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PREY SELECTION AND FORAGING PATTERNS OF THE WHITE-RUMPED SANDPIPER (*CALIDRIS FUSCICOLLIS*) AT PENÍNSULA VALDÉS, PATAGONIA, ARGENTINA

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Resumen. – Selección de presa y patrones de forrajeo del Playero de Rabadilla Blanca (*Calidris fuscicollis*) en Península Valdés, Patagonia, Argentina. – Se estudio la dieta y el patrón de alimentación del Playero de Rabadilla Blanca (*Calidris fuscicollis*) en Playa Fracasso, Península Valdés Argentina en el período Febrero–Mayo de 1999. Se comparó la densidad de las presas potenciales en las diferentes zonas del intermareal con las áreas usadas por las aves, durante un ciclo completo de marea, y se analizó la dieta basándonos en el análisis de fecas. Las presas más importantes fueron el poliqueto *Travisia olens* y la almeja *Darina solenoides*. Secundariamente fueron el poliqueto *Laeonereis acuta* y crustáceos anfípodos; los insectos resultaron ser presas ocasionales. Las aves seleccionaron para alimentarse las zonas intermedias de intermareal, en donde la oferta de las principales presas es muy abundante. Mostraron una preferencia para presas de tamaño intermedio, tanto para las almejas y como para los poliquetos.

Abstract. – The diet and feeding patterns of White-rumped Sandpipers (*Calidris fuscicollis*) were studied during migratory stopover at Fracasso Beach, Península Valdés, Argentina, from February to May 1999. The occurrence and densities of potential prey species at different tidal zones are compared with the areas used for feeding during a complete tidal cycle and with the species taken by the birds, based on faecal analysis. The main prey species taken were the polychaete *Travisia olens* and the clam *Darina solenoides*. Secondary items were the polychaete *Laeonereis acuta* and amphipod crustaceans; insects were occasional prey. Birds selectively fed at intermediate tidal zones, which offered the greatest density of preferred prey *D. solenoides* and *T. olens*. They also preferred prey of intermediate size classes, which were selected against the smallest and large size classes. *Accepted 30 August 2006*.

Key words: White-rumped Sandpiper, *Calidris fuscicollis*, food availability, diet, defecation interval, spatial distribution, prey selection, Savage index.

INTRODUCTION

Shorebirds spend up to five-sixths of the year on migration and wintering grounds. Environmental conditions and food resources encountered in migration at stopover areas are important for survival and reproduction (Blem 1980, Meier & Fivizzani 1980, Myers 1983). Stopovers are especially important for many kinds of migratory shorebirds (Charadriiformes: Charadridae and Scolopacidae) that, unlike most Nearctic migrants, concentrate in small areas to accumulate energy reserves for continued flight (Morrison 1984, Senner & Howe 1984, Myers *et al.* 1987). Because shorebirds travel as much as 30,000 km each year, they must take advantage of seasonally abundant food resources at intermediate stopover areas to build up fat reserves for the next long distance non-stop

flight (McNeil 1970). Protection of stopover areas is necessary for conservation of food and habitat resources and to manage migrant species dependent on them (Myers *et al.* 1987).

The White-rumped Sandpiper (*Calidris fuscicollis*) is a Nearctic migrant which spends much of its non-breeding period in southeastern South America, predominantly on the Patagonian coast (Hayman *et al.* 1986). It is regular on Fracasso Beach between February and April (Harrington *et al.* 1991, Morrison *et al.* 2001), with maximum numbers in March (Bala *et al.* 2001, 2002; Hernández *et al.* 2004). White-rumped Sandpipers generally occur at Fracasso with Red Knots (*C. canutus)* and Two-banded Plovers (*Charadrius falklandicus*), and the total number of shorebirds count during March and April can be as high as 12,197 (Bala *et al.* 2001). Shorebirds concentrate at Fracasso beach mainly because of the abundance of intertidal invertebrate prey, especially the clams *Tellina* and *Darina* (Bala *et al.* 2001). Fracasso beach is currently being evaluated for inclusion in the Ramsar list of wetlands of international importance and has been nominated as a site of international importance within the Western Hemisphere Shorebird Reserve Network on account of the large number of shorebirds that stopover during the austral spring and autumn (Bala *et al.* 2001, 2002; Hernandez *et al.* 2004).

