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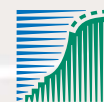
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Waterbirds around the world

A global overview of the conservation,
management and research of the
world's waterbird flyways

Edited by G.C. Boere, C.A. Galbraith and D.A. Stroud

*Assisted by L.K. Bridge, I. Colquhoun, D.A. Scott,
D.B.A. Thompson and L.G. Underhill*



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voedselkwaliteit



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Migration in the balance: tight ecological margins and the changing fortunes of shorebird populations

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ABSTRACT

Dependent as they are on rare and remote open habitats for breeding and survival, shorebirds connect continents and hemispheres with their individual movements. Although many of the wetland systems on which shorebirds rely, especially in the rich West, have now some form of protection, two case studies on man-induced declines of Red Knots *Calidris canutus* in The Netherlands and the USA demonstrate that despite the legislation in these countries, the responsible authorities have tragically failed to provide the necessary safeguards. At the same time, these examples indicate how instructive shorebirds can be in elucidating ecosystem changes at local, and at global, scales. I advocate continued close scientific scrutiny of complementary sets of shorebird species so that we can be informed about their fate, and about the fate of ecosystems world-wide that are so effectively connected by their movements.

INTRODUCTION

Seasonal migration, the phenomenon of birds commuting between parts of the world where they do not reproduce to areas where they do, is a massive phenomenon that has attracted enormous ornithological attention. Shorebirds, or waders, are an important group of truly long-distance migrant waterbirds. These shorebirds connect continents and hemispheres with their individual movements, dependent as they are on rare and remote open habitats for their breeding (mainly in the far north), and on the coastal fringes of the continents or the ephemeral freshwater habitats of continental basins for their survival during the non-breeding season (van de Kam *et al.* 2004, Gill *et al.* 2005). By their very nature, they are particularly susceptible to the effects of human encroachment on coastal habitats, over-exploitation of marine resources, loss of scarce freshwater resources and global climate change (Piersma & Baker 2000,

