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Foraging Behavior and Diet of Northward Migrating Bar-Tailed Godwits (*Limosa laponica*) and Great Knots (*Calidris tenuirostris*) at a Key Stopover Site

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Abstract

After the completion of the Saemangeum reclamation, the Geum Estuary has emerged as a key feeding and rooting site (staging site) for shorebirds in South Korea. However, there has yet to be any study conducted on the behavior and diet of shorebirds in this region. In this study, we first compared behavior and diet of two representative shorebird species with different morphologies, Bar-tailed Godwits (*Limosa laponica*) and Great Knots (*Calidris tenuirostris*) that co-occur in the tidal flat of Yubu Island near the Geum Estuary. During the April to May of 2016, using a camera equipped with a telescope, we recorded 36 individuals during low tide. Behavior was significantly different between the two shorebird species (Chi-square test, $P = 0.037$), although feeding success rate was similar between the two species (ANOVA, $P > 0.05$); the Bar-tailed Godwit showed more probings and less peckings than the Great Knot. In addition, Bar-tailed Godwits walked less (ANOVA, $P < 0.001$) and were less alert (ANOVA, $P < 0.005$) than Great Knots. On the other hand, diet composition was significantly different between them (Chi-square test, $P = 0.010$); Both species fed mainly upon Mollusca but the Great Knot fed on noticeably more Annelida (lugworms) than the Bar-tailed Godwit. Among Mollusca, both species consumed more gastropods than bivalves (ANOVA, $P < 0.001$).

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Based on these results, it is thought that Bar-tailed Godwits may save energy through less pecking together with less walking and less being alert, since it fed on less food than Great Knots. These results on behavior and diet will be helpful for conservation of the two species in the Geum Estuary tidal flats, a key stopover site of many shorebirds in the East Asian-Australasian Flyway (EAAF).

Keywords: Bar-tailed Godwits; behavior; diet; Great Knots; Yubu Island Bar-tailed Godwits; behavior; diet; Great Knots; Yubu Island.

1. Introduction

In shorebird studies, foraging includes a wide range of topics, including feeding behavior, prey selection, feeding composition, etc. [1]. As with other birds, migratory shorebirds spend most of their time feeding to ingest sufficient energy to maintain their high metabolic rates in relation to flight, homeothermy, and future reproduction [2]. In particular, feeding is the most important activity for shorebirds using the mudflats that provide food resources to survive during their migration to breeding sites. In non-breeding sites, shorebirds experience particularly rigorous energetic demands for their long migrations [2]. Therefore, sufficient feeding in staging sites (stopover sites used by migratory shorebirds to prepare for a long flight across continents that needs substantial fuel stores, such as the Geum Estuary in South Korea and Yalu Jiang Estuary in China) is the key whether or not, shorebirds from non-breeding sites can survive and therefore breed in breeding sites in spring season.

Several species of migratory shorebirds occur throughout the whole world. They vary in their body lengths (130 to 650 mm) and bill size (13 to 219 mm) [3]. Information on seasonal and regional patterns of prey selection by shorebirds could provide insights toward the conservation of wetlands [1]. Also, information on feeding strategies and habitat use of shorebirds could be important to their protection [2]. Many species feed on prey detected using visual cues, and either glean or pick prey from tidal flats [2]. The morphology of shorebirds is important in restricting the range of feeding strategies [4, 5, 6]. In general, differences in prey selection are partly due to the different bill lengths or body sizes, with larger birds and birds with longer bills taking larger prey buried deeper in the sediment [8]. Also, time spent feeding varies with respect to the size of the bird [7]. For example, larger birds spent less time feeding than smaller birds by eating larger and more profitable prey.

