Wader populations are declining – how will we elucidate the reasons?

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Worldwide, many wader populations have been shown to be in decline, though for some information is still lacking. Not all populations are declining, but long-distance migrants (a majority) appear to be at particular risk. Also at risk are sedentary species with small populations, which comprise a majority of the extinct and globally threatened species. The latter are better studied, and threats to their future are relatively well understood. Large-scale population changes in Arctic and north-temperate regions are generally better documented than in the tropics or the Southern Hemisphere. The reasons for declines in large and widespread populations are not well understood and explanations are mostly based on sparse and uncoordinated data.

The International Waterbird Census (IWC), coordinated by Wetlands International, provides a framework for monitoring non-breeding populations at a global scale. However, wader counts are not yet available from most countries for enough years to allow meaningful population trend analyses. Nevertheless there is considerable potential for trend analyses using IWC data in the future. Many other studies use different and uncoordinated methods. We still lack facilities for broad-scale analyses which would allow the reasons for observed changes in wader populations to be explored. A GIS referenced, decentralised, web-based database interface is proposed which would help explain these changes by linking wader monitoring initiatives, and by providing integration with other environmental monitoring schemes.

EXISTING KNOWLEDGE OF POPULATION STATUS

Global approaches

Wetlands International has been publishing results of the IWC and trends in certain waterbird populations for many years (Atkinson Willes 1976, 1978, 1981, Rüger *et al.* 1986, van der Ven 1987, 1988, Monval & Pirot 1989, Scott & Rose 1989, Perennou *et al.* 1990, Perennou, 1991, 1992, Perennou & Mundkur 1991, 1992, Rose 1992, Mundkur & Taylor 1993, Taylor & Rose 1994, Rose 1995, Dodman & Taylor 1995, 1996, Lopez & Mundkur 1997, Dodman *et al.* 1997, 1998, Delany *et al.* 1999, Blanco & Carbonell 2001, Gilissen *et al.* 2002). This work has provided important baseline information about waterbird numbers, and successful population trend analysis has been possible for certain groups, notably Anatidae in Europe. The census results (and hence the IWC data) are incomplete for certain sites, species or regions. Because of these gaps, methodological inconsistencies and other constraints, trend data are still lacking for many populations. Significant efforts are being made at present to improve this situation. Waders have only been included in IWC in most countries for the most recent 10 or so years of its 35-year history, and no wader data are included in the IWC database for years before 1989. Information about population trends in waders is thus only now becoming available, although prospects for future trend analyses for waders based on IWC data are very good.

Global assessments produced every three to five years by Wetlands International estimate the numbers and summarise the status of waterbird populations, but also demonstrate the gaps in our knowledge (Rose & Scott 1994, Rose & Scott 1997, Wetlands International 2002). Wetlands International (2002) compiled estimates of numbers and trends for 499 populations of 209 species recognised as "waders". Table 1 summarises the number of species in each wader family, the number of biogeographic populations into which these families have been divided, the number of population estimates and trends presented for each family, and the number of these trends which were estimated to be increasing, stable, or decreasing. Seven populations which have become extinct since 1750 are also included.

Population estimates are now available for a majority (424, 85%) of wader populations (Table 1). The number of populations for which the trend is now known is about half of this (207, 41%). Of the populations with known trends, 92 (44%) show a decreasing trend, 81 (39%) appear to be stable and only 27 (13%) show an increasing trend. The baseline of available population estimates continues to grow, and we also expect the quantity and quality of population trend data to show improvements in the coming years. These improvements will include an increase in the number of wader species for which sufficient data are available for trend analysis to be meaningful. An expected increase in coverage by IWC, and the development of monitoring of Important Bird Areas (IBAs) under BirdLife International's IBA programme, will

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Table 1. Summary of data presented for waders in Waterbird Population Estimates – third edition (Wetlands International 2002).

Family	No of species	No of bio-geographic populations	No of population estimates presented	No. of population trends presented	Details of presented trends			
					Increasing	Stable	Decreasing	Extinct
Rostratulidae Painted snipes	2	4	2	1	0	0	1	0
Dromadididae Crab plovers	1	1	1	1	0	1	0	0
Haematopodidae Oystercatchers	12	20	20	9	5	3	0	1
Ibidorhynchidae Ibisbill	1	1	0	0	0	0	0	0
Recurvirostridae Stilts & Avocets	10	25	23	14	4	9	1	0
Burhinidae Thick-knees	9	25	14	5	0	0	5	0
Glareolidae Coursers,Pratincoles	17	46	33	12	0	6	6	0
Charadriidae Plovers & allies	67	156	134	59	11	19	28	1
Scolopacidae Snipes, Sandpipers, Phalaropes & allies	90	221	197	106	7	43	51	5
Total	209	499	424	207	27	81	92	7
% of populations			**85%**	**41%**	**13%**	**39%**	**44%**	**4%**

also be significant in this respect. The challenge will be to effectively combine and present the results of numerous and diverse studies at a number of scales in a meaningful and accessible manner.

