.0000703	0.0000385
<i>optemp</i>	2178	1	<0.001	0.2086	0.0181
<i>date</i> +	104	2	0.032	0.266	0.135
<i>date</i> ²				-0.00430	0.00181

The arthropod numbers in the dry series show, as they did in other years, a more clearcut seasonal pattern than the numbers in the wet series (Fig. 8.4). On average numbers in both lines were similar but the distribution over groups was different. (Fig. 8.5). Spiders (Araneae) and flies (Diptera: Brachycera & Cyclorrapha) were more abundant in the wet series, while midges (Nematocera, including crane flies (Tipulidae) and wasps (Hymenoptera) occurred in higher numbers in the dry series. Beetles (Coleoptera) were equally abundant in both series.

If the supply of arthropods that emerge in one summer is finite the cumulative number of arthropods plotted against the cumulative temperature should become asymptotic. This is only true for 2001 and 2002 but not for 2000 (Fig. 8.6). Despite the later season of 2000 the cumulative number of arthropods over the season was higher than in 2001. As the total temperature sum was lower, this is somewhat surprising. When the wet series and dry series are considered separately the cumulative number of arthropods was higher in the wet series than in the dry series in 2000 but the pattern was reversed in 2001. The increase with temperature was highest in the dry series in 2001 and in the wet series in 2000. In 2002 both series were very similar in their cumulative numbers and ended up at the lowest level of the three years.

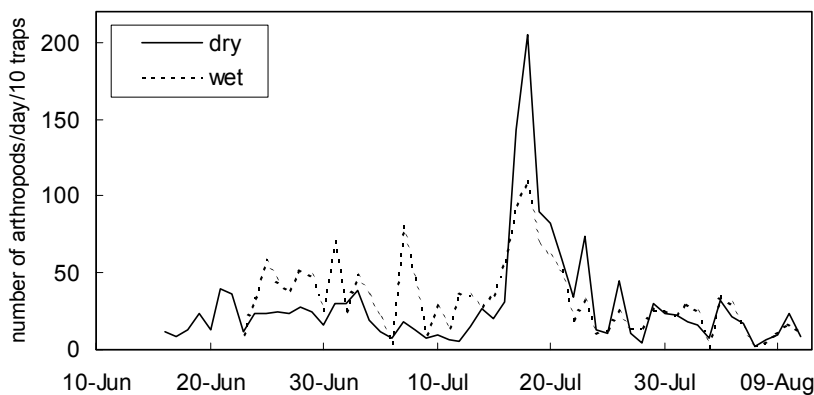


Figure 8.4. Seasonal pattern of arthropods for the dry and the wet series separately

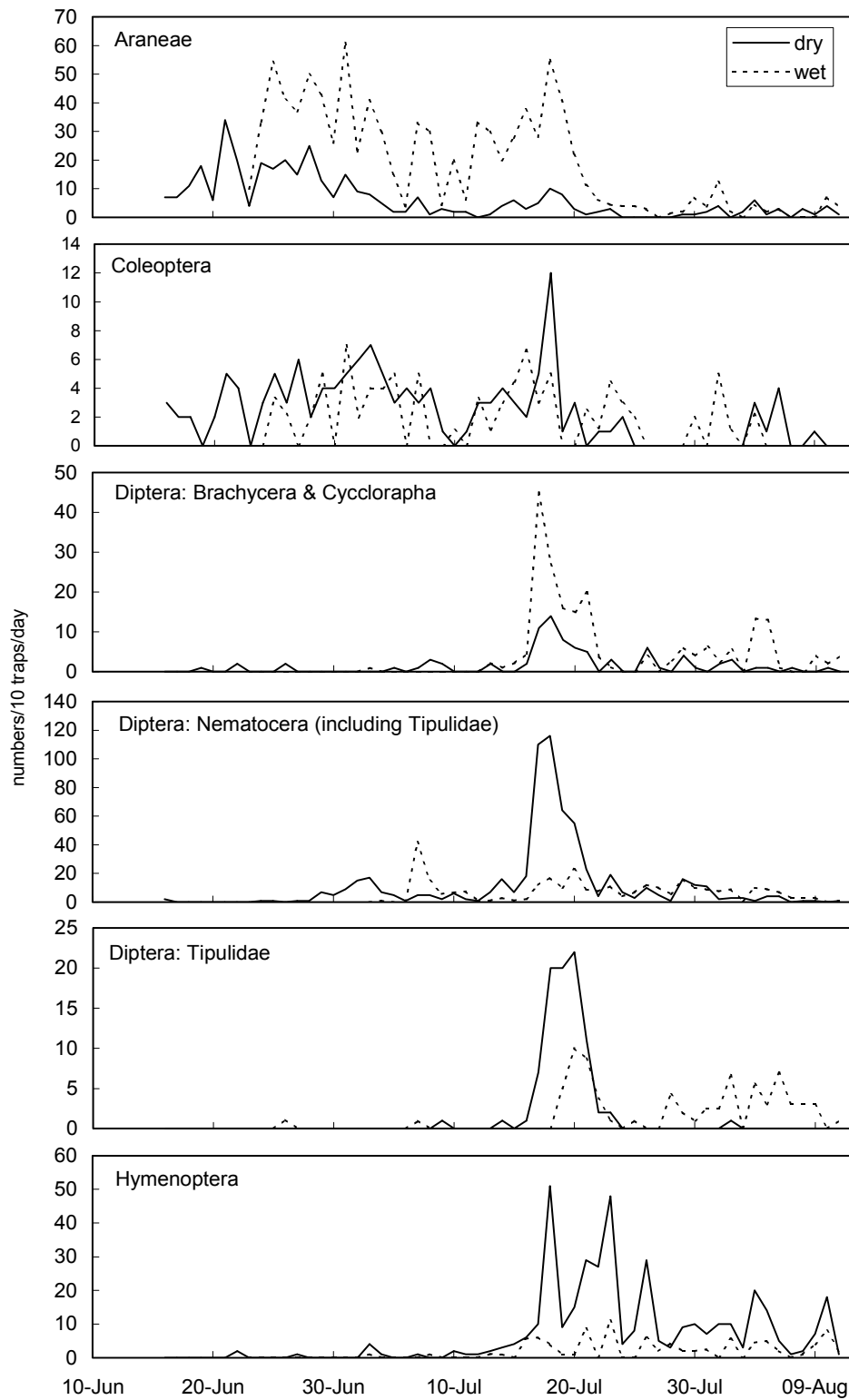


Figure 8.5. Seasonal pattern (numbers per 10 traps per day) of several groups of arthropods for the dry and the wet series separately. Diptera are divided in Brachycera and Cycclorapha and Nematocera, because of the difference in shape and therefore energetic equivalent between these groups: Brachycera (and Cycclorapha) are relatively short and thick, while Nematocera are long and thin

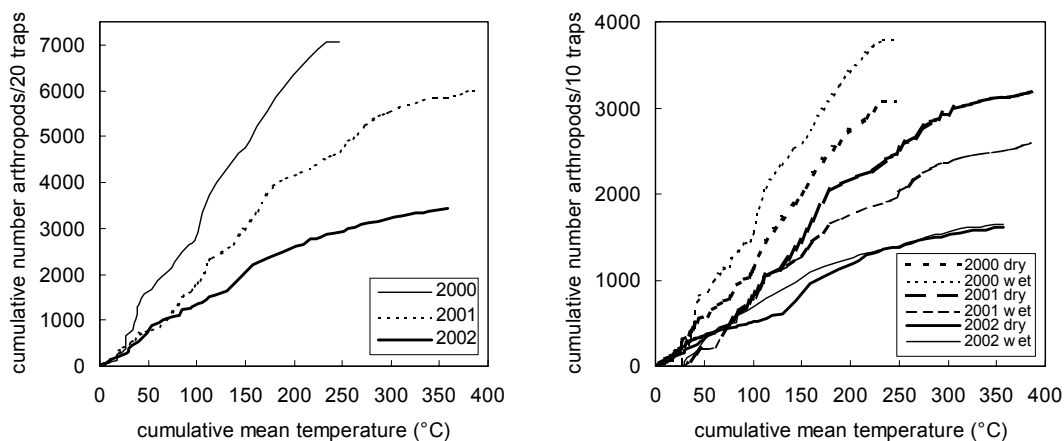


Figure 8.6. Cumulative total number of arthropods in 2000, 2001 and 2002 plotted against cumulative mean temperature for the two series combined (left) and for the wet and dry series separately (right)

8.3 Breeding phenology in relation to snow melt and arthropod availability

Upon their arrival in the tundra in the first two weeks of June, shorebirds generally find the largest part of the tundra surface still covered in snow. However, the year-to-year variation in snow cover exactly in the period when most birds need to start choosing territories in order to attract a mate is very large (Fig. 8.7). For instance on 5 June 2000 not even half of the study area was snow-covered, while in 2001 over 80% was covered on the same date and in 2002 the snow cover was even more complete. Also the rate at which snow disappeared was different, with rapid snowmelt in 2001 due to warm weather, resulting in a practically snow-free tundra by 15 June. In contrast, in 2000, characterised by a very cold June, this stage was only reached in the last week of June, and in 1996 only in the last days of June (Tulp *et al.* 1997). In 2002 the snowmelt was the latest ever recorded during studies at Medusa Bay: up until 18 June snow cover was 70%. Even comparing only these few years it is striking how large variation in arrival conditions is.

As the occurrence of surface-active arthropods is highly correlated with weather conditions, the summer peak in abundance also shows variation between years (Fig. 8.7). Despite this variation, the timing of shorebird breeding was highly similar between 2000 and 2001. In 2002 however the spread around the median date was much smaller than in the previous years (fig. 8.8, see also chapter 5.4). The consequence of such a late season as in 2002 is that there is relatively little possibility for producing replacement clutches (see chapter x). As a result of the relatively late peak in arthropod abundance in 2000 and 2002, most chicks were born when food was abundant. In 2001 however, numbers of arthropods were already declining by the time that the first chicks hatched.

