Extract only - complete publication at www.jncc.gov.uk/worldwaterbirds

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

EDINBURGH, UK: THE STATIONERY OFFICE

Extract only - complete publication at www.jncc.gov.uk/worldwaterbirds

© Scottish Natural Heritage 2006

First published in 2006 by The Stationery Office Limited
71 Lothian Road, Edinburgh EH3 9AZ, UK.

Applications for reproduction should be made to Scottish Natural Heritage,
Great Glen House, Leachkin Road, Inverness IV3 8NW, UK.

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN 0 11 497333 4

Recommended citation:
Boere, G.C., Galbraith, C.A. & Stroud, D.A. (eds). 2006.
Waterbirds around the world. The Stationery Office, Edinburgh, UK. 960 pp.

Names used for geographical entities do not imply recognition, by the organisers of the *Waterbirds around the world* conference or other supporting organisations or governments, of the political status or boundaries of any particular territory. Names of territories used (and any alternatives) are included solely to help users of this publication apply information contained within this volume for waterbird conservation purposes. The views expressed in papers included within this volume do not necessarily represent views of the editors or the organisations and governments that supported the conference and this publication.

Cover photography: Whooper Swans *Cygnus cygnus* arriving at Martin Mere, England. Photo: Paul Marshall. (www.paulmarshallphotography.com)

Copyright of all photographs used in this publication resides with the named photographers.

Cross-cutting research on a flyway scale - beyond monitoring

David B. Lank & Silke Nebel[1]
Centre for Wildlife Ecology, Department of Biological Sciences, Simon Fraser University, 8888 University Dr., Burnaby, British Columbia, V5A 1S6, Canada. (email: dlank@sfu.ca)
[1]Present address: School of Biological, Earth & Environmental Sciences, University of New South Wales, Kensington, Sydney NSW 2052, Australia.

Lank, D.B. & Nebel, S. 2006. Cross-cutting research on a flyway scale – beyond monitoring. *Waterbirds around the world*. Eds. G.C. Boere, C.A. Galbraith & D.A. Stroud. The Stationery Office, Edinburgh, UK. pp. 107-112.

ABSTRACT
Research on the population ecology of migratory birds is facilitated by a holistic or "cross-cutting" approach that synthesizes information gathered across the entire flyway, throughout the annual cycle and utilizing different research disciplines. Radio-tracking Western Sandpipers *Calidris mauri* from non-breeding to breeding grounds documented migration timing and usage of stopover sites. Data collected throughout the non-breeding range showed that females migrated farther south than males, and that juveniles were over-represented towards the extremes. Collaboration documented a latitudinal "life-history divide": northerly juveniles migrate and attempt to breed, while southerly juveniles oversummer at non-breeding sites. As predicted by life history theory, southerly birds appear to have higher annual survival rates than migrants. Comparing daily survival rates during breeding, non-breeding and annual periods permits the calculation of survival rates during migratory periods. Integrated studies of behavioral ecology, demography and physiology allowed interpretation of an apparent local population decline in migrating Western Sandpipers. Dramatically decreased usage of a small stopover site occurred despite abundant food resources, and appeared to be caused by a behavioral change in response to increasing falcon populations, rather than a decrease in numbers of migrants. The combination of approaches allowed testing alternative hypotheses as likely causes for the change in site usage.

INTRODUCTION
Understanding population regulation is a key issue in the study of migratory birds, but it acquires special urgency in species that suffer from decreasing population numbers. In shorebirds (family Scolopacidae), population declines are widespread: more than half of all shorebird populations world-wide are thought to be declining (International Wader Study Group 2003, Stroud *et al*. 2004, 2006), and within North America, this estimate is as high as 80% (Morrison *et al*. 2001).

A long-term research program organized by the Centre for Wildlife Ecology (CWE) at Simon Fraser University, Canada, is using a cross-seasonal and cross-disciplinary approach to study population ecology and, ultimately, population regulation of a migratory shorebird (Nebel & Lank 2003). This holistic approach is based on the synergy gained from synthesizing information sampled across the entire flyway, throughout the annual cycle, and utilizing different research disciplines, creating opportunities for conservation work (Harrington *et al*. 2002).

The Western Sandpiper *Calidris mauri* was chosen as a model species, being the most abundant shorebird on the American Pacific coast. Western Sandpipers breed in western Alaska and eastern Siberia, and overwinter along the American Pacific coast between southern Canada and Peru, and, in smaller numbers, along the Atlantic coast and in the Caribbean (Wilson 1994, Nebel *et al*. 2002). Over 90% of captured birds may be confidently assigned a sex based on bill lengths (Page & Fearis 1971).

