ORNITOLOGIA NEOTROPICAL 21: 283–294, 2010

SEASONAL ABUNDANCE AND TROPHIC ECOLOGY OF THE HUDSONIAN GODWIT (*LIMOSA HAEMASTICA*) AT RÍO GALLEGOS ESTUARY (PATAGONIA, ARGENTINA)

Zulma Lizarralde, Silvia Ferrari, Susana Pittaluga, & Carlos Albrieu

Universidad Nacional de la Patagonia Austral, Unidad Académica Río Gallegos,
Lisandro de la Torre 1070 (9400) Río Gallegos, Santa Cruz, Argentina.
E-mail: zlizarralde@uarg.unpa.edu.ar

Resumen. – Abundancia estacional y ecología trófica de la Becasa de Mar (*Limosa haemastica*) en el estuario del río Gallegos (Patagonia, Argentina). – La Becasa de Mar (*Limosa haemastica)* es, de todas las vadeadoras que reproducen en Norteamérica, una de las más pobremente estudiadas, existiendo escasa información sobre su hábitat y ecología alimentaria. Sin embargo, es una especie de alto interés en conservación y que está en declinación poblacional, por lo que resulta prioritario aportar información en los distintos sitios de escala migratoria. Se estudió la abundancia y las fluctuaciones es-tacionales de la Becasa de Mar en el estuario del río Gallegos (Argentina) y su ecología trófica (densidad y biomasa de las presas disponibles, y composición de la dieta) en los años 2003 y 2007. La Becasa de Mar utilizó el estuario en su paso migratorio hacia el sur (Octubre–Diciembre) y en el retorno hacia las áreas reproductivas (Febrero–Abril), aunque la abundancia fue mayor en este último período. El número máximo de individuos se observó en Marzo de 2003 (n = 504). La presa más importante fue la almeja *Darina solenoides,* secundariamente consumió poliquetos y como presa ocasional, al mejillón *Mytilus edulis platensis*. La densidad poblacional promedio de la almeja registró una disminución en el 2007, así como también la proporción de individuos de las tallas más grandes. Las aves mostraron pre-ferencia por presas de tamaño intermedio, aunque en el 2007 ante la menor oferta de almejas de estas tallas, aumentaron la ingesta de las presas secundarias.

Abstract. – The Hudsonian Godwit (*Limosa haemastica*) is one of the least studied waders that breeds in North America. Although the species is of conservation interest, studies of its habitat and feeding ecology are scarce. In particular, information about its migratory stopover sites is needed because the Hudsonian Godwit population is declining. We studied abundance and trophic ecology (density and biomass of available prey, and diet composition) at Río Gallegos Estuary (Argentina) in 2003 and 2007. Hudsonian Godwits used the estuary during southward migration (October–December) and northward migration (February–April), with abundance being higher in the latter period. The maximum number of individuals we observed were 504 in March 2003. The prey items consumed most often by Hudsonian Godwits were the clam *Darina solenoides,* followed by polychaetes and occasionally the mussel *Mytilus edulis platensis*. Mean clam population density and proportion of big-sized clams were lower in 2007. Godwits showed a preference for medium-sized prey in 2007; however, with reduced availability of medium-sized clams, godwits consumed a higher number of secondary prey. *Accepted 20 May 2010.*

Key words: Hudsonian Godwit, *Limosa haemastica*, food availability, diet, prey selection, Río Gallegos Estuary, Patagonia, Argentina, stopover ecology.

INTRODUCTION

Shorebirds are especially vulnerable to environmental degradation or changing environmental conditions, in part because many species undertake long migrations, concentrate major portions of their population at a limited number of sites and use habitats that are often targets of industrial or recreational development (Myers *et al.* 1987). At migratory stopover sites, shorebirds use habitats rich in soft-bottom benthic organisms, which comprise the main food items in their diet (Myers *et al.* 1987, Morrison & Ross 1989). Shorebirds are therefore considered indicators of wetland health because they are closely associated with those habitats and are clearly affected by environmental changes (Hayman *et al.* 1986, Morrison *et al.* 2001). Identifying the sites used by shorebirds as well as when and how those sites are used is important for designing conservation strategies (Davidson *et al.* 1998). Knowing the precise location of migratory stopover sites, the structure of the macrozoobenthic community, the seasonal variation in abundance and availability of the main prey species is necessary because these factors determine bird presence and may even influence survival of migrants.