Feeding ecology of migratory shorebirds has been widely studied throughout various regions under the major flyways. For example, the composition of shorebird guilds based on body size and foraging method was actively studied from Atlantic coast and North American interior region of the US-Canada border, US side of the Gulf of Mexico, Central and South America in Pacific, Mississippi, and Atlantic Flyway, respectively [1]. In the East Atlantic Flyway (EAF), shorebird feeding ecology has been considerably studied in the north (Europe) and in the south (Southern Africa) temperate ends of the flyway [10]. To date, only a few studies have been conducted on feeding ecology of migratory shorebirds in the East Asian-Australasian Flyway (EAAF). A previous work conducted during northward migration in one of the most important stopover sites for shorebirds in EAAF evaluated the degree of dietary overlap (e.g., prey items and prey size) in the dominant four shorebirds species including Bar-tailed Godwits and Great Knots [10]. However, the foraging behavior including feeding success

was not compared between shorebird species.

The purpose of this study is to compare the foraging behavior and diet of two migrating shorebird species that are at opposite extremes of the body size and bill length: the Bar-tailed Godwit (*Limosa laponica*) and the Great Knot (*Calidris tenuirostris*).

2. Materials and Methods

2.1. Study sites

We selected a tidal flat of Yubu Island near the Geum Estuary in Seocheon County of Chungcheongnam Province, South Korea as a study site (N 35° 59', E 126° 36'; Fig. 1). It is surrounded by a mudflat [11]. It is located 4 km off from Gunsan City of Jeollabuk Province. At high tide, the total area of this island is 3.1 km^2. This island is a critically important stopover site of shorebirds including many internationally threatened species, such as Spoon-billed Sandpipers (*Eurynorhynchus pygmeus*), Bar-tailed Godwits, Great Knots, and Far Eastern Curlews (*Numenius madagascariensis*). In addition, this island is the most important overwintering site of Eurasian Oystercatchers (*Haematopus ostraegus*). The highest number of the species was 3,200 in December, 1999 [11]. Currently, less than 60 people live on the island, occupying about 30 houses and no regular transportation is available between mainland and the island. Thus, Yubu Island has been relatively well-protected than any other places with high diversity of not only benthic fauna but also avian fauna feeding benthic fauna.

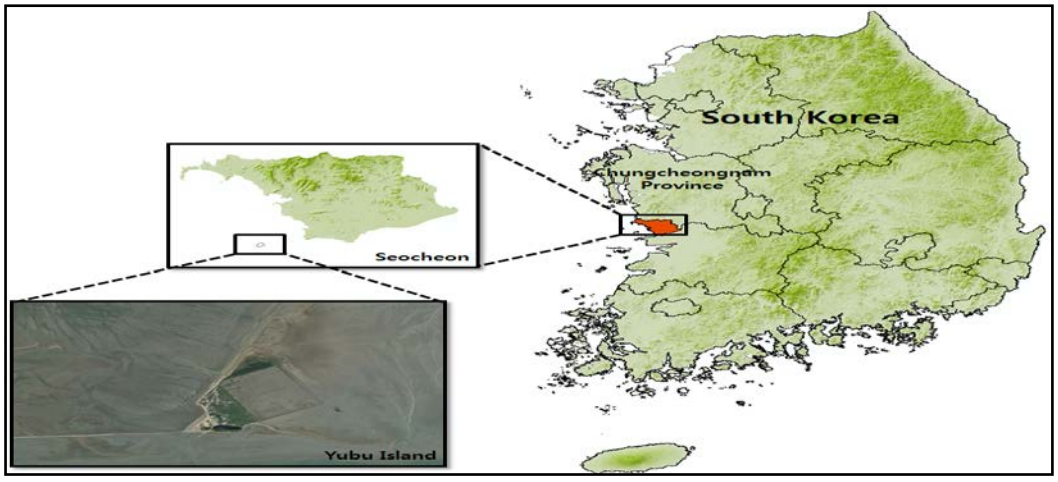

Figure 1: The location of Yubu Island of the Geum Estuary, South Korea.