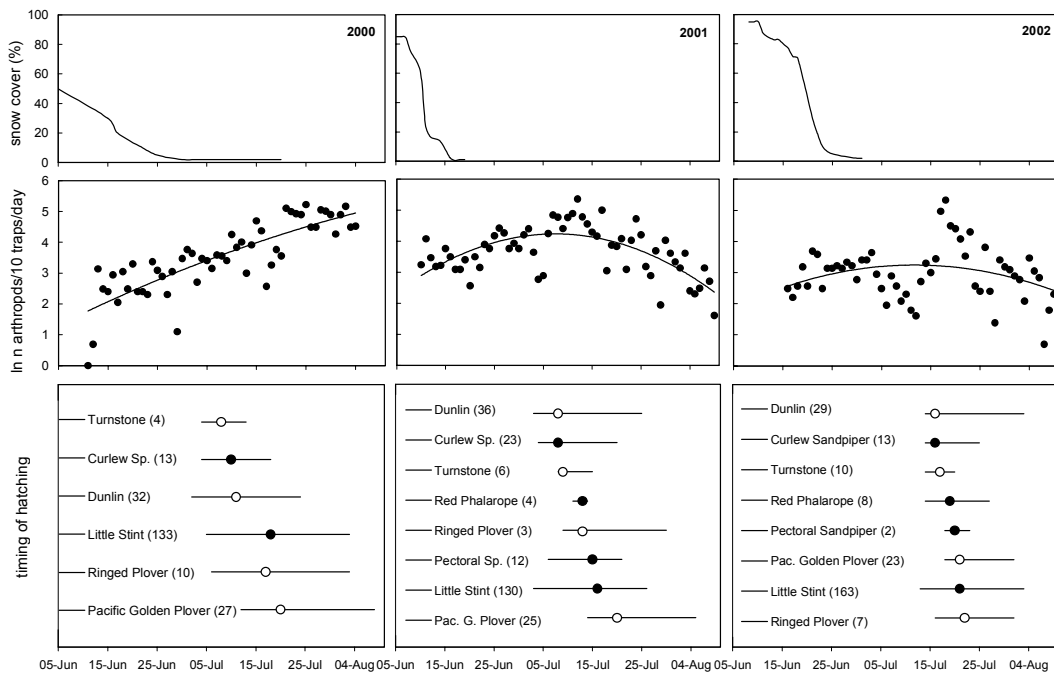


Figure 8.8 Breeding phenology (bottom) in relation to snow melt (top) and arthropod abundance (middle) in 2000, 2001 and 2002. In the lower graph lines indicate ranges of hatching dates and dots represent median hatching dates. Open symbols represent biparental incubators, closed symbols uniparental species; number of nests between parentheses



9 Chick growth

9.1 Methods

On the expected hatching date, nests were visited to ring and measure the newly hatched young. Afterwards, chicks were retrapped whenever a known family (with colour-ringed adult) was encountered and new families (of which we did not find the nest) were also caught and ringed. Chicks of known families were caught as often as possible to measure growth over intervals of several days. The presence of chicks can be easily deduced from the adults' behaviour. Using alarm calls they warn their chicks that crouch until danger has disappeared. Chicks were searched for by looking from a distance until the parent bird stopped alarming and chicks started moving again. Using the chicks, the unringed parents of new families could often be caught, because of their urge to brood the young. This only works under cold conditions, otherwise the chicks do not cool down and stay quiet. Only in Little Stint enough recaptures were made to search for patterns with weather and/or food abundance.

Because mass growth is not linear in shorebirds but follows an S-shaped curve, growth rates of chicks at different ages and over different intervals cannot be compared directly. Therefore, growth rates were transformed to an index, by dividing the observed growth by the growth expected over the same interval from logistic curves based on published growth data (Schekkerman *et al.* 1998a). Hence, a growth index of 1 means that chicks grew exactly as fast as expected from this curve, while 0 denotes that chicks did not grow at all, and negative values indicate mass loss. These growth indices were used to analyse the dependence of growth rate on temperature and food availability (surface-active arthropods) during the recapture interval. Since wader chicks often loose mass during the first day(s) after hatching, and this is not reflected in the fitted standard growth curves, growth indices for chicks first weighed when less than a day old (often still in the nest) tend to be lower than those for older chicks. Therefore, we analysed neonates (<5 g, resp. <8 g at start of recapture interval) and older chicks separately.

9.2 Results and discussion

Figure 9.1 shows the mass and wing development of Little Stint chicks of which the age was known because they were ringed when still in the nest, with published growth curves shown for comparison. Figure 9.2 shows growth rates over recapture intervals, in relation to mid-interval date and arthropod availability. Chick growth rate was positively related to arthropod availability. Because the average arthropod biomass declined strongly with mid-interval date, especially after 15 July, chicks grew more slowly as the season progressed. These relationships were more clearly expressed in very young Little Stints than in older ones.

Growth rates of chicks may be influenced both by the availability of surface-active arthropods (affecting feeding success) and by temperature (affecting energy expenditure and the time available for foraging instead of being brooded by a parent). Regression analyses suggested that arthropod biomass was a better predictor of growth rate than temperature. This was also found in another arctic-breeding wader species, the Red Knot (Schekkerman *et al.* MS).

In summary, our data show that Little Stints in 2002 hatched late in relation to the seasonal peak in arthropod availability, but because of the very late snow melt, an earlier start of breeding was not possible. Also the peak in food abundance was very narrow this year compared to other years. Growth rate of chicks suffered accordingly. Due to this narrow peak in food abundance (15-20 July, Fig. 8.2) and the low variability in food supply, the relationship between growth indices and food abundance was less clear than in 2001 (Fig. 9.2).

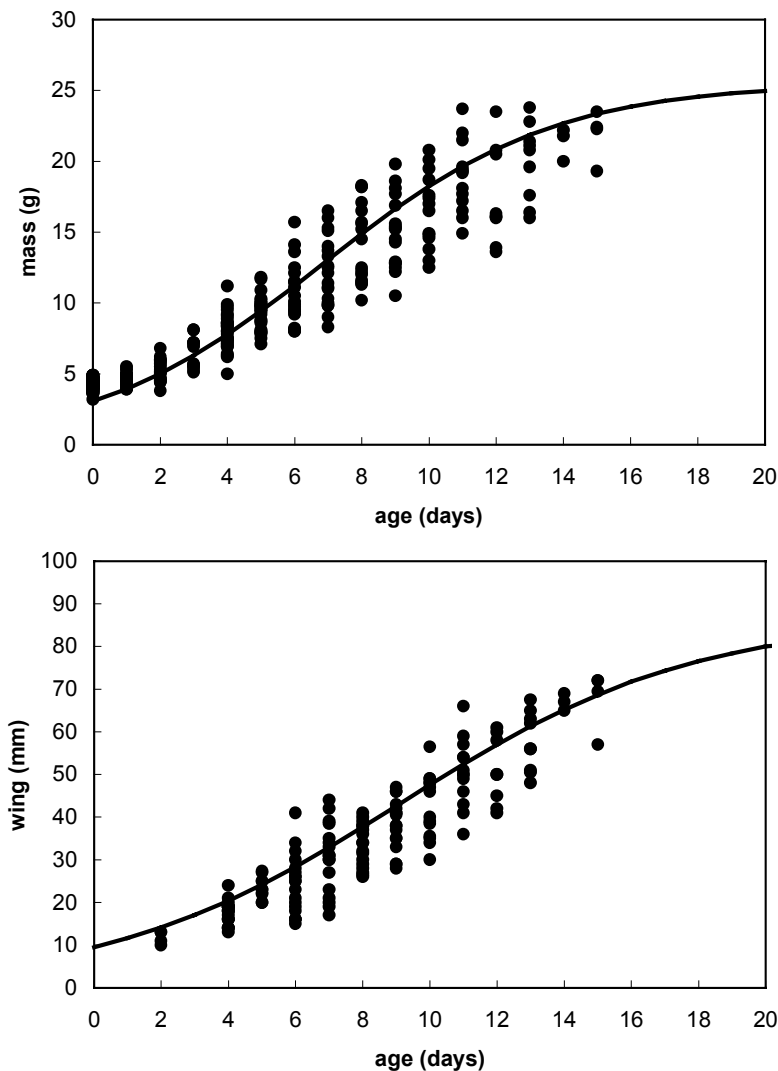


Figure 9.1. Development of body mass in chicks of Little Stint of which the exact age was known (ringed when still in the nest; dots). The lines show published growth curves (Schekkerman *et al.* 1998)

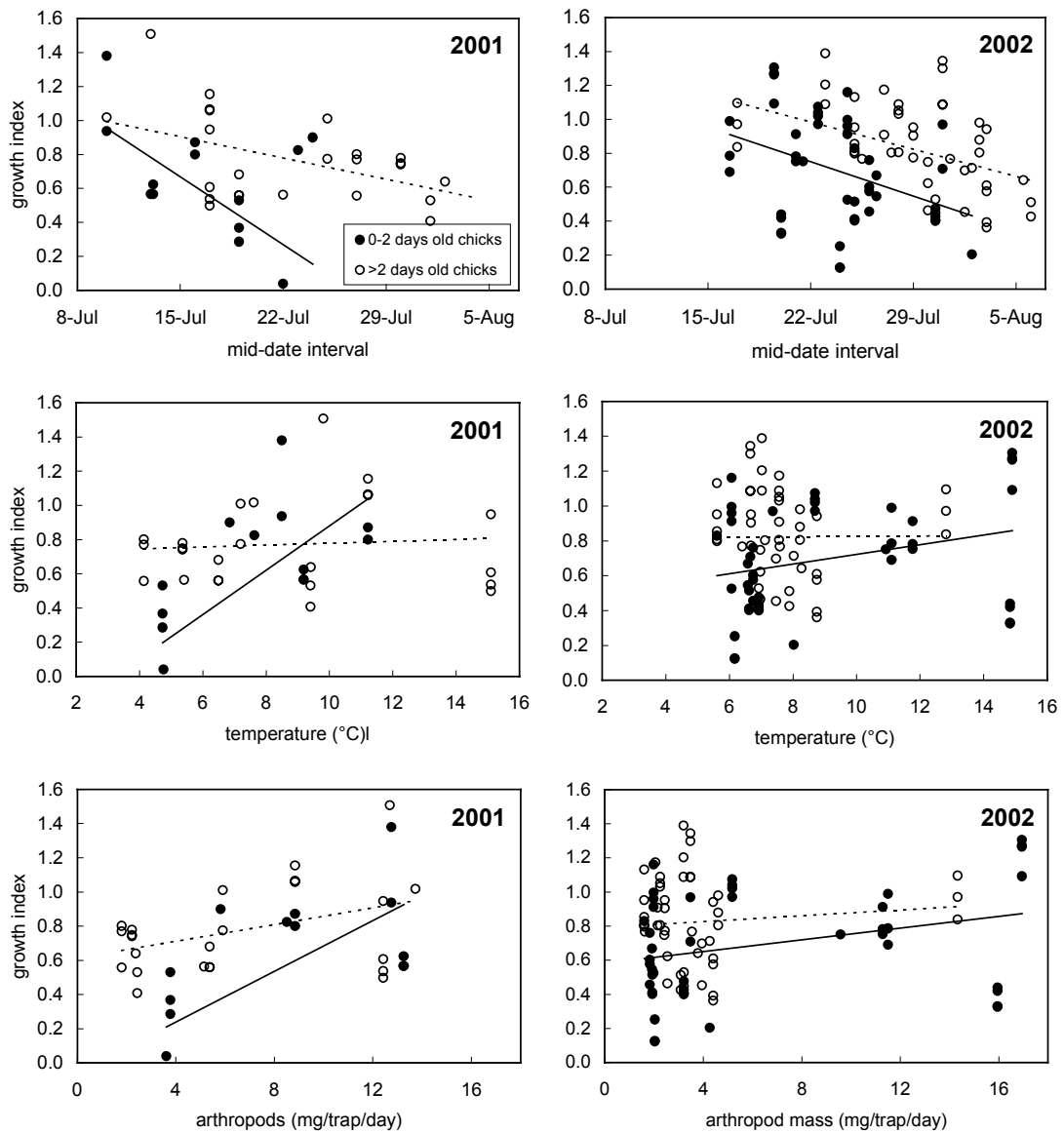


Figure 9.1 Growth index over recapture intervals in relation to mid-interval date (upper two graphs), mean temperature (middle two graphs) and arthropod availability (lower two graphs). For the explanation of growth index see text