The CWE fostered research on diverse aspects of the species' biology by organizing a loose association of researchers working throughout the species' range to collaborate and exchange information (see Acknowledgements). Members consulted with government wildlife managers and non-governmental agency scientists, recruited academics in complimentary fields to work with the species, steered post-doctorate, graduate and undergraduate students towards particular projects, and provided seed funding for researchers elsewhere, particularly in Latin America. The group created a sense of common purpose during annual workshops, which attracted additional participants to the network, and through an electronic list-server.

CUTTING ACROSS THE FLYWAY
A series of radio-tracking studies of migrant Western Sandpipers conducted over five seasons between 1995 and 2004 during northward migrations from Mexico and California to Alaska capitalized on this network. Collaborators produced detailed information on the movements and stopovers of individual shorebirds with respect to age, sex, time of year, weather conditions, staging site, and year (Iverson *et al*. 1996, Butler *et al*. 1997, Bishop & Warnock 1998, Warnock & Bishop 1998, Butler *et al*. 2002). These studies strengthened the evidence that 80-90% of the Western Sandpiper population use the Copper River Delta, Alaska, towards the end of their northward migration. The length of stay estimated for that site from radio-tracking data was integrated with census data to improve estimates of the species' total population size (Bishop *et al*. 2000). Further analysis of the wealth of data generated by this work will help test individually-based models of migratory strategy, which may be used to predict the population consequences of migratory habitat change.

As a second example, we improved the resolution of a pattern of sexual segregation of Western Sandpipers during the non-breeding season by combining information from 13 different sites, and discovered a novel pattern with respect to age (Nebel *et al*. 2002). Females migrate farther south than males, creating a latitudinal cline between sex ratio and Great Circle distance from the breeding grounds (Fig. 1). The local proportions of juveniles fit a significant U-shape with respect to migration distance (Fig. 2), which interacts with the sexual segregation such that juvenile males are substantially over-represented in samples from the northern end of the distribu-

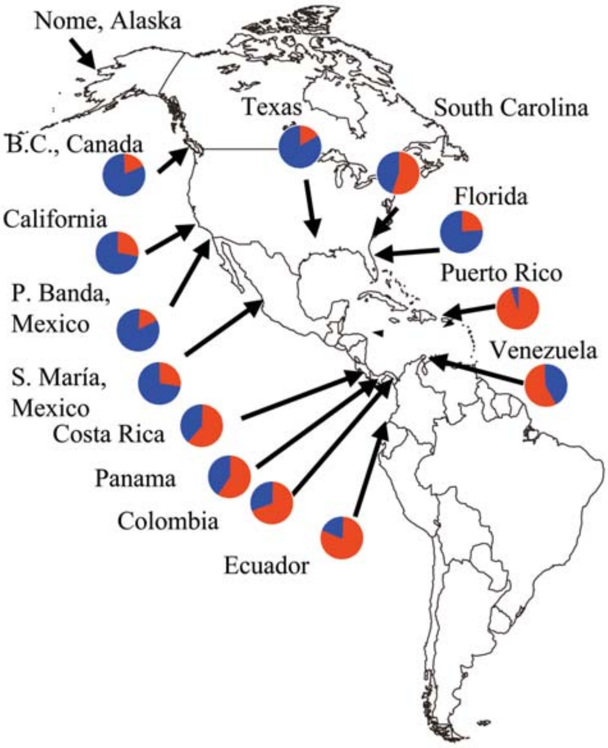

Fig. 1. The proportion of female (red) and male (blue) Western Sandpipers *Calidris mauri* on the non-breeding grounds.

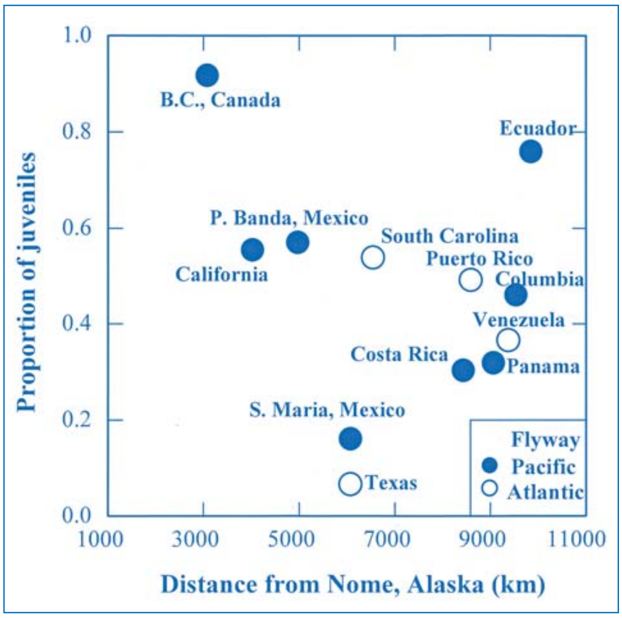

Fig. 2. Age ratios of Western Sandpipers *Calidris mauri* captured at 12 non-breeding locations. The local proportions of juveniles caught at each site vs. migration distance described a U-shaped pattern ($F_{1,22}=5.08$, $P<0.005$; after Nebel *et al.* 2002, reproduced with permission from The Auk).

tion, and juvenile females over-represented in samples from the southern end.

