

Environmental factors affecting roost use of shorebirds in the southern Kanghwa Island, Republic of Korea

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강화도 남단에 도래하는 도요새들의 해안 내륙 휴식지 이용과 이들의 이용에 영향을 미치는 환경요인들

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Abstract

There are some factors affecting the shorebirds in selecting a coastal inland roost site where they have to stay during the high tide when the entire intertidal zone is covered with water. We investigated eight species (Eastern Curlews *Numenius madagascariensis*, Green Shanks *Tringa nebularia*, Bar-tailed Godwits *Limosa lapponica*, Grey Plovers *Pluvialis squatarola*, Dunlins *Calidris alpina*, Whimbrels *Numenius phaeopus*, Eurasian Curlews *Numenius arquata* and Terek Sandpipers *Xenus cinereus*) to identify the spatial and temporal variability in coastal inland roost use in the area and the factors influencing the use. We considered the area and length of the standing water in the roost site, temperature, wind speed, the time of migration and the intensity of disturbance. As a result, number of individuals and type of species using the roost site varied across spatial and temporal scales. And the factors affecting the roost use was species-specific. The roost site of the study area was a closed shrimp farm however, it has been converted to a *Salicornia herbacea*, a salt marsh plant, farm recently. In a situation where coastal inland roost site is needed, we hereby describe a resolution for the juxtaposition of shorebirds and farming.

Keywords : coastal inland roost, conservation, EAAF, Kanghwa Island, roost site shorebirds, stopover site

요약

도요·물떼새들은 만조시에 해안 내륙 휴식지에서 휴식을 취하는데, 휴식지를 선택할 때 여러 가지 요소들을 고려한다. 우리는 도요·물떼새 8종(알락꼬리마도요 *Numenius madagascariensis*, 청다리도요 *Tringa nebularia*, 큰뒷부리도요 *Limosa lapponica*, 개꿩 *Pluvialis squatarola*, 민물도요 *Calidris alpina*, 중부리도요 *Numenius phaeopus*, 마도요 *Numenius arquata*, 뒷부리도요 *Xenus cinereus*)을 대상으로 휴식지의 시공간적 이용과 그 이용에 영향을 미치는 요인들을 분석하였다. 휴식지 내 고인 물의 면적과 길이, 기온, 풍속, 종별로 이동시기, 방해정도를 변수로 고려하였다. 시공간적으로, 이용하는 종이 달랐으며 개체수 또한 변동을 거듭하였다. 그리고 도요·물떼새의 휴식지 이용에 영향을 미치는 요인은 종-특이적이었다. 연구지역의 휴식지는 폐장한 새우양식장이었으나 조사 기간 중 염생습지에서 자라는 함초 *Salicornia herbacea* 농장으로 전환하였다. 휴식지가 필요한 상황에서, 도요·물떼새들의 생태를 기초로 해서 기존 휴식지를 관리할 것을 권한다. 더불어, 여름철 가뭄에는 양식장의 수문을 열어주어 도요·물떼새들이 물을 이용해 체온관리를 할 수 있게 해주고, 만조시 도요·물떼새들이 양식장 안으로 날아 들어올 수 있도록 새들이 휴식지를 찾기 시작하는 만조 전 네 시간부터는 농장 작업을 안 할 것을 권한다.

핵심용어 : 도요새, 휴식지, 강화도, 보전, 해안 내륙 휴식지, 중간 기착지, 동아시아대양주 이동경로

1. Introduction

Migratory shorebirds forage in the mudflat and from the rising tide they become forced to wade to the near

coastline and roost in the intertidal habitats (Rogers *et al.* 2006a). However, when it becomes spring tide, or the time when the mudflat and the coast is completely covered with water, shorebirds fly inland to nearest roost

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sites for example, rice paddies, salt pans, salt marshes, shrimp farms etc. and many congregated shorebirds are found in coastal inland roost sites behind the intertidal zone (Kim 2003a, Rogers *et al.* 2006a). Similar to the intertidal roost site shorebird species, Dunlins *Calidris alpina*, Black-tailed Godwits *Limosa limosa* (pers.obs.), (Common) Green Shanks *Tringa nebularia*, are observed to forage in the flooded rice paddy to refuel its' energy (Kim 2003b) and some species were found to forage in the rice paddy although the mudflat was available (pers.obs.) and if the coastal inland roost site is close to the foraging area the shorebirds could minimize energy expenditure (Piersma *et al.* 1993). Moreover, the local shorebird population could be affected by a human disturbance in the roost site (Pfister *et al.* 1992). From these cases the coastal inland roost site is imperative to the shorebirds. However, with ongoing developments in the coastal habitats (Mackinnon *et al.* 2012a), the rice paddies, salt pans, fish farms located in the coastal areas have been changed for other purposes and have negatively affected the shorebird population (Mackinnon *et al.* 2012b).