Acknowledgements

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Appendix 1 Estimation of incubation day from egg floats

The following table can be used for estimating the incubation day from measurements on wader's eggs submerged or floating in water (see chapter 5.2 for details on methods and float curves).

	incubation day (days relative to hatching date)			
	Curlew Sandpiper Pectoral Sandpiper	Dunlin	Little Stint Temminck's Stint	Pacific Golden Plover
angle between longitudinal axis of submerged egg and horizontal (°)				
20	-20	-20	-20	-25
30	-18	-19	-19	-22
40	-17	-18	-18	-21
50	-16	-17.5	-17.5	-20.5
60	-16	-17	-17	-20
70	-15	-16.5	-16	-19
80	-14	-16	-15	-18
90	-13	-15	-14	-16
distance between top of floating egg and water surface (mm)				
0	-13	-15	-13	-15
1	-11.5	-13	-11	-13
2	-10	-10.5	-8	-11.5
3	-8.5	-8	-6	-10
4	-7	-5	-4	-8.5
5	-5.5	-3	-2	-7
6	-4			-5
7				-4
egg starred	-2	-2	-1	-2
egg pipped	-1	-1	0	-1

Incubation day can also be calculated from regression equations given below:

Regression coefficients for predicting incubation day (relative to hatching) on (A) x = the logit of the proportional angle of the submerged egg (proportion of 20°-90° range), or (B) x = the height that the egg tip emerges above the water surface (mm). Regression equation: days to hatching = $Ax + C$.

species	A coefficients for logit (prop angle)						B coefficients for float distance					
	C	se	A	se	R ²	N	C	se	A	se	R ²	N
Pacific Golden Plover	-20.14	0.66	1.25	0.32	0.64	9	-14.7	1.23	1.56	0.29	0.85	6
Curlew Sandp., Pectoral	-16.03	0.4	0.85	0.23	0.27	36	-13.03	0.72	1.51	0.29	0.62	17
Dunlin	-17.65	0.43	0.57	0.34	0.11	15	-15.5	2.22	2.53	0.93	0.52	7
Little & Temminck's Stint	-17.13	0.37	0.89	0.16	0.44	38	-13.18	0.42	2.35	0.2	0.71	57

Appendix 2 Mean egg size and start of incubation by nest

Appendix 2a. Egg size measurements and estimated start of incubation of wader clutches. Given are number of eggs measured, mean length and width (measured to nearest 0.1 mm), and mean volume (calculated as $0.5 \times \text{length} \times \text{width}^2$) of measured eggs, as well as the difference in volume between the largest and the smallest egg of the clutch (Δ volume). Data are ordered by species (alphabetical) and nest ID.

Species	nest ID	N eggs	Mean Length (mm)	Mean Width (mm)	Mean Volume (ml)	Δ volume (ml)	Start of incubation	
Curlew Sandpiper	HS44CS	4	38.30	25.98	12.92	0.30	24-Jun	
	CS	HS45CS	4	35.73	26.33	12.39	1.19	30-Jun
	CS	HS86CS	4	36.00	25.48	11.69	1.07	29-Jun
	CS	IT03CS	4	37.10	25.48	12.04	0.22	24-Jun
	CS	IT12CS	4	36.60	26.58	12.92	0.67	23-Jun
	CS	IT20CS	4	35.65	25.38	11.48	0.37	25-Jun
	CS	IT23CS	4	35.80	25.60	11.73	0.37	24-Jun
	CS	IT42CS	4	37.43	25.03	11.72	0.69	24-Jun
	CS	IT75CS	4	36.43	25.33	11.68	1.27	1-Jul
	CS	IT86CS	4	36.33	26.05	12.32	0.62	4-Jul
	CS	JL06CS	4	35.73	26.28	12.33	0.12	29-Jun
	CS	JL38CS	4	35.20	26.80	12.64	1.02	2-Jul
	CS	KC07CS	4	36.78	26.38	12.79	0.45	24-Jun
	Dotterel	SK05DO	3	41.30	28.30	16.54	1.15	?
Dunlin	HS01DU	3	33.73	24.53	10.13	2.83	25-Jun	
	DU	HS02DU	4	36.08	25.35	11.59	0.17	25-Jun
	DU	HS04DU	4	35.78	25.58	11.70	0.53	23-Jun
	DU	HS06DU	4	33.58	24.10	9.75	1.26	23-Jun
	DU	HS07DU	4	36.50	25.50	11.87	0.72	26-Jun
	DU	HS09DU	4	35.78	25.58	11.70	0.47	24-Jun
	DU	HS11DU	4	34.70	25.55	11.33	0.45	23-Jun
	DU	HS12DU	4	33.58	24.58	10.14	1.03	24-Jun
	DU	HS13DU	4	34.78	25.58	11.37	0.53	24-Jun
	DU	HS20DU	4	34.88	24.90	10.81	0.76	24-Jun
	DU	HS21DU	4	35.10	24.15	10.24	1.16	25-Jun
	DU	HS22DU	4	36.43	25.28	11.64	0.97	23-Jun
	DU	HS28DU	4	35.65	24.80	10.97	0.80	24-Jun
	DU	HS33DU	4	35.88	25.35	11.53	1.27	23-Jun
	DU	HS46DU	4	35.75	24.63	10.84	0.26	27-Jun
	DU	HS66DU	4	35.68	25.78	11.85	1.09	25-Jun
	DU	HS75DU	4	35.73	24.85	11.03	0.50	24-Jun
	DU	HS89DU	4	35.23	24.28	10.38	0.41	25-Jun
	DU	HS91DU	4	34.98	24.65	10.63	1.29	25-Jun
	DU	IT14DU	4	35.43	25.40	11.43	0.72	24-Jun
	DU	IT33DU	4	35.60	24.68	10.84	0.61	23-Jun
	DU	IT47DU	4	35.13	24.87	10.86	0.35	26-Jun
	DU	JL09DU	4	35.80	25.48	11.62	0.39	28-Jun

Species	nest ID	N eggs	Mean Length (mm)	Mean Width (mm)	Mean Volume (ml)	Δ volume (ml)	Start of incubation
Dunlin (<i>continued</i>)	KC04DU	4	35.28	24.35	10.46	0.51	25-Jun
DU	KC26DU	4	35.78	24.13	10.41	0.21	24-Jun
DU	KC35DU	>3	36.33	24.17	10.61	0.64	24-Jun
DU	TK02DU	4	35.05	24.30	10.35	0.25	27-Jun
Pacific Golden Plover	HS05GP	4	46.23	31.70	23.22	0.43	26-Jun
GP	HS26GP	4	47.13	33.08	25.78	0.84	24-Jun
GP	HS30GP	4	48.55	32.40	25.50	3.27	3-Jul
GP	HS34GP	4	46.95	31.98	24.00	1.73	29-Jun
GP	HS49GP	4	48.25	33.50	27.06	0.80	28-Jun
GP	IT07GP	4	48.48	33.25	26.80	2.17	26-Jun
GP	IT16GP	4	47.00	33.08	25.71	1.86	26-Jun
GP	IT22GP	4	45.85	32.58	24.33	1.39	27-Jun
GP	IT25GP	4	46.40	32.68	24.77	1.31	28-Jun
GP	IT27GP	4	47.45	33.23	26.20	2.31	26-Jun
GP	IT29GP	4	49.43	33.00	26.91	0.48	24-Jun
GP	IT30GP	4	46.63	34.08	27.07	2.84	26-Jun
GP	IT31GP	>3	46.13	33.27	25.54	2.58	27-Jun
GP	IT34GP	4	47.65	32.80	25.64	2.03	29-Jun
GP	IT40GP	4	47.68	32.53	25.22	1.09	27-Jun
GP	IT46GP	4	46.25	32.95	25.10	0.89	28-Jun
GP	IT49GP	4	48.03	33.63	27.15	0.97	26-Jun
GP	IT72GP	4	48.70	32.33	25.45	1.51	27-Jun
GP	IT77GP	4	47.55	32.03	24.39	2.42	27-Jun
GP	IT81GP	4	47.55	32.98	25.85	0.80	29-Jun
GP	IT83GP	4	47.73	34.43	28.28	1.15	1-Jul
GP	JL12GP	4	49.03	32.85	26.45	2.13	26-Jun
GP	KC43GP	4	48.05	33.08	26.29	2.13	8-Jul
Grey Plover	HS10GR	4	52.95	36.60	35.47	2.78	27-Jun
Little Stint	HS14LS	4	29.55	20.03	5.92	0.20	24-Jun
LS	HS15LS	4	29.38	21.43	6.74	0.36	24-Jun
LS	HS18LS	4	26.38	19.75	5.14	0.16	27-Jun
LS	HS19LS	4	28.73	20.05	5.78	0.41	27-Jun
LS	HS31LS	4	28.70	21.25	6.48	0.21	30-Jun
LS	HS32LS	4	28.93	20.75	6.23	0.54	30-Jun
LS	HS36LS	4	29.30	21.08	6.51	0.51	30-Jun
LS	HS38LS	4	24.65	20.60	5.24	0.87	27-Jun
LS	HS39LS	4	29.05	20.30	5.99	0.16	1-Jul
LS	HS40LS	2	29.15	21.30	6.61	0.32	3-Jul
LS	HS41LS	4	29.33	19.95	5.84	0.34	30-Jun
LS	HS42LS	4	28.33	19.78	5.54	0.15	30-Jun
LS	HS43LS	4	28.38	20.93	6.21	0.63	1-Jul
LS	HS50LS	4	29.00	21.83	6.90	0.62	2-Jul
LS	HS53LS	4	29.08	20.98	6.40	0.23	2-Jul
LS	HS58LS	4	28.95	20.95	6.35	0.15	4-Jul
LS	HS59LS	4	28.45	20.98	6.26	0.15	1-Jul
LS	HS60LS	4	29.28	19.98	5.84	0.32	2-Jul