The distributions of sex and age classes also interact with a latitudinal difference in life history strategy (Fernández *et al.* 2004, O'Hara *et al.* 2005). Juveniles at non-breeding sites in Mexico predominantly migrate north and attempt to breed as one-year-olds, while juveniles in Panama do not migrate, and instead "oversummer" on the non-breeding grounds. We infer that juveniles adopt one of two life history strategies, with shorter-distance migrants opting to attempt migration and breeding at a younger age, and longer-distance migrants maximizing first year survival at the expense of an earlier potential breeding opportunity.

This difference in strategies could map onto biological population differentiation, but none is currently recognized, and disproportionate representation of the sexes at different non-breeding areas makes this seem an unlikely situation. Alternatively, we may have documented two tactics of a conditional strategy (*sensu* Gross 1996), in which case the choice of tactics depends on an environmental cue, such as hatch date, and/or on developmental characteristics, such as body size. In this situation, migration distance itself might follow from a life-history decision based on condition made in Alaska prior to migration, or the opposite might occur, namely that the life history difference might follow from factors determining migration distance (O'Hara *et al.* 2002, O'Hara *et al.* 2005).

If lifetime reproductive success of individuals migrating south to different latitudes is similar, annual survival rates should be higher among oversummering juveniles than among juveniles migrating north in their first year, in order to offset the earlier age of first reproduction of migrants. Western Sandpiper researchers throughout the range and annual cycle have used mark-recapture studies to estimate ϕ, the rate of local survival, which provides a minimum estimate of true annual survival rate (Table 1), and return rates, which will approach ϕ if detection rates are high. Estimates of survival rates obtained at breeding and non-breeding grounds show some general agreement, assuming similar levels of permanent emigration. As predicted, local annual survival is lower in Mexico than Panama. As mark-recapture studies proliferate, comparisons among local survival rates derived from different situations and/or populations may refine our views of local habitat suitability and other aspects of population structure.

CUTTING ACROSS THE ANNUAL CYCLE

Population managers recognize that partitioning the timing of annual mortality across seasons and locations improves their ability to target conservation action. Studies based on band recovery data can rarely address this question directly. The development and widespread availability of capture-recapture analysis tools (Lebreton *et al.* 1992, White & Burnham 1999) enabled researchers at different sites and seasons to collaborate to obtain the necessary information. The best examples are studies of individually marked geese, which carry conspicuous markers that facilitate re-sightings. For some populations, lower daily survival rates occurred during migration than in winter or summer (Owen & Black 1991, Clausen *et al.* 2001), perhaps due to hunting (Ward *et al.* 1997). Other studies found lower survival rates during breeding seasons (including migratory flights) (Madsen *et al.* 2002), concluded that breeding, wintering and even migration seasons had similar rates of natural mortality (Gauthier *et al.* 2001), or that seasonal patterns differed by sex (Schmutz & Ely 1999). Each study suggests specific management actions, and the ecological reasons for the diversity of situations contribute towards our general understanding of population regulation.

The use of mark-recapture information was taken a step further by combining information derived from different

Table 1. Annual local survival rates for Western Sandpipers *Calidris mauri* studied at breeding (B) and non-breeding sites (N).

Location	Season	Estimates of ϕ or return rates (rr)	Source
Nome, Alaska	B	0.62, 0.57 males* 0.59, 0.55 females*	Sandercock *et al.* 2000
Yukon-Kuskokwim Delta, Alaska	B	*rr* = 0.58 males *rr* = 0.49 females 0.67 males** 0.40 females**	Holmes 1971, Oring & Lank 1984 Ruthrauff & McCaffery, pers. comm.
Cabo Rojo, Puerto Rico	N	0.56 adults 0.61 juveniles	Rice 1995
Chitré, Panama	N	0.54 males 0.62 females	O'Hara *et al.* 2002
Punta Banda, Mexico	N	0.49 adult males 0.45 juvenile males	Fernández *et al.* 2003