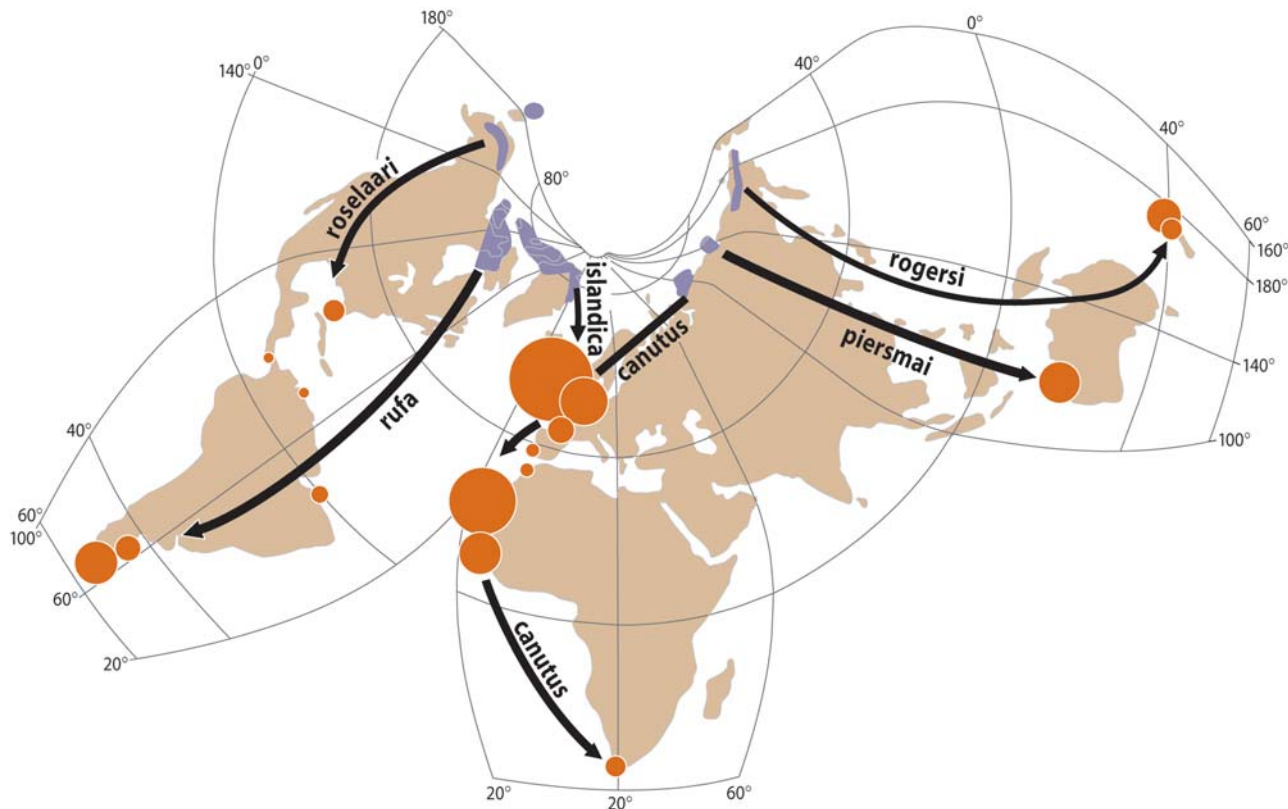


Fig. 1. The world-wide network of flyways of the six subspecies of the Red Knot *Calidris canutus*. The dots scale to the approximate size (in 2004) of the respective wintering populations

Piersma & Lindström 2004). A recent survey by the International Wader Study Group has shown that of 207 shorebird populations with known population trends (out of a total of 511), almost half (48%) are now known to be in decline whereas only 16% are increasing (International Wader Study Group 2003, Stroud *et al.* 2006). With three times as many populations in decline as are increasing, shorebirds must be considered as one of the most globally threatened group of the world's long-distance migrants.

In this contribution, I will focus on two case studies that show how human interference at key staging sites can threaten the survival of supposedly large and healthy migrant shorebird populations. The stories emphasize that the human hand is often involved in population declines. My focal species will be the Red Knot *Calidris canutus*. The first case study concerns the recent population history of Red Knots of the *islandica* subspecies trying to establish themselves in the Dutch Wadden Sea after their return from the breeding grounds in Greenland and north-eastern Canada; the second reveals a similar story for the *rufa* subspecies which, at quite some risk, is now dependent on a single stopover site during its northward migration, Delaware Bay in the USA.

Red Knots are a suitable model species because of their highly specialized feeding behaviour and habitat requirements, which restrict their occurrence outside the breeding season to open coastal intertidal wetland habitats, and their diet to hard-shelled molluscs and crustaceans. Red Knots are sandpipers that breed only on high Arctic tundra but move south from their disjunct, circumpolar breeding areas to non-breeding sites on the coasts of all continents (apart from Antarctica), between latitudes 58°N and 53°S (Fig. 1). Due to their specialized sensory capabilities (Piersma *et al.* 1998), Red Knots generally eat hard-shelled prey found on intertidal, mostly soft, substrates (Piersma *et al.* 1995, 2005a). As a consequence, ecologically suitable coastal sites are few and far between, so they must routinely undertake flights of many thousands of kilometres. The six separate tundra breeding areas each host a population with a sufficiently distinct external appearance during the breeding season (body size and plumage) as to have been assigned subspecific status (Piersma & Davidson 1992, Tomkovich 1992, 2001). There appears to be little overlap in occurrence between any combination of subspecies except for the temporary overlap of some *canutus* and *islandica* Knots in the Wadden Sea, an extensive area of intertidal flats shared by The Netherlands, Germany and Denmark (Davidson & Wilson 1992, Piersma *et al.* 1995, Nebel *et al.* 2000), and of *roselaari* and *rufa* in Delaware Bay in the eastern USA (Piersma *et al.* 2005a, Atkinson *et al.* 2005). The extant Red Knots shared a common ancestor as recently as within the last 20 000 years or so (Baker *et al.* 1994, Buehler & Baker 2005). As a result of a recent expansion from this severely bottlenecked stock, the subspecies show little genetic divergence across their world-wide range (Buehler & Baker 2005, Buehler *et al.* 2006).