Species	nest ID	N eggs	Mean Length (mm)	Mean Width (mm)	Mean Volume (ml)	Δ volume (ml)	Start of incubation
Little Stint (<i>continued</i>)	HS62LS	4	28.43	20.63	6.05	0.42	4-Jul
LS	HS67LS	4	26.70	19.93	5.30	0.25	30-Jun
LS	HS68LS	4	28.33	20.13	5.74	0.18	4-Jul
LS	HS74LS	4	28.58	20.58	6.05	0.13	2-Jul
LS	HS76LS	4	28.05	19.60	5.39	0.41	29-Jun
LS	HS77LS	4	28.80	20.10	5.82	0.06	4-Jul
LS	HS78LS	4	28.83	20.48	6.04	0.48	25-Jun
LS	HS79LS	4	28.75	20.18	5.85	0.18	30-Jun
LS	HS82LS	4	30.45	20.68	6.51	0.30	2-Jul
LS	HS83LS	4	29.68	20.60	6.30	0.42	2-Jul
LS	HS84LS	4	29.38	20.80	6.36	0.33	2-Jul
LS	HS85LS	4	28.08	20.20	5.73	0.44	5-Jul
LS	HS87LS	4	29.83	21.23	6.72	0.16	29-Jun
LS	HS88LS	4	30.60	20.93	6.70	0.72	4-Jul
LS	HS90LS	4	28.55	20.68	6.10	0.21	4-Jul
LS	HS94LS	4	27.68	20.25	5.67	0.31	30-Jun
LS	HS95LS	4	30.20	20.23	6.18	0.26	4-Jul
LS	HS96LS	3	29.33	20.67	6.27	0.85	30-Jun
LS	IT11LS	4	29.70	20.15	6.03	0.42	26-Jun
LS	IT17LS	4	28.73	20.15	5.83	0.58	27-Jun
LS	IT18LS	4	27.65	19.38	5.19	0.68	27-Jun
LS	IT24LS	4	27.58	19.80	5.40	0.23	28-Jun
LS	IT38LS	4	27.93	20.15	5.67	0.73	25-Jun
LS	IT39LS	4	29.65	20.98	6.52	0.28	28-Jun
LS	IT41LS	4	28.58	20.55	6.03	0.06	30-Jun
LS	IT43LS	4	28.73	20.27	5.90	0.42	2-Jul
LS	IT44LS	4	28.05	20.10	5.67	0.11	30-Jun
LS	IT45LS	4	27.85	20.63	5.92	0.13	30-Jun
LS	IT51LS	4	28.40	19.90	5.62	0.21	2-Jul
LS	IT52LS	4	30.10	20.58	6.37	0.23	25-Jun
LS	IT54LS	4	29.33	20.43	6.12	0.52	2-Jul
LS	IT56LS	4	28.00	20.13	5.67	0.42	4-Jul
LS	IT57LS	4	28.88	20.58	6.11	0.31	29-Jun
LS	IT59LS	4	28.43	20.83	6.16	0.07	1-Jul
LS	IT60LS	4	28.63	20.75	6.16	0.36	29-Jun
LS	IT61LS	4	27.70	20.80	5.99	0.16	27-Jun
LS	IT62LS	4	27.90	19.83	5.48	0.27	27-Jun
LS	IT64LS	4	28.23	20.25	5.79	0.81	29-Jun
LS	IT66LS	4	28.38	19.88	5.60	0.86	1-Jul
LS	IT68LS	4	29.33	21.45	6.75	0.41	2-Jul
LS	IT69LS	4	27.98	20.68	5.98	0.17	7-Jul
LS	IT70LS	4	29.15	20.25	5.98	0.56	28-Jun
LS	IT71LS	4	27.83	20.60	5.91	0.50	1-Jul
LS	IT74LS	4	28.05	20.85	6.10	0.51	9-Jul
LS	IT76LS	4	29.10	20.55	6.14	0.24	4-Jul
LS	IT79LS	4	29.65	20.88	6.46	0.17	3-Jul
LS	IT80LS	4	29.25	21.08	6.50	0.43	9-Jul
LS	IT82LS	4	28.00	20.78	6.05	0.68	1-Jul
LS	IT84LS	4	28.60	20.25	5.86	0.36	3-Jul

Species	nest ID	N eggs	Mean Length (mm)	Mean Width (mm)	Mean Volume (ml)	Δ volume (ml)	Start of incubation
Little Stint (<i>continued</i>)	IT87LS	4	27.13	20.50	5.70	0.24	7-Jul
LS	IT89LS	4	28.45	20.70	6.10	0.11	4-Jul
LS	IT90LS	4	27.38	21.13	6.11	0.37	7-Jul
LS	IT91LS	4	27.78	20.58	5.88	0.46	30-Jun
LS	IT92LS	4	28.75	21.10	6.40	0.37	8-Jul
LS	IT94LS	4	29.13	21.20	6.55	0.79	4-Jul
LS	IT97LS	4	27.93	20.65	5.95	0.13	5-Jul
LS	JL02LS	4	28.80	20.58	6.10	0.25	29-Jun
LS	JL03LS	4	27.23	20.70	5.84	0.63	1-Jul
LS	JL04LS	4	27.05	20.80	5.86	0.84	
LS	JL05LS	4	29.75	20.20	6.07	0.28	3-Jul
LS	JL08LS	4	29.85	21.13	6.66	0.36	1-Jul
LS	JL10LS	4	28.48	20.23	5.82	0.21	3-Jul
LS	JL11LS	4	28.20	20.80	6.10	0.83	3-Jul
LS	JL14LS	4	28.15	20.85	6.12	0.33	1-Jul
LS	JL15LS	4	27.50	20.38	5.71	0.26	4-Jul
LS	JL16LS	4	28.40	20.75	6.12	0.56	3-Jul
LS	JL17LS	4	28.70	20.23	5.87	0.33	28-Jun
LS	JL18LS	4	28.40	20.68	6.07	0.79	1-Jul
LS	JL19LS	4	30.20	21.23	6.80	0.50	4-Jul
LS	JL20LS	4	28.70	20.68	6.14	0.46	26-Jun
LS	JL22LS	4	29.90	21.15	6.69	0.28	8-Jul
LS	JL23LS	4	29.05	20.98	6.39	0.62	1-Jul
LS	JL24LS	4	29.45	20.95	6.47	0.68	9-Jul
LS	JL25LS	4	29.10	20.88	6.34	0.75	2-Jul
LS	JL26LS	4	29.43	20.45	6.15	0.62	1-Jul
LS	JL27LS	4	27.83	20.75	5.99	0.47	3-Jul
LS	JL33LS	4	29.38	21.23	6.62	0.39	8-Jul
LS	JL34LS	4	28.63	20.85	6.22	0.37	5-Jul
LS	JL35LS	4	29.60	20.23	6.05	0.10	3-Jul
LS	JL36LS	4	29.68	20.60	6.30	0.05	11-Jul
LS	JL37LS	4	28.70	19.68	5.56	0.28	2-Jul
LS	JL40LS	4	28.73	20.63	6.11	0.35	9-Jul
LS	JL41LS	4	29.53	20.80	6.39	0.52	10-Jul
LS	JL43LS	4	29.28	21.15	6.55	0.66	8-Jul
LS	JL44LS	4	28.90	20.30	5.96	0.42	3-Jul
LS	JL45LS	4	29.18	21.00	6.43	0.43	8-Jul
LS	JL46LS	4	30.57	20.60	6.49	0.38	3-Jul
LS	KC02LS	4	29.55	21.03	6.53	0.71	25-Jun
LS	KC03LS	4	29.25	20.98	6.44	0.51	29-Jun
LS	KC06LS	4	27.67	20.10	5.59	0.24	2-Jul
LS	KC08LS	4	28.70	20.15	5.83	0.21	30-Jun
LS	KC09LS	4	28.57	20.27	5.87	0.26	2-Jul
LS	KC10LS	4	26.65	19.60	5.12	0.13	1-Jul
LS	KC11LS	4	29.30	20.73	6.29	0.67	29-Jun
LS	KC14LS	4	27.90	20.63	5.93	0.28	29-Jun
LS	KC15LS	4	29.50	21.20	6.63	0.21	24-Jun
LS	KC16LS	4	29.00	20.98	6.38	0.39	1-Jul
LS	KC17LS	4	27.73	20.10	5.60	0.43	30-Jun

Species	nest ID	N eggs	Mean Length (mm)	Mean Width (mm)	Mean Volume (ml)	Δ volume (ml)	Start of incubation
Little Stint (<i>continued</i>)	KC19LS	4	28.33	20.30	5.84	0.32	3-Jul
LS	KC20LS	4	28.85	20.65	6.15	0.24	3-Jul
LS	KC22LS	4	29.50	20.95	6.48	0.63	28-Jun
LS	KC23LS	4	27.45	20.45	5.74	0.18	30-Jun
LS	KC24LS	4	28.93	21.10	6.44	0.24	2-Jul
LS	KC25LS	4	28.78	20.75	6.19	0.27	3-Jul
LS	KC27LS	4	29.88	21.13	6.67	0.35	5-Jul
LS	KC29LS	4	29.33	20.73	6.30	0.36	2-Jul
LS	KC31LS	4	28.48	20.70	6.10	0.39	10-Jul
LS	KC32LS	4	29.30	20.68	6.26	0.20	3-Jul
LS	KC34LS	4	29.43	21.70	6.93	0.30	4-Jul
LS	KC36LS	4	28.28	20.73	6.07	0.58	3-Jul
LS	KC37LS	4	27.97	20.97	6.15	0.26	3-Jul
LS	KC40LS	4	27.05	20.65	5.77	0.51	1-Jul
LS	KC42LS	4	27.38	20.15	5.56	0.23	3-Jul
LS	KC44LS	4	30.05	20.60	6.38	0.34	
LS	KC46LS	4	29.18	20.50	6.14	0.71	30-Jun
LS	KC49LS	4	29.25	20.93	6.40	0.36	23-Jun
Red Phalarope	HS72PH	4	32.08	22.53	8.14	1.23	29-Jun
PH	IT78PH	3	31.33	23.23	8.46	0.92	25-Jun
PH	IT88PH	4	33.70	22.68	8.66	0.42	6-Jul
PH	IT96PH	4	32.20	22.85	8.41	0.45	8-Jul
PH	JL07PH	4	33.05	22.78	8.57	0.49	29-Jun
PH	KC30PH	4	30.55	23.43	8.38	0.45	4-Jul
PH	KC39PH	3	32.60	22.50	8.25	0.15	26-Jun
Pectoral Sandpiper	HS80PS	4	38.40	26.35	13.33	0.76	2-Jul
PS	IT21PS	4	36.30	26.40	12.65	0.68	27-Jun
Red-necked Phalarope	IT58RN	4	29.63	20.70	6.35	0.29	27-Jun
Ringed Plover	IT05RP	3	33.50	24.57	10.11	0.83	23-Jun
RP	IT06RP	4	35.28	25.50	11.47	0.87	24-Jun
RP	IT08RP	4	34.18	24.80	10.51	0.36	24-Jun
RP	IT67RP	4	33.00	24.58	9.97	0.57	29-Jun
RP	JL21RP	4	35.58	25.55	11.61	0.89	6-Jul
RP	KC33RP	3	32.37	25.37	10.41	0.09	9-Jul
Ruff	HS69RU	4	45.50	29.95	20.41	1.70	6-Jul
RU	IT63RU	4	43.65	31.23	21.30	3.14	27-Jun
Temminck's Stint	JL32TS	4	27.53	20.88	6.00	0.40	10-Jul
Turnstone	HS08TU	4	38.97	29.23	16.66	2.02	24-Jun
TU	HS16TU	4	38.63	28.05	15.19	1.28	24-Jun
TU	HS17TU	4	40.33	28.13	15.95	0.55	25-Jun
TU	HS25TU	4	39.65	28.93	16.58	0.60	22-Jun