* estimates from two years, samples of nearly all adults
** data from 1998-2002

populations of marked individuals. Sillett & Holmes (2002) obtained estimates of seasonal and annual survival rates from separate local populations of Black-throated Blue Warblers *Dendroica caerulescens* on the breeding grounds in New Hampshire, USA, and on the wintering grounds in Jamaica. Under the assumption that the individuals studied were representative of summer and winter populations, they combined their seasonal estimates with estimates of annual survival rates, and calculated survival rates during the migratory periods, which could not be studied directly. They concluded that the daily mortality rate during migration was 15 times higher than during the two residency seasons. Multiple mark-recapture data sets are becoming available for many non-game species, and comparisons among them may permit additional analyses along these lines. With Western Sandpipers, for example, we hope to develop techniques for combining information from the mark-recapture studies shown in Table 1 to address questions about seasonal survival rates and relative habitat quality.

CUTTING ACROSS DISCIPLINES

Wildlife managers are often called upon to act in response to changes in local population size. Over the past decade, the cumulative number of Western Sandpipers counted during southward migration at the Sidney Island lagoon, a small stopover site in British Columbia, Canada, declined drastically from c. 16 000 to 4 000 (Ydenberg *et al*. 2004), creating a strong incentive to understand the factors causing this change. Members of the Western Sandpiper research group have collaborated, integrating behavioral, ecological, demographic and physiological studies to address this question.

The Sidney Island lagoon includes c. 100 ha of mudflat, surrounded on three sides by a forest and beach. Across the Strait of Georgia, 40 km east of Sidney Island, is the Fraser River estuary, the major stopover site in British Columbia, with over 5 000 ha of open mudflats that are used by up to a million shorebirds every autumn and spring. We do not know whether population changes have also occurred at the Fraser estuary because the size of the site makes it difficult to census. However, comparisons of attributes of both areas, and of birds captured at them, have been useful in our analysis of this situation (Lissimore *et al.* 1999, Ydenberg *et al*. 2002, Ydenberg *et al*. 2004).

At Sidney Island, migrating Western Sandpipers were captured, measured, individually marked, and re-sighted daily during the years of population decline; birds were also captured and measured at the Fraser estuary. At Sidney Island, the body mass of captured birds decreased by c. 10% during this period, while no change was observed at the Fraser estuary. Mark-recapture analysis showed a decline in the length of stay of southbound Western Sandpipers using Sidney Island, falling from about eight days in 1992 to about three days in 2001. These changes suggested that deteriorating food conditions at Sidney Island might cause changes in sandpiper numbers.

Western Sandpipers feed on soft-bodied macro-faunal and meio-faunal invertebrates (Sutherland *et al*. 2000, Wolf 2001), making it difficult and time-consuming to measure food abundance directly. However, recent advances in physiological methods offer novel ways to obtain indicator values for the quality of the resources at a site. Blood plasma triglyceride levels in Western Sandpipers correlate with fattening rates as well as with direct measures of food abundance (Williams *et al*. 1999, Guglielmo *et al*. 2005, Seaman 2003). Triglyceride levels of Western Sandpipers caught at Sidney Island in 1996 were twice as high as at the Fraser estuary (Ydenberg *et al*. 2002), casting doubt on lower food availability as an explanation for decreased usage of Sidney Island. Why, then, did Western Sandpipers leave Sidney Island before reaching a body mass comparable to birds at the nearby Fraser Estuary?

The past two decades have seen a steady increase in populations of the Peregrine Falcon *Falco peregrinus* in western North America (Hoffman & Smith 2003), following severe declines caused by the extensive use of DDT after the Second World War. Daily Peregrine sightings during southward migratory periods in the Strait of Georgia increased steeply since at least 1985 (Ydenberg *et al*. 2004). Western Sandpipers are preyed upon by Peregrines, and their escape performance decreases with increasing body mass (Burns & Ydenberg 2002). Individuals accumulating fat for onward migration are therefore especially vulnerable to predators. Peregrines are most successful when

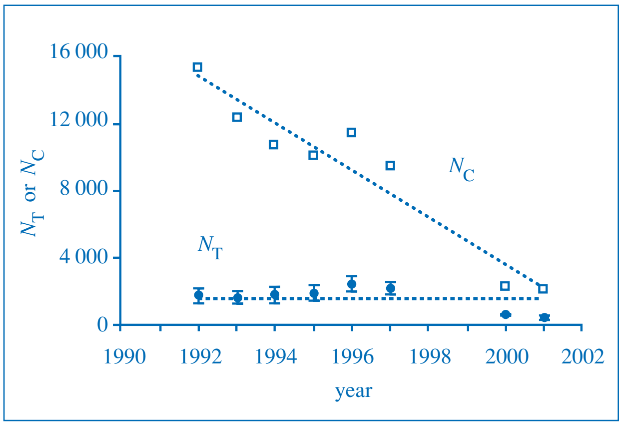

Fig. 3. Comparison of annual cumulative daily counts (NC) of Western Sandpipers *Calidris mauri* stopping over at Sidney Island with estimates of the true number (NT), which take into account the estimate of length of stay. The values for NC indicate a significantly declining trend of c. 18% per year. In contrast, estimates of NT indicate no significant ($P = 0.24$) decline (after Ydenberg *et al.* 2004; reproduced with permission from The Royal Society of London).