The Hudsonian Godwit (*Limosa haemastica*) is a wader species that breeds in North America. During the non-breeding season, it gathers in numbers at sites with large expanses of coastal mudflats. Godwits winter in flooded grasslands or pampas, and in a few key tidal flats along the southern coast of South America. At least half of all Hudsonian Godwits spend the winter in Argentine-Chilean Tierra del Fuego (Morrison & Ross 1989).

This species is one of the most poorly understood waders breeding in North America. No systematic counts of Hudsonian Godwits have been conducted on any of the breeding grounds (Donaldson *et al.* 2000) and comparatively little is known about their habitat and feeding ecology (Elphick & Klima 2002). Because of this lack of information as well as the species' small population size of an estimated 50,000–70,000 individuals (Morrison *et al.* 2006, Wetlands International 2006), the U.S. (Brown *et al.* 2001, Morrison *et al.* 2001, 2006) and Canadian Shorebird Conservation Plans (Donaldson *et al.* 2000) categorized the Hudsonian Godwit as a species of high conservation concern (Senner 2008).

During migration, Hudsonian Godwits use numerous coastal wetlands in Argentina (Morrison & Ross 1989, Blanco & Canevari 1995, Blanco *et al.* 1995, Botto *et al.* 1998), including the Río Gallegos Estuary. This estuary, located in the province of Santa Cruz, southern Patagonia, is a Western Hemisphere Shorebird Reserve Network (WHSRN) Site of International Importance because it provides habitat not only for this species but also for a large number of Nearctic shorebirds and Patagonian plovers (Ferrari *et al.* 2002, 2007, 2008).

We describe the patterns of seasonal variation in Hudsonian Godwit abundance and trophic ecology at Río Gallegos Estuary, including characteristics of feeding areas (composition, density and biomass of food resources) and diet composition in 2003 and 2007.

METHODS

Study area. The work was conducted at Río Gallegos Estuary, on the southeastern end of continental Patagonia, province of Santa Cruz, Argentina (51°36'S, 69°15'W), at the converging mouths of the rivers Gallegos and Chico (Fig. 1). This 45 km long macrotidal estuary discharges into the Atlantic Ocean. The southern shore is dominated by vast muddy intertidal flats, salt marshes, and complex channels, whereas the northern shore is high, with cliffs and gravel beach plains

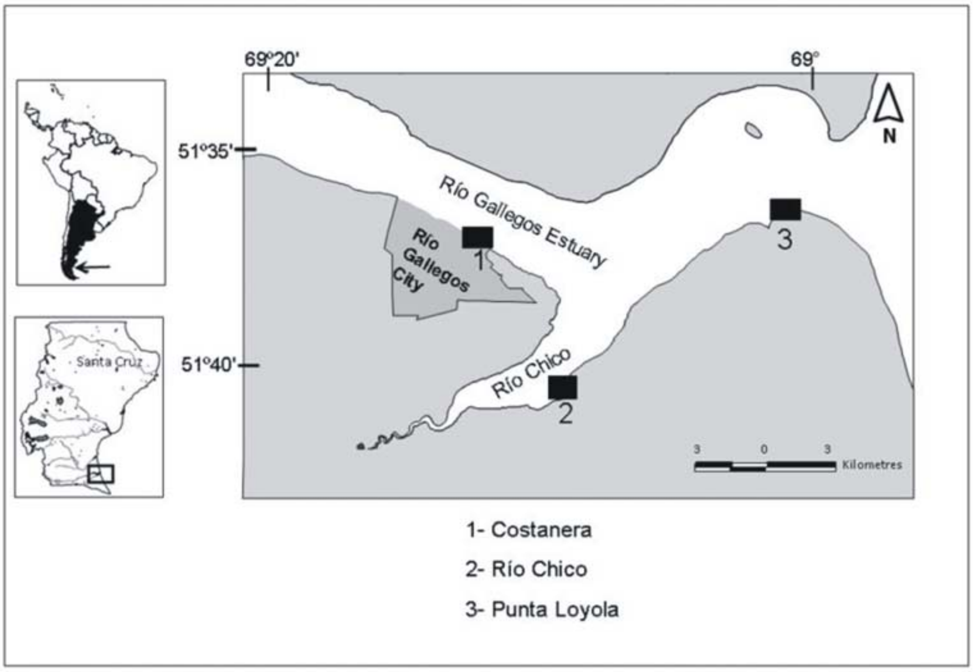

FIG. 1. Study area at Río Gallegos Estuary, located in the south of Santa Cruz Province, Patagonia, Argentina.

