

7th WESTERN SANDPIPER WORKSHOP Jan 17-19
Simon Fraser University,
Burnaby, B.C., Canada

ABSTRACTS

* = Poster

Conservation implications of a changing predator landscape

Rob Butler, Canadian Wildlife Service

Variation in shorebird use of diurnal, high tide roosts: How traditional are roosts?

Mark A. Colwell, T. Danufsky, N. Fox, J. Roth and J. Conklin

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In coastal environs during the non-breeding season, many shorebirds congregate at roosts, long considered to be traditional sites where individuals coalesce when high tides inundate feeding areas. Few studies, however, have quantified spatial and temporal variation in the number of birds using roosts. Consequently, we surveyed roosts to assess variation in use (frequency of use and proportional abundance), concentrations (Shannon-Wiener Index, H' of species' proportional abundances), and repeatability (Kendall's coefficient of concordance, gauging consistency of ranked importance of roosts) among seasons of 14 shorebird species using diurnal, high tide roosts around Humboldt Bay, California during 2002. We identified 240 roosts used by 30 species. Interspecific differences among the 14 most abundant taxa correlated with abundance – more abundant species were less concentrated at more roosts compared to less common species. Repeatability of roost use was high for all 14 species among seasons, although daily variation in species' abundances was considerable. Among species, this variation in roost use spans a continuum of ephemeral to traditional; causes of variation in species' abundances at roosts is probably correlated with tide height, weather, and presence of predators (especially *Falco peregrinus*) and human disturbance. We continue to explore these causes by studying movements of radio-marked dunlin (*Calidris alpina*) and focal sampling the most used roosts.

Peregrine Falcon predation on Dunlins in relation to the tidal cycle.

Dick Dekker

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At Boundary Bay, British Columbia, the interaction of Dunlins and Peregrine Falcons was studied on 133 days during November-January 1994-2002. A total of 590 hunts were recorded, resulting in the capture of 84 Dunlins. Adult peregrines were significantly more successful than immatures. The two main hunting methods were: (1) open attacks on Dunlins in flight, and (2) stealth attacks on resting and feeding Dunlins. Their respective success rates are given. Dunlins were captured from flocks or after they had separated from flocks. The highest capture rate resulted from stealth attacks on Dunlins roosting on the edge of the saltmarsh. The great majority of Dunlins flew out over the ocean before high tide and stayed away from shore for 2-4 hrs. Separate hunting success rates are given for November, December, and January. The timing of kills and the kill rate per hour relative to the tidal cycle are analyzed and presented graphically.

Marching to a different bill: New notions on Western Sandpiper feeding and distribution

Robert Elner, Kim Mathot, Silke Nebel & Dana Seaman, Canadian Wildlife Service and SFU

Sex-related differences in foraging behaviour of Western Sandpipers on the wintering grounds.

Guillermo Fernández, Centre for Wildlife Ecology, Depart Biol Sciences, Simon Fraser University

Differences in foraging behaviour and habitat use of Western Sandpiper (*Calidris mauri*) were investigated during the nonbreeding season at Bahia Santa Maria, Mexico. Three habitat types were categorized: large open brackish flats, mangrove-salt marsh with moderate flats, and cattail marsh with small beaches. Sex composition was consistently male-biased in brackish flats, more evenly in cattail marshes, and more variable in mangrove flats. Age composition was consistently adult-biased for both sexes in brackish and mangrove flats than in cattail marshes. Females were better adapted to deep feeding while males were better surface feeders as indicated by disproportionate use of sewing and pecking, respectively. Males as a surface-feeders had lower foraging and higher walking rates than females; however, they had larger and more cohesive flocks. Birds pecked more in brackish and mangrove flats meanwhile they sewed more in cattail marshes. Foraging behaviour was affected by water cover and depth, with individual levels of pecking decrease and sewing increase as water cover and depth increase. Males used shallower sites with less water cover than females, and brackish and mangrove flats had deeper sites with less water cover than cattail marshes. Individual's body size (bill length and overall size) does not determine their foraging strategy, with males having a more opportunistic foraging repertoire than females. These sex-related foraging specialisations probably reduce intersexual interactions on the wintering grounds and may have implications in their flocking behaviour, such as the presence of single-sex flocks and territorial behaviour.

Present and Future Shorebird Studies in Alaska

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Shorebird enthusiasts from Alaska, Canada, and the Pacific Northwest participated in the 8th annual meeting of the Alaska Shorebird Group (ASG) in December 2002. During this meeting, the ASG formalized their "terms of reference" and discussed a revision to the Alaska Shorebird Plan. Presentations over the 3 day meeting included monitoring efforts, including numerous talks on the Program for Regional and International Shorebird Monitoring (PRISM), and other species-specific monitoring efforts, a multi-site study on shorebird nest survival in relation to predator numbers in industrial areas on the North Slope, subsistence hunting of shorebirds, and other species-specific studies. I will highlight many of these topic areas, and discuss upcoming studies proposed for 2003. The latter includes studies on testing intensive plot protocols within PRISM, breeding shorebird studies on the North Slope, and efforts to coordinate shorebird monitoring in southeast Alaska.