We describe prey selection and feeding behavior in relation to available prey densities and prey size distributions at six levels in a sandy intertidal area.

STUDY AREAS AND METHODS

The study was conducted at Fracasso Beach (42º25'S, 64º04'W), located in the southeast of San José Gulf, Peninsula Valdés, Patagonia, Argentina. This is an intertidal area composed mainly of fine sandy sediments. It has a gentle slope and is limited by rocky shores on either side. During low tide, an area of about 1.6 km^2 is exposed. The mean tidal amplitude is 6.14 m, reaching a maximum of 8.95 m. Fieldwork was carried out between February and May 1999. We established four transects across six zones in relation to tidal level (D'Amico & Bala 2004) in which we measured the composition of the benthic community, made feeding observations of White-rumped Sandpipers and studied their diet. Zone 1 corresponded to the lowest part of the intertidal area, and zone 6 to the highest.

Prey abundance. The abundance, sizes and species composition of intertidal invertebrates were measured to assess food availability for the birds on 19 February 1999. We took three benthic samples to a depth of 15 cm using a 20 cm diameter cylinder from each tidal zone in each transect. The samples were sieved *in situ* through a 0.5 mm mesh sieve. All prey items retained in the sieve were sorted to species and counted, and numbers were transformed to density per m^2. We measured the shell length of mollusks and the length of polychaete worms with calipers to the nearest 0.1 mm in the laboratory.

Choice of feeding site. In order to study the pattern of use of the intertidal area, we made observations on undisturbed birds throughout a complete tidal cycle (high-low-high tide). We recorded the spatial distribution of White-rumped Sandpiper flocks in relation to tidal level every 15 min.

Diet and intake of birds. Observations were made with 15–60x telescopes to estimate the defecation rate of focal individuals. The observations were made during active feeding and at differing tidal levels. The interval between successive droppings was timed with a stopwatch.

The diet of the White-rumped Sandpipers was determined by faecal analysis. Droppings