(Perillo *et al.* 1996). Spring tidal range is up to 12 m. Salt marshes with a dominant community of perennial glasswort *Sarcocornia perennis* are left uncovered during low tide. Intertidal mudflats support an abundant benthic community, dominated by the clam *Darina solenoides* and various polychaete species. The climate is cool with a mean annual temperature of 7.2ºC and almost constant westerly winds of a mean speed of 35 km/h. The city of Río Gallegos is located on the southern coast and has a population of 100,000 inhabitants.

Seasonal variation in Hudsonian Godwit abundance. We studied seasonal variation in abundance of Hudsonian Godwits in 2003 and 2007 by conducting surveys at least twice per month and more frequently during the migratory period (austral spring and autumn). We studied the southern shore of the estuary at three intertidal sites with the highest records of bird numbers (Ferrari *et al.* 2002): Costanera, río Chico, and Punta Loyola (Fig. 1). At each site, two observers on foot made censuses along the shoreline, covering approximately 1.5 km during high tide. Hudsonian Godwits were counted using binoculars and telescope. Birds occurring in small flocks were counted individually. We estimated numbers in large flocks by counting a small portion of a flock then extrapolating to the remainder of the flock. Because local abundance was influenced by tidal height, maximum monthly count was used as the best index of the species local population size (Burger 1984, Blanco *et al.* 1995). To detect possible differences in Hudsonian Godwit abundance between years an ANOVA was performed (Sokal & Rohlf 1981).

Characterization of the intertidal and benthic macrofauna in the feeding area. Benthic macrofauna composition was studied in Costanera (Fig. 1), the site where the highest abundance of foraging godwits was recorded. Quantitative sampling was conducted in March 2003 and March 2007, along two transects established 50 m apart. Along each transect, we sampled at three locations: an upper intertidal site adjacent to the dry zones, a lower intertidal site near the water line during low tide, and a middle intertidal site between the upper and lower sites. At each site, six samples were randomly taken using a 15 cm diameter corer inserted to a depth of 30 cm into the sediment. Samples were then passed through a sieve (0.5 mm mesh). Macrofauna organisms were identified to species level and their density (number of individuals/m^2) was estimated. Biomass of each taxonomic group was determined as ash-free dry weight (AFDW)/m^2) after oven drying at 60ºC for 48 h and combustion at 500ºC for 6 h. An ANOVA was used to detect possible differences in the number of the clam *Darina solenoides* and in biomass of macrofauna species between 2003 and 2007 (Sokal & Rohlf 1981).

We measured shell length of *Darina solenoides* with a caliper to the nearest 0.1 mm; size frequency distribution was compared between the two years with a Chi-Squared Test (Fowler *et al.* 2001).

Diet of Hudsonian Godwit. We studied godwit diet in the Costanera site by using fecal analysis (Fig. 1). Droppings were collected at low tide in March 2003 (n = 149) and March 2007 (n = 72), stored at 20ºC until processing and further analyzed under a dissecting microscope. Key structures, such as mollusc hinges and shell fragments, mandibles or chaetae of polychaetes, and crustacean fragments were identified (Dekinga & Piersma 1993), assuming that there is no differential destruction of the fragments present in the feces (Hernández *et al.* 2008). The frequency of occurrence of each prey type (expressed as a percentage of the total sample) was estimated as the number of occurrences of each prey type divided by the total number of feces.

We measured hinge height of the bivalve *Darina solenoides* present in the droppings. To infer shell length (L in mm), we used the following regression model: shell length (L) = 10.04 (hinge height) + 4.95 ($r^2 = 0.91$, n = 100). We used a Chi-squared test to compare size of individuals available in the habitat with that of individuals actually consumed. To estimate prey size selection we used Ivlev's electivity index (Jacobs 1974). This index is defined as: $E = (rp)/(r+p)$ where r = proportion of each size class consumed and p = fraction of that size class present in the sample. Positive E values indicate preference; negative values denote prey consumed in smaller numbers than present in the habitat.