Effects of Predation Danger on Migration Strategies of Sandpipers

David B. Lank, Robert W. Butler, John Ireland and Ronald C. Ydenberg

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We examine the potential selective importance of predation danger on the evolution of migration timing and routes of western (*Calidris mauri*) and semipalmated (*C. pusilla*) sandpipers. Adults of both species depart their arctic breeding grounds early, truncating parental care 2-4 weeks prior to fledging of young, for reasons apparently unrelated to levels of food abundance on the breeding areas or at migratory stopover sites. The duration of parental care decreases during the season, suggesting a shifting fitness trade-off between providing parental care and adult

survivorship. In south-western British Columbia, southbound adult western sandpipers pass through rapidly in July, preceding migratory peregrine falcons (*Falco peregrinus*) by almost a month. Adult western sandpipers remain ahead of migrant falcons all the way south to their non-breeding areas, where they rapidly moult flight feathers, completing the transition to new plumage just as migratory falcons arrive in late September-October. Juvenile Western Sandpipers pass through British Columbia in August, when migrant falcon numbers start to increase. However, the later-migrating juveniles do not moult flight feathers therefore do not face a period of higher vulnerability after falcon arrival on non-breeding grounds..

East of the Rocky Mountains, the southbound migration of falcons begins 4-6 weeks later, providing sandpipers a much longer window of safety during migration. Adult and young semipalmated sandpipers passing through the Dakotas and the Bay of Fundy make long migration stopovers during July and early August, but their lengths of stay shorten prior to falcon migration in September. Predation danger also may affect the evolution of migration routes. Southbound western sandpipers make a direct 2400 km flight over the Gulf of Alaska, saving 11.8 – 24.8 days and 2.3 g in fat, relative to the 3300 km coastal route that they use when northbound in spring. We estimate that the trans-Gulf route would also be more economical on northward migration. However, preparation for a northward trans-Gulf flight would expose sandpipers to mass-dependent increased danger level from migratory falcons, which travel north coincident with migrants in spring. In contrast, few falcons are present during preparation for the southbound flight. A temporal and spatial window of safety is also permissive of semipalmated sandpipers doubling their lean mass and becoming potentially extremely vulnerable to predation while preparing for trans-Atlantic southward flights from Maritime Canada and New England. These examples show that danger management can account for previously enigmatic features of calidridine migration strategies, and likely those of other birds. ,

Distributional and experimental evidence that feather wear influences the migratory decisions of sandpipers

Patrick D. O'Hara, David B. Lank and Guillermo Fernández CWE, Simon Fraser University, BC

We show that the propensity to oversummer (remaining on the non-breeding grounds during the breeding season) in shorebirds is latitude dependent by comparing mass gain and prealternate moult (into bright breeding plumage) for populations of arctic breeding Western Sandpipers (*Calidris mauri*) that spend the non-breeding season in México and Panamá. Data for this comparison was collected from 1995-98. We found that most, if not all, individuals in México prepare for migration in the spring, whereas in Panamá, most, if not all, juveniles show no sign of preparing for migration, while adults do. Primary feather wear probably increases with migratory distances flown, and this wear may provide a mechanism for this latitudinal trend observed in oversummering propensity in juveniles. Juveniles do not replace any of their primary feathers upon arrival on the non-breeding grounds as adults do. In 1998, we tested the hypothesis that feather wear may affect the decision to migrate by experimentally clipping primary feathers, shortening wing chord by an amount that we estimate is equivalent to wear from one migratory flight between Panamá and the breeding grounds. We found that clipped adults were more likely to be resighted (colour combinations) in Panamá than control adults, and that there was a slightly opposite trend in juveniles. We also found that clipped adults recaptured after treatment were significantly lower in mass and gained mass at a slower rate than control adults. These results suggest that wing feather wear can influence the decision to migrate, and that this may be a behavioral response as adults gain insufficient mass for migration because of reduced flight performance due to clipping.