There has been active research on the types of roost sites the shorebirds use and the environmental factors related to the incidence (Colwell and Dodd 1997, Danufsky and Colwell 2003, Kim 2003a, Peters and Otis 2007, Rogers *et al.* 2006a). According to the available information on roosting ecology of shorebirds, they consider the energetic costs (Rogers *et al.* 2006b), predator risk (Dekker 1998, Dekker and Ydenberg 2004), the area flooded (Kelsy and Hassall 1989), the wind speed (Peters and Otis 2007), temperature (Rogers *et al.* 2006b) etc. when selecting a roost site. It's also suggested that human disturbance and activities could affect the shorebirds in determining the roost site (Burton *et al.* 1996). Furthermore there has been a work on a spatial and temporal scales of roost site selection (Peters and Otis 2007). However, most of the research was conducted in wintering sites or breeding sites therefore, we are lacking information on the stopover sites where shorebirds replenish in the middle of migration (Mackinnon *et al.* 2012c). Furthermore, the shorebirds' condition in the staging sites affects the survival of the individual in the breeding site (Skagen 2006, Morrison and Hobson 2004) which conveys the importance and the need for a research in the stopover site.

Here we examine the southern Kanghwado Island, Republic of Korea, a staging site in the East coast of the

Yellow Sea on the East Asian-Australasian Flyway (EAAF) to 1) examine the daily and annual use of coastal inland roost sites, 2) determine how the anthropogenic factor affects the use, 3) identify which environmental factors such as temperature and the wind speed affects the shorebirds' use and 4) suggest a management plan for the site.

2. Methods

2.1 Study Area

Southern part of Kanghwado Island (Latitude:37.58, Longitude:126.40; Fig. 1), Republic of Korea is located in one of the 16 key areas of shorebirds in the EAAF (Mackinnon *et al.* 2012d) and designated as a Key Area among Important Bird Area (IBA)s, IBA number 5 (Mackinnon *et al.* 2012e), having high biodiversity of shorebirds (Mackinnon *et al.* 2012e). And the mudflat in the southern part of Kanghwado Island is also designated as a natural monument (6 July, 2000; no.419) by the Cultural Heritage Administration of the Republic of Korea and evaluated as grade V according to Lee *et al.* 2004 therefore, provides a safe and high quality foraging area. However, many hinterlands of tidal flat areas are being developed following road constructions, restaurants, motels in Republic of Korea (Moores 2007) and so does the

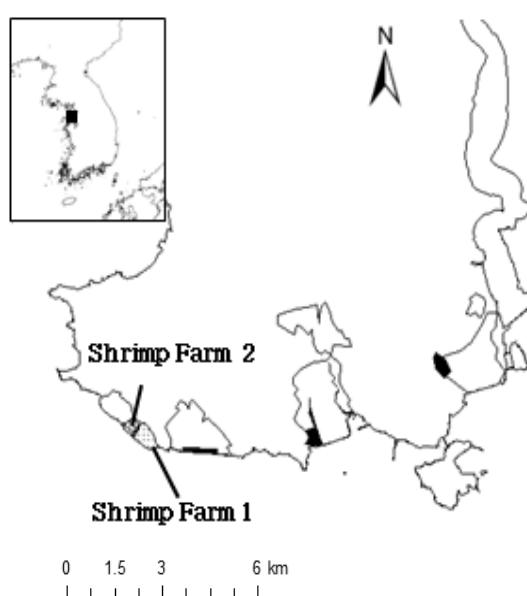


Fig. 1. Study area of the Shrimp Farms in the southern part of Kanghwado Island, Republic of Korea. The total shorebird census of the southern Kanghwado Island were carried out along the coastline.

southern Kanghwa Island constructing motels, restaurants, and eco-tourism trails (Nadeulgil) along the coastline disrupting the shorebirds (pers.obs.).