Species	nest ID	N eggs	Mean Length (mm)	Mean Width (mm)	Mean Volume (ml)	Δ volume (ml)	Start of incubation
Turnstone (<i>continued</i>)	HS27TU	5	38.42	29.08	16.25	1.11	27-Jun
TU	HS57TU	4	39.05	27.58	14.85	0.58	25-Jun
TU	HS65TU	4	40.23	29.10	17.03	0.08	27-Jun
TU	IT28TU	4	39.75	28.93	16.63	0.78	25-Jun
TU	IT36TU	4	39.28	27.75	15.12	0.49	25-Jun

Appendix 2b. Egg size measurements of selected non-shorebird species. Given are number of eggs measured, mean length and width (measured to nearest 0.1 mm), and mean volume (calculated as $0.5 \times \text{length} \times \text{width}^2$) of measured eggs, as well as the difference in volume between the largest and the smallest egg of the clutch (Δ volume).

Species	nest ID	N eggs	Mean Length (mm)	Mean Width (mm)	Mean Volume (ml)	Δ volume (ml)
Brent Goose	BG01	4	73.55	47.80	84.08	9.75
BG	BG03	6	71.47	48.40	83.73	6.91
BG	BG04	6	69.58	45.05	70.81	20.37
BG	HS23BG	6	70.35	45.20	71.85	2.71
BG	HS71BG	6	72.03	46.40	77.54	2.17
Long-tailed Duck	KC38LD	>6	54.79	39.26	42.26	6.38
Long-tailed Skua	HS56LO	2	52.60	37.00	36.01	1.81
LO	IT35LO	2	53.65	40.70	44.43	1.20
LO	IT50LO	2	53.30	37.30	37.09	2.31
Pomarine Skua	HA00PO	6	61.85	43.70	59.06	1.91
PO	HS37PO	2	65.20	44.90	65.73	6.03
PO	HS47PO	2	64.75	45.25	66.28	1.07
PO	HS51PO	2	59.85	45.10	60.91	6.13
PO	HS52PO	2	72.00	44.10	70.01	1.89
PO	HS54PO	2	65.95	45.95	69.64	4.34
PO	HS61PO	2	63.20	44.90	63.73	4.53
PO	HS63PO	2	66.70	43.75	63.85	3.60
PO	HS73PO	2	62.30	45.70	65.03	0.91
PO	HS81PO	2	64.40	44.30	63.19	1.20
PO	HS92PO	2	62.45	41.65	54.18	3.29
PO	HS97PO	2	64.10	44.35	63.04	0.66
PO	IT04PO	2	67.85	46.20	72.42	3.07
PO	KC12PO	1	61.00	43.50	57.71	0.00

Appendix 3. Biometrics of captured shorebirds

The table below lists all full-grown shorebirds that were captured for ringing in 2002, with details on capture date, phase of breeding cycle, colour-marks, nest number, age, sex and measurements (in mm) of bill length, total head length, wing length, tarsus, tarsus+toe and body mass (in g). Data are ordered by ring number within species; 'R' behind the ring number denotes a recapture of a ringed bird.

Phase of breeding cycle denotes whether the bird was trapped during the spring migration/arrival period (spring), while incubating a clutch (incubation), tending chicks (brood), or during autumn migration/departure (autumn).

Colour ring positions are denoted as: left tibia/left tarsus;right tibia/right tarsus, with colours abbreviated as: r red, w white, y yellow, k pink, b blue, m metal ring.

All sex determinations are based on plumage characters or size; those for Little Stint and Dotterel are tentative.

ring number	date	phase	nest	colour-rings	sex	age	bill	total head	tarsus	tarsus +toe	wing	mass
Curlew Sandpiper												
DEAD	10-Aug	autumn				1	36.9	62.0	34.1	57.0	130	53.2
KS04473	4-Aug	autumn				1	39.3	63.8	32.0	55.0	136	55.0
KS04479	9-Aug	autumn				1	35.0		30.7	52.5	134	50.7
KS04831	10-Jul	nest	JL06CS	y/yy;y/km	F	>2	38.7	63.5	29.4	54.0	134	69.5
KS04838	16-Jul	nest	JL38CS	b/yb;w/km	F	>2	38.5	63.8	31.2	54.5	136	59.0
KS04842	30-Jul	autumn			F	>2	43.8	68.2	33.7	57.8	133	72.0
KS04843	30-Jul	autumn			F	>2	37.9	61.8	31.2	55.0	132	62.0
KS04844	30-Jul	autumn			F	>2	39.4	64.7	33.2	54.5	130	51.8
KS06301	14-Jun	spring			M	>2	36.5	62.0	30.9	51.5	132	58.8
KS06302	14-Jun	spring			F	>2	43.1	68.8	33.1	56.5	141	65.1
KS06306	17-Jun	spring			M	>2	39.8	64.2	32.2	55.0	135	59.5
KS06327	10-Jul	nest	HS44CS	r/rr;k/km	F	>2	41.4	65.4	31.6	55.0	131	61.7
KS06328	10-Jul	nest	HS75CS	r/bb;k/km	F	>2	42.8	67.2	30.6	56.0	129	63.7
KS06345	16-Jul	nest	IT86CS	r/ww;k/km	F	>2	39.6	64.1	31.2	55.0	139	65.0
KS06351	4-Jul	nest	IT03CS	r/rr;k/km	F	>2	41.7	67.2	32.2	56.5	136	65.0
KS06356	7-Jul	nest	IT20CS	y/br;k/km	F	>2	41.2	65.3	32.4	57.0	135	64.5
KS06357	7-Jul	nest	KC07CS	r/yy;y/km	F	>2	44.3	68.2	34.4	58.0	136	59.0
KS06360	10-Jul	nest	IT23CS	r/bb;y/km	F	>2	40.8	65.2	31.3	54.0	133	56.5
KS06361	10-Jul	nest	HS86CS	r/kk;y/km	F	>2	39.1	65.4	32.9	58.0	137	61.7
KS06362	10-Jul	nest	IT42CS	w/yw;w/km	F	>2	39.3	64.4	33.0	57.0	131	65.0
KS06382	15-Jul	brood	IT12CS	b/by;y;k/m	F	>2	37.5	61.8	28.5	52.5	137	60.9
KS07481	11-Jun	spring			F	>2	39.3	63.8	30.7	51.0	138	59.0
KS07486	10-Jun	spring			F	>2	38.3	62.5	31.4	53.5	137	61.6
KS07487	10-Jun	spring			M	>2	37.3		30.7	56.0	131	56.3
Dotterel												
HS008741	20-Jun	spring			M	>2	19.5	53.0	40.0	66.0	162	135.0
HS008742	20-Jun	spring			F	>2	16.2	49.2	35.7	59.0	163	127.0
HS008743	20-Jun	spring			F	>2	17.2	49.2	36.2	61.0	151	121.5
HS008746	21-Jun	spring			M	>2	16.0	49.3	38.7	64.0	156	120.0
HS008747	13-Jul	nest	SK05DO		M	>2	15.5	49.9	37.2	61.5	157	110.0