2.2. Study species

Two representative shorebird species, Bar-tailed Godwits and Great Knots, were selected as target species. The two species are one of the dominant species in Yubu Island. They feed in a similar tidal flat competing for the preys in the key stopover site during northward migration in spring. During the peak of northward migration of 2016, the maximum population size was 15,420 (14.6%) and 27,800 (26.3%) for Bar-tailed Godwits and Great

Knots in the Geum Estuary, respectively (unpublished data). The former is known as a ubiquitous species but the latter is known as an endemic species to the EAAF (Piersma and his colleagues 1996). Bar-tailed Godwits and Great Knots are designated as near threatened (NT) and endangered (EN) in the Red list of IUCN, respectively. They have a different morphology in bill size or shape and body length [13]. The former is a quite large shorebird with slightly upturned bill and showed 39 cm bill-to-tailed length and the latter is a medium-sized shorebird with a straight, slender bill and 29 cm bill-to-tailed length. Bar-tailed Godwits feed on a variety of benthos including bivalves, crustaceans, and cumaceans as a generalist but mainly polychaetes on non-breeding sites [10, 12, 14, 15, 16, 17, 18, 19]. Unlike Bar-tailed Godwits, Great Knots mainly feed on bivalves as a specialist, even though they also feed on other preys including polychaetes, crustaceans, gastropods, and rhizomes [10, 15, 20, 21, 22, 23, 24].

2.3. Survey of foraging behavior and diet

During low tide in the April to May of 2016, using binoculars or field scopes, we observed the behavior of two shorebird species, Bar-tailed Godwits and Great Knots. We chose a random individual, and after identifying the species we started recording the feeding behavior of the individual. A total of 36 individuals (n = 17 for *L. laponica* and n = 19 for *C. tenuirostris*) was filmed using a video camera (Cannon, Korea) equipped with a 400 mm telescope (Cannon, Korea) for 5 minutes. During each observation bout, activities such as probes, pecks, walking, being alert, and resting, and prey items swallowed were filmed. Godwits including Bar-tailed Godwits detect prey using tactile cues and tend to insert bills to varying depths of mudflats and either probe singly or in a rapid stitching motion until they detect prey, and Calidrine sandpipers including Great Knots principally use tactile cues to locate prey, and their feeding strategies are typified by probing of the bill to varying depths to extract prey [2].

2.4. Data analysis

The behavior of the two shorebird species in Yubu Island mostly consisted of feeding, walking, being alert, and resting. They spent most of time to search food items by probes putting the bills into substrate and moving the bills side to side (probing). Once they detected food items, they tried to feed by pecks once (pecking once) or more than once (pecking more than once). Sometimes, they pecked more than once with stirring their bills into substrate to take the food items. Probing and pecking are defined as inserting bill into substrate and striking prey at substrate, respectively. From the video, we extracted the following variables; frequencies of feeding activities (A: probing, B: pecking once, and C: pecking more than once) and the other activities, such as walking, being alert, and resting. Also, the proportion of successful feeding, frequencies of successful feeding / (frequencies of type B + frequencies of type C), was recorded. For successful feeding, we recorded prey items and sorted them into four groups; Annelida (lugworms), Arthropoda (crabs), Mollusca (bivalves and gastropods), and unidentified groups. Among the four groups, we excluded the unidentified group in the comparison of diet composition. One-way ANOVA tests were carried out to compare the proportion of successful feeding, frequency of walking, being alert, and resting, diet composition (bivalves and gastropod) between the two species. Chi-square tests were used to compare the proportion of different type of feeding activities and diet composition (Annelida, Arthropoda, and Mollusca) between the two species. All data were analyzed by using

SPSS program version 12.0 (ESRI Inc., U.S.A.).