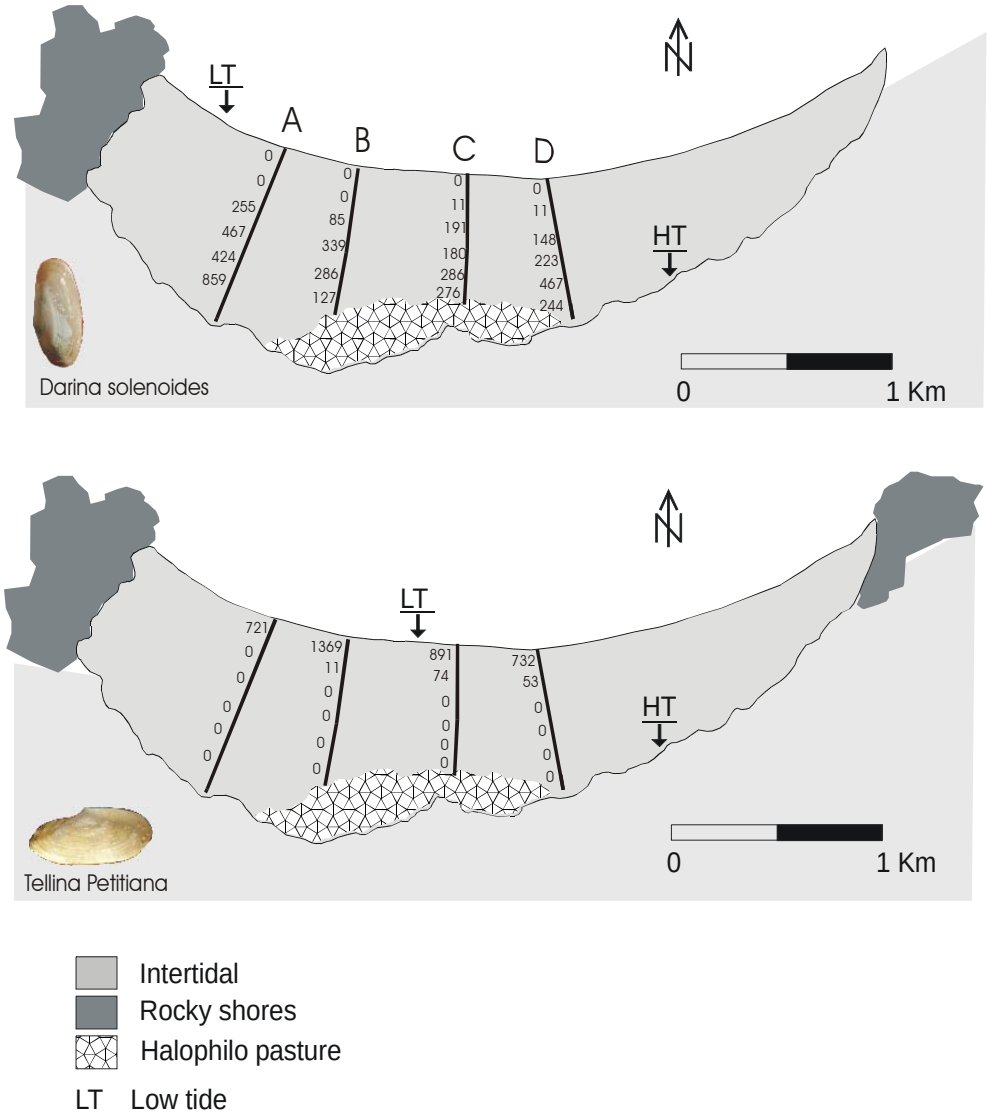

FIG. 1. Diagram Fracasso beach with 4 transects and 6 zones. The numbers indicate clam density (individuals/m^2) en each zone.

were collected and preserved individually by freezing at –20ºC. We analyzed each dropping under a zoom binocular microscope (5–20x magnification) and identified food items using structures such as mollusk shell fragments, polychaete mandibles and chaeta, and fragments of crustaceans and insects (Dekinga & Piersma 1993). We determined the proportion of droppings in which a prey species occurred. However, some structures also permitted a biomass equivalent analysis of the prey (biomass measured as flesh dry mass).

TABLE 1. Mean densities (± SD) of invertebrates at Fracasso beach expressed as individuals/m^2, according to intertidal level. Zone 1 is the lowest level and zone 6 the highest level. Twelve samples were collected from each zone.

	Species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Mollusks	*Tellina petitiana*	928 ± 303	34 ± 35	–	–	–	–
	Darina solenoides	–	5 ± 6	170 ± 71	302 ± 129	366 ± 142	377 ± 328
	Buccinanops globulossum	3 ± 5	151± 111	16 ± 25	5 ± 11	–	–
	Olivella plata	56 ± 75	69 ± 48	–	–	–	–
	Tornatina candei	–	13 ± 26	–	–	–	–
Polychaetes	*Travisia olens*	–	3 ± 5	58 ± 43	504 ± 237	639 ± 513	50 ± 94
	Laeonereis acuta	–	–	–	–	–	993 ± 348
	Glycera americana	31 ± 23	21 ± 17	8 ± 11	18 ± 18	3 ± 5	–
Crustaeans	*Cycloleberis pouseni*	8 ± 11	3 ± 5	5 ± 6	–	–	–
	Cyrtograpsus altimanus	3 ± 5	8 ± 11	–	–	–	–
	Excirolana sp.	–	–	–	–	–	24 ± 28
	Amphipods	90 ± 104	–	8 ± 16	5 ± 11	5 ± 6	3 ± 5
	Isopoda anthuridea	5 ± 6	–	–	–	–	–
Density of all invertebrates in each zone		1124	307	265	834	1013	1447

The hinge height of the bivalve clam *Darina solenoides* and the height of mandibles of the polychaete worm *Laeonereis acuta* found in the droppings were measured.