RESULTS

Seasonal variation in Hudsonian Godwit abundance. Hudsonian Godwits used the entire estuary as a stopover site during both southward (October to December) and northward migration. The highest abundance was recorded between February and April (austral autumn). In 2007 abundance was lower than in 2003, except in October (Fig. 2). The mean number of Hudsonian Godwits in 2003 was 157.78 ± 196.69, with a peak of 504 individuals in March; whereas in 2007, the mean number was 71 ± 74.71, with a peak of 180 individuals in April. Significant differences in Hudsonian Godwit abundance were recorded between 2003 and 2007 ($F = 4.73$, $P < 0.05$).

Characterization of the intertidal and benthic macrofauna in the feeding area. The benthic community in the intertidal of the Costanera site consisted of five species of molluscs, nine of

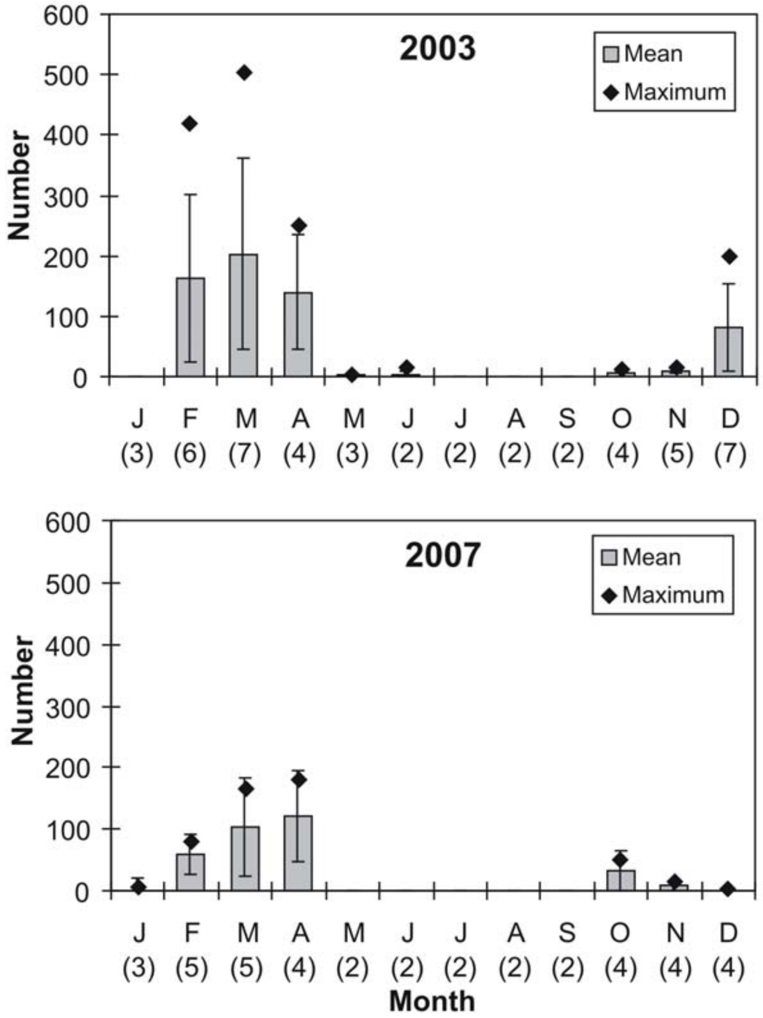

FIG. 2. Mean (± DE) and maximum number of Hudsonian Godwits counted in 2003 and 2007 at Río Gallegos Estuary (total number of counts conducted during each month are in parentheses).

polychaete, three of crustaceans, and one of priapulids (Table 1).

No significant differences were detected in total macrofauna biomass between years ($F = 3.73$, $P > 0.005$). Biomass of *Darina solenoides* accounted for 52% of the total biomass available in 2003 and 45% of that available in 2007; no significant differences were detected between years ($F = 3.48$, $P > 0.005$) (Fig. 3).

Mean population density of *Darina solenoides* differed significantly between March 2003 (Table 1) and March 2007 ($F = 7.84$, $P < 0.05$). Significant differences were also observed in size frequency distribution between 2003 and 2007 ($\chi^2 = 959$, df = 25, $P < 0.001$). In 2003, the greatest proportions of *Darina solenoides* present in the population corresponded to individuals between 2030 mm

TABLE 1: Mean density (± SD) of invertebrates present in the intertidal zone of Rio Gallegos Estuary (individuals/m²).