3. Results

Behavior was surveyed and analyzed for 17 Bar-tailed Godwits and 19 Great Knots in Yubu Island. The mean frequency of three types (A, B, and C) of feeding behavior was significantly different between the two species (χ^2 = 6.585, *df* = 2, *P* = 0.037; Table 1). The Bar-tailed Godwit showed more probings (type A) and less peckings (type B and C) than the Great Knot. However, mean proportion of feeding successes did not differ between the two species, although the Great Knot showed a slightly higher feeding success (38.6%, 163 successful trials / 422 total trials) than the Bar-tailed Godwit (37.7%, 107 successful trials / 284 total trials) (ANOVA, *P* > 0.05; Fig. 2). In addition, Great Knots walked more often (ANOVA, *P* < 0.001; Fig. 3A) and stayed alert more often (ANOVA, *P* < 0.005; Fig. 3B) than Bar-tailed Godwits. Great Knots walked twice and were alert five times than Bar-tailed Godwits. In contrast, mean resting frequency was slightly higher in Bar-tailed Godwits than in Great Knots but was not significantly differed between the two species (ANOVA, *P* > 0.05; Fig. 3C). Only three Bar-tailed Godwit individuals took a rest during feeding activity (12, 31, or 28 seconds).

Table 1: Summary of three different types of feeding activities of two shorebird species (Mean ± S.D.)

Species	Feeding activities		
	Type A (probing)	**Type B** (pecking once)	**Type C** (pecking more than once)
Bar-tailed Godwits	45.6 ± 16.7	13.3 ± 3.8	3.4 ± 1.4
Great Knots	44.6 ± 16.9	17.2 ± 6.2	5.0 ± 2.2

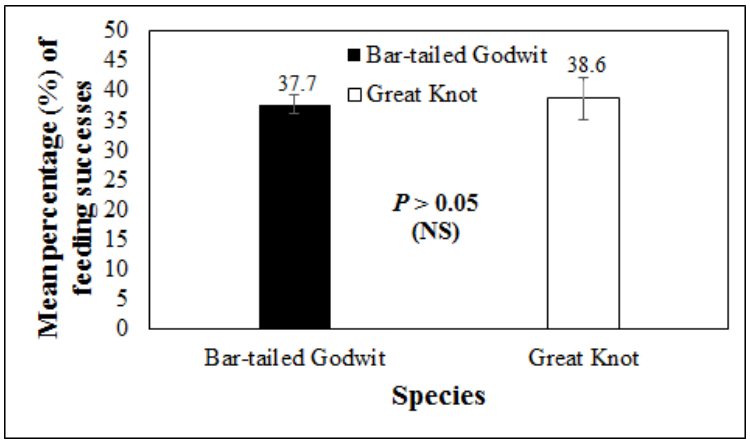

Figure 2: Feeding success per peck of Bar-tailed Godwits and Great Knots.