ring number	date	phase	nest	colour-rings	sex age	bill	total head	tarsus	tarsus +toe	wing	mass
Dunlin											
KS02673	4-Aug	brood	KCDU01		M >2	32.2	56.7	26.5	48.0	120	
KS04474	6-Aug	autumn			M >2	37.0	60.8	27.6	50.5	116	52.5
KS04475	6-Aug	autumn			M >2	33.0	57.2	26.8	48.5	109	44.5
KS04476	6-Aug	autumn			M >2	32.5	56.7	24.8	47.0	115	47.3
KS04477	6-Aug	autumn			M >2	32.1	55.3	23.4	46.0	114	43.5
KS04478	8-Aug	autumn			F >1	37.1	60.7	25.7	49.0		54.0
KS04480	10-Aug	autumn			1	31.9	55.7	26.2	49.0	122	48.3
KS04481	10-Aug	autumn			M >2	33.9	57.2	25.2	48.0	120	43.0
KS04806	15-Jul	brood	HS04DU	k/km;w/bw	M >2	31.3	56.6	25.4			50.8
KS04845	11-Aug	autumn			M >1	33.5	55.6	27.6	50.0	117	47.2
KS04846	11-Aug	autumn			M >1	34.0	58.2	28.3	48.0	120	58.0
KS04847	11-Aug	autumn			F >1	32.2	55.5	26.8	49.0	116	47.5
KS04882	18-Jul	nest	KC35DU	b/rw;b/km	F >1	38.0	61.4	27.2	50.0	118	55.2
KS06123	R 13-Jul	nest	HS91DU	k/rk;k/km	M >2	34.1	57.2	25.3	48.5	118	51.0
KS06303	14-Jun	spring		y/wb;k/km	M >2	34.5	58.9	25.5	48.0	119	50.2
KS06304	15-Jun	spring		w/kk;k/km	M >2	31.2	55.6	24.6	45.5	117	43.7
KS06305	15-Jun	spring		y/yk;k/km	M >2	32.7	57.1	26.0	47.0	117	43.7
KS06307	17-Jun	spring		w/rr;w/km	M >2	33.3	57.6	26.2	49.5	117	46.0
KS06308	17-Jun	spring		y/ww;y/km	F >2	36.7	61.0	25.9	48.0	121	53.3
KS06321	1-Jul	nest	CK04DU	r/rb;k/km	F >2	36.8	61.5	26.2	49.0	124	55.8
KS06326	3-Jul	nest	HS09DU	y/bb;b/km	F >2	37.3	61.0	25.5	47.0	120	50.0
KS06329	12-Jul	nest	HS09DU	w/ww;w/km	M >2	33.1	55.1	24.8	46.5	118	57.3
KS06331	13-Jul	nest	HS13DU	r/wr;r/km	M >2	33.0	56.2	24.9	46.0	118	53.5
KS06332	14-Jul	nest	HS04DU	w/rb;k/km	F >2	37.9	62.2	26.6	50.0	121	55.5
KS06337	14-Jul	nest	IT47DU	r/rw;y/km	M >2	29.8	54.0	24.3	45.5	117	52.5
KS06352	4-Jul	nest	HS22DU	y/bk;b/km	F >2	35.6	61.0	27.5	50.0	127	59.0
KS06353	5-Jul	nest	TK02DU	y/rb;m/kw	M >2	33.2	57.0	26.6	49.0	119	55.0
KS06354	6-Jul	nest	HS01DU	w/ky;w/km	F >2	35.9	60.8	24.1	47.0	121	52.0
KS06355	7-Jul	nest	IT33DU	k/ky;k/km	F >2	37.4	62.0	28.9	51.0	125	56.0
KS06358	8-Jul	nest	IT14DU	b/yw;w/km	F >2	34.9	59.1	26.3	49.0	121	57.5
KS06363	10-Jul	nest	HS46DU	y/wk;y/km	M 2	31.4	55.2	25.5	48.5	115	48.0
KS06364	11-Jul	nest	KC04DU	r/ky;k/km	M >2	33.2	58.3	26.1	49.0	119	54.8
KS06365	11-Jul	nest	HS66DU	w/rk;w/km	M 2	33.4	56.9	25.5	47.5	119	48.9
KS06366	11-Jul	nest	KC26DU	w/kb;w/km	M 2	30.8	54.8	25.2	47.0		51.0
KS06367	11-Jul	nest	IT33DU	r/kw;w/km	M >2	32.2	56.8	26.2	49.0	118	52.2
KS06368	12-Jul	nest	TK02DU	y/wr;b/km	F >2	36.9	60.8	25.7	49.5	117	55.2
KS06369	12-Jul	nest	HS07DU	r/wy;r/km	F >1	36.0	60.0	28.3	49.0		56.9
KS06390	15-Jul	brood	IT14DU	b/kb;k/km	M 2	33.3	57.5	24.2	46.0	114	46.5
KS07204	R 7-Jul	nest	HS01DU	r/yb;w/km	M >2	33.8	57.3	27.4	49.0	113	52.7
KS07480	9-Jun	spring		y/bw;w/km	M >2	36.5	59.6	25.2	45.5	119	46.0
KS07482	10-Jun	spring		k/yby/km	M >2	32.6	56.7	26.3	51.0	117	46.3
KS07483	10-Jun	spring		r/ry;y/km	F >2	36.0	61.4	27.6	51.0	121	48.4
KS07484	10-Jun	spring		w/bk;b/km	F 2	38.6	63.6	26.7	49.0	118	51.1
KS07485	10-Jun	spring		r/rr;r/km	F >2	41.0	65.9	27.2	50.5	121	57.1
KS07491	10-Jun	spring		w/ry;y/km	M >2	35.4	65.0	26.8	50.0	125	54.5
KS07492	11-Jun	spring		r/by;w/km	M >2	30.9	55.3	26.1	47.5	116	49.3
KS07493	12-Jun	spring		w/wr;k/km	F >2	38.3	63.1	25.6	48.0	118	53.4
KS07494	13-Jun	spring		w/br;y/km	M >2	30.6	55.2	24.3	45.0	113	41.8
KS07495	13-Jun	spring		r/kk;r/km	F >2	37.3	62.0	28.1	51.0	121	52.7
KS07496	13-Jun	spring		b/br;r/km	F >2	36.6	60.6	27.0	49.5	120	45.3
KS07497	13-Jun	spring		r/bw;w/km	M >2	33.0	57.1	26.6	48.0	118	47.3
KS07498	13-Jun	spring		y/yr;r/km	M >2	31.5	55.2	23.8	45.0	118	44.6
KS07499	13-Jun	spring		r/rb;w/km	M >2	32.9	57.8	25.2	47.0	118	49.7
KS07500	13-Jun	spring		y/rw;w/km	F >2	36.6	60.8	28.0	50.0	122	52.7

ring number	date	phase	nest	colour-rings	sex age	bill	total head	tarsus	tarsus +toe	wing	mass
Pacific Golden Plover											
7696846	R 22-Jul	brood	IT16GP	r/km;r/br	M >2	24.1	58.8	41.9	72.2	167	137.0
HS004605	R 22-Jul	brood	IT16GP	r/w;r/km	F >2						133.0
HS004615	23-Jul	nest	IT77GP		M >2	22.6	57.5	44.5	75.0	173	124.0
HS004619	23-Jul	nest	IT40GP		M >2	20.8	56.2	41.5	71.5	170	128.0
HS004620	23-Jul	nest	IT40GP		F >2	20.5	54.6	43.5	74.0	172	143.0
HS004625	25-Jul	nest	HS34GP	w/yy;y/km	M >2	21.6	55.5	42.2	72.5	162	128.0
HS004626	25-Jul	nest	HS34GP	w/ry;w/km	F >2	22.0	55.6	41.5	71.0		140.0
HS004669	R 23-Jul	nest	IT77GP	w/rw;w/km	F >2						126.0
HS004683	22-Jul	brood	JL12GP	y/br;b/km	M >2	22.3	56.8	43.4	74.0	165	123.0
HS004684	22-Jul	brood	JL12GP	w/bb;r/km	F >2	22.1	55.6	41.4	71.0	175	130.0
HS004688	22-Jul	brood	IT07GP	y/kb;y/km	F >2	23.1	58.4	44.7	75.0	173	146.0
HS004690	22-Jul	brood	IT07GP	b/ky;r/km	M >2	21.3	54.3	41.8	72.0	169	
HS008779	23-Jul	nest	IT31GP	w/wr;b/km	M >2	23.6	58.7	40.1	74.0	172	133.0
HS008780	23-Jul	nest	IT31GP	y/km;r/yr	F >2	24.8	56.8	43.6	75.0	167	131.0
HS008785	23-Jul	nest	IT72GP	w/br;w/km	M >2	23.8	57.5	41.4	74.0	169	134.5
Red Knot											
HS004752	30-Jul	brood	ITKN06		M >2	35.2	64.8	32.1	60.0	177	124.0
HS008737	14-Jun	spring			>2	33.2	60.9	33.2	61.5	168	134.0
HS008738	15-Jun	spring			>2	35.0	63.9	30.0	56.0	168	138.5
Little Stint											
DEAD	7-Aug	autumn			1	18.3	38.8	21.7	39.5	96	22.8
FS11001	13-Jun	spring			F >1	18.8	39.6	22.2	40.0	103	20.5
FS11002	21-Jun	spring		r/ry;y/km	M >1	17.1	38.4	21.1	39.0	98	24.4
FS11003	22-Jun	spring		w/wr;b/km	M >1	19.6	40.8	22.6	40.0	96	28.8
FS11004	3-Jul	nest	IT52LS	k/bw;w/km	>1	19.2	39.3	22.0	42.0	97	31.0
FS11005	5-Jul	nest	IT17LS	b/yb;w/km	M >1	18.5	39.1	21.4	41.0	98	26.8
FS11005	R 21-Jul	brood	IT71LS		>1						23.3
FS11006	5-Jul	nest	IT18LS	w/wy;y/km	F >1	17.8	38.4	22.1	40.0	97	27.1
FS11007	9-Jul	nest	HS68LS	b/yk;y/km	M 2	18.8	39.4	21.3	39.0	100	28.4
FS11008	10-Jul	nest	JL16LS	b/ww;w/km	M >1	20.0	39.5	21.1	39.5	99	30.3
FS11009	10-Jul	nest	IT68LS	k/yy;k/km	M >1	19.0	39.7	22.6	41.0	99	29.9
FS11010	10-Jul	nest	HS84LS	b/rb;y/km	M >1	18.7	39.6	22.0	40.0	93	26.8
FS11011	10-Jul	nest	HS87LS	k/ry;k/km	M >1	19.0	39.2	21.8	41.0	100	31.5
FS11012	12-Jul	nest	IT79LS	r/rw;b/km	F >1	19.2	40.5	23.5	43.0	100	27.8
FS11013	14-Jul	nest	KC02LS	r/rw;w/km	>1	19.8	40.5	23.2	40.5	99	29.3
FS11014	14-Jul	nest	KC27LS	w/yr;b/km	>1	18.1	39.1	21.1	39.0	97	32.0
FS11015	15-Jul	nest	IT76LS	b/rb;r/km	F >1	18.3	39.1	22.6	41.0	100	28.7
FS11016	15-Jul	nest	IT64LS	r/rb;y;km	M >1	18.2	38.7	22.7	41.0	97	32.0
FS11017	15-Jul	nest	IT62LS	y/rb;r/km	F >1	18.0	38.8	21.0	40.5	99	29.3
FS11018	15-Jul	nest	IT60LS	b/rb;b/km	M >1	17.4	37.5	20.7	38.0	95	29.0
FS11019	15-Jul	nest	IT61LS	r/yy;w/km	>1	16.8	38.1	21.5	41.0	98	31.0
FS11024	15-Jul	nest	IT59LS	y/ww;y/km	F >1	18.5	39.2	21.6	40.0	102	34.0
FS11025	15-Jul	nest	JL08LS	k/kb;k/kb	M >1	18.4	38.4	21.1	39.5	94	25.8
FS11026	15-Jul	nest	IT56LS		F >1	18.5	37.9	21.1	40.5	104	27.5
FS11031	16-Jul	nest	IT84LS	w/kb;w/km	F >1	17.6	38.2	20.7	39.0	100	28.7
FS11032	16-Jul	nest	IT87LS	r/bw;r/km	M >1	18.4	39.0	19.5	37.0	95	24.5
FS11033	17-Jul	nest	IT67LS	w/wy;w/km	F >1	17.9	38.5	22.0	40.5	99	29.3
FS11034	17-Jul	nest	IT90LS	w/ry;y/km	M >1	17.8	39.0	20.9	39.0	98	29.0
FS11035	17-Jul	nest	IT91LS	r/rb;w/km	F >1	18.4	38.5	20.8	39.5	99	28.7
FS11041	18-Jul	nest	JL23LS	b/ww;y/km	M >1	17.5	37.5	20.7	39.0	95	31.0
FS11059	20-Jul	Nest	IT94LS	b/br;r/km	M >1	17.2	38.1	21.0	39.0	96	27.8