Europe

A major analysis of wader trends in the Western Palearctic, using IWC data, is planned, and a preliminary analysis for one species, the Eurasian Oystercatcher *Haematopus ostralegus* was presented in February 2002 (Haanstra *in prep*).

BirdLife International/European Bird Census Council (2000) reported that about 24 of the 42 wader populations breeding in Europe showed a decreasing trend whereas only nine showed an increase. A further nine species showed an unclear trend but several of these were also thought to be in decline. More recent data also suggest a declining trend for Curlew *Numenius arquata* in Northern Germany (Melter *et al.* 1998) and for Ringed Plover *Charadrius hiaticula* around the North Sea (Hälterlein *et al.* 2000).

Gilissen *et al.* (2002) reported a sharp decrease in the number of non-breeding Red Knot *Calidris canutus* in The Netherlands between 2000 and 2002 (source: T. Piersma *in litt.*). Similarly, Red Knot in the neighbouring very important staging area of the Schleswig-Holstein Wadden Sea showed a decline between 1988 and 1999 of about 35% (Günther & Rösner 2000).

Of 21 wader species monitored over 12 years in the Wadden Sea, only five have increased whereas nine species have shown persistent declines. Günther & Rösner (2000) recorded decreases in five Arctic-breeding species of which four were waders that had previously been increasing (Grey Plover *Pluvialis squatarola*, Red Knot, Dunlin *Calidris alpina* and Redshank *Tringa totanus*). They related these trends to possible changes in the climate. Data from Zackenberg in the central high Arctic of Greenland also showed decreasing numbers of Red Knot during 1995–2002 but stable or increasing numbers of five other shorebird species breeding there (Meltofte *in press*). Breeding Ruff *Philomachus pugnax* populations have declined substantially all over temperate Europe and reduced numbers have also been found on wintering grounds in West Africa. However, data from the Arctic are currently too sparse to conclude that there has been an overall decline in the population of this still very abundant species (Zöckler 2002).

The Americas

Considerable effort is put into shorebird conservation in North America, and comprehensive conservation plans have been prepared for the USA (Brown *et al.* 2000) and Canada (Donaldson *et al.* 2000). Morrison *et al.* (2001) presented population estimates and trends for North America based on a wide variety of sources, and listed 28 (80%) of the 35 wader species in North America as declining. Of these, 19 species (54%) showed statistically significant or persistent negative trends. For some species, such as Red Knot, a previously non-significant declining trend has sharpened and this species seems to be in steep decline in the New World as well as the Old World (Baker *et al.* 2000).

Most American shorebirds are long-distance migrants from Arctic and sub-Arctic breeding grounds, which are monitored by a number of schemes during the breeding, migration and non-breeding seasons. The Western Hemisphere Shorebird Reserve Network (WHSRN) is the largest of these, and includes 54 sites (see: http://www.manomet.org/WHSRN/learn.php). American and Canadian biologists have developed a method for monitoring Arctic wader populations in the breeding season, and are trying to establish a harmonised monitoring programme for all North American breeding populations (Johnston 2001, Skagen, this volume). Efforts are also being made to establish IWC in North America, which remains the most sizeable gap in the network. IWC is well established in parts of South America, but monitoring in the Caribbean and in Central and South America remains small in scale, and the proportion of waterbird populations for which estimates are available is lower in the Neotropical region than in any of the other five Ramsar regions (Wetlands International 2002).

Africa

Zwarts *et al.* (1998), recorded a decrease between counts in 1980 and 1997 at Banc d'Arguin, the most important site for coastal waders in Africa, in 11 of the 15 species monitored. Hagemeijer *et al.* (2000, in press) found lower numbers in 2000 than in 1997 for only one species (Kentish Plover *Charadrius alexandrinus*). Eleven species were found in higher numbers in 2000 than in 1997, but numbers of nine out of the 15 species were still lower than in 1980. Six species showed an increase compared with 1980.

Zwarts *et al.* (1998) also compared their results with those of Salvig *et al.* (1994), who counted the second most important coastal site in Africa for waders, the mudflats and mangroves in the Bijagos Archipelago, Guinea Bissau. For five species, they were able to demonstrate that the changes in Mauritania had been compensated by decreases or increases in the Bijagos Archipelago. However, there was an overall declining trend in both of these key international West African wintering areas for at least six waders, five of them Arctic-breeders. The results of the first simultaneous censuses of both of these important areas in 2001 still await publication and are expected to shed more light on population developments.