Red Knots are amenable to studies in captivity, and this has enabled us to quantify in great detail the relationships between environmental conditions, time budgets, levels of energy expenditure, prey quality and quantity, and relevant features of the digestive tract (e.g. van Gils *et al.* 2003, 2005a, 2005b, Battley *et al.* 2005). Of particular relevance here is the fact that prey is ingested whole and crushed in a strong muscular stomach, or gizzard (e.g. Piersma *et al.* 1999, Zwartz & Blomert 1992,

Battley & Piersma 2005). This information has turned out to be very important in enabling us to interpret information collected in the field.

THE DECLINE OF *ISLANDICA* KNOTS IN THE DUTCH WADDEN SEA

The intertidal flats of the Dutch Wadden Sea are a State Nature Monument, and are protected under the Ramsar Convention on Wetlands and the EU Habitats and Birds Directives (Reneerkens *et al.* 2005). Despite this high-level conservation status and the widespread scientific and political concerns about the damaging effects of shellfish-dredging to marine benthic ecosystems (e.g. Hall & Harding 1997, Jackson *et al.* 2001, Coleman & Williams 2002, Dayton 2003), until 2004, three-quarters of the intertidal flats of the Dutch Wadden Sea were open to mechanical dredging for edible cockles *Cerastoderma edule*. A direct, immediate effect of dredging is the complete removal of all organisms larger than 19 mm in the top 5-cm layer. As the dredged sites are usually the most biodiverse (Kraan *et al.* 2006), dredging may also affect smaller cockles, other bivalves such as blue mussels *Mytilus edulis*, Baltic tellins *Macoma balthica* and sandgapers *Mya arenaria*, polychaetes, and crustaceans such as shore crabs *Carcinus maenas*. More indirectly, and over longer time scales, sediments lose fine silts during dredging events, it is this that may lead to long-term reductions in settlement success in both cockles and Baltic tellins (Piersma *et al.* 2001, Hiddink 2003). Between the winters of 1997/1998 and 2002/2003, the numbers of wintering Red Knots in north-west Europe declined by about 25% (from c. 330 000 to c. 250 000; unpubl. data of BTO, SOVON and others), and the numbers in the Dutch Wadden Sea by some 80%, from a level of c. 100 000 to 20 000 or fewer (van Roomen *et al.* 2005). Here we ask whether the decline in the Dutch Wadden Sea can be explained by the short- and long-term effects of suction-dredging, and whether this local decline can then explain what has happened in north-west Europe as a whole. The original analysis is provided by van Gils *et al.* (2006a).

We studied dredging-induced changes in food quantity and quality and their effects on digestive physiology and survival in Red Knots. In an area of roughly 250 km² in the western Dutch Wadden Sea, we annually sampled the density and quality of knot food in great detail. Each year from early September into December, immediately after completion of our sampling programme, mechanical dredging took place at some of the intertidal flats previously mapped for benthos. Using the black-box GPS data on dredging activity that fishery organizations are obliged to present annually to the Dutch Government (Kamermaans & Smaal 2002), we could categorize 1 km² sample blocks as dredged or undredged. During the years of the study, Red Knots mostly consumed first-year cockles (58%, based on 174 dropping samples of 50-100 droppings), and for this reason we focused our analysis on the effects of dredging on freshly settled, first-year cockles (the so-called "spat"; 16 mm).

It emerged that in dredged areas densities of cockle spat remained stable, whereas densities increased by 2.6% per year in undredged areas (van Gils *et al.* 2006a). This result is consistent with a previous assessment that showed that dredged areas become unattractive for cockles to settle in, perhaps because such sediments lose silt and good structure (Piersma *et al.* 2001). In addition, the quality of cockle spat declined by 11.3% per year in dredged areas and remained stable in undredged areas,