“Advertisement in Breeding Western Sandpipers: Uncertainty About the Target Audience”

Brian J. McCaffery, Yukon Delta National Wildlife Refuge, PO Box 346, Bethel, AK 99559

The function of aerial displays in breeding sandpipers has been debated for decades. The two major hypotheses to explain such behavior are the mate attraction hypothesis and the territory defense hypothesis. Current formulations of predictions generated by these hypotheses, however, are often weak and/or imprecise. In particular, some of these predictions rest on untested assumptions about the function and duration of territoriality in breeding sandpipers. A recent study of Western Sandpipers near Nome, Alaska, concluded that aerial displays functioned primarily for mate attraction, and secondarily for territorial defense. I repeated aspects of this study at Kanaryarmiut Field Station on Yukon Delta National Wildlife Refuge, where densities of Western Sandpipers are more than an order of magnitude higher than at Nome. The two studies were in agreement in most cases where each had data to test specific predictions, but the weakness of some predictions precluded definitive conclusions about the function of aerial displays. On the Yukon Delta, courtship calling from the air and singing from the ground were more predictably associated with mate attraction and courtship, respectively, than was aerial flight singing. I could not compare the effect of mate fidelity on display rates between the two study sites, because on the Yukon Delta, none of 16 focal males with known histories paired with the previous year's mate. In terms of site fidelity (i.e., local breeding experience), however, results from the Yukon Delta differed from those at Nome. The experience of the female had no effect on the display rate of experienced males, and for experienced females, the experience of their mate had no effect on his display rate.

“Absentee landlords, squatters, and dual residency: Observations on breeding territoriality in the Western Sandpiper”

Brian J. McCaffery, Yukon Delta National Wildlife Refuge, PO Box 346, Bethel, AK 99559

I studied Western Sandpiper territoriality in nesting habitat at the Kanaryarmiut Field Station on Yukon Delta National Wildlife Refuge. Despite the theoretical costs of temporary absence, males regularly left their territories early in the breeding season. From territory establishment through clutch completion, an interval when the benefits of holding a territory may be highest, males left their territories 2.42 times/hr and remained off territory for about 24 min/hr (40% of the time). The pairing status of the male (paired vs. unpaired) did not affect the amount of time spent off-territory, and among paired males, the presence of the female did not affect the likelihood of male departures. Among paired males during the females' fertile period, males were separated from their mates during 55% of all 30-min samples. Among 30-min samples during which the pair was seen together at least once on territory, the male left his mate and the territory during $\geq 44\%$ of the samples. When a male is absent from his territory, neighboring males trespass overtly, displaying over, and even fighting with other males on, the temporarily vacated territory. Interpretation of absenteeism is confounded by the fact that male Western Sandpipers also perform aerial displays, defend space, and court and copulate with females in wetland habitats which are spatially separated from territories in nesting habitat. The theoretical costs and benefits of absence from a nesting territory have yet to be evaluated quantitatively.

Kidney, liver and bone cadmium content in the western sandpiper in relation to migration.

C.N.McFarland, L.I. Bendell-Young, C. Guglielmo and T. D. Williams, SFU

Cadmium content was measured in kidney, liver and tarsus bones of western sandpipers (*Calidris mauri*) at a temperate migratory stopover site (Fraser Delta, British Columbia, Canada) and a wintering site (Playa el Agallito, Chitre, Panama) over a two year period. Cadmium content in liver and kidney was age and sex dependent. Adult females generally had lower kidney and liver cadmium than adult males ($P \ll 0.05$), but a sex difference was not detected in juveniles. Cadmium increased with age in kidney, liver and to a lesser extent in bone ($P \ll 0.001$) with average “steady-state” kidney and liver content being reached within the sandpipers first year. In general, tissue cadmium residues in adult males and females were independent of sampling location although for bone, site-specific differences did occur ($P \ll 0.001$). Bone cadmium was lower in females sampled from their wintering grounds as compared to temperate stopover sites suggesting that bone cadmium may be mobilized during periods of feather molt. Comparison of cadmium residues among sandpipers of increasing age suggest that exposure is occurring along the Pacific Coast, at stopover sites as the birds migrate north to Alaska and south to Panama. This study points to the importance of considering the ecology of the species (e.g., in this case migratory behavior) in interpreting trace metal residues.

The effects of predation on site choice in Western Sandpipers

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The Western Sandpiper (*Calidris mauri*) is a classic example of a ‘differential migrant’, as during the non-breeding season, the proportion of females increases steadily from British Columbia to Peru. Here, I am investigating whether differences in predation danger between sites and in vulnerability to predation between males and females can affect choice of non-breeding site.

I hypothesise that latitude-specific environmental variability affects vulnerability to predation and that vulnerability is dependent on body size and mass, and that it affects site of choice sandpipers on both a local and a latitudinal scale. I predicted that (1) female Western Sandpipers have higher wing loading than males due to their larger body size, that (2) females get killed more often by predators than males, that (3) wing loading decreases in each age and sex class from north to south due to decreasing environmental variability, that (4) perceived predation danger in the south is equal to or lower than in the north, that (5) individuals show a less pronounced flight response to predation events further south as they carry less body fat and are therefore less vulnerable, that (6) wing loading decreases less steeply in females than in males as the additional fat in the north is thought to be more costly for the larger females, and that (7) within latitude, wing loading is lower at small sites than at large sites, as the latter are thought to be safer.