To infer shell length (mm) and dry biomass (mg); we used the following regression models established from samples from the same area: Clam shell length = 13.476 · hinge height – 0.1191 (r = 0.98, N = 165) and clam biomass = 0.0202 · shell length $^{1.9965}$ (r = 0.92, N = 38) for *D. solenoides*. For the polychaete, the regression models used were from Hernández & Bala (2005). Worm length= 80.657 · mandible height – 14.17 (r = 0.95, N = 30) and worm biomass = 0.017 · mandible length $^{1.3948}$ (r = 0.82, N = 30) for *L. acuta*.

Dry mass was transformed to ash free dry mass (AFDM) by multiplying the obtained values by 0.75 (n = 30 DS = 0.07) for *D. solenoides* and 0.85 (N = 34 DS = 0.06) for *L. acuta*. These transformation factors were calculated from samples of clams and worms, that were first dried and weighed, and subsequently incinerated for 5 h at 550ºC, and weighed again to determine the ash mass and, by subtraction from dry mass, AFDM.

To analyze any size class selection for the clam *D. solenoides* and the polychaete *L. acuta*, we used the Savage selectivity index, which is defined as $W_i = U_i / Q_i$ where U_i = fraction of a certain size class taken by the White-rumped Sandpipers, and Q_i = fraction of that size class present in the intertidal. This selectivity index varies from 0 (maximum negative selection) to infinity (maximum positive selection), with unity being the value expected by chance (Manly *et al.* 1993).

RESULTS

Prey abundance. Thirteen invertebrate species were found in the six intertidal zones of the beach: clams, polychaetes, gastropods and crustaceans. However, numerically, the inter-

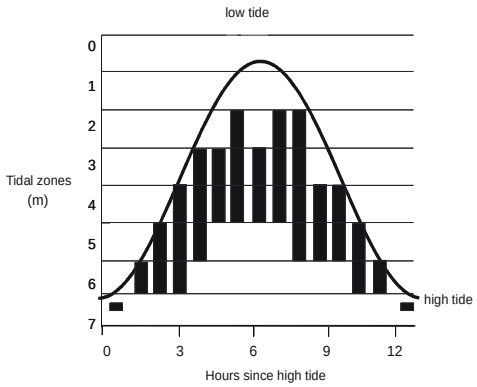

FIG. 2. Intertidal zones used by White-rumped Sandpipers throughout the tidal cycle. The line shows tidal height, the black bars the distribution of birds over the tidal levels.

tidal area was dominated by the bivalve mollusks *Tellina petitiana* and *Darina solenoides* and the polychaete *Travisia olens*. *Tellina petitiana* was mainly found in zone 1 and, to a lesser extent, in zone 2 (Fig. 1a). *Darina solenoides* was found from zones 2 to 6 (Fig. 1b). *Travisia olens* was found in zones 2 to 6, and was most abundant in zone 5. The polychaete *Laeonereis acuta* only occurred in the highest zone (6), but there it was found at particularly high density (Table 1).

Choice of feeding site. With the outgoing tide, birds followed the water line with a lag: e.g., when the tide was in zone 3, the birds fed in zones 3 and 4. However, during the incoming tide, birds were not associated with the water line and foraged more intensively in zones 3–5. Therefore, although White-rumped Sandpipers were observed foraging at all tidal levels, they mostly fed in zones 3–5 (Fig. 2).