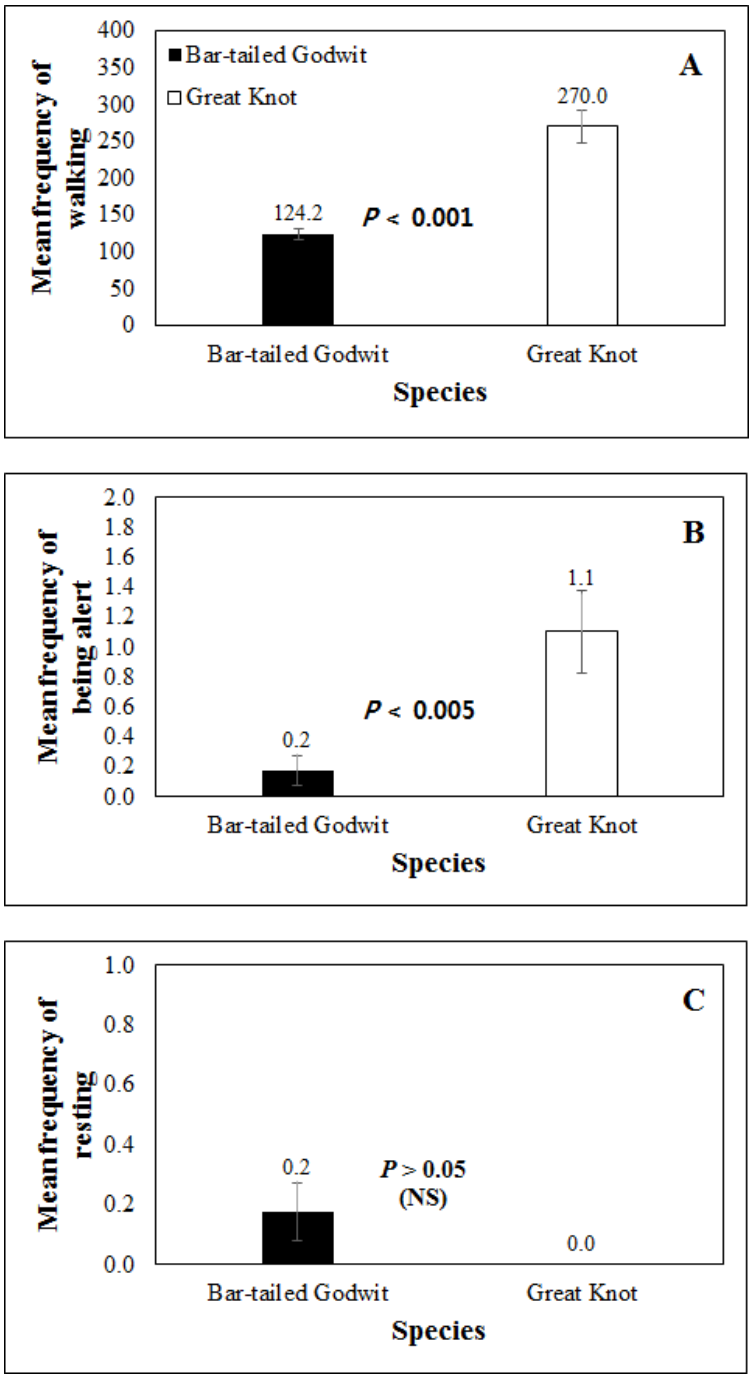

Figure 3: Behavioral differences between Bar-tailed Godwits and Great Knots at the mudflats.

On the other hand, we found a difference in diet composition between the two shorebird species ($\chi^2 = 6.584$, $df = 1$, $P = 0.010$; Table 2). The Bar-tailed Godwit fed on much more Annelida than the Great Knot, although both shorebird species consumed Mollusca more than Annelida and Arthropoda. Mean frequency of feeding in Bar-tailed Godwits was 3.7, 0.5, and 0 for Mollusca, Annelida, and Arthropoda, respectively. Similarly, mean frequency of feeding in Great Knots was 4.8, 2.5, and 0 for Mollusca, Annelida, and Arthropoda, respectively. No Arthropoda was consumed by the two species. For Mollusca, both shorebird species fed on more gastropods

than bivalves (ANOVA, $P < 0.001$ Fig. 4).

Table 2: Diet composition of two shorebird species, based on analyses of observations in a tidal flat of Yubu Island near the Geum Estuary during April to May of 2016 (Mean ± S.D.)

Species	Prey items			
	Annelida	**Mollusca**	**Arthropoda**	**Unidentified**
Bar-tailed Godwits	0.5 ± 0.5	3.6 ± 1.1	0	2.1 ± 0.6
Great Knots	2.5 ± 1.0	4.8 ± 1.9	0	1.3 ± 1.5

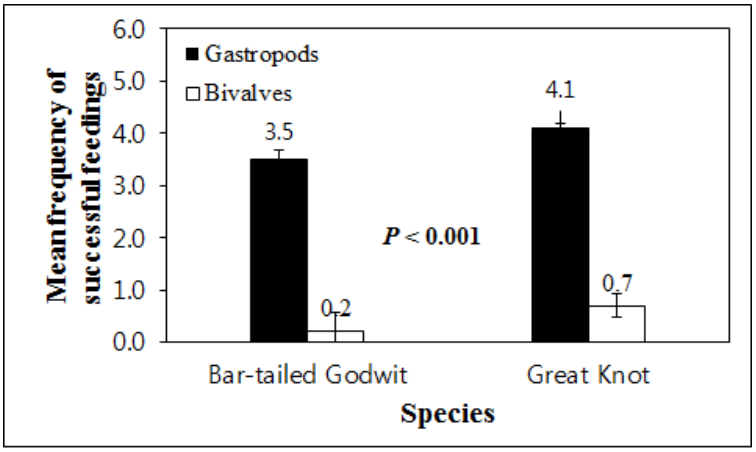

Figure 4: Types of prey consumed by Bar-tailed Godwits and Great Knows.