Only predictions (3) and (7) were supported by our data. There is no evidence that females are more vulnerable to predation than males, and the hypothesis that site choice of sandpipers along a latitudinal scale is explained by differences in vulnerability and predation danger is not supported, while site choice on a local scale might be affected by difference in perceived predation danger.

Inter-annual variation in the migratory timing of Western Sandpipers: What is the effect of breeding phenology?

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For Western Sandpipers breeding on the Alaskan tundra, snowmelt defines the beginning of the breeding season; the end of the season is defined by the need to begin migrating southward. The southward migratory timing of sandpipers varies substantially among years, perhaps reflecting adjustments made by birds to compensate for varied climate conditions at breeding sites.

In this study, I investigate how climatic variation on the breeding grounds influences breeding and migratory phenology in Western Sandpipers (1978-2000). Based on known patterns of parental care, I predict the effects of early or late snowmelt on parental departure and compare the 'earliness' or 'lateness' of breeding initiation with the relative migratory timing of males and females. Finally, I evaluate long-term climate change in the Western Sandpipers' breeding area and suggest possible impacts of climate change on arctic-breeding shorebirds.

Hatch timing of shorebirds in western Alaska was strongly associated with the timing of snowmelt. However, the 'earliness' or 'lateness' of the breeding season could not be used to predict migratory timing, indicating that variation in the migration of Western Sandpipers among years cannot be traced to the timing of breeding. Although snowmelt dates did advance over the period of study, the trend was not significant.

Climate influences the breeding schedule of Western Sandpipers, and future changes in snowmelt and temperature are likely to affect the phenology of arctic-nesting shorebirds. Adult sandpipers may compensate behaviorally for inter-annual climatic variation, but long-term trends should be carefully monitored.

Foraging in a Risky Landscape: Fear and the Western Sandpiper

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To maximize fitness during migration, animals should choose stopover habitats with the lowest ratio of mortality risk to the duration of migration, thereby minimizing mortality per distance covered. Current stopover ecology recognizes the importance of mortality (either by starvation or predation) to migratory animals, but often neglects the costs an animal must pay to minimize the risk of predation.

My objective was to determine how food availability and predation risk affect habitat use by the western sandpiper (*Calidris mauri*) at Boundary Bay, British Columbia, during northward migration. I predicted that if food abundance determines sandpiper distribution, then sandpipers would use areas of the mudflat highest in invertebrate abundance. If sandpiper distribution is determined by the risk of predation, then sandpiper use will be highest where the risk of predation is low. However, if sandpipers balance food intake with predation risk then we expect use to be highest where the net benefit is optimized.

To test this hypothesis I measured invertebrate abundance, sandpiper use, and sandpiper behaviour at varying distances from the marsh edge at three, 1 km long transects perpendicular to the shoreline. High-risk areas are those nearest to the shoreline, where falcons can use cover, such as marsh grasses, to conceal an attack.

Results indicate that invertebrate abundance declines with increasing distance from the shoreline. Although invertebrate abundance is high nearest to the shoreline, habitat use by

sandpipers is low in these high-risk areas of the mudflat and peaks at areas of intermediate food abundance. This pattern of habitat use suggests that migratory western sandpipers balance the benefits of foraging with the costs of minimizing predation risk. These results may have important implications when we consider how migratory animals select and use migration stopover habitats.

Seasonal and age-related trends in the reproductive output of Western Sandpipers at Kanaryaraq, Alaska

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We studied the seasonal and age-related effects on reproductive output of Western Sandpipers at Kanaryaraq, Alaska, in 1999 through 2001. We examined variation in date of nest initiation, clutch size, average egg volume per clutch, nest daily survival rate, fledging success, reproductive success, and parental brood attendance. Western Sandpipers exhibited seasonal declines in all measures of reproductive output. To assess trends with respect to age and experience, we categorized breeding Western Sandpipers as yearlings (birds less than one year old, attempting their first breeding effort), new adults (birds more than one year old, attempting their first breeding effort), or old adults (birds more than one year old, attempting at least their second breeding effort). Effects of age and experience were more pronounced in females than males. Older, more experienced Western Sandpiper females exhibited increased reproductive output compared to younger, less experienced birds. This result is of special interest given the low rates of female survival at Kanaryaraq.

The effects of sex and age on the survival of Kentish Plovers breeding in southern Turkey.