Underhill *et al.* (2001) and Venter *et al.* (2002) noted a decline in Arctic-breeding Turnstone *Arenaria interpres* and Curlew Sandpiper *Calidris ferruginea* populations in South Africa over the last two decades of the 20th century. Although the trend data were only based on single summer surveys during 1999–2001 and compared with 1981, they confirmed trends observed in other areas along the same flyway (Browne *et al.* 1996 for British non-estuarine coastal waders, Günther & Rösner 2000 for the German Wadden Sea area). These trends will, in the coming years be clarified, together with those of many other populations, by the growth in time series of wader data held on the IWC database. In Western Africa, in Senegal and around Lake Chad, numbers of Black-tailed Godwits *Limosa limosa* and Ruffs (OAG Münster 1991, 1996, Triplet & Yésou 1998) appear to have declined considerably, but again the data do not yet allow a final conclusion. The possibility cannot be excluded that both these numerous species might have redistributed themselves into many smaller flocks spread over a larger area and hence have been overlooked (Triplet & Yésou 1998, Brouwer & Mullié 2001). The forthcoming publication of African IWC results for 1999–2001 (Dodman & Diagana in press) will contain all of the above information for that period, complemented by the results from all other countries that participated in the AfWC over these years and will contribute considerably to the understanding of population developments.

Asia–Pacific

For the Asia–Pacific flyways, fewer data are currently available for population trend assessments. Important baseline work has been undertaken in Australia (e.g. Watkins 1993) and recently in perhaps the most important single staging area in the region, the Yellow Sea (Barter 2002). A comprehensive review and publication of results of the Asian Waterbird Census is expected in late 2003. The population size of the globally threatened Spoon-billed Sandpiper *Eurynorhynchus pygmea* continues to decline steeply and gives cause for concern (Tomkovich *et al.* 2002). Nordmann's Greenshank *Tringa guttifer* is similarly threatened (BirdLife International 2000) and many specialised island forms are globally threatened (Table 2). Minton *et al.* (2001) recorded the proportion of juveniles in trapped samples of birds, and identified low breeding success for several species, but an increase both in the proportion of juveniles and in overall numbers of one species, Red-necked Stint *Calidris ruficollis*, in the wintering grounds in Australia (see also Minton, this volume). This remains one of the few known examples of an increasing sandpiper population in the region. Kashiwagi (2002) reported that the Dunlin population in Japan is declining.

Arctic regions

Recent initiatives have included an attempt to monitor breeding conditions for waterbirds in the Arctic on a circumpolar basis under the Arctic Breeding Conditions Monitoring programme coordinated by Moscow University (Soloviev *et al.* 1998). Meltofte (e.g. 2001 and http://biobasis.dmu.dk) set up a long-term programme for monitoring waders in NE Greenland relating their numbers and breeding performance to other features of biodiversity and climate. Exo & Solovieva (*in prep.*) proposed a similar monitoring scheme for the Lena Delta in Arctic NE Russia. E. Pierce & H. Meltofte (*in litt.*) have proposed a pan-Arctic shorebird monitoring network (PASRN), which will analyse existing time series of data from the breeding as well as staging and wintering areas in relation to climatic variables, and discuss common standards for future monitoring.

Little has so far been done to link all these datasets and explore possible reasons for changes in numbers of waders and other waterbirds.

REASONS FOR THE DECLINES

Here we struggle and the wide range of reasons given (e.g. BirdLife International 2000) includes: development of coastal wetlands for industry, infrastructure, and aquaculture; habitat loss and modification due to global climate change and agricultural intensification; increasing predation pressure, pollution, hunting and other forms of direct human disturbance. Barter (2002) details the considerable and pressing threats to the shorebirds of the Yellow Sea (for example, over 1,100 km^2 of tidal flats are known to have been destroyed in the 20th century, and further destruction on a vast scale is continuing). In most cases, the conclusions remain rather speculative due to a lack of baseline monitoring, inconsistent data series and little integration of different studies. Around the Yellow Sea, baseline monitoring has begun, but too late to allow an understanding of what has been lost. In many cases, when no obvious reason is apparent, the first thought is climate change. The decline of nearly half of all known populations throughout all global regions does suggest underlying global phenomena. But among the many causes of population declines often considered, direct loss of habitat is frequently suspected (e.g. Morrison *et al.* 2001, Tomkovich *et al.* 2002, Johnston 2001). Other globally operating phenomena such as eutrophication, with nutrient over-enrichment in wader habitats changing breeding conditions and food supplies, have also been considered (Beintema *et al.* 1995, Zöckler 2002). No doubt a complex matrix of many inter-correlated factors impacts on wader populations. Some of these factors are discussed below.

