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The presence of top predators can affect prey behaviour, morphology and life history, and thereby can produce indirect population consequences greater and further reaching than direct depredation would have alone. Raptor species in the Americas are recovering since restrictions on the use of dichlorodiphenyltrichloroethane (DDT) and the implementation of conservation measures, in effect constituting a hemisphere-wide predator-reintroduction experiment, and profound effects on populations of their prey are to be expected. Here, we document changes in the behaviour of western sandpipers (*Calidris mauri*) at migratory stopover sites over two decades. Since 1985, migratory body mass and stopover durations of western sandpipers have fallen steadily at some stopovers in the Strait of Georgia, British Columbia. Comparisons between years, sites and seasons strongly implicate increasing danger from the recovery of peregrine falcons (

dangerous (Alerstam & Lindström 1990; Lindström 1990), even if those sites are richer in food (Ydenberg *et al.* 2002). In this paper, we test some of these predictions about danger-mitigating changes in migratory behaviour with data on western sandpipers collected over two decades at stopover sites in the Strait of Georgia, southwestern British Columbia.

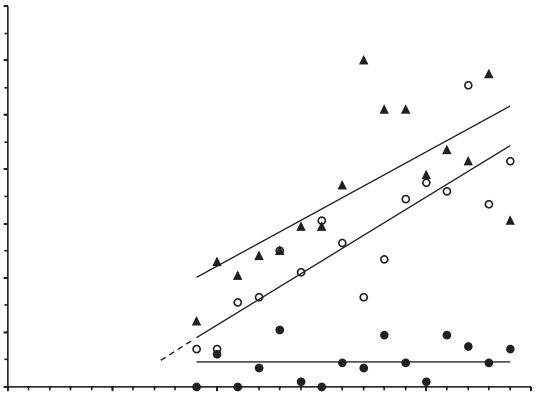
2. METHODS

We have studied migrant western sandpipers in the Strait of Georgia in southwestern British Columbia since 1978. In the spring, these birds stop over while northbound to Alaskan and Siberian breeding areas. After breeding, adult sandpipers depart the Arctic and make a direct flight to the Strait of Georgia, where they again stop *en route* to southern temperate and tropical non-breeding areas. Juveniles (young-of-the-year) pass through our study areas in August, about one month later than adults. Dates for the three migration periods used in analyses below are: (i) spring northwards 15 April–20 May; (ii) adult southwards 24 June–5 August; and (iii) juvenile southwards 1 August–15 September. The dates for (ii) and (iii) enclose 98% of adult and 95% of juvenile western sandpiper passage, respectively, based on 997 adults and 1752 juveniles aged by plumage coloration.

Unlike the staging periods of several weeks recorded in the literature for some migrating shorebirds (see, for example, Gudmundsson *et al.* 1991), the length of stay (LOS) of each individual western sandpiper in the Strait of Georgia is brief. Consequently, we do not observe large seasonal changes in mean body mass, as is observed when an entire cohort of birds stages for several weeks to put on fuel. Instead the body masses recorded from day to day cluster around a well-defined mean, and birds transit our study areas continuously during each of the above periods, with arrivals and departures taking place on most days.

We collected data at several locations in the Strait of Georgia (see map in Ydenberg *et al.* 2002). Two large tidal flats (Boundary Bay and Robert's Bank; both more than 5000 ha) located 10 km apart on the delta of the Fraser River are known collectively as the 'Fraser estuary' stopover site. A smaller (*ca.* 100 ha) stopover site is located on Sidney Island in the middle of the Strait, *ca.* 40 km distant. Sandpipers were captured in mist-nests during both northward and southward migrations on the Fraser estuary site, but at Sidney Island during southward migration only, as small sites like this are little used during the northward migration (O'Reilly & Wingfield 1995). Captured western sandpipers ($n = 13\,682$) were weighed, measured and banded following standard procedures (Ydenberg *et al.* 2002).

Peregrine abundance was indexed by the number of peregrines sighted during standardized near-daily surveys made beginning in 1986 at the George C. Reifel Migratory Bird Sanctuary, located on the Fraser estuary. The index was derived by averaging the daily number of sightings during each migratory period in each year. Statisticals3759.8-317.3av-304.3(we5-479.5(the)falc357.8(wexed)-5J0 -1.3302 TD[(stag-310.78site)ipers)-49.2(be)-4phome



of migrants at a site (Bishop *et al.* 2000). Less well recognized is that changes in the LOS alter the number of birds censused, even if the total population does not change. To estimate the true number of birds (N_T) stopping over at Sidney Island, we incorporated our LOS estimates with the N_C values in an arrival–stopover–departure model (Frederiksen *et al.* 2001). The outcome (figure 4) provides no evidence for a drop in N_T. The steep decline in N_C can be explained entirely or almost entirely by the shortening stopover times of southbound migrants; perhaps N_T in 2000 and 2001 is somewhat reduced. Thus the strongly declining trend indicated by the census data is created by behavioural changes of the sandpipers, and there is little or no evidence at Sidney Island to support the hypothesis of a true population decline.

Population estimates and trend analyses of shorebirds and other neotropical migrants often use indices (e.g. mean, sum, maximum counts) based on repeated censuses made at one or more stopover sites, raising the possibility that shortened LOS and other danger-mitigation tactics such as site avoidance are contributing to the reported declines. As raptor population recovery is taking place on a continental scale, this mechanism has the potential to be general. Protocols being developed by conservation agencies in North America (Donaldson *et al.* 2000; Brown *et al.* 2001) to monitor populations of neotropical migrants need to take this possibility into account.

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