4. Discussion

The largest reclamation project occurred at Saemangeum (35° 58´ N and 35° 36´ N, 126° 26´ E and 126° 44´ E) where 400 km^2 of tidal flats of the Mangyeong and Dongjin Estuaries were impounded behind a 33 km long sea-wall in 2006. During the early 2000s, changes in abiotic (e.g., sediment composition) and biotic (e.g., benthic species distribution) conditions were caused by the Saemangeum reclamation project [25]. Afterwards, starting at least since 2003, in some areas, a severe collapse occurred in the abundance of many benthic macro-invertebrates, including bivalves and gastropods [26]. During the spring and fall of 2003, approximately 316,000 and 257,000, respectively, shorebirds used the Saemangeum tidal flats [27, 28]. After the completion of the Saemangeum sea-wall, the number of shorebirds showed a rapid decline [29]. For example, between 2006 and 2008, a minimum of 128,000 shorebirds have been lost during northward migration. In 2014, the Saemangeum support only a small number of shorebirds, less than 5,000 during northward migration [30]. After the Samangeum sea-wall project was completed, shorebirds instead began to use the nearby Geum Estuary during their northward migration: about 180,000 shorebirds stopped over the Geum Estuary in 2016 (unpublished data). Despite of the importance of the Geum Estuary tidal flats for shorebirds, feeding ecology of migratory shorebirds has not yet been studied.

According to our results, both shorebird species had a very similar frequency of feeding success but showed a very different behavior; The Bar-tailed Godwit with a longer bill length and body size showed more energy-efficient behaviors, such as less walking together with less being alert and maybe more resting than the Great Knot. In addition, the two shorebird species mainly fed on gastropods although the diet composition was different between them. In general, it was known that larger birds generally spend less time for feeding than smaller birds by eating larger and more profitable prey. We guess that the larger Bar-tailed Godwit may save energy through such behaviors (especially, eating more profitable prey) because the Bar-tailed Godwits fed on a higher proportion of Mollusca vs. Annelida than the Great Knot although both species fed mainly on gastropods. However, it is not clear how much energy can be saved by such behaviors in the larger Bar-tailed Godwit, compared with the smaller Great Knot.

On the other hand, based on a previous study using diet analysis in the Yalu Jiang of China [10], Great Knots selected mostly the bivalve, *Potamocorbula laevis*, whereas Bar-tailed Godwits had a broader diet and showed selection for polychaetes, even though most of their biomass intake was of *P. laevis*. They showed a similar size selection (preferring medium-sized *P. larvis*) and feeding method (swallowing *P. laevis* whole). In spite of evidence of niche differentiation in prey selection, the diet between the two species with a high population size substantially overlapped. Their coexistence was presumed to be enabled by high food resource availability rather than niche differentiation in China. In the present study, a similar result could be obtained but the Great Knot fed on more polychaetes than the Bar-tailed Godwit in the Geum Estuary of South Korea. Also, both species fed on more gastropods than bivalves in Mollusca. The heterogeneity of diet might be due to a different prey composition of the two study sites. Such a heterogeneity of diet was previously reported for Great Knots between different spring stopover periods (early vs. late) in a year or years at Chongming Dongtan, China [30].