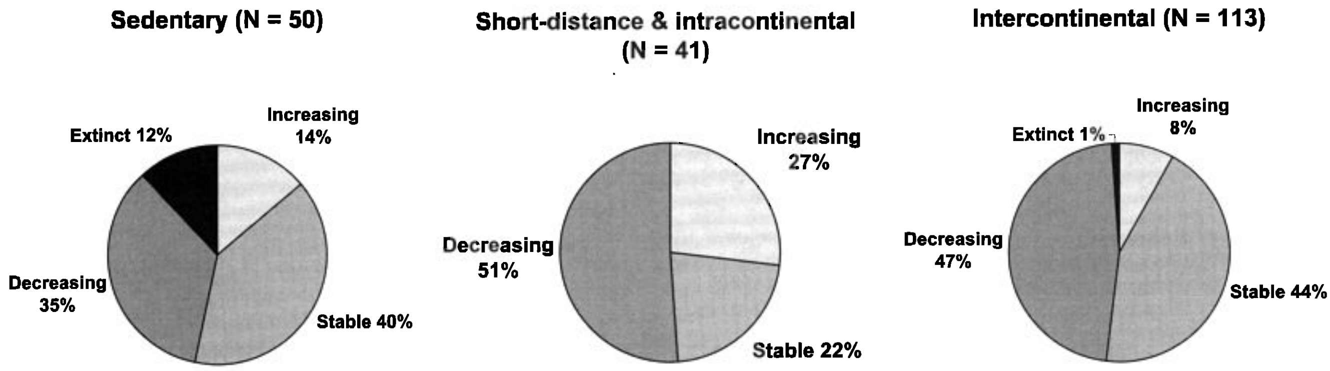

Fig. 1. Trends in Wader populations summarised according to their migration behaviour. Sedentary = not known to migrate at all; Short distance and Intra-continental migrant = migrates within, but not across the boundaries of Ramsar regions; Intercontinental migrant = migrates across boundaries of Ramsar regions.

Predation

The relationships between Lemming cycles, predation by Arctic Foxes and mortality of Arctic nesting birds (Summers & Underhill 1987) has been widely recognised and similar relationships have been recorded in regions outside the Arctic. The data from Siberia and the connected flyways support the lemming theory (Underhill *et al.* 1989). However, eight years of data from high Arctic Greenland (Meltofte 2001, *in litt.*) do not support such a simple correlation for this part of the Arctic. There has been good or moderate breeding success irrespective of lemming numbers and never a poor breeding year coinciding with low lemming densities. The predation pressure on breeding waders in temperate wet grassland by foxes, weasels and crows has been demonstrated (e.g. Beintema *et al.* 1995, Schoppenhorst 1996) and links between wader population size and rodent abundance seem likely (Schoppenhorst in prep). However, apart from sedentary island forms where predation by humans during and after settlement, and by rats, cats and other commensal predators is a particular problem, there is little evidence that predation has been the primary cause of long-term population changes in waders.

Migratory behaviour

Population trends appear to be associated with the migratory behaviour of wader species (Fig. 1). There are also differences between the wader families. The *Haematopodidae* and *Recurvirostridae* include a high proportion of non-migratory populations, and their populations are, with notable exceptions, mostly stable or increasing (Table 1). The two largest families, *Charadriidae* and *Scolopacidae* include a high proportion of long-distance migrants and show similar population trends, with 47% (*Charadriidae*) and 48% (*Scolopacidae*) of their known populations in decline, and only 19% and 7% respectively of their populations increasing. Six of the increasing plover populations are sedentary tropical lapwing species, and if these are excluded, the proportion of the populations of plovers that are increasing is reduced to 8%. There are exceptions, such as the Red-necked Stint and the Purple Sandpiper *Calidris maritima*, but a disproportionate number of migratory wader populations appear to be in decline. 47% of intercontinental migrant populations with known trends and 51% of intra-continental and short-distance migrants are in decline. However, in those sedentary populations for which trends are known, the proportion in decline is rather lower at only 34% (Fig. 1). In comparison, increasing trends are found in 14% of sedentary species and in 27% of short-distance and intra-continental migrants, but in only 8% of intercontinental migrants.

There seems to be no clear reason why migrant populations should be declining more than others. Possibly the risks of migration have increased because of some globally acting change. However, this is mere speculation. Coordinated and consistent monitoring, combined with powerful and sensitive spatial analysis using all available datasets, will enable us to reach a better understanding of this apparent correlation. Furthermore this underlines the need for a flyway approach in the conservation of these species. Fortunately, the Ramsar Convention, with its network of designated sites, and the Bonn Convention with the African–Eurasian Migratory Waterbird Agreement (AEWA), as well as other regional conservation strategies, are formulated to take account of the special requirements of long distance migrants.