Taxa	Mean density (± SD)	
	2003	2007
Mollusca		
Bivalvia		
Darina solenoides	2430.0 (629)	1120.0 (701)
Mytilus edulis platensis	960.0 (245)	1080.0 (321)
Mysella sp.	35.6 (16.5)	54.2 (22.3)
Gastropoda		
Natica falklandica	26.9 (13.0)	32.7 (23.0)
Trophon geversianus	39.0 (12.3)	25.0 (17.1)
Polychaeta		
Scolecolepides uncinatus	280.0 (88.0)	148.0 (62.5)
Hemipodus patagonicus	37.8 (53.5)	51.0 (57.7)
Eteone sculpta	80.3 (56.1)	101.5 (44.0)
Kinbergonuphis dorsalis	286.2 (75.6)	208.0 (44.0)
Glycinde armata	38.0 (53.5)	55.5 (86.2)
Lumbrinereis cingulata	56.4 (80.3)	85.0 (32.0)
Aglaophamus praetiosus	108.0 (28.5)	96.3 (65.0)
Notocirrus lorum	97.3 (18.0)	79.0 (19.0)
Travisia sp.	4.4 (6.5)	7.2 (11.1)
Crustacea		
Monoculopsis vallentini	78.2 (23.9)	87.3 (11.6)
Edotia sp.	25.1 (17.9)	39.6 (16.8)
Halicarcinus planatus	18.0 (11.0)	11.9 (6.0)
Priapulida		
Priapulus sp.	21.2 (12.5)	19.8 (9.8)

(40%) in size. In 2007 the greatest proportions corresponded to clams smaller than 1 mm (51%) (Fig. 4).

Diet of the Hudsonian Godwit. Hudsonian Godwits consumed three bivalve mollusc species, three species of polychaetes and one amphipod (Table 2). The clam *Darina solenoides* was the most important prey item consumed in both years; the second most important item was mussels in 2003 and polychaetes in 2007.

In 2003, size distribution of *Darina solenoides* ingested by Hudsonian Godwits was reconstructed by using measurable fragments of 105 clams found in the droppings (n = 149) (Fig. 4). Mean size of individuals ingested was significantly higher than that of the available population (t = 3.86, $P < 0.05$, df = 335) (Table 3). Size class distribution of *Darina solenoides* individuals ingested differed significantly from that of individuals available in the habitat ($\chi^2 = 181$, df = 25, $P < 0.001$). Although the size range of clams available was wide (1–45 mm), Hudsonian Godwits showed a clear preference for intermediate-sized clams (13–37 mm; Fig. 4). The Ivlev index showed that godwits positively selected individuals within a size range between 15–25 and 33–37 mm (Fig. 5).

In 2007, size distribution of *Darina solenoides* ingested by godwits was reconstructed by using measurable fragments of 44 clams

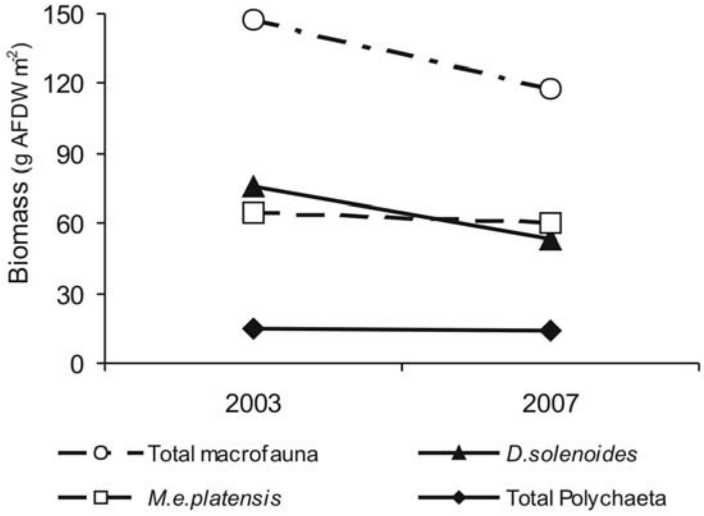

FIG. 3. Mean biomass of prey available in the intertidal zone of Río Gallegos Estuary in 2003 and 2007.