Diet and intake rate of birds. A total of 169 defecation intervals discriminated by tidal level were obtained. The mean at each level was: 87.4 s (SD ± 25.5, N = 69) for zones 2 and 3, 92.1 s (SD ± 20.7, N = 48) for zone 4, 95.6 s (SD ± 36.2, N = 41) or zone 5, and 137.1 s (SD ± 25.4, N = 11) for zone 6. A comparative analysis of the means for groups with heterogeneous variance (Games & Howell test; Sokal & Rohlf 1979) showed that the mean defecation rate in zone 6 differed significantly from all other levels ($P < 0.001$).

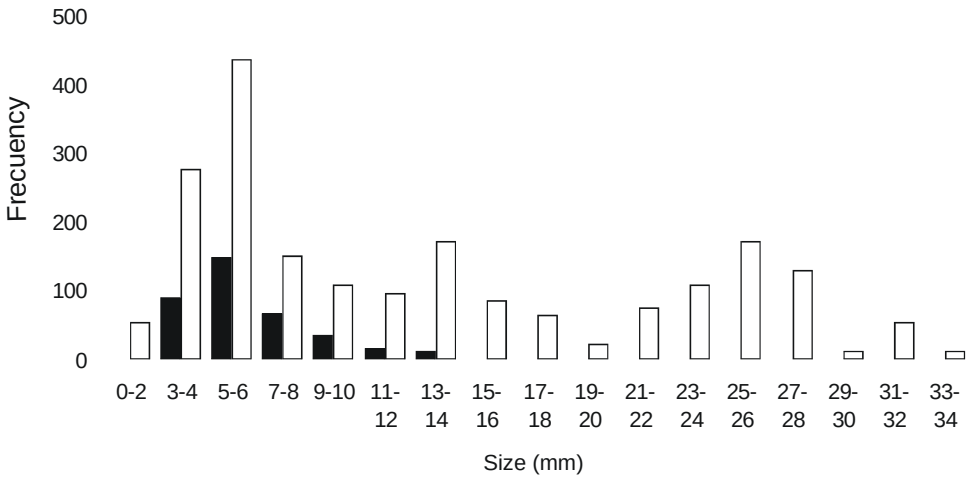

FIG. 3. Size classes of the clam *Darina solenoides* available in the intertidal zone of Fracasso Beach (white bars), and sizes of clams found in White-rumped Sandpiper droppings (black bars).

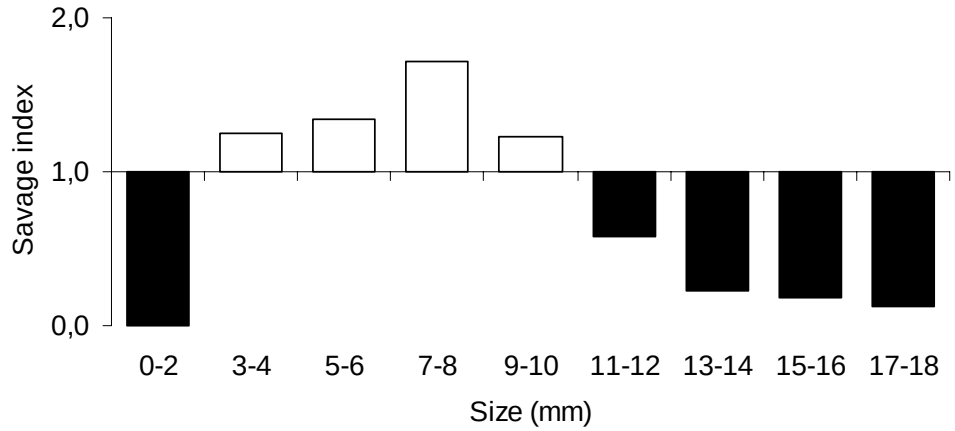

FIG. 4. Sizes of the clam *D. solenoides* significantly selected by White-rumped Sandpipers (using the Savage index). White bars show the sizes that were significantly selected, black bars show the sizes that were rejected.