Sedentary species with small populations also appear to be at particular risk because of the high proportion that appear in the 30 populations that are globally threatened or have become extinct since the year 1750 (Table 2) 14 of these populations are (or were) sedentary. 13 occur (or occurred) in Oceania and 10 in Asia. 18 can be categorised as specialised island forms, 12 as plovers and allies with specialised habitat requirements and 5 as long distance migrants (Eskimo Curlew, Bristle-thighed Curlew, Slender-billed Curlew, Nordmann's Greenshank and Spoon-billed Sandpiper). Two populations, both susceptible to habitat loss or modification, do not fit into these categories: Jerdon's Courser *Rhinoptilus bitorquatus*, and Wood Snipe *Gallinago nemoricola*. Generally, globally threatened populations are better studied, and the threats to them better understood than is the case for more numerous and widespread species. Partly this is a reflection of successful priority setting by organisations such as BirdLife International. The challenges now are to implement effective conservation action for globally threatened species, and to identify the relative importance of the threats impacting more numerous and widespread species.

Climate change

Climate change is already affecting wader populations and is predicted to have a very much more substantial impact, mostly negative, over the next 50–100 years (Rehfisch &

Table 2. Summary of globally threatened and extinct wader populations (Sources: Wetlands International 2002, BirdLife International 2000).

Explanation of the columns:
Species/Population – the taxa are listed at the level of biogeographical populations (see Wetlands International 2002);
Ramsar Regions – the Ramsar Convention on Wetlands divides the world into 6 Regions: Asia, Oceania, Africa, Europe, North America and South America;
Migratory Behaviour – Sedentary = not known to migrate at all, – Intra-continental migrant = migrates within, but not across the boundaries of Ramsar regions, – Intercontinental migrant = Migrates across boundaries of Ramsar regions
IUCN Threat Status – EXT = Extinct, CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near-Threatened (See BirdLife International 2000). Subantarctic Snipe is included because two sub-species (=biogeographical populations in this case) have become extinct, although the species as a whole is not considered to be globally threatened by IUCN, which works at species level.
Population trend – EXT = Extinct, DEC = Decreasing, STA = Stable, INC = Increasing

Species/ population	Range (Ramsar region(s))	Migratory behaviour	IUCN Threat Status	Population estimate	Population trend
Canarian Black Oystercatcher *Haematopus meadewaldoi*	Africa	Sedentary	EXT	0	EXT
Chatham Island Oystercatcher *Haematopus chatamensis*	Oceania	Sedentary	EN	140–150	INC
Black Stilt *Himantopus novaezelandiae*	Oceania	Intra-continental migrant	CR	40	DEC
Jerdon's Courser *Rhinoptilus bitorquatus*	Asia	Sedentary	CR	50–250	DEC
Javanese Wattled Lapwing *Vanellus macropterus*	Asia	Sedentary	CR	<50	EXT?
Sociable Lapwing, *Vanellus gregarious* wintering NE Africa	Asia, Africa	Intercontinental migrant	VU	400–1,200	DEC
Sociable Lapwing, *Vanellus gregarious* wintering South Asia	Asia	Intra-continental migrant	VU	200–600	DEC
New Zealand Dotterel *Charadrius obscurus aquilonius*	Oceania	Intra-continental migrant	VU	1,450	INC?
New Zealand Dotterel *Charadrius obscurus obscurus*	Oceania	Intra-continental migrant	VU	150	INC
Piping Plover *Charadrius melodus melodus*	North America	Intra-continental migrant	VU	2,920	INC
Piping Plover *Charadrius melodus circumcinctus* (Great Lakes)	North America	Intra-continental migrant	VU	72	STA
Piping Plover *Charadrius melodus circumcinctus* (Prairies)	North America	Intra-continental migrant	VU	2,950	DEC
St Helena Plover *Charadrius sanctaehelenae*	Africa	Sedentary	EN	435	STA
Mountain Plover *Charadrius montanus*	North America	Intra-continental migrant	VU	8,000–9,000	DEC
Shore Plover *Thinornis novaeseelandiae*	Oceania	Sedentary	EN	159	STA

Crick, this volume; Smart & Gill, this volume). Its effect can vary from direct impacts affecting breeding performance (Boyd & Madsen 1996, Ganter & Boyd 2000, Zöckler & Lysenko 2000) to indirect impacts caused by changes in habitat conditions (Zöckler 2002) or availability. Further indirect effects might occur via the food chain if predators are forced to switch from eating rodents to wader chicks after climate change has altered the vole or lemming cycles. Evidence of the impact of global warming on the vole cycle has been demonstrated for the Lake Constance area in South Germany (Schuster *et al.* 2002).