found in the droppings (n = 72) (Fig. 4). The mean size of individuals ingested was significantly greater than that of the available population (t = 3.8, $P < 0.05$, df = 147) (Table 3). Significant differences were also observed between size class distribution of *Darina solenoides* ingested and that of individuals available in the habitat ($\chi^2 = 124$, df = 25, $P < 0.001$). Although the size range of clams available was between 1 and 41 mm (Fig. 4), Hudsonian Godwits consumed clams between 15 and 29 mm in size. The Ivlev index showed that godwits positively selected individuals within a size range of 15–25 mm (Fig. 5). Mean size of *Darina solenoides* consumed differed significantly between 2003 and 2007 (t = 5.49, $P < 0.05$, df = 131).

DISCUSSION

The pattern of occurrence of Hudsonian Godwits at Río Gallegos Estuary shows that the species uses the area during southward migration, although in low numbers, before arriving in northern Tierra del Fuego (Argentina and Chile), one of the most important areas for its non-breeding season. Maximum abundance was observed at Río Gallegos Estuary during northward migration. This pattern suggests that the species uses different routes on the two migratory flights; the pattern is similar to that observed in the beaches of San Antonio Oeste (40°46'S, 65°02'W) and Península Valdés (42°22'S, 64°03'W), Argentina (Blanco *et al.* 1995, Brayton & Schneider 2000).

Abundance of Hudsonian Godwits decreased by 50% as compared with the maximum number of 1000 individuals recorded in the 1997/99 seasons (Ferrari *et al.* 2002). The difference we observed in numbers in 2003 and 2007 also is consistent with a decline because the maximum abundance we recorded in 2007 was 64% lower than in 2003. The decrease in the Hudsonian Godwit abundance at the estuary may be partly attributed to the general population decline reported by Morrison *et al.* (2001, 2006) based on data collected at different Hudsonian Godwit breeding sites in Canada and USA. Habitat loss and degradation are the most serious threats to shorebirds today (Bildstein *et al.* 1991) and

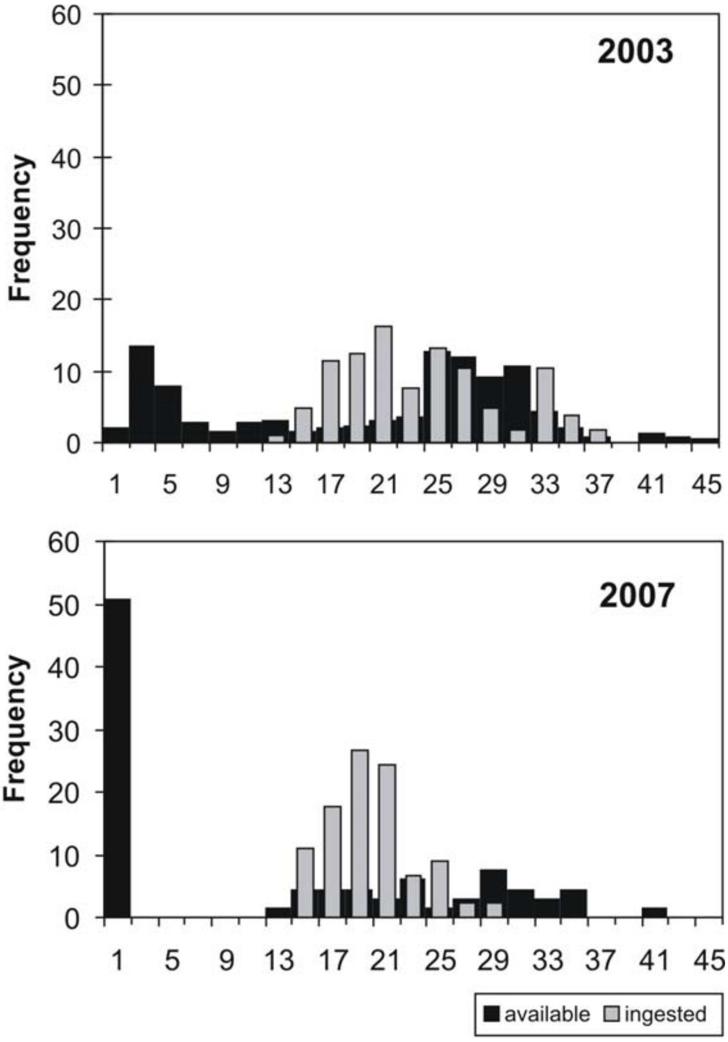

FIG. 4. Size classes of the clam *Darina solenoides* available (%) in the intertidal zone (black bars) and ingested (%) (grey bars) by Hudsonian Godwits.