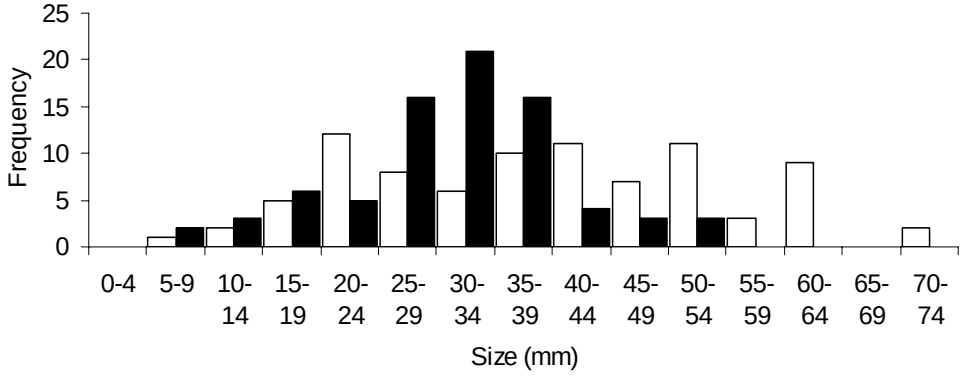

FIG. 5. Size classes of the polychaete *Laeonereis acuta* available in the intertidal zone of Fracasso Beach (white bars), and sizes found in the White-rumped Sandpiper droppings (black bars).

Although there were 13 available intertidal invertebrate species, the analyses of droppings (N = 154) revealed the occurrence of only five in the diet of the White-rumped Sandpipers. The species with the highest frequency of occurrence were the clam *D. solenoides* (48%), the polychaetes *T. olens* (61%) and *L. acuta* (15 %), and insects (21%).

In the droppings sampled (N = 154), 385 individuals of *D. solenoides* were found (2.5 per dropping) corresponding to a total biomass of 184.25 mgAFDM. If these values are adjusted to the average defecation interval of 99.9 s, the White-rumped Sandpipers ingest an average of 1.2 mgAFDM biomass of *Darina* per min.

The 154 droppings contained the remains

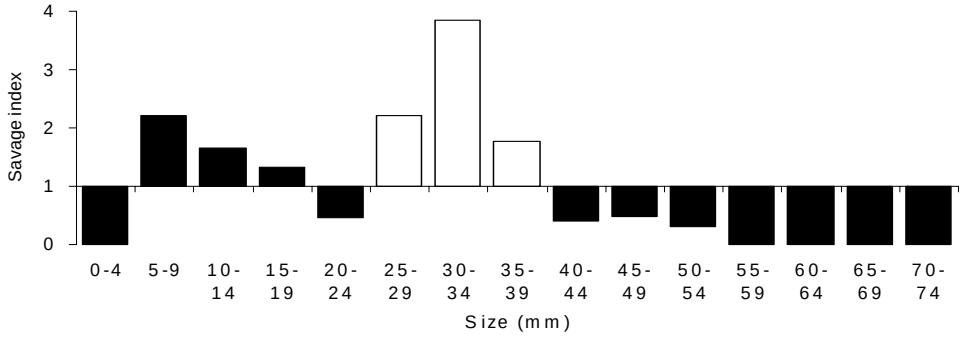

FIG. 6. Sizes of the polychaete *Laeonereis acuta* significantly selected by White-rumped Sandpipers (using the Savage index). White bars show the sizes that were significantly selected, black bars show the sizes that were rejected.

of 79 individual *L. acuta* (0.51 per dropping) corresponding to a total biomass of 133.32 mgAFDM, indicating an ingestion rate of 0.51 mgAFDM/min.

Although a wide range of *D. solenoides* length classes was available (1–34 mm), White-rumped Sandpipers consumed only those in the range 3–13 mm (Fig. 3), and significantly selected those in the range 3–10 mm long ($P < 0.05$, Savage index, Fig. 4). The range of length classes available for *L. acuta* was 6–74 mm; White-rumped Sandpipers consumed only those in the range 5–54 mm (Fig. 5), and significantly selected those in the range 25–39 mm long ($P < 0.05$, Savage index, Fig. 6).