THE ADVANTAGES OF INTEGRATED SPATIAL ANALYSIS

The total effort that goes into waterbird monitoring all over the world is huge. There are well organised international initiatives like the International Waterbird Census and Important Bird Areas programmes, but there are also many more small-scale monitoring schemes that are inconsistent with these major activities. Most monitoring is dependent on local or national level facilities, logistical support and funding. It is incomplete in both species and spatial coverage and

Table 2 cont. Summary of globally threatened and extinct wader populations (Sources: Wetlands International 2002, BirdLife International 2000).

Explanation of the columns:
Species/Population – the taxa are listed at the level of biogeographical populations (see Wetlands International 2002);
Ramsar Regions – the Ramsar Convention on Wetlands divides the world into 6 Regions: Asia, Oceania, Africa, Europe, North America and South America;
Migratory Behaviour – Sedentary = not known to migrate at all, – Intra-continental migrant = migrates within, but not across the boundaries of Ramsar regions, – Intercontinental migrant = Migrates across boundaries of Ramsar regions
IUCN Threat Status – EXT = Extinct, CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near-Threatened (See BirdLife International 2000). Subantarctic Snipe is included because two sub-species (=biogeographical populations in this case) have become extinct, although the species as a whole is not considered to be globally threatened by IUCN, which works at species level.
Population trend – EXT = Extinct, DEC = Decreasing, STA = Stable, INC = Increasing

Species/ population	Range (Ramsar region(s))	Migratory behaviour	IUCN Threat Status	Population estimate	Population trend
Wrybill *Anarhynchus frontalis*	Oceania	Intra-continental migrant	VU	4,100–4,200	DEC
Amami Woodcock *Scolopax mira*	Asia	Sedentary	VU	2,500–10,000	DEC
Moluccan Woodcock *Scolopax rochussenii*	Asia	Sedentary	VU	2,500–10,000	DEC
Chatham Island Snipe *Coenocorypha pusilla*	Oceania	Sedentary	VU	2,000	STA
Subantarctic Snipe *Coenocorypha aucklandica barrierensis*	Oceania	Sedentary	NT	0	EXT
Subantarctic Snipe *Coenocorypha aucklandica iredalei*	Oceania	Sedentary	NT	0	EXT
Wood Snipe *Gallinago nemoricola*	Asia	Intra-continental migrant	VU	2,500–10,000	DEC
Eskimo Curlew *Numenius borealis*	North America, South America	Intercontinental migrant	CR	<50	EXT?
Bristle-thighed Curlew *Numenius tahitiensis*	North America, Oceania	Intercontinental migrant	VU	10,000	DEC
Slender-billed Curlew *Numenius tenuirostris*	Asia, Europe, Africa	Intercontinental migrant	CR	<50	DEC
Nordmann's Greenshank *Tringa guttifer*	Asia	Intra-continental migrant	EN	250–1,000	DEC
Tuamotu Sandpiper *Prosobonia cancellata*	Oceania	Sedentary	EN	250–1,000	DEC
Ellis's Sandpiper *Prosobonia ellisi*	Oceania	Sedentary	EXT	0	EXT
White-winged Sandpiper *Prosobonia leucoptera*	Oceania	Sedentary	EXT	0	EXT
Spoon-billed Sandpiper *Eurynorhynchus pygmaeus*	Asia	Intra-continental migrant	VU	<3,000	DEC

in time series. Moreover, there is a lack of good integration and linkage with other biological or scientific initiatives.

Waterbird monitoring has strongly advanced in recent years, and IWC is providing an ever more effective framework. BirdLife International is also developing monitoring based on its network of IBAs. Many of these are wetlands and in those cases IWC data have often been used to identify them. However, the opportunities for spatial and intertaxonomic integration as well as the integration of observer networks have not yet been fully explored. This has been recognised by Wetlands International, BirdLife International and the UNEP–World Conservation Monitoring Centre and flyway scale projects have been designed to link data gathering, databases and the spatial reference.

The incomplete, scattered and unevenly distributed status of trend data across the Arctic and northern temperate regions and between taxa has been recognised by the Council on Arctic Flora and Fauna (CAFF) biodiversity monitoring working group. At present, this consists of eight active species networks working on Polar Bears, seabirds and seals, as well as Arctic Char, Reindeer, geese, vegetation and waders. They all aim to operate at a circumpolar scale and to harmonise population trend data for integration purposes.

The Arctic region has the great advantage of relatively few direct negative impacts from human activity. Mineral exploitation and resulting acid rain, together with overgrazing by livestock in some regions, have considerable impact, but the sheer geographical scale of the region and very low human population densities mean that there are still vast areas of pristine wilderness. Because direct human impact in the Arctic remains at a very low level, most developments that have been observed there can be interpreted as natural effects or global phenomena, such as climate change and eutrophication. Current problems with existing monitoring programmes include the lack of information on many relevant taxa, a bias towards harvested, and/or rare species, inconsistency of coverage, gaps in data series and, perhaps most importantly, a lack of integrated analyses.