ring number	date	phase	nest	colour-rings	sex	age	bill	total head	tarsus	tarsus +toe	wing	mass
Little Stint (continued)												
FS11062	20-Jul	brood	ITLS01	b/kr;w/km	M	>1	19.9	39.9	21.4	39.5	98	26.8
FS11066	23-Jul	nest	IT79LS	b/wr;w/km	M	>1	18.4	39.3	21.8	40.5	98	32.9
FS11074	26-Jul	brood	ITLS04	b/wr;w/km	M	>1	19.3	39.2	21.7	38.0	98	25.3
FS11077	26-Jul	brood	ITLS05	b/yr;k/km	F	>1	20.6	39.9	22.2	41.0	103	25.3
FS11091	30-Jul	brood	JLS03	w/yb;b/km	F	>1	19.3	40.2	22.4	40.5	100	27.7
FS11096	30-Jul	autumn			F	>1	18.9	40.0	22.4	40.0	103	30.8
FS11097	30-Jul	autumn				>1	18.9	38.1	20.7	39.5	97	25.5
FS11098	30-Jul	autumn				>1	20.0	39.4	20.9	40.0	97	25.4
FS11100	31-Jul	brood	JLS05	k/ry;w/km	M	>1	17.1	36.1	21.0	40.5	97	25.4
FS11101	8-Jul	nest	IT70LS	y/bk;w/km	M	>1	20.0	40.1	21.8	40.0	99	30.0
FS11102	8-Jul	nest	JL17LS	w/wy;y/km	M	>1	18.7	38.3	20.2	40.0	96	29.0
FS11103	9-Jul	nest	JL15LS	k/wb;y/km	F	>1	18.3	39.3	21.1	39.0	101	26.9
FS11104	9-Jul	nest	JL20LS	w/by;y/km	F	>1	18.6	39.2		39.0	101	29.0
FS11105	10-Jul	nest	KC09LS	r/bk;w/km	F	>1	19.3	41.0		41.0	104	29.9
FS11106	12-Jul	nest	JL27LS	y/rb;y/km	M	>1	18.2	38.5		38.0	95	28.5
FS11107	15-Jul	nest	HS76LS			>1						28.9
FS11108	15-Jul	nest	HS79LS	r/kr;b/km		>1	19.0	39.8	22.1	41.5	98	31.8
FS11109	15-Jul	nest	HS70LS	b/bk;y/km	F	>1	18.2	38.6	22.1	41.0	101	31.0
FS11110	15-Jul	nest	HS74LS	k/wr;r/km	M	>1	17.6	38.8	21.2	38.2	96	28.0
FS11111	16-Jul	nest	JL34LS	w/bb;y/km	F	>1	18.7	39.8	20.9	40.0	102	26.9
FS11112	16-Jul	nest	JL33LS	y/kb;y/km	F	>1	18.9	39.7	22.1	41.0	103	27.8
FS11113	16-Jul	nest	JL37LS	r/yy;k/km	F	>1	19.5	39.2	20.7	40.5	104	29.5
FS11114	16-Jul	nest	JL35LS	b/by;y/km		>1	17.1	37.5	20.5	40.0	98	27.7
FS11115	17-Jul	nest	JL43LS	k/kr;r/km	M	>1	16.8	36.4	20.3	39.5	96	24.0
FS11116	17-Jul	nest	JL44LS	b/rw;y/km	M	>1	18.4	39.7	20.6	40.0	100	28.0
FS11117	17-Jul	nest	JL45LS	k/bb;w/km	M	>1	17.8	37.6	19.8	38.5	96	24.0
FS11118	17-Jul	nest	JL41LS	y/br;y/km	F	>1	18.5	39.4	22.3	40.5	100	26.2
FS11129	23-Jul	brood	JL46LS		F	>1	19.2	39.8	21.7	41.7	102	30.5
FS11130	8-Jul	nest	IT71LS	w/ry;y/km	F	>1	19.6	40.2	21.8	40.5	104	34.0
FS11131	8-Jul	nest	HS38LS	w/kr;w/km		>1	19.1	40.0	21.9	40.0	102	28.3
FS11132	8-Jul	nest	IT66LS	y/rw;y/km	F	>1	18.0	38.8	21.4	38.5	100	29.5
FS11133	8-Jul	nest	KC25LS	y/wy;b/km	M	>1	18.1	39.0	22.3	40.0	98	30.0
FS11133	R 1-Aug	autumn	KC25LS	y/wy;b/km		>1						26.8
FS11134	9-Jul	nest	HS38LS	b/wb;k/km	F	>1	19.4	41.7	23.6	43.5	103	30.1
FS11135	9-Jul	nest	HS58LS	b/bk;k/km	M	>1	19.0	38.9	21.9	41.5	96	24.9
FS11146	23-Jul	nest	JL36LS	k/kw;k/km	F	>1	17.7	38.6	21.0	41.1	104	30.0
FS11152	19-Jul	nest	HS96LS	b/kw;y/km	M	>1	18.0	39.6	22.6	40.0	98	32.3
FS11163	1-Aug	autumn				>1	19.5	39.2	21.0	39.0	101	28.5
FS11164	5-Aug	autumn				>1	18.7		20.8	39.0	95	23.3
FS11168	6-Aug	autumn				1	19.0	39.0	21.0	38.5	97	22.4
FS11169	6-Aug	autumn				1	17.7	38.8	21.5	40.5	100	23.2
FS11170	6-Aug	autumn				1	18.3	39.0	23.0	40.5	101	23.2
FS11171	6-Aug	autumn				1	17.7	37.7	21.6	39.5	95	20.6
FS11172	6-Aug	autumn				1	17.0	36.8	21.2	39.0	96	25.3
FS11174	8-Aug	autumn				1	17.7	38.7	21.6	40.0	98	24.2
FS11175	8-Aug	autumn				1	18.0	38.8	20.9	39.5	98	24.8
FS11176	10-Aug	autumn				1	18.6	39.3	22.1	42.0	101	25.3
FS11177	10-Aug	autumn				1	19.0	39.2	22.1	40.0	98	
FS11178	10-Aug	autumn				1	19.9	39.4	21.7	40.0	102	24.8
FS11179	10-Aug	autumn				1	18.1	38.9	21.2	40.0	99	22.8
FS11180	10-Aug	autumn				1	18.0	39.4	22.3	40.5	103	28.1
FS11181	10-Aug	autumn				1	17.6	38.5	22.0	40.0	97	28.7
FS11182	10-Aug	autumn				1	18.2	39.3	21.2	41.5	101	28.5
FS11201	31-Jul	autumn	KCLS06		F	>1	18.7	38.7	22.2	41.0	101	27.8

ring number	date	phase	nest	colour-rings	sex	age	bill	total head	tarsus	tarsus +toe	wing	mass
Little Stint (continued)												
FS11202	1-Aug	autumn	KCLS06		F	>1	18.8	38.8	21.6	41.0	100	27.9
FS11203	1-Aug	autumn			F	>1	19.3	39.8	22.5	41.0	100	24.6
FS11204	1-Aug	autumn			M	>1	19.4	39.5	21.5	40.5	93	25.5
FS11205	1-Aug	autumn			F	>1	18.8	38.7	21.4	40.0	100	28.0
FS11206	1-Aug	autumn			F	>1	19.3	39.6	22.9	42.0	103	30.5
FS11207	1-Aug	brood	ITLS08	w/kk;w/km	M	>1	18.1	38.5	21.3	40.0	99	26.5
FS11212	2-Aug	autumn				>1	19.1	39.9	22.2	39.5	97	30.0
FS11215	7-Aug	autumn			F	>1	18.6	38.6	21.9	40.5	99	26.8
FS11216	7-Aug	autumn				>1	19.7	39.7	22.3	41.0	97	26.0
FS11217	7-Aug	autumn				1	19.2	39.7	23.7	43.0	101	26.3
FS11235	1-Aug	brood	HSLS05	k/rb;y/km	M	>1	18.0	38.2	20.5	38.0	100	24.8
FS11303	19-Jul	brood	HSLS03	y/rk;w/km	M	>1	17.9	38.8	22.5	41.0	95	30.3
FS11308	19-Jul	nest	KC46LS	y/wb;r/km	M	>1	18.7	39.5	23.6	41.0	96	35.2
FS11309	20-Jul	nest	IT80LS	y/bw;y/km	M	>1	18.5	39.2	23.1	42.0	100	30.2
FS11351	23-Jul	nest	JL40LS			>1	16.4	36.6	20.7	40.4		29.4
FS11380	29-Jul	brood	JLLS02	r/yk;b/km		>1	18.5	38.3	21.2	38.0	96	24.0
FS11381	31-Jul	brood	ITLS07	r/wk;r/km		>1	18.2	37.5	21.1	39.5	99	29.1
FS11393	11-Aug	autumn				1	19.5	38.0	23.0	40.0	98	23.2
FS11401	7-Jul	nest	HS67LS	b/rr;b/km	F	>1	18.4	39.2	21.2	40.0	98	25.7
FS11402	7-Jul	nest	IT38LS	b/yw;w/km	M	>1	17.8	38.0	22.8	40.0	97	27.2
FS11403	9-Jul	nest	KC24LS	y/yr;k/km	M	>1	17.3	37.3	22.2	40.5	96	26.6
FS11404	10-Jul	nest	IT39LS	y/yy;r/km	M	>1	19.8	39.6	20.9	40.0	99	28.7
FS11405	10-Jul	nest	HS19LS	w/by;r/km	F	>1	18.0	40.2	21.4	40.0	102	29.0
FS11406	10-Jul	nest	HS42LS	k/rr;y/km	M	>1	17.3	37.7	20.2	37.0	94	23.7
FS11407	10-Jul	nest	KS20LS	y/kw;r/km	M	>1	17.2	38.1	21.3	39.0	98	28.8
FS11408	12-Jul	nest	HS90LS	w/yy;y/km	M	>1	18.3	38.6	21.4	40.0	99	28.3
FS11409	14-Jul	brood	HS59LS	r/br;w/km	M	>1	16.8	37.5	21.1	39.0	100	30.4
FS11410	16-Jul	nest	HS94LS	k/wk;y/km	F	>1	18.2	38.3	22.3	40.5	101	28.0
FS11411	16-Jul	nest	IT43LS	k/kw;w/km	M	>1	19.0	39.7	22.2	40.0	96	27.7
FS11412	17-Jul	nest	HS95LS	w/kw;k/km	M	>1	18.3	39.2	21.9	41.0	98	29.8
FS11413	17-Jul	nest	IT82LS	k/bw;b/km	M	>1	17.5	38.5	21.5	39.0	97	28.7
FS11414	17-Jul	nest	HS36LS	k/br;y/km	M	>1	18.9	40.0	21.4	40.0	97	28.2
FS11415	18-Jul	brood	HSLS02	y/yb;b/km	M	>1	16.3	36.8	20.5	39.0	98	28.6
FS11424	19-Jul	autumn				>1	18.0	38.8	22.0	40.0	99	21.2
FS11450	8-Jul	nest	HS82LS	r/kw;k/km	F	>1	19.9	40.2	22.8	42.0	103	33.5
FS11451	8-Jul	nest	KC06LS	k/ky;w/km	F	>1	18.7	38.8	21.7	39.5	95	27.0
FS11452	8-Jul	nest	JL06LS	b/ky;w/km	M	>1	18.0	37.4	21.5	39.0	95	28.0
FS11453	8-Jul	nest	IT54LS	w/ww;r/km	M	>1	18.3	39.1	22.6	39.0	97	29.5
FS11454	8-Jul	nest	HS18LS	y/kk;w/km	M	>1	17.2	38.3	22.1	40.0	96	29.0
FS11455	9-Jul	nest	KC29LS	w/kr;w/km	M	>1	17.4	38.2		41.5	95	28.3
FS11456	9-Jul	nest	KC14LS	y/rw;k/km	F	>1	18.1	38.4	22.6	39.5	97	24.5
FS11457	10-Jul	nest	KC23LS	r/by;y/km	M	>1	19.0	39.2	23.2	41.0	97	26.7
FS11458	10-Jul	nest	KC11LS	b/yk;b/km	F	>1	19.9	39.4		40.0	102	29.2
FS11459	10-Jul	nest	IT45LS	r/rw;k/km	M	>1	18.5	39.4	22.1	39.0	96	25.0
FS11460	10-Jul	nest	KC10LS	b/yy;b/km	M	>1	19.5	39.2	23.6	40.0	100	25.7
FS11461	10-Jul	nest	KC03LS	r/rk;y/km	F	>1	20.1	39.4	23.6	41.0	103	31.2
FS11462	10-Jul	nest	HS43LS	w/br;w/km	F	>1	18.8	38.5	22.0	39.5	102	24.7
FS11463	10-Jul	nest	HS88LS	b/bb;w/km	M	>1	19.9	39.5	22.0	41.0	100	25.5
FS11464	15-Jul	nest	KC22LS	y/kw;w/km	M	>1	18.2	39.4	24.0	42.0	100	28.2
FS11465	12-Jul	nest	KC36LS	r/yb;r/km	F	>1	19.1	40.7	23.4	42.0	103	29.2
FS11466	13-Jul	nest	IT51LS	r/bw;b/km	M	>1	20.1	40.3	22.9	42.0	99	30.0
FS11466	R 1-Aug	brood	IT51LS	r/bw;b/km	M	>1						28.8
FS11467	13-Jul	nest	HS53LS	r/bw;k/km	M	>1	18.5	38.4	22.3	38.0	94	25.7
FS11468	13-Jul	Nest	KC37LS	r/kk;w/km	F	>1	19.8	39.8	23.6	42.0	102	30.7