The biomass analysis of the polychaete *T. olens* was not realized because they lack of detectable hard parts in the bird droppings. Only the presence and/or absence of quetas was quantified in the droppings.

DISCUSSION

From the biogeographical point of view, Península Valdés is located between the two marine provinces, Argentina and Magallánica. The Argentina province is extended from the south of Brazil up to Península Valdés. The Magallánica province is extended form the Península Valdés, up to the south Argentinian-Chilean region (Stuardo 1964). The clam *D. solenoides* is distributed along the Magallánica province, while the clam *T. petitiana* is found only falong the Argentina province (Olivier *et al.* 1966, Castellanos 1967, Otaegui & Zaixso 1974, Zaixso 1975, Scarabino 1977, Zaixso & Pastor 1977). In this sense, in Península Valdés both clams can be found (Pastorino, 1995).

Brayton & Scheider (2000) proposed that the clam *Tellina petitiana* is the only clam in the whole intertidal zone. In contrast, in Fracasso beach, *Tellina petitiana* is available between levels 1 and 2, while *Darina solenoides* is distributed on the whole intermareal zone, with high densities from levels 2 to 6 (Pagnoni 1997, Hernández 2000, D´Amico & Bala 2004, D´Amico *et al.* 2004).

Tide cycles influence the distribution of shorebirds in many beach and marsh environments as they alter habitat availability (Fleischer 1983, Burger 1984a, 1984b; Burger & Gochfeld 1991). In Fracasso beach, White-rumped Sandpipers mainly forage in the intermediate levels of the intertidal zone, i.e., between levels 3 to 5. This behavior was observed in Two-banded-Plovers on the same

beach (D´Amico & Bala 2004) and appears to be associated with the high densities of preferred prey at these levels. Nevertheless Brayton & Scheider (2000) observed that some shorebirds species [Red Knots, Sanderling (*C. alba*), White-rumped Sandpipers] were spread over the lower muddy zone, or were close to rivulets and pools left by the tide farther up the beach.

Faecal analysis and preferred foraging areas indicate that there are two main prey species in the diet of White-rumped Sandpipers: the clam *D. solenoides* and the polychaete *T. olens*. These same species are also consumed by Two-banded Plovers (D´Amico & Bala 2004, D´Amico *et al.* 2004) at Fracasso Beach.

White-rumped Sandpipers consume clams 3–10 mm long, and thereby avoid direct competition with species such as Red Knots (Pagnoni 1997) which take larger sizes, and Two-banded Plovers which take small sizes ones (D´Amico *et al.* 2004).

Other prey species were taken less frequently and can be considered of secondary importance (the polychaete *Laeonereis acuta*, amphipod crustaceans, and occasional insects).

In terms of prey biomass present, *D. solenoides* is the most important because it occurs at high density and has a wide spatial distribution. Although *L. acuta* occurs in high density patches, it is found at the lowest intertidal level (zone 6). Amphipod crustaceans were at high densities only at the highest intertidal level (zone 1). The abundance of insects was not quantifiable. However, they only occur occasionally in the intertidal zone when blown from inland by offshore winds.

The defecation intervals of White-rumped Sandpipers feeding at the lowest intertidal level (zone 6) were significantly slower (137 s) than those in other levels (87–96 s). Zwarts & Blomert (1992) established that a major determinant of defecation rate is the proportion of inorganic material in the prey. Of all species consumed by White-rumped Sandpipers, the clam *D. solenoides* is the prey with the highest content of inorganic material due to its shell. We therefore suggest that the low defecation rate in zone 6 is due to a lower consumption of clams, and the foraging on the polychaete *L. acuta*, which has little inorganic material.

It appears that White-rumped Sandpipers consume the clam *Darina solenoides* and the polychaete *Travisia olens*, by choice, but are opportunistic in incorporating the polychaete *Laeonereis acuta* in their diet when it is available at low water.

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