As knowledge of the flyways used by different populations increases, it becomes possible to relate populations monitored in the non-breeding season to defined areas of the Arctic. The comparison of two distinct Australian wintering populations of Red Knot monitored in SE and NW Australia, for example, give evidence about the different breeding performance of each population, although the precise breeding distribution of each of these populations is still poorly known (Minton *et al.* 2001).

Rare species naturally receive more attention and are more likely to be monitored than common species (Table 2.). Therefore some changes may be recorded more readily among rare species. However, those factors affecting changes in numbers that are of a more global, overriding character can only be detected by monitoring commoner species. The decline in the non-breeding population of Dunlin in Japan might be caused by the same problems that affect Spoon-billed Sandpipers. However, the reasons for the sharp decline of the Spoon-billed Sandpiper have not yet been identified (Tomkovich *et al.* 2002). More data on the larger wader populations, as well as other taxa and environmental parameters in the Asia–Pacific region are required before we can properly evaluate the various hypotheses.

In order to facilitate an understanding of the reasons for declines in wader populations we propose to design a web-based GIS interface (also known as a "portal", see Fig. 2), to integrate efforts to monitor biodiversity throughout the Arctic. We plan that this will comprise a collation of decentralised and distributed web databases containing monitoring data and other relevant spatial datasets. The same can be done within each of the major flyway systems and a proposal has been prepared to implement this (not only for waders but for all waterbirds) for the AEWA region.

The design of the new interface will allow these data to be accessed and displayed geographically through the Internet and overlaid with physical data relating to variables such as climate, nutrient levels and pollution. The web portal will link and make accessible geo-referenced databases of monitoring data from many different Arctic or flyway biota. It will serve as a platform for connecting and accessing all available data for the Arctic or flyway region. It will also allow access to data on parameters such as habitat type, protected area status and others. The portal, here a selected prototype for the Arctic region, will help to combine trend data of wader populations with those of other taxa, if available, using advanced GIS applications. It is designed to handle data at different scales and of different types, harmonised in a collation of databases, which will allow integration, comparisons and finally trend analyses. In addition, the data can be integrated with those of land use and land management, climate, acidification, water level changes, industrial and agricultural pollution and others such as reindeer density, mining sites and infrastructure. Many of the required data are not fully available or are in development, but the monitoring of physical parameters and pollution are well established (e.g. the Global Terrestrial Observation System GTOS) and are covered for the Arctic region by the Arctic Monitoring and Assessment Programme (AMAP) of the Arctic Council. The prototype is aimed towards the design of a geo-referenced web portal starting with a selected set of database applications that will allow preliminary integration and analyses of geographically harmonised data. Further development will gradually improve access to more and more databases. A preliminary demonstration web site with only local database access has been established and can be downloaded at http://trinity.unep-wcmc.org/imaps/arcticBirds/viewer.htm.

Many important components of biodiversity are not monitored at all, or monitoring data are only available for selected regions. Few efforts have been made to achieve a circumpolar monitoring of Arctic biodiversity. Most noteworthy is the Arctic Breeding Conditions Monitoring programme run by Moscow University (Soloviev *et al.* 1998) and supported by the Dutch Government. Similar programmes are in development for Reindeer, Arctic Char, and seabirds and to some extent for geese and some waders, but rarely on a circumpolar basis, involving more than just one country. A large number of wader populations breed in the Arctic region and the Wader Study Group is ideally positioned and well experienced to contribute substantially with their data to integrated monitoring of Arctic Biodiversity.

The concept proposed here is based on an interactive interface that could provide access to separately maintained and updated species databases with trend data and information such as lemming density and weather parameters hosted at different locations. Fig. 2 shows a proposed prototype for the Arctic region with a few selected layers on biodiversity taxa, including data on protected areas and the potential for extension to include many other species and parameters.

The potential output is enormous but will very much depend on the initial input and the maintenance of decentralised or distributed databases. Each participating organisation or data custodian would maintain their own specialist data in their own database, with the advantages of familiarity and regular updating of information. The most obvious challenge lies in the analysis of biodiversity trend data, both in itself and in relation to factors such as climate change. The Arctic region and its biota seem certain to experience pronounced changes in climate in the coming years (IPCC 2001, Rehfisch & Crick, this volume) and the proposed portal could provide the integration of essential data sets and allow analysis of the relative importance of different parameters.