Southern part of Kanghwa Island is consisted of a mountain, few forests, rice paddies (partly closed), closed shrimp farms, reservoir and a beech. Roost sites shorebirds could use are the rice paddies, closed Shrimp Farm 1 and 2, which are attached to each other locating just behind the mudflat divided by a dyke (Fig. 1). Reservoir cannot be used as a roost site because people fish there and it is near to houses and a road. However, compared to year 2002 (Kim 2003a) rice fields are only partially running and as a consequence most of the area are unflooded being unattractive to the shorebirds (Moores 2006). Shrimp Farm 1 is surrounded by a dyke and ground cover is homogeneous filled with mudflats. Shrimp Farm 2 delineated into three sectors with a dyke the ground is also filled with mudflats. The two attached Shrimp Farms are currently the last available coastal inland roost sites. However, the Shrimp Farm 2 is too narrow to accommodate all the shorebirds and most of all the least area has slopes therefore only available for a specific species. What's worse the new owner of the Shrimp Farm 1 has converted the empty farm into a *Salicornia herbacea*, a salt marsh plant prescribed in traditional medicines for a long time (Park *et al.* 2009), farm. Here we use the term Shrimp Farm through out the literature instead of *S. herbacea* Farm. Since then there has been consistent changes in the Shrimp Farm 1 draining off water in early April 2012, sowing as the water level decreases, occasional entrance inside the roost till September 2012 and harvest since the early October 2012. An alternate roost site exists in the Yeongjong Island across the mudflat 10km far (Kim and Yoo 2004, pers.obs) which is an empty dredged soil reclamation area however, as there were no environmental changes in the empty area affecting the shorebirds (per.obs.) we did not consider this site into account.

2.2 Survey Methods

We conducted 26 bird surveys from September 2011 to November 2012. On the main migratory seasons (March, April, May, July, August, September, October, November) we surveyed twice a month every other week and once in the non-migratory season. After the bird census was conducted near the coastline, we have conducted a separate roost site survey in the Shrimp Farm 1, 2 and rice paddy

before half an hour to high tide when the population was stable; rice paddy not presented in this article. In order to be precise of the shorebird counts, census was conducted on the day when the high tide was over 780cm, when the high tide covered all the intertidal habitats.

2.3 Roost Site and Environmental Variables

The wind speed and temperature data was obtained from the nearest weather station 3.5km away from the study area (downloaded from the Korea Meteorological Administration) and used data matching with the census date. The mean value of the ten minutes-interval data (N=13) two hours prior to the high tide (Appendix) was used. Disturbance variable was based on the farming schedule obtained from the owner of the *S. herbacea* Farm. We divided the variable into three stages: before any measures were taken, after sowing process and the harvest period and have given a dummy number respectively, 0, 1 and 2. And to see the relationship between the roost use and migration cycles of the shorebirds, we applied the Julian date (Peters and Otis 2007) and named the variable Time of Year.

The area of the standing water affects the shorebird distribution (Connor and McCoy 1979) and the species congregate around the line of the water (Danufsky and Colwell 2003) as the depth is suitable for the shorebirds therefore, we measured the area of the (standing) water and the circumference of the water. Here we use, the term 'length of water' throughout the passage to state the circumference of the water. Based on ground truth data, we used the Landsat TM images to calculate the values of the variables (Fig. 2). We used nine Landsat images (3 September 2011, 22 November 2011, 13 March 2012, 30 April 2012, 1 June 2012, 5 September 2012, 7 October 2012, 23 October 2012, 24 November 2012) available from the U.S. Geological Survey and concerning with the technical problems with the Scan Line Corrector of Landsat 7 (U.S Geological Survey, <http://calval.cr.usgs.gov/LDGST.php>), prior to analysis we filled the gaps with the latest images with similar environmental status. Exclusive of the nine data extracted from the satellite images, to calculate the 17 other values matching the survey data, we used a simple linear regression equation to predict the values from the nine satellite images (Appendix). Shorebirds roost in a point where they feel safe, especially in the middle (Stillman *et al.* 2005), likewise roosted 100m away from the dyke (pers.obs.), so we have set up a