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The life-histories of shorebirds are characterized by low productivity, high rates of nest and brood failure and high adult survival. Robust estimates of survival are essential for understanding the population dynamics of shorebirds and other long-lived vertebrates. In this study, we use resighting data and mark-recapture statistics to estimate apparent survival for a population of Kentish Plovers (*Charadrius alexandrinus alexandrinus*) breeding in Turkey. Estimates of survival for Kentish Plovers and the conspecific Snowy Plover (*C. a. nivosus*) are of interest because both subspecies are of conservation concern, and have a peculiar mating system.

A total of 2077 plovers were captured and banded over a 5-year period. The proportion of juveniles returning was 0.04, with no difference between males and females. Apparent survival was low among juveniles that survived 0-28 days (= 0.09) and somewhat higher among young that survived until fledging (= 0.13). Most juveniles started breeding as yearlings. Apparent survival rates of adult plovers were 0.60-0.64, and males had higher resighting rates than females (0.84 vs. 0.74). The lack of a sex difference in survival is puzzling and difficult to reconcile with a male-biased sex ratio among adults. Overall, our estimates are consistent with return rates reported for other small-bodied *Charadrius* plovers.

The Effects of a Late Season on Nesting Western Sandpipers at Cape Espenberg, Alaska **Douglas Schamel¹, Diane M. Tracy², Jay T. Schamel², Juliann T. Schamel², and Yuri Zharikov³**

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We studied aspects of breeding biology of Western Sandpipers (*Calidris mauri*) at Cape Espenberg in northwestern Alaska from 1994-99 and 2001. The winter of 2001 was prolonged, and resulted in the latest snowmelt in over 30 years in this area. In a typical year, clutches are initiated in late May or early June. In 2001, the Cape had a complete snow in Western Sandpiper habitat until after June 10. We predicted a delay in nest initiation, a truncated nesting season, and decreases in egg size, clutch size, nesting success, fat scores of adults, number of nesting birds, and proportion of nesting yearlings. The nesting season was delayed and truncated, with a majority of birds initiating clutches within the first 3 days. We found no decrease in egg size or clutch size, compared to other years. Fat scores of nesting birds did not differ between sexes or among years. Fewer yearling males nested in 2001 than other years; the proportion of nesting yearling females did not differ among years. Yearling males may have been delayed in migration, and low in fat reserves, thus making them less competitive for establishing and holding territories. The sharply truncated end of the nest initiation period suggests strong selection on timing of chick hatching. As found in other studies, egg size and clutch size seems fairly robust, even in potentially stressful situations. The strong correlation of nesting success and nesting phenology was surprising; we have not yet examined this relationship in other species or in other areas.

Landscape physiology: Differences in fattening rates, as indicated by plasma metabolites, in free-living migratory Western Sandpipers

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The ultimate expression of the quality of a site is in the condition of the individuals using it. In migratory birds, success of migration is linked to the rate of fat deposition at stopover sites. Therefore fattening rates can serve as an index for habitat quality of migratory stopover sites. Size-corrected body mass has been used as an index for body condition, but only provides information at a single point in time. Previous studies by our group have shown that plasma triglyceride concentrations can predict mass change in free-living birds and provide information on the physiological condition of birds. In this study, we demonstrate significant site differences in predicted fattening rates in migrating Western Sandpipers (*Calidris mauri*) at stopover sites within the Georgia Basin/Puget Sound based on metabolite analysis. Stronger site effects were detected during northward than southward migration. There was within site consistency between seasons in plasma concentrations for the reference site that was sampled during each of the migration stages. This study also highlights the inconsistencies between size-corrected body mass and triglyceride levels at the various sites. There was a positive relationship between triglyceride levels and total prey macrofaunal abundance. Future work will explore correlations with other underlying ecological factors that may explain the remaining variation in fattening rates.

Detecting seasonal differences in diet quality with digestive enzymes

R. Will Stein, Tony D. Williams, Carlos Martinez del Rio, and Allen R. Place

The Western Sandpiper (*Calidris mauri*) exhibits hypertrophy of the small intestine (in association with hyperphagia) while refueling during migration. In addition, the Western Sandpiper is an invertebrate generalist that exhibits no major seasonal preference in prey, as determined from prey remains in fecal samples. We sampled Spring and Fall migrants at Boundary Bay, British Columbia, to examine seasonal variation in digestive organ size and enzyme activity in refueling migrants. We detected no seasonal differences in the size of any of the digestive organs (proventriculus, gizzard, pancreas, or small intestine) after correcting for body mass. Only one of five digestive enzymes, pancreatic amylase (glycogen), did not exhibit seasonal variation in activity. Refueling Spring migrants had significantly higher proventricular chitobiose (chitin), pancreatic lipase (triglycerides), and intestinal maltase (maltose) and aminopeptidase-N (polypeptides) activities, than Fall migrants. Due to the mechanisms of enzyme induction, the seasonal differences in digestive enzyme activities strongly support seasonal differences in diet quality, which may be reflected in refueling behaviour, i.e. foraging rates and or stopover duration.