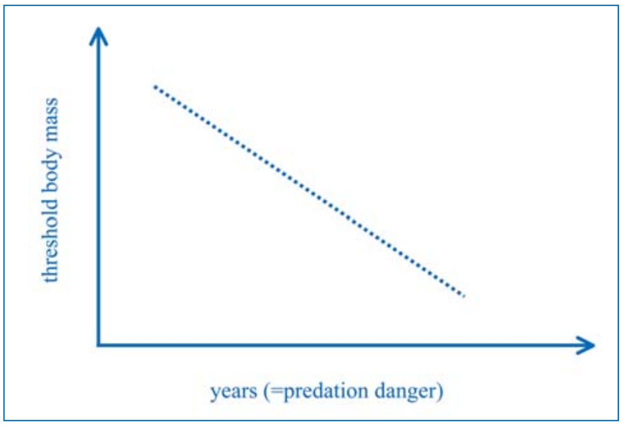

Fig. 4. A bird should switch from a more dangerous but more profitable site to a safer but less profitable site as a function of body mass, which determines its relative escape performance. With increasing predation danger over time, the threshold body mass for changing habitats decreases.

attacking by surprise, which is facilitated by cover, such as high vegetation. The Fraser estuary is large and open, and therefore a relatively safe place for a foraging sandpiper, while Sidney Island is small, enclosed, and inherently more dangerous (Ydenberg *et al.* 2002).

Within this context, Ydenberg *et al.* (2004) developed a hypothesis to explain the change in census numbers at Sidney Island: site choice is driven by a mass-dependent trade-off between local predation danger and foraging profitability. An individual is predicted to switch from a profitable, but dangerous site, to a less profitable, but safer site, contingent on relative marginal fitness values which may be represented as a threshold mass (Fig. 4). With increasing falcon abundance, this trade-off is thought to have led to the following dynamics at Sidney Island: increased danger ⇒ lower mass departure threshold ⇒ shorter length of stay ⇒ fewer birds counted.

Estimates of the true population size of migrants based on census data are particularly sensitive to length of stay. Ydenberg *et al.* (2004) used the mark-recapture data to estimate the actual annual number of birds moving through Sidney Island, incorporating information on length of stay. There was no evidence that fewer individuals passed through the site in later years (Fig. 3); instead, the steep census decline was accounted for almost entirely by the shortened length of stay. Thus, a change in behaviour, rather than a decrease in local population size, was responsible for the apparent decline.

Recoveries in raptor populations are taking place on continental scales in both the eastern and western hemispheres (Cade *et al.* 1988, Kjellén & Roos 2000, Hoffman & Smith 2003), and must have direct effects on mortality rates of their prey. More important, however, may be indirect effects, such as the changes in habitat usage as illustrated here, in response to changes in environmental danger (*sensu* Lank & Ydenberg 2003). The evidence for declining shorebird populations in North America comes primarily from counts made during migration (Morrison *et al.* 2001). Changes in length of stay alter the cumulative number of birds censused and peak counts, both of which are commonly used as indices in analyses of trends in population size. If changes in the use of smaller stopover sites, which are more easily monitored with precision, are taking place elsewhere, behavioral changes could account for part of the perceived population declines (Ydenberg *et al.* 2004). Other behavioral variables that could affect census data include changes in the timing or route of migration, which also may be influenced by predation danger (Lank *et al.* 2003). The potential effects of habitat or other behavioral changes should be taken into account when designing monitoring programs and interpreting data from them.

CONCLUSION

The potential benefits of "cross-cutting" approaches to studies of the population ecology of migratory species may seem obvious, but what are the additional costs associated with this approach? These include generating and adopting common protocols for gathering data, steering students towards projects suitable for thesis topics, and spending far more time in the production of multi-authored reports than might be the case for more independent research. Enticing researchers who work in related fields to address questions of interest is potentially a highly cost-effective approach, as these researchers may subsequently bring more resources to the table as their interests grow, but it has the disadvantage that progress with a project will be limited by the schedules of multiple collaborators, each of whom can slow things down. We have invested considerable time in organizing meetings; this time paid off not only with exchange of information, but also in fostering a sense of common purpose and identity that kept participants engaged with the work. But fundamentally, we have found that collaborations are most likely to prosper if they take advantage of pre-existing interests in the populations or topics being addressed. Much of the success of our network came simply by identifying persons already enthusiastic about a question, supporting their individual efforts, and fostering communication and collaboration among them and with ourselves.