Hudsonian Godwits are not immune to this threat despite the remoteness of the locations at which they spend much of the year (Senner 2008). In addition, shorebirds have been reported as sensitive to persistent disturbances that produce loss of feeding opportunities or movement to suboptimal areas, probably affecting their survival (Cayford 1993). Changes in local abundance of the Hudsonian Godwit at the Río Gallegos Estuary might be attributed to increased human encroachment on the shore (sea wall construction, recreational use), disturbance by people and dogs, and modification or loss of feeding areas (Ferrari *et al.* 2007, 2008).

Prey availability might also play an important role in local and regional distribution and abundance of wintering shorebirds (Butler *et*

TABLE 2. Percent frequency of prey items consumed by Hudsonian Godwits at Río Gallegos Estuary (*Limosa haemastica*). n = number of droppings analyzed.

Prey items	2003 (n = 149)	2007 (n = 72)
Bivalve molluscs		
Darina solenoides	92.6	92.9
Mytilus edulis platensis	24.8	2.8
Mysella sp.	-	2.8
Polychaetes		
Scolecolepides uncinatus	1.5	17.8
Aglaophamus praetiosus	2.9	21.4
Kimbergonuphis dorsalis	2.1	10.7
Crustaceans		
Monoculopsis valentini	10.7	4.17

al. 2001). At the intertidal zone of Río Gallegos Estuary 18 benthic invertebrate species were recorded. The analysis of droppings, however, showed that the diet of Hudsonian Godwits comprised only seven species, belonging to bivalve, polychaete and crustacean taxa. This finding is consistent with records from wintering populations of other godwit species along the Atlantic and Pacific coasts (Piersma *et al.* 1996).

The main food item in the diet of Hudsonian Godwits was *Darina solenoides,* the most abundant resource in the Costanera site. This clam has also been reported as the most important item in the diet of Hudsonian Godwits in Península Valdés, northern Patagonia (Hernández *et al.* 2008), where it shows preference for this prey. The proportion of polychaetes consumed increased in 2007, probably due to the lower numbers of *D. solenoides* individuals available in the substrate in that year. Low numbers of *Darina* may have caused Hudsonian Godwits to widen the composition of their diet and include species that were secondary or absent in 2003. Another possible reason for the lower importance of *Darina* in the diet is the increase in the proportion of very small (1 mm) clams in 2007, which were not preferentially selected by the Hudsonian Godwit according to the Ivlev index.

TABLE 3. Mean length (mm ± SD) of individuals of the clam *Darina solenoides* available in the substrate and consumed by Hudsonian Godwits (*Limosa haemastica*) at Río Gallegos Estuary.

2003		2007	
Mean length available (n =253)	Mean length ingested (n = 105)	Mean length available (n = 120)	Mean length ingested (n = 44)
19.31 ± 11.39	22.91 ± 6.07	13.37 ± 13.02	18.26 ± 3.42

Hudsonian Godwits consumed *Darina solenoides* individuals between 13–37 mm in size, and avoided ingesting the smallest and the biggest-sized individuals available. These observations are consistent with findings of Zwarts & Blomert (1992) in that some shorebirds exert a greater predation pressure on medium-sized clams, either because handling time of medium-sized clams is smaller or because small ones are not profitable enough or are out reach. The Ivlev index showed that in 2003, Hudsonian Godwits selected clams of between 15–25 and 33–37 mm in size, whereas in 2007 they preferred the former. These differences and the discontinuity in sizes selected might be attributed to a sampling bias in food supply or a differential selection by sex (Nebel *et al.* 2000). Hernández *et al.* (2008) also recorded a discontinuous size selection in Península Valdés and indicated as one of the possible reasons that these size classes were not well represented in the intertidal zone. This reason is not true for the Río Gallegos Estuary, since all clam sizes were present. The size range of selected clams in 2003 was higher than that recorded in Península Valdés, where the Hudsonian Godwit preferred individuals between 9–22 and