5. Conclusion

The two shorebird species showed a unique foraging strategies with similar diet niche under high prey resource availability in a tidal flat of the Geum Estuary. However, our results addressed the foraging behavior and diet of only two shorebird species. Therefore, more shorebird species stopping over this site need to be studied for the topics. Moreover, the foraging behavior and diet of shorebirds should be compared between staging sites and non-staging sites to explain the coexistence of many shorebirds because their coexistence can be affected by either high resource availability or niche differentiation, depending on the sites. Such a foraging behavior and diet study will be greatly useful for future conservation and management of key stopover sites as well as many endangered shorebird species in the EAAF.

6. Conflicts of interest

The authors declare that there is no conflicts of interest.

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References

[1]. S.K. Skagen and H.D. Oman. "Dietary flexibility of shorebirds in the western hemisphere". The Canadian Field-Naturalist, vol. 110, pp. 419-444, 1996.

[2]. M.A. Colwell. Shorebird Ecology, Conservation, and Management. Berkeley, CA: University of California Press, 2010, pp. 131-158.

[3]. P. Hayman, J. Marchant and T. Prater. Shorebirds: an identification guide to the waders of the World. Boston, MA: Houghton Mifflin Company, 1986.

[4]. T.E. Martin and J.R. Karr. "Behavioral plasticity of foraging maneuvers of migratory warblers: multiple selection periods for niches?". Studies in Avian Biology, vol. 13, pp. 353-359, 1990.

[5]. M.C.K. Soh. "Foraging behaviour of two tailorbirds in Singapore: habitat, morphological and temporal comparisons". The Raffles Bulletin of Zoology, vol. 49, pp 173-180, 2001.

[6]. N.A. Norazlimi and R. Ramli. "The relationships between morphological characteristics and foraging behavior in four selected species of shorebirds and water birds utilizing tropical mudflats". The Scientific World Journal, vol. 2015, pp 105296, 2015.

[7]. L. Zwarts and B.J. Ens. "Predation by birds on marine tidal flats" in Proc. 22nd International Ornithological Congress, 1999, pp. 2309-2327.

[8]. Y. Ntimao-Baidu, T. Piersma, P. Wiersma, M. Poot, P. Battley and C. Gordon. "Water depth selection, daily feeding routines and diets of waterbirds in coastal lagoons in Ghana". Ibis, vol. 140, pp 89-103, 1998.

[9]. P.M. Lourenco, T. Catry and J.P. Granadeiro. "Diet and feeding ecology of the wintering shorebird assemblage in the Bijagos archipelago, Guinea-Bissau". Journal of Sea Research, vol. 128, pp 52-60, 2017.

[10]. C.Y. Choi, P.F. Battley, M.A. Potter, Z. Ma, D.S. Melville and P. Sukkaewmanee. "How migratory shorebirds selectively exploit prey at a staging site dominated by a single prey species". Auk, vol. 134, pp. 76-91, 2017.

[11]. H. Lee, J.Y. Yi, H.C. Kim, S.W. Lee and W.K. Paek. "Yubu Island, the important waterbird habitat on the west coast of Korea and its conservation". Ocean and Polar Research, vol. 24, pp. 115-121, 2002.

[12]. T. Piersma, Y. Verkuil and I. Tulp. "Family Scolopacidae (sandpipers, snipes and phalaropes)" in

Handbook of the Birds of the World, vol. 3. J. del Hoyo, A. Elliott and J. Sargatal, Ed. Barcelona: Lynx Edicions, 1996, pp. 444-533.

[13]. W.S. Lee, T.H. Koo and J.Y. Park. A field guide to the birds of Korea. Seoul: LG Evergreen Foundation, 2010, pp. 134-147.

[14]. T. Piersma. "Foraging of Bar-tailed Godwits" in Wintering Wader on the Banc d'Arguin. W. Altenburg, M. Engelmoer, R. Mes and T. Piersma, Ed. Leiden: Stichting Veth tot steun aan Waddenonderzoek, 1983, pp. 135-148.

[15]. T. Piersma, A. Koohlaas and A. Dekinga. "Interactions between stomach structure and diet choice in shorebirds". Auk, vol. 110, pp. 552-564, 1993.