ACKNOWLEDGEMENTS

We thank the Western Sandpiper Research Network, including the persons listed below, each of whom has made a substantial original contribution, knowingly or not. Fred Cooke and Rob Butler (Canadian Wildlife Service) initiated the CWE's focus on this species. For work covered in this review: Nils Warnock, Mary

Anne Bishop and John Takekawa organized northward radio-tracking; Patrick O'Hara worked with Franciso Delgado and others in Panama; Guillermo Fernández worked with Horacio de la Cueva and others in Mexico; Tony Williams and his students Chris Guglielmo and Dana Seaman pursued physiological approaches; and Ron Ydenberg promoted interest in the potential effects of predators on everything. Additional researchers working on the breeding grounds include: Bart Kempenares, Rick Lanctot, Brian McCaffery, Julie Neville, Dan Ruthrauff, Brett Sandercock, and Doug Schamel and family; on migration: Pat Baird, James Burns, Colin Clark, Oliver Egeler, Bob Elner, D.L. Jackson, Gary Kaiser, Barbara Kus, Moira Lemon, Darren Lissimore, James Lyons, Kim Mathot, Edmund Martinez, Amanda Niehaus, Katie O'Reilly, Lew Oring, Brent Ortego, Andrea Pomeroy, Pippa Sheppard, Mary Sewell, Will Stein, Barry Smith, Terri Sutherland, Nick Wolf, Peggy Yen, and Janet Yu; and on the wintering grounds: Felipe Becerril, Alejandra Buenorostro, Roberto Carmona, Jaimie Collazo, Daniel Estrada, Ben Haase, Brian Harrington, Francine Mercier, Susan Rice, Yolanda Sandoval, and Brian Watts.

Barbara Ganter pointed us towards studies of seasonal survival rates in geese, and Ron Ydenberg provided feedback on drafts of the manuscript.

Participants in the Western Sandpiper Research Network have received support from: the Centre for Wildlife Ecology and other programs at Simon Fraser University, The Canadian Wildlife Service and its Latin America Program, Environment Canada, the National Research and Engineering Council of Canada, the Department of Northern and Indian Affairs, Queen's University (Canada), and the Killiam Postdoctoral Program at the University of British Columbia; the US Geological Survey, US Fish and Wildlife Service, National Parks Service, Forest Service, National Science Foundation, Department of Defence, and Environmental Protection Agency; the Smithsonian Tropical Research Station; the Marine Ecosystem Health Program; the National Fish and Wildlife Foundation; Centro de Investigación Científica y de Educación Superior de Ensenada (CICISE); the Consejo Nacional de Ciencia y Tecnología (CONACYT, Mexico); the Patolandia Hunting Club; the European Science Agency; the Konrad Lorenz Institute for Comparative Ethology; the Belgium Fund for Scientific Research; the Point Reyes Bird Observatory; the American Wildlife Research Foundation, Inc.; Chase Wildlife Foundation; Ducks Unlimited; the Lincoln Park Zoo; Sigma Xi; and the John Cooper, Frank M. Chapman, and Jennifer Robinson Memorial Funds.

The authors thank the organizers of the Waterbirds around the world Conference for the invitation to present this work, and Wetlands International for financial support that facilitated Silke Nebel's participation at the meeting.

REFERENCES

Bishop, M.A. & Warnock, N. 1998. Migration of Western Sandpipers: links between their Alaskan stopover areas and breeding grounds. Wilson Bulletin 110: 457-462.

Bishop, M.A., Meyers, P.M. & McNeley, P.F. 2000. A method to estimate migrant shorebird numbers on the Copper River Delta, Alaska. Journal of Field Ornithology 71: 627-637.

Burns, J.G. & Ydenberg, R.C. 2002. The effects of wing loading and gender on the escape flights of least sandpipers (*Calidris minutilla*) and western sandpipers (*Calidris mauri*). Behavioral Ecology and Sociobiology 52: 128-136.

Butler, R.W., Williams, T.D., Warnock, N. & Bishop, M.A. 1997. Wind assistance: a requirement for migration of shorebirds? Auk 114: 456-466.

Butler, R.W., Shepherd, P.C.F. & Lemon, M.J.F. 2002. Site fidelity and local movements of migrating western sandpipers on the Fraser River estuary. Wilson Bulletin 114: 485-490.