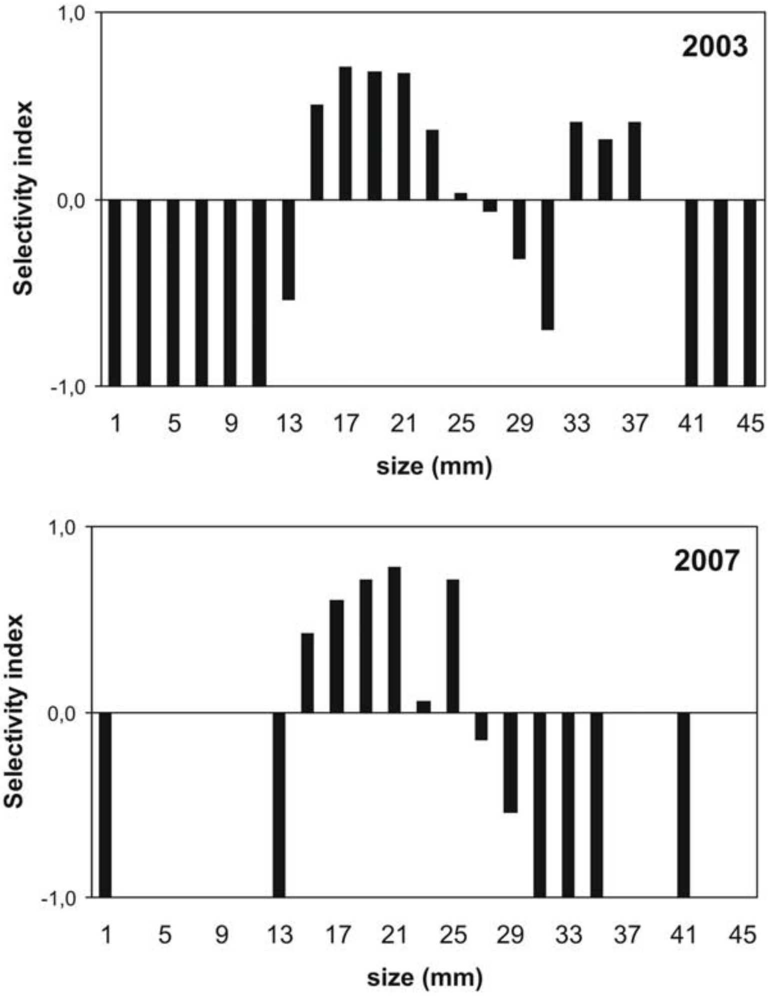

FIG. 5. Size classes of the clam *Darina solenoides* selected by Hudsonian Godwits. The zero line denotes no selection, positive values indicate positive selection, and negative values indicate negative selection or rejection.

between 33–34 mm in size (Hernández *et al.* 2008).

Despite the great abundance and high biomass of the mussel *Mytilus edulis platensis* present in the intertidal area, Hudsonian Godwits seemed to ingest them only occasionally. Some authors suggest that shorebirds foraging in this type of environment prefer thinner-shelled prey or prey that have a higher ratio of proportion of flesh to shell (Zwarts & Blomert 1992, González *et al.* 1996). Godwits might be selecting clams because the shell is thinner than that of mussels.

Some shorebird species have such a specialized diet that they depend on just a few intertidal stopover and foraging sites along their migratory route (Dierschke *et al.* 1999). The Hudsonian Godwit's primary preference for individuals of *Darina solenoides* in different Patagonian coastal areas despite the availability of other benthic resources indicates the importance of preserving these environments and of conducting further studies to understand the contributions of food at these sites to provide energy necessary for successful migration.

ACKNOWLEDGMENTS

We are grateful for the financial support provided by Universidad Nacional de la Patagonia Austral through Project PI A180 and from Project ARG/PNUD ARG/02/018 Conservación de la Diversidad Biológica y Prevención de la Contaminación Marina en Patagonia, Donación FMAM/BIRF 28.385-AR, executed by the Secretaría de Ambiente y Desarrollo Sustentable of the Ministerio de Salud y Ambiente de la Nación. We thank Katiza Dragnic, Tomás Isola, and Mariano Bertinat for their assistance in field data collection. Finally, we are especially grateful to anonymous reviewers.

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