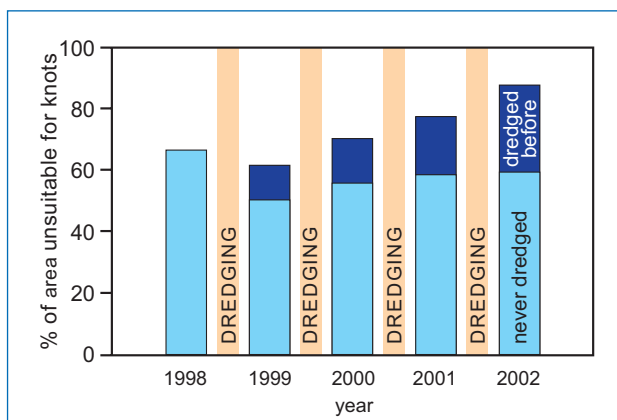


Fig. 2. The percentage of intertidal area in the western Dutch Wadden Sea that yielded insufficient intake rates for Red Knots *Calidris canutus* ($< 4.8\text{ W}$) increased between 1998 and 2002 due to an increase in blocks made unsuitable by dredging in previous years (filled bars, as opposed to open bars indicating unsuitable blocks that were never dredged). Based on an analysis of 272 sample blocks of one km^2 (van Gils *et al.* 2006b).

something we explain by supposing that coarser sediments lead to worse feeding conditions (Drent *et al.* 2004) and therefore to reduced body condition in deposit-feeding bivalves such as freshly settled cockles (Rossi *et al.* 2004). Thus, both the abundance and the quality of the food of Red Knots decreased in areas where dredging took place. The consequences of these declines were quantified by calculating, for each year, the percentage of the intertidal area that would yield insufficient intake rates for Red Knots to maintain a positive energy balance (Fig. 2). In the Wadden Sea, only a limited part of the available intertidal flats is rich enough in suitable prey to be of any use to foraging Red Knots (Piersma *et al.* 1995, van Gils *et al.* 2006b). From 1988 to 2002, the percentage of 1 km^2 blocks that were too poor for Red Knots to obtain a threshold intake rate of 4.8 W increased from 66% to 87% (van Gils *et al.* 2006a). This loss was entirely due to an increase in previously suitable blocks that were dredged; the number of previously unsuitable (and undredged) blocks did not increase.

As a consequence of the widespread dredging in the most biodiverse areas of intertidal flat (Kraan *et al.* 2006), diet quality declined by 11.7% per year and, to compensate for such reductions in prey quality, Red Knots should (Dekinga *et al.* 2001, van Gils *et al.* 2003) and did (van Gils *et al.* 2006a) increase gizzard mass. Nevertheless, re-sightings of individually colour-banded birds of which the gizzards were measured before release demonstrated that birds not seen in our study area within a year after release had undersized gizzards, whereas individuals that we did see again had gizzards that enabled them to achieve a balanced daily energy budget (van Gils *et al.* 2006a). The local annual survival rate (calculated from re-sighting rates of colour-banded birds) increased with year-specific food quality. In summary, this means that birds arriving from the tundra breeding areas with too small a gizzard needed more time to adjust their gizzard than their fat stores allowed them: they faced starvation unless they left the area.

Colour-banded Red Knots that disappeared from our study area may have died or, perhaps more likely for a wide-ranging migrant, emigrated to other areas such as estuaries in the UK. Here they probably paid a mortality cost due to the extra travel

and/or due to uncertainties in the food supply at their new destination. Whatever happened to them, the dramatic decline in numbers of Red Knots wintering in the Dutch Wadden Sea can be satisfactorily explained by these documented population effects of deteriorating feeding conditions (van Gils *et al.* 2006a). The local disappearance can also account for much of the 25% decline of the entire north-west European wintering population over the same period. We must thus conclude that the industrial forms of commercial exploitation allowed by the Dutch Government in one of its best legally protected nature reserves have been directly responsible for the population decline of a long-distance migrant shorebird species which itself is fully protected. Precisely the same conclusion has been reached in studies of the decline of another fully protected shellfish-eating shorebird, the Eurasian Oystercatcher *Haematopus ostralegus*, in the Dutch Wadden Sea (Verhulst *et al.* 2004) and a nearby estuary (the Wash) in the UK (Atkinson *et al.* 2003).