Sexual selection and the evolution of breeding systems in shorebirds.

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Shorebirds exhibit an impressive range of breeding behaviours. I will focus on two aspects of this diversity: (i) does sexual selection influence sexual size dimorphism (SSD), and (ii) why does the intensity of sexual selection vary among shorebird species? These questions will be addressed using phylogenetic comparative analyses. Firstly, the direction and extent of shorebirds' SSD is consistent with predictions of sexual selection theory, because more polygynous species (or the ones in which the male has non-agile courtship displays) exhibit male-biased SSD, whereas more polyandrous species (or the ones with agile male displays) exhibit female-biased SSD. Niche-division of ecological resources appears to be unrelated to SSD. Secondly, the intensity of sexual selection is related to the pattern of parental care. However, it remains to be shown whether such relationship is driven by parental care, or there is a feedback relationship between mating behaviours and patterns of care. Finally, I will outline some of the major unresolved questions of shorebird breeding systems, and discuss potential avenues for future research.

Travel strategies of migration Western Sandpipers, Dunlin, and Dowitchers,

AVEL Nils Warnock, Point Reyes Bird Observatory, Stinson Beach, CA; Mary Anne Bishop, Prince William Sound Science Center, Cordova, AK; and John Y. Takekawa, BRD, USGS, Vallejo, CA.

Almost no data exist on the travel strategies of individual migrating birds with mass <200 g. We present data on lengths of stay, sustained rates of travel, and site use of Western Sandpipers, Dunlin and dowitchers over a 7000 km stretch of the Pacific Flyway of North America. Data were collected in 1995, 1996, 2001 and 2002, during the course of the shorebirds northward migration. In total, we radio-marked 191 Western Sandpipers, 48 Long-billed Dowitchers, 42 Short-billed

Dowitchers, and 28 Dunlin. Banding locations varied by year of study and included Bahia de Santa Maria, Sinaloa, Mexico (2002), San Francisco Bay, CA (1995, 1996, 2001), Honey Lake, CA (1995, 1996), and Grays Harbor, WA (1995, 1996, 2001). For Western Sandpipers, Dunlin and dowitchers banded in California and Washington, our recovery rates of radio-marked birds in Alaska (at the Copper River Delta) were high (>70%), indicating the importance of this site to all of these species. Average length of stays (>16 days) of Western Sandpipers and Long-billed Dowitchers at the Sinaloa banding site were generally more than a week longer than average length of stays of Western Sandpipers, Dunlin and dowitchers at banding sites in California and Washington. Past banding sites, average length of stays of these species were short (1-3 days), with a few exceptions (average LOS for Western Sandpipers at San Francisco Bay and dowitchers at Willapa Bay was >5 days). We found that Western Sandpipers took an average of 28.3 d to cover 6230 km (220 km d⁻¹) from wintering grounds in Mexico to breeding grounds in western Alaska. Implications of our findings will be discussed.

A decadal change in western sandpiper migration tactics on a recovering predator landscape

Ronald C. Ydenberg, Robert W. Butler, David B. Lank, Barry D. Smith & John Ireland

Populations of many raptor species in North America are recovering since the ban on DDT and the implementation of conservation measures, in effect constituting a continent-wide predator-reintroduction experiment. The presence of top predators is known to affect prey behaviour, and here we document changes in the migratory behaviour of western sandpipers (*Calidris mauri*) occurring over two decades at two stopover sites in the Strait of Georgia, British Columbia. The changes are associated with the recovery of populations of an important predator, the peregrine falcon (*Falco peregrinus*). We show that since 1985 and the onset of peregrine recovery, migratory body mass of western sandpipers has fallen and stopover duration has shortened. These effects are more marked at a relatively dangerous stopover site, and during more dangerous migration periods. The shortened stopover duration can account for an apparent reduction in the number of migrant sandpipers using these stopover sites, as estimated by sequential counts. These observations have implications for the population monitoring and conservation of other sandpiper species, and for neotropical migrants in general.

The wintering distribution of migratory sandpipers: an evolutionary settlement game with mobile predators and prey

Ron Ydenberg & Don Hugie

The autumn migration returns sandpipers from high latitude breeding areas to lower latitude wintering areas. Predators of sandpipers such as falcons migrate to wintering sites at about the same time. This paper considers characteristics of the geographical distribution that results when both predators and prey are mobile and able to choose a wintering site. Sandpipers are assumed to be less vulnerable to predators at wintering sites at which a low level of reserve fat is required during the midwinter period, and the probability of starvation at each of the sites is assumed to be density dependent. A game model of site choice with these simple assumptions provides a novel perspective on wintering site choice, emphasizing the role of vulnerability to predators.

