Reports

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Materials and Methods

Video images

Foraging and defecation by Western Sandpipers were recorded (30 frames/s) using a digital camcorder (Canon, XL1S) with telephoto lens (Canon, EF 400 mm f/2.8L IS USM) through a lens adaptor (Canon, EF Adaptor XL). Video images with a focal length of 2880 mm (82.3× optical magnification) were acquired by this system. Video images were replayed and analyzed frame-by-frame to document the feeding actions of individual sandpipers (Kuwae 2007).

Sampling

Western Sandpipers were collected (Permit #59-03-0398 and amendment #1 from Environment Canada) from Roberts Bank (49°05′ N, 123°12′ W) on the Fraser River estuary, British Columbia, Canada, during northward migration (April/May 2003 and 2004). Their stomachs were fixed with 80% ethanol and contents identified to the lowest possible taxonomic level. The frequency of occurrence and estimated percentage of total stomach volume were recorded for individual taxa (Swynnerton and Worthington 1940), and sediment subsamples of each stomach were examined for unbroken microphytobenthos. Nine stomach samples were frozen, freeze-dried, and powdered for isotopic analyses. A further nine samples were frozen for individual photopigment analysis.

Western Sandpiper droppings (<30 min after defecation) were collected from the intertidal of Roberts Bank (n = 20, 3 May 2005; n = 89, 5 May 2005). To test if biofilm formed on mud sediment surfaces contributes to the food sources for the sandpipers, surface sedimentssystfied 123n= ⇐←

Stable isotope analyses

Droppings from Western Sandpipers were pretreated prior to stable isotope analyses to remove potential metabolites, such as uric acid, urea, and ammonium. Subsamples of each powdered sample (~5 mg) were placed in microtubes, mixed with a 1.4 mL 1:1 chloroform : methanol solution, centrifuged for 15 min

We used samples of bird droppings to represent the isotopic signature of Western Sandpiper diets. Droppings are likely to be enriched in indigestible diet components relative to stomach contents (Sponheimer et al. 2003). For Western Sandpipers, indigestible components are primarily comprised of invertebrate hard parts (e.g., jaws and setae of the polychaete Nereis), as indicated by the difference in isotopic compositions of stomach contents and droppings. Therefore, use of droppings to represent diet provides an extremely

biofilm- and microphytobenthos-dominated signature in the stomach contents to a relatively invertebrate-dominated signature in the droppings suggests that biofilm and microphytobenthos are digested to a greater extent than invertebrates. The error bars indicate considerable individual variation within the dropping and stomach content values, which may reflect intra-species partitioning of diet, perhaps based, variously, on age, sex, and morphology (Durell 2000, Mathot and Elner 2004), and a study of diet in relation to these parameters is underway.

We further examined the relative dietary contribu-

to some shorebirds. Threats to biofilm, either directly from coastal development, or indirectly through changing hydrodynamic processes, as well as additional grazing pressures from invasives such as the gastropod Batillaria (Miura et al. 2006), are not currently considered in environmental assessment procedures. Adverse cascading trophic interactions could be triggered by direct competition between higher vertebrates and invertebrates, leading to decreases in biofilm availability as a food for shorebirds, potentially contributing to population-level declines (Clark and Butler 1999). Thus, conservation of biofilm should be an explicit consideration not only for native invertebrate species but also higher trophic level organisms that have overlapping food sources.

Overall, our findings underscore the importance of microbial biofilms to ecosystem processes (Battin et al. 2003) and the physical and functional integrity of the intertidal system (Emmerson et al. 2001, Lundkivist et al. 2007). Further work on the dynamics of biofilm production and consumption by shorebirds, as well as the dynamics of sediment-stabilizing exopolymeric substances (mucopolysaccharide) produced mainly by benthic diatoms (Lundkivist et al. 2007), is necessary considering the estimated scale of shorebird grazing. A stop-over site such as the 6000-ha intertidal mudflat of Roberts Bank hosts over 1×10^6 Western Sandpipers over an ~15-day period during northward migration (Butler et al. 1987; M. Lemon and R. W. Butler, unpublished data). With each sandpiper ingesting 190 g wet mass of biofilm material per day (Table 1), approximately seven times mean body mass, $\sim 19.0 \times 10^3$ kg wet mass would be consumed per day by an

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