THE DECLINE OF RUFKA KNOTS USING DELAWARE BAY AS A STAGING SITE

Most of the *rufa* subspecies of Red Knots make an enormous annual return migration of 30 000 km between over-wintering sites in Tierra del Fuego and breeding sites in the Canadian Arctic. To achieve this feat, they must make stopovers at a few productive refuelling sites at strategic locations in the flyway. As these Red Knots are moving northwards to their breeding grounds in the central Canadian Arctic, the timing of departure from the stopover sites becomes increasingly synchronized, and at the last stopover site in Delaware Bay, departure for the breeding grounds occurs within a period of a few days (Myers 1986, Clark *et al.* 1993). Here, in Delaware Bay, Red Knots feed almost exclusively on a superabundant supply of eggs of spawning horseshoe crabs *Limulus polyphemus* (Castro & Myers 1993, Tsipoura & Burger 1999). This has traditionally enabled them to approximately double their body mass from 90-120 g on arrival to 180-240 g on departure (Baker *et al.* 2001). At an average rate of mass increase of 4.6 g/day (Piersma *et al.* 2005a), the highest recorded, the birds need to refuel over a period of approximately 17 days. Birds depart from Delaware Bay *en masse* on about 28-30 May each year (Baker *et al.* 2001). Based on an average fat-free mass of 130 g (Piersma 2002), Red Knots need to achieve a departure mass of at least 180-200 g just to cover the costs of the flight to the breeding grounds and to survive an initial few days of snow cover.

Over the past 15 years, there has been a dramatic increase in the commercial fishery of horseshoe crabs by so-called "watermen". This fishery, which provides bait for eel and conch fisheries, began in 1990 and peaked in 1995/96 (Walls *et al.* 2002). There was a six-fold decline in the numbers of horseshoe crabs caught in survey trawls in Delaware Bay by the Delaware Division of Fish and Wildlife (Andres 2003). The analyses by Baker *et al.* (2004) have provided strong evidence that the decline in food resources at this last stopover site during northward migration is negatively impacting the staging *rufa* population. Baker *et al.* (2004) showed that the proportion of well-conditioned Red Knots (200 g or greater) in Delaware Bay near the departure time in late May decreased significantly by 70% between 1997/98 and 2000/02. Within 2-3 days of the mass departure for the Arctic, mean body masses declined from 183 g in 1997 to 162 g in 2002. The annual survival of birds marked and re-sighted in Tierra del



Fig. 3. Locations of recoveries and re-sightings (up to December 2005) yielded by 2 400 Ruffs *Philomachus pugnax* that were captured in the spring of 2004 and 2005 in south-west Fryslân, The Netherlands, and marked with individual colour-ring combinations.

Fuego and Patagonia declined significantly from an average of 87% in the three migration years from 1994/95 to 1997/98 to 55% in the ensuing three year period to 2000/01 (Baker *et al.* 2004). On the basis of a larger mark-recapture data set for the whole flyway (Tierra del Fuego, Patagonia, southern Brazil and Delaware Bay) for the period 1993/94 to 2001/02, Baker *et al.* (2004) detected a similar large decline in annual survival, and pinpointed it to after the birds left Delaware Bay in 2000.

The increases in annual mortality were reflected in the aerial censuses of the non-breeding flocks in Tierra del Fuego: there were 51 000 Red Knots in February 2000, 37 000 in February 2001 and 27 000 in January 2002 (Morrison *et al.* 2004), confirming the large mortality in 2000. The peak count of Red Knots during the stopover in Delaware Bay in May 2000 was only 5 000 lower than the peak count in 1999, again suggesting that the largest loss of birds occurred after departure from this key site. A demographic model suggested that if the 1997/98 to 2000/2001 levels of annual survival were to prevail, *rufa* knots would reach extremely low numbers by 2010 (Baker *et al.* 2004). The aerial census data collected on the non-breeding

grounds in Tierra del Fuego (Morrison *et al.* 2004, pers. comm.) have so far confirmed this doomsday scenario.