Cade, T.J., Enderson, J.E., Thelander, C.G. & White, C.M. 1988. Peregrine falcon populations, their management, and recovery. The Peregrine Fund, Inc., Boise, ID.

Clausen, P., Frederiksen, M., Percival, S.M., Anderson, G.Q.A. & Denny, M.J.H. 2001. Seasonal and annual survival of East-Atlantic Pale-bellied Brent Geese *Branta hrota* assessed by capture-recapture analysis. Ardea 89: 101-111.

Fernández, G., de la Cueva, H., Warnock, N. & Lank, D.B. 2003. Apparent survival rates of Western Sandpiper wintering in northwest Baja California, Mexico. Auk 120: 55-61.

Fernández, G., O'Hara, P.D. & Lank, D.B. 2004. Tropical and subtropical Western Sandpipers (*Calidris mauri*) differ in life history strategies. Ornitología Neotropical 15 (S): 385-394.

Gauthier, G., Pradel, R., Menu, S. & Lebreton, J.D. 2001. Seasonal survival of Greater Snow Geese and effect of hunting under dependence in sighting probability. Ecology 82: 3105-3119.

Gross, M.R. 1996. Alternative reproductive strategies and tactics: diversity within sexes. TREE 11: 92-98.

Guglielmo, C.G., Cerasale, D.J. & Eldermire, C. 2005. A field validation of plasma metabolites profiling to assess refueling performance of migratory birds. Physiological and Biochemical Zoology 76: 116-125.

Harrington, B.A., Brown, S.C., Corven, J. & Bart, J. 2002. Collaborative approaches to the evolution of migration and the development of science-based conservation in shorebirds. Auk 119: 914-921.

Hoffman, S.W. & Smith, J.P. 2003. Population trends of migratory raptors in western North America, 1977-2001. Condor 105: 397-419.

Holmes, R.T. 1971. Density, habitat, and the mating system of the Western Sandpiper (*Calidris mauri*). Oecologia 7: 191-208.

International Wader Study Group 2003. Are waders world-wide in decline? Reviewing the evidence. Wader Study Group Bulletin 101/102: 8-12.

Iverson, G.C., Warnock, S.E., Butler, R.W., Bishop, M.A. & Warnock, N. 1996. Spring migration of Western Sandpipers along the Pacific coast of North America: a telemetry study. Condor 98: 10-21.

Kjellén, N. & Roos, G. 2000. Population trends in Swedish raptors demonstrated by migration counts at Falsterbo, Sweden 1942-97. Bird Study 47: 195-211.

Lank, D.B. & Ydenberg, R.C. 2003. Death and danger at migratory stopovers: problems with "predation risk". Journal of Avian Biology 34: 225-228.

Lank, D.B., Butler, R.W., Ireland, J. & Ydenberg, R.C. 2003. Effects of predation danger on migration strategies of sandpipers. Oikos 103: 303-319.

Lebreton, J.-D., Burnham, K.P., Clobert, J. & Anderson, D.R. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62: 67-118.

Lissimore, D., Lemon, M., Lank, D.B., Butler, R.W. & Ydenberg, R.C. 1999. Large and consistent body mass differences of migrant *Calidris* sandpipers at adjacent stopover sites: phenomenon and possible explanations. Wader Study Group Bulletin 88: 55-58.

Madsen, J., Frederiksen, M. & Ganter, B. 2002. Trends in annual and seasonal survival of Pink-footed Geese *Anser brachyrhynchus*. Ibis 144: 218-226.

Morrison, R.I.G., Aubry, Y., Butler, R.W., Beyersbergen, G.W., Donaldson, G.M., Gratto-Trevor, C.L., Hicklin, P.W., Johnston, V.H. & Ross, R.K. 2001. Declines in North American shorebird populations. Wader Study Group Bulletin 94: 34-38.

Nebel, S. & Lank, D.B. 2003. Cross-seasonal and cross-disciplinary studies of migratory shorebirds. Wader Study Group Bulletin 100: 118-121.

Nebel, S., Lank, D.B., O'Hara, P.D., Fernández, G., Haase, B., Delgado, F., Estela, F.A., Evans Ogden, L.J., Harrington, B., Kus, B.E., Lyons, J.E., Mercier, F., Ortego, B., Takekawa, J.Y., Warnock, N. & Warnock, S.E. 2002. Western Sandpipers during the nonbreeding season: spatial segregation on a hemispheric scale. Auk 119: 922-928.

O'Hara, P.D., Lank, D.B. & Delgado, F.S. 2002. Is the timing of moult altered by migration? Evidence from a comparison of age and residency classes of Western Sandpipers *Calidris mauri* in Panama. Ardea 90: 61-70.