What may explain the southward increase in the proportion of females in populations of Far Eastern Curlews (*Numenius madagascariensis*) wintering in Australia?

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A comparison of three latitudinally distinct sites in Australia, the tropical Roebuck Bay (18°S), subtropical Moreton Bay (27°S) and temperate Westernport Bay (38°S) showed that the proportion of females in the local non-breeding populations of Far Eastern Curlews increased from 40% to 53% to 67% respectively.

Attempting to provide possible explanations for this cline, we examined available data on latitudinal distribution of potential predators (large raptors) and known prey (decapod crustaceans) of the shorebird. We found that the potential predator numbers likely increase in the same direction as the proportion of females. This implies that the females tend to occur in the areas with a potentially higher predation risk. We also found that locally (within a site) as well as at the continental scale male curlews tended to dominate in areas with high densities of large epibenthic crabs of genus *Macrophthalmus*, whereas the females were relatively more common in areas populated by burrow-dwelling Thalassinid shrimp of genus *Trypaea*. We suggest that the southward cline in the proportion of females may be best explained by the combined effect of (1) morphological differences between sexes: females may be better adapted for capturing burrowing prey while males may be better adapted for capturing surface-active prey and (2) competitive displacement of the smaller sex (males) by the larger (females). This is because *Trypaea*, as compared to *Macrophthalmus*, likely provide for a food source, which is much more predictable spatially as well as temporally.

POSTERS

***Long-billed Curlew spatial distributions**

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Understanding a species' spatial distribution is important in applied ecology and key insights derive from analyses conducted at several spatial scales. Consequently, we quantified low-tide distributions (uniform, random and aggregated) of non-breeding Long-billed Curlews (*Numenius americanus*) at three spatial scales, within individual home ranges (1-8 ha), in a local estuary (~50 ha), and regionally in intertidal habitats of Humboldt Bay (62 km²), CA. Individuals (n = 8) most often (75%) foraged in territories in a manner that produced a uniform distribution; patterns tended toward random (16%) and aggregated (8%) when individuals moved over larger areas. In the estuary, curlews often (73%) were distributed uniformly, although patterns became random (27%) when more curlews were present during summer and autumn. At this scale, uniform patterns were a consequence of territoriality. Across Humboldt Bay, curlews were consistently aggregated in certain areas and absent from others. At each spatial scale, food probably had the strongest influence on these patterns; predation risk played a relatively minor

role in determining dispersion patterns. Overall, we estimate that 250-300 curlews winter at Humboldt Bay, which represents approximately 1% of the species' population.

***Functional significance of sexual dimorphism in western sandpipers: sex related differences in foraging mode**

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Differences in bill structure have been related to differences in foraging behaviours in numerous species of shorebirds. Western sandpipers, *Calidris mauri*, are strongly sexually dimorphic, with females being larger than males and having disproportionately longer bills. Despite the high degree of bill dimorphism in this species, its functional significance has not previously been reported.

The objective of this study was to investigate whether or not bill dimorphism in western sandpipers correlates with differences in feeding strategies. Two general categories of foraging behaviours exist in western sandpipers: epifaunal (pecking) and infaunal (probing). We predicted that females would engage in infaunal feeding more so than males because longer bills have been found to be better suited for probing than shorter bills in other shorebird species.

The foraging behaviour of western sandpipers was observed at a migratory stopover site in the Fraser River delta, British Columbia. Birds were sexed by eye as male, female or intermediate based on bill length. Males had the highest proportion of epifaunal feeding (0.9646), followed by intermediates (0.9486) and females (0.8397). Female foraging behaviour differed significantly from both males ($p < 0.001$, $df = 105$, $t = -8.493$) and intermediates ($p < 0.001$, $df = 93$, $t = -6.622$). Foraging rate also differed between sexes, with males having the highest rate (61.85 behaviours*min⁻¹), followed by intermediates (55.34 behaviours*min⁻¹) and females (54.21 behaviours*min⁻¹). The mean male foraging rate was significantly greater than that of females ($p < 0.001$, $N = 108$, $t = -4.384$) and intermediates ($p < 0.001$, $df = 104$, $t = -3.361$).

As males and females foraged in mixed flocks, the behavioural differences in foraging mode found in this study cannot be accounted for by differences in habitat. The observed differences are consistent with sexual specialization in foraging modes arising from sexual dimorphism in bill characteristics. As in other shorebird species, the longer billed sex was found to engage in sub-surface feeding to a greater extent than the shorter billed sex. Although subsurface feeding likely confers greater access to larger prey such as polychaetes, there appears to be a greater time cost associated with probing than with pecking, resulting in lower foraging rates for birds that engage in more subsurface feeding events.