The over-harvesting of horseshoe crabs in Delaware Bay has led Red Knots to concentrate their feeding activity on fewer and fewer sites where crab eggs are still abundant. The increasing dependence of birds on so few vulnerable areas and the increasing proportion of birds in poor condition at the time of departure now seem to threaten the viability of the *rufa* subspecies.

SHOREBIRDS AS INTEGRATIVE SENTINELS OF GLOBAL ENVIRONMENTAL CHANGE

As the two foregoing case studies have shown, even shorebirds that embrace the entire globe within their migration routes provide us with information about local environmental changes. At the same time, they integrate phenomena at larger spatial scales. As proposed by Piersma & Lindström (2004), variations in the number, phenotype and behaviour of particular shorebirds could help provide us with biological “integrators” of global environmental information in ways that no network of observers

could realistically ever give us. Weather stations and GIS analyses of land use can tell us about ongoing changes, but bird populations integrate this information in potentially insightful and surprising ways. To illustrate the use of shorebirds as integrative sentinels of our changing world, I will now briefly introduce a third case, involving long-term studies of a species that is doing rather well, the Eurasian Golden Plover *Pluvialis apricaria*. Annual catches of 2 000-3 000 Golden Plovers that make autumn and spring stopovers in The Netherlands have enabled us to monitor their breeding success (a likely function of body condition in spring, summer weather and predator densities) (Jukema *et al.* 2001). We have also been able to follow changes in the degree of stopover site philopatry (a function of the quality of the staging area in terms of food and predation risk), condition and moult in autumn (a function of the food quality at the staging area, that is itself partly weather dependent), timing of southward migration (possibly a function of the quality of the staging area and weather), wintering area (a function of weather, food and predators further south), alternative staging sites in spring (a function of weather and food), condition and moult in spring (a function of weather, food and predation risk), and population size (a demographic function of “everything” listed above) (Jukema *et al.* 2001, Piersma *et al.* 2005b).

Thus, even with relatively simple programmes such as this, we can monitor life cycles that integrate environmental factors from the whole of western and northern Europe. It would be even more informative if sets of complementary species were monitored in similar ways. For example, inclusion of the Northern Lapwing *Vanellus vanellus* and Ruff *Philomachus pugnax* in the comparison would enable us to distinguish between environmental changes on the breeding grounds (the three species breed in different habitats) and on the wintering grounds (the Northern Lapwing and Eurasian Golden Plover winter in Europe, the Ruff in tropical Africa) or en route (they show considerable overlap in the staging areas). Inclusion of shorebird species frequenting intertidal staging areas, such as the Red Knot and Bar-tailed Godwit *Limosa lapponica*, would further increase the scope for relevant comparisons and enable the rejection of more competing explanatory hypotheses. If the Eurasian Golden Plover, Red Knot and Bar-tailed Godwit all showed population declines, but Ruff and Northern Lapwing did not, changes occurring in the northern dry tundra might provide a suitable explanation, especially if the percentage of juveniles in the catches was low. However, if only the Ruff decreased, we would seek changes in the environmental conditions in the Sahel region of Africa, especially if such a decline coincided with reduced survival rates, late arrival in spring, and arriving birds that were lean and showed little development of their nuptial plumage.

Thus, in a comparative framework, the failures and fortunes of migrating shorebirds could be highly informative about the state of their world as well as ours (Piersma & Spaans 2004). In the case of the Ruff, my research team at the University of Groningen recently individually colour-marked as many as 2 400 birds over two spring seasons. All these birds were captured by traditional methods by artisanal bird-catchers (the “wilsternetters”), a group of ringers that also keeps a tally of Eurasian Golden Plovers (Jukema *et al.* 2001). Observers over much of Europe and in West Africa ensured that within a short period of time quite a comprehensive picture of the flyway of Ruffs staging in the west of the province of Fryslân was built up (Fig. 3; Piersma 2006). The fact

that this has been achieved within two years of study also means that we should be able to document changes in flyways in real time; flyway changes that, as we have seen, may often be a consequence of human-induced habitat loss and modification.

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Red Knots *Calidris canutus rufa* feeding on the eggs of Horseshoe Crabs *Limulus polyphemus* in Delaware Bay, USA. Photo: Rob Robinson.