O'Hara, P.D., Fernández, G., Becerril, F., de la Cueva, H. & Lank, D.B. 2005. Life history varies with migratory distance in Western Sandpipers (*Calidris mauri*). Journal of Avian Biology 36: 191-202.

Oring, L.W. & Lank, D.B. 1984. Breeding area fidelity, natal philopatry, and the social systems of sandpipers. In: J. Burger & B.L. Olla (eds) Shorebirds: Breeding Behavior and Populations. Plenum Publishing Corporation, New York: 125-147.

Owen, M. & Black, J.M. 1991. The importance of migration mortality in non-passerine birds. In: C.M. Perrins, J.-D. Lebreton & G.J.M. Hirons (eds) Bird Population Studies: Relevance to Conservation and Management. Oxford University Press, Oxford: 360-372.

Page, G.W. & Fearis, B. 1971. Sexing Western Sandpipers by bill length. Bird Banding 42: 297-298.

Rice, S.M. 1995. Residency rates, annual return rates and population estimates of Semipalmated and Western Sandpipers at the Cabo Rojo Salt Flats, Puerto Rico. MSc thesis, University of Puerto Rico, Puerto Rico.

Sandercock, B.K., Lank, D.B., Lanctot, R.B., Kempenaers, B. & Cooke, F. 2000. Ecological correlates of mate fidelity in two Arctic-breeding sandpipers. Canadian Journal of Zoology 78: 1948-1958.

Schmutz, J.A. & Ely, C.R.E. 1999. Survival of Greater White-fronted Geese: Effects of year, season, sex, and body condition. Journal of Wildlife Management 63: 1239-1249.

Seaman, D.A. 2003. Landscape physiology: plasma metabolites, fattening rates and habitat quality in migratory Western Sandpipers. MSc thesis, Simon Fraser University, Burnaby.

Sillett, T.S. & Holmes, R.T. 2002. Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology 71: 296-308.

Stroud, D.A., Davidson, N.C., West, R., Scott, D.A., Haanstra, L., Thorup, O., Ganter, B. & Delany, S. (compilers, on behalf of the International Wader Study Group) 2004. Status of migratory wader populations in Africa and Western Eurasia in the 1990s. International Wader Studies 15: 1-259.

Stroud, D.A., Baker, A., Blanco, D.E., Davidson, N.C., Delany, S., Ganter, B., Gill, R., González, P., Haanstra, L., Morrison, R.I.G., Piersma, T., Scott, D.A., Thorup, O., West, R., Wilson, J. & Zöckler, C. (on behalf of the International Wader Study Group). 2006. The conservation and population status of the world's waders at the turn of the millennium. Waterbirds around the world. G.C. Boere, C.A. Galbraith & D.A. Stroud (Eds.), The Stationery Office, Edinburgh, UK. 643-648.

Sutherland, T.F., Shepherd, P.C.F. & Elner, R.W. 2000. Predation on meiofaunal and macrofaunal invertebrates by western sandpipers (*Calidris mauri*): evidence for dual foraging modes. Marine Biology 137: 983-993.

Ward, D.H., Rexstad, E.A., Sedinger, J.S., Lindberg, M.S. & Dawe, N.K. 1997. Seasonal and annual survival of adult Pacific Brant. Journal of Wildlife Management 61: 773-781.

Warnock, N. & Bishop, M.A. 1998. Spring stopover ecology of migrant Western Sandpipers. Condor 100: 456-467.

White, G.C. & Burnham, K.P. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 S: 120-138.

Williams, T.D., Guglielmo, C.G., Egeler, O. & Martyniuk, C.J. 1999. Plasma lipid metabolites provide information on mass change over several days in captive Western Sandpipers. Auk 116: 994-1000.

Wilson, W.H. 1994. Western Sandpiper (*Calidris mauri*). In: A. Poole & F. Gill (eds) The Birds of North America. Academy of Natural Sciences, Philadelphia, Pennsylvania; American Ornithologists' Union, Washington, D.C.

Wolf, N. 2001. Foraging ecology and stopover site selection of migrating Western Sandpipers (*Calidris mauri*). MSc thesis, Simon Fraser University, Burnaby.

Ydenberg, R.C., Butler, R.W., Lank, D.B., Guglielmo, C.G., Lemon, M. & Wolf, N. 2002. Trade-offs, condition dependence and stopover site selection by migrating sandpipers. Journal of Avian Biology 33: 47-55.

Ydenberg, R.C., Butler, R.W., Lank, D.B., Smith, B.D. & Ireland, J. 2004. Western sandpipers have altered migration tactics as peregrine populations have recovered. Proceedings of The Royal Society of London B 271: 1263 - 1269.