[16]. B. McCaffery and R. Gill. "Bar-tailed Godwit (Limosa lapponica)" in The Birds of North America 581. A. Pool and F. Gill, Ed. Philadelphia: Birds of North America, 2001.

[17]. G. Scheiffarth. "The diet of Bar-tailed Godwits Limosa lapponica in the Wadden Sea: Combining visual observations and faeces analyses". Ardea, vol. 89, pp. 481-494, 2001.

[18]. Y. Zharikov and G.A. Skilleter. "Sex-specific intertidal habitat use in subtropically wintering Bar-tailed Godwits". Canadian Journal of Zoology, vol. 80, pp. 1918-19029, 2002.

[19]. S. Duijns, N.A. Hidayati and T. Piersma. "Bar-tailed Godwits Limosa I. lappponica eat polychaete worms wherever they winter in Europe". Bird Study, vol. 60, pp. 509-517, 2013.

[20]. A. Dekinga and T. Piersma. "Reconstructing diet composition on the basis of faeces in a mollusk-eating wader, the knot Calidris canutus". Bird Study, vol. 40, pp. 144-156, 1993.

[21]. I. Tulp and P. de Goeij. "Evaluating wader habitats in Roebuck Bay (north-western Australia) as a springboard for northbound migration in waders, with a focus on Great Knots". Emu, vol. 94, pp. 78-95, 1994.

[22]. X. Zhang, N. Hua, Q. Ma, W.J. Xue, X.S. Feng, W. Wu, C.D. Tang and Z.J. Ma. "Diet of Great Knots (Calidris tenuirostris) using spring stopover at Chongming Dongtan, China". Chinese Birds, vol. 2, pp. 27-32, 2011.

[23]. H.Y. Yang, B. Chen, Z.J. Ma, N. Hua, J.A. van Gils, Z.W. Zhang and T. Piersma T. "Economic design in a long-distance migrating molluscivore: How fast-fuelling red knots in Bohai Bay, China, get away with small gizzards". Journal of Experimental Biology, vol. 216, pp. 3627-3636, 2013.

[24]. J.A. van Gils, S. Lisovski, T. Lok, W. Meissner, A. Ozarowska, J. de Fouw, E. Rakhimberdiev, M.Y. Soloviev, T. Piersma and M. Klaassen. "Body shrinkage due to Arctic warming reduces Red Knot fitness in tropical wintering range". Science, vol. 352, pp. 819-821, 2016..

[25]. J. Ryu, J. Nam, J. Park, B. Kwon, J. Lee, S.J. Song, S. Long, W.K. Chang and J.S. Kim. "The Saemangeum tidal flat: long-term environmental and ecological changes in marine benthic flora and fauna in relation to the embankment". Ocean and Coastal Management, vol. 102, pp. 559-571, 2014.

[26]. J. Hong, H. Yamashita and S. Sato. "Towards predicting the effect of salt-marsh reclamation on feeding bird numbers on the Wash". Journal of Applied Ecology, vol. 29, pp. 330-340, 2007.

[27]. J.Y. Yi. "Status and habitat characteristics of migratory shorebirds in Korea" in The Proceedings of the 2004 International Symposium on Migratory Birds, Gunsan: Ornithological Society of Korea, 2004, pp. 87-103.

[28]. N. Moores, D.I. Rogers, K. Rogers and P.M. Hansbro. "Reclamation of tidal flats and shorebird declines in Saemangeum and elsewhere in the Republic of Korea". Eum, vol. 116, pp. 136-146, 2016.

[29]. J. MacKinnon, Y.I. Verkuil and N. Murray. IUCN situation analysis on East and Southeast Asian intertidal habitats, with particular reference to the Yellow Sea (including the Bohai Sea). Gland and Cambridge: IUCN, 2012.

[30]. Wetlands International. Waterbird Population Estimates, 4th ed., Wageningen: Wetlands International, 2006.