One output might be the development of "Arctic Species Trend Indices" in line with the Living Planet Index currently undertaken by WWF and UNEP-WCMC (Loh 2002), or the Natural Capital Index (ten Brink 2000). Depending on the variety of taxa included in the monitoring programme, regional subsets of the indices could be developed. A marine or terrestrial index would illustrate differences in trends between these biomes and regional subsets could highlight differences between regional seas or between selected terrestrial regions. Furthermore, the interface could be set up to allow habitat or ecosystem related indices. Another possible distinction in the interface could refer to migratory species, including whales, seabirds, geese and waders. Comparing trends of migratory taxa with those sedentary in the Arctic (including, e.g., mammals, freshwater fishes and plants) would provide further indications on the geographical origins of observed trends. Trend data on waders are still scarce, but those well established

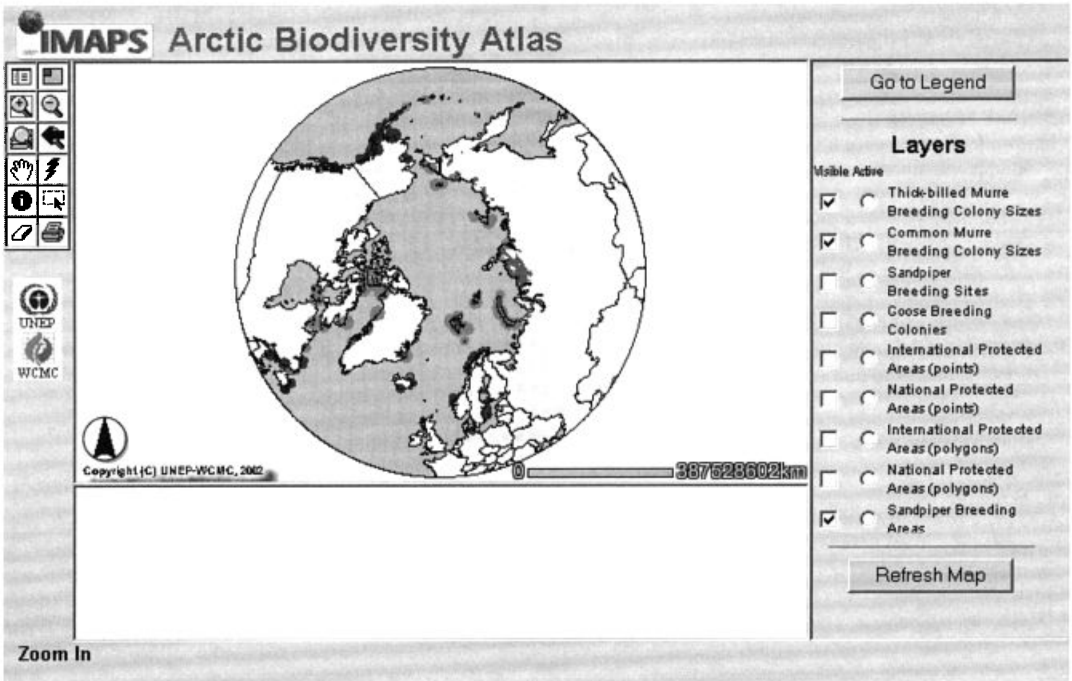

Fig. 2. Suggested prototype of an interactive interface for the Arctic region, serving as a platform to access, manage and integrate monitoring data (and other relevant spatial datasets) using modern web-based GIS applications.

as in East Greenland (Meltofte 2001) or on a circumpolar scale (Soloviev *et al.* 1998, Soloviev & Tomkovich 2001) could be readily integrated, others encouraged to join and even those networks such as the IWC operating outside the Arctic could be linked to the Arctic region, when we know the breeding distributions of the monitored populations.

Another valuable opportunity would be to correlate wader trend data with natural fluctuations, such as small rodent cycles, and also with anthropogenic impacts such as pollution (AMAP data), climate change and others. With improvements in the quality and quantity of available data from various sources we should become more confident in our ability to distinguish climate-related changes or other anthropogenic factors from natural fluctuations.

Ideally, the structure of the interface should be designed in such a way that it can be transferred and made applicable for other regions and biomes. The advantages of starting with an Arctic prototype are:

- The relatively small number of species
- The opportunity to build on an existing intergovernmental programme (CAFF and AMAP) under the Arctic Council
- The opportunity to build on existing and well established networks, such as Wetlands International and the Wader Study Group
- The relatively few direct human impacts
- The opportunity to evaluate the potentially large regional impact of climate change.

The need to extend and enhance waterbird monitoring has frequently been highlighted. The continuing declines of many wader populations and speculation about the relative importance of the many reasons behind these declines would benefit from additional coordinated monitoring schemes and analysis with sophisticated modern database, GIS and web facilities. If funding for this approach can be obtained, it should also allow better networking between and within research groups and better coordination of monitoring as well as better use of modern GIS applications.

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