***Shorebird Distribution across the Hemispheres: Ecological Mechanisms or Life-History Strategies?**

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The Western Sandpiper (*Calidris mauri*) is a migratory shorebird whose non-breeding range extends from southern Canada to Peru. Two interesting patterns emerge: females winter further south than males, while the proportion of juveniles is high at the northern and southern end of the range and low in the centre.

With regard to the distribution of the sexes, two factors are considered as possible explanations: predation risk and feeding behaviour. Females are larger than males and might thus be more vulnerable to predation by falcons. If predation risk decreases towards the south and/or individuals are less vulnerable because they carry less fat, this gradient might be able to drive the observed pattern.

Females also have longer bills, which allows probing at greater depth for food. It is suggested that closer to the equator, invertebrates can move faster due to higher environmental temperatures and are thus able to retrieve quicker when approached by a feeding shorebird. Alternatively, they might avoid the upper layer of the sediment due to high temperatures. Therefore, a longer bill might facilitate foraging at warmer regions.

With regard to the distribution of the juveniles, it is suggested that two different life-history strategies exist which are related to the higher cost of feather wear for juveniles compared to adults. Juveniles complete three long-distance migrations on one set of flight feathers, adults only two. Juveniles overwinter either far north, thereby reducing UV- or migration induced feather wear or far south and spend the summer on the non-breeding area. Those individuals will have grown new primaries before their first northward migration, which makes feather wear less of a factor.

***Female-first temporal patterns in southward-migrating Western Sandpipers (*Calidris mauri*)**

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The temporal patterns of migration relate to many aspects of avian life history, including breeding phenology, non-breeding distribution and ability to survive. We used banding data from w. Alaska and sw. British Columbia (1978-2000) to assess temporal patterns in southward-migrating Western Sandpipers. We then relate these findings to known life history patterns of this species. We found that in both sites adult females preceded adult males (1.3 days in British Columbia). The trend for juveniles was much weaker, but females did precede males by 0.6 days in British Columbia. The migratory timing of adults and juveniles varied together. Sex ratios vary across the season, reflecting not only the female-first nature of the southward migration, but also a late-season return to high female ratios. The differential timing we observe is likely due to differences in departure timing from staging sites in Alaska, and geographical origin may play a role in the seasonal trends in sex ratio observed. We suggest that female-first migratory patterns reflect gender-based differences in migration distance, participation in parental care, and vulnerability to predation.

***The use of color infrared photography as an indicator of invertebrate fauna at migration stopover sites of the western sandpiper**

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Color infrared photography is sensitive in the visible green, red, and near infrared spectral regions. It has been used to classify plant communities in grassland, forest, and coastal regions (Nilsen et al. 1999). This technique may be useful to quantify primary productivity and relate it to invertebrate fauna at mudflats. I tested the method of color infrared photography as an indicator of invertebrate fauna at migratory stopover sites of the western sandpiper in the Fraser River estuary and Georgia strait, British Columbia, in 2001 and 2002. I quantified invertebrate fauna at each site by extracting mud core samples according to protocol outlined in Sutherland et al. (2000). I measured the amount of infrared light reflected by the mud surface by taking infrared photographs of the mudflat prior to taking invertebrate sample cores. Color scores were obtained from the photographs by analyzing the digitized images with Adobe Photoshop. At one of three sites invertebrate density was positively and significantly correlated with photograph hue. The use of this technique for comparing invertebrate fauna between sites will be discussed.

***Age-related variation in small intestine size in the Western Sandpiper (*Calidris mauri*): Effects of early ontogeny, stage of migration, and cestode infection**

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The Western Sandpiper (*Calidris mauri*) exhibits age-related variation in small intestine size during fall migration; however, the causal factors and functional importance of this difference are unclear. This study was designed to examine the temporal onset, possible causes, and functional significance of this age-dependent difference. We collected pre-migrants and migrants (Alaska and British Columbia, respectively) to investigate age-related and migration-related changes in small intestine size. Prior to initiating fall migration juveniles had 10% longer small intestines than those of adults. This suggests that the age-related difference in small intestine size was primarily due to an ontogenetic effect. However, after a relatively long migratory flight the small intestines of both adults and juveniles increased in length (9% and 6%, respectively) and diameter (7% and 13%, respectively); this is evidence for a training effect associated with commencing migration. Among refueling birds, juveniles had a higher prevalence of cestode infection in one year. Infected individuals had heavier small intestines (after controlling for length, body mass, and year effects) than uninfected individuals in both adults and juveniles (7% and 11%, respectively). Finally, fecal samples from juveniles contained 10% more organic material than those from adults. The contrasting age-related differences in fecal sample composition and small intestine length suggests an age-related difference in digestive strategy, i.e. juveniles appear to exhibit shorter retention times and lower digestive efficiency while refueling during migration.