ring number	date	phase	nest	colour-rings	sex	age	bill	total head	tarsus	tarsus +toe	wing	mass
Little Stint (continued)												
FS11469	13-Jul	nest	JL19LS	r/yk;k/km	F	>1	19.0	39.1	21.7	42.0	104	29.7
FS11474	14-Jul	nest	KCLS01	r/wy;w/km	M	>1	17.7	38.7	20.7	38.5	101	28.1
FS11475	14-Jul	nest	HS60LS	k/rw;w/km	M	>1	16.4	36.8	21.1	40.0	101	28.5
FS11476	15-Jul	nest	HS39LS	b/ky;b/km	M	>1	19.6	40.6	22.6	41.0	99	29.2
FS11477	15-Jul	nest	HS50LS	b/kb;w/km	M	>1	18.6	39.8		40.0	101	24.2
FS11478	15-Jul	nest	KC40LS	w/wr;y/km	F	>1	18.9	39.5	24.4	42.0	100	27.7
FS11479	15-Jul	nest	KC31LS	w/rb;r/km	M	>1	18.1	39.0	23.3	40.0	98	28.5
FS11480	15-Jul	nest	JL25LS	b/yl;r/km	F	>1	18.3	39.7	24.5	41.5	102	30.0
FS11481	16-Jul	nest	HS31LS	b/wy;b/km	M	>1	16.9	38.1	22.5	38.5	99	28.7
FS11482	16-Jul	nest	JL22LS	w/rr;y/km	F	>1	18.8	39.9	23.2	42.0	101	25.7
FS11483	16-Jul	nest	IT74LS	r/bb;y/km	M	>1		41.0	22.7	41.0	96	25.2
FS11488	16-Jul	nest	KC34LS	w/rw;y/km	F	>1	17.0	38.3		42.0	103	29.2
FS11489	16-Jul	nest	HS62LS	r/ry;w/km	M	>1	18.9	37.8	21.5	39.0	99	25.7
FS11490	16-Jul	nest	JL14LS	b/yb;b/km	F	>1	19.6	40.7	23.8	42.0	102	28.2
FS11491	16-Jul	nest	JL29LS	b;rk;r/km	F	>1	19.5	40.6		42.0	101	29.2
FS11492	16-Jul	nest	KS42LS	r/yw;y/km	M	>1	18.4	38.4	23.3	39.0	94	24.2
FS11493	17-Jul	nest	JL26LS	k/bk;w/km	F	>1	17.6	38.3	21.6	40.0	102	29.7
FS11493	R 23-Jul	brood	JL26LS	k/bk;w/km		>1						28.1
FS11494	17-Jul	nest	KC32LS	k/kby/km	F	>1	19.3	41.0	22.8	40.0	103	33.0
FS11495	17-Jul	nest	KC44LS	k/yb;b/km	F	>1	20.7		23.0	42.5	103	35.7
FS11497	18-Jul	nest	KC45LS	y/ky;k/km	M	>1	19.3	39.0	23.0	41.0	99	31.2
Pectoral Sandpiper												
KS06347	18-Jul	nest	HS80PS		F	>2	28.2	53.6	29.0	56.0	136	67.7
KS06359	10-Jul	nest	IT21PS		F	>2	26.3	51.5	27.4	54.5	135	65.5
Purple Sandpiper												
KS07488	10-Jun	spring				>2	29.4	55.0	23.9	50.0	132	69.3
KS07489	10-Jun	spring				>2	29.2	54.8	23.4	50.0	131	69.2
Red Phalarope												
KS04848	11-Aug	autumn				1	21.6	45.8	22.5	47.5	131	31.0
KS04871	15-Jul	nest	KC39PH		M	>1	23.3	45.8	24.0	50.0	133	40.0
KS04873	15-Jul	nest	KC30PH		M	>1	21.8	48.0	24.7	46.0	136	51.0
KS06309	24-Jun	spring			F	>2	24.3	49.7	23.6	48.0	139	57.0
KS06310	24-Jun	spring			F	>2	24.0	48.7	22.3	46.0	141	69.0
KS06311	24-Jun	spring			F	>2	24.1	49.9	22.8	48.0	142	61.7
KS06312	24-Jun	spring			M	>2	22.2	46.2	22.3	46.0	135	46.3
KS06313	24-Jun	spring			F	>2	23.6	48.1	22.5	48.0	138	50.5
KS06314	24-Jun	spring			F	>1	24.7	49.9	23.3	48.0	141	71.0
KS06315	29-Jun	spring			F	>1	24.8	49.3	23.7	48.5	144	56.0
KS06316	29-Jun	spring			F	>1	24.6	49.6	22.9	47.0	141	63.8
KS06317	29-Jun	spring			F	>1	22.8	47.7	23.2	47.5	142	65.0
KS06318	29-Jun	spring			M	>1	22.7	45.9	22.8	46.0	134	51.5
KS06318	R 21-Jul	nest	HS98PH			>1						49.8
KS06319	29-Jun	spring			F	>1	24.0	49.5	23.1	43.0	142	67.5
KS06320	29-Jun	spring			M	>1	23.4	46.1	21.9	46.5	135	54.7
KS06322	1-Jul	spring			F	>1	24.0	47.6	23.2	48.5	142	51.4
KS06323	1-Jul	spring			F	>1	23.7	47.4	21.4	44.5	139	65.5
KS06324	1-Jul	spring			M	>1	23.3	47.4	22.7	47.0	132	46.5
KS06325	1-Jul	spring			F	>1	23.4	47.5	22.5	48.0	141	55.0
KS06330	12-Jul	nest	IT78PH		M	>2	23.2	46.0	23.6	48.0	135	47.3
KS06346	16-Jul	nest	IT88PH		M	>2	23.0	46.4	22.8	48.0	136	53.5

ring number	date	phase	nest	colour-rings	sex age	bill	total head	tarsus	tarsus +toe	wing	mass
Ruff											
HS008745	21-Jun	spring			M >2	31.7	59.0	47.1	85.0	191	180.5
Ruddy Turnstone											
FS11030	16-Jul	nest	JL31TS		>1	18.3	37.4	18.3	35.0	100	27.0
HS004612	3-Jul	nest	HS08TU	r/bb;w/km	F >2	21.8	49.0	28.3	51.0	155	108.0
HS004642	11-Aug	autumn			1	21.8	49.7	28.2	56.0	158	94.0
HS008734	10-Jun	spring			M >2	22.6	48.7	26.5	51.0	151	94.0
HS008735	10-Jun	spring			F >2	21.2	49.7	26.8	50.0	156	117.0
HS008736	13-Jun	spring			M >2	21.6	49.5	28.3	50.0	161	103.0
HS008739	15-Jun	spring		y/br;b/km	M >2	20.7	48.1	25.9	51.0	155	97.5
HS008740	15-Jun	spring		y/yy;k/km	F >2	22.3	51.7	26.8	53.0	158	105.5
HS008744	21-Jun	spring			M >2	20.9	49.5	25.7	50.5	152	97.0
HS008786	11-Aug	autumn			1	21.9	49.9	27.0	56.0	150	88.0
HS008787	11-Aug	autumn			1	19.8	47.6	27.6	53.0	144	78.0
HS008788	11-Aug	autumn			1	20.7	49.6	26.4	51.0	156	98.7