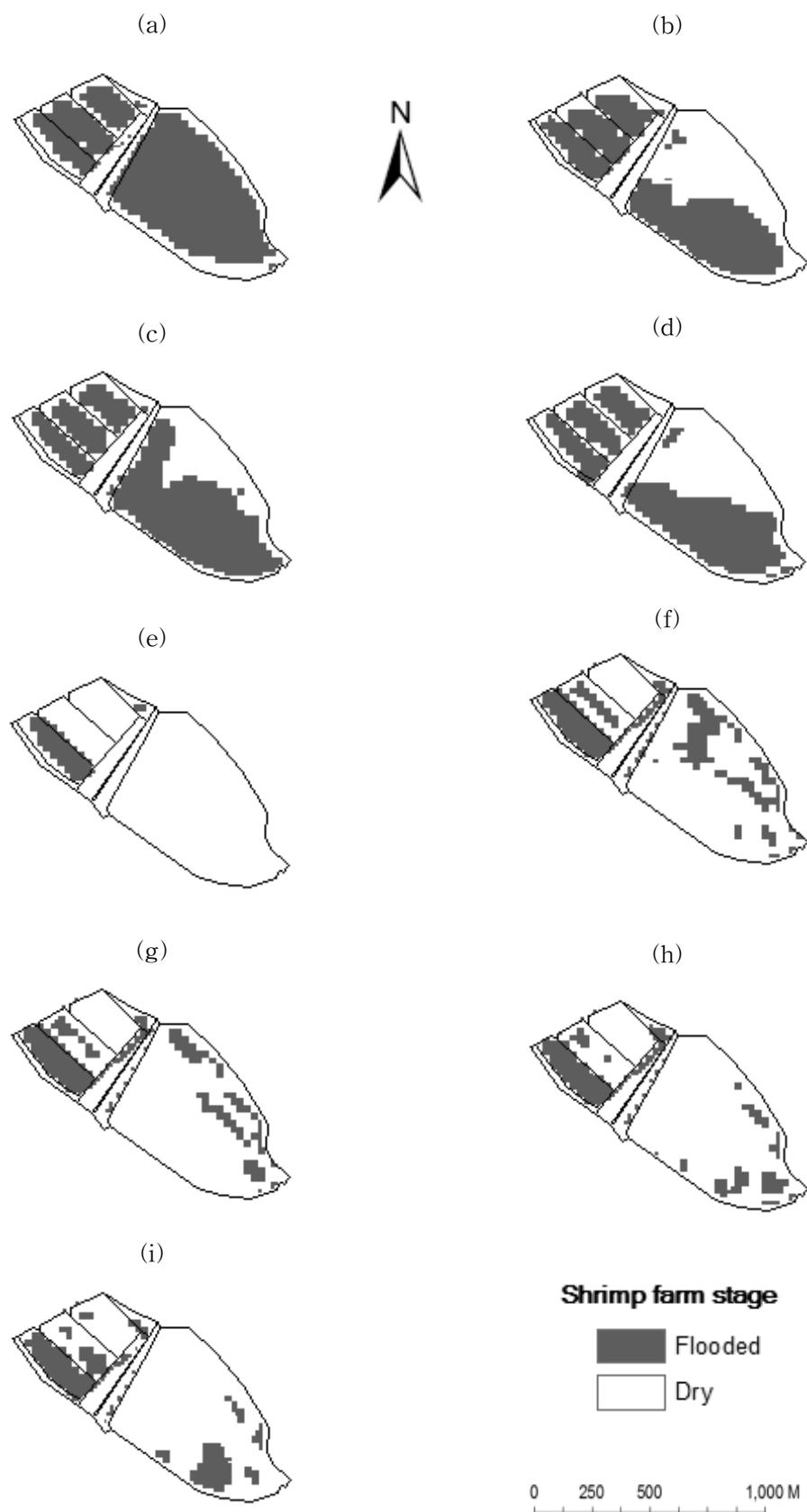


Fig. 2. Change of the flooded area based on Landsat images:(a) 3 September 2011, (b) 22 November 2011, (c) 13 March 2012, (d) 30 April 2012, (e) 1 June 2012, (f) 5 September 2012, (g) 7 October 2012, (h) 23 October 2012, (i) 24 November 2012.

Table 1. Spearman correlation coefficients for environmental factors measured during the 26 surveys in the southern Kanghwa Island, Republic of Korea. Correlations significant at $P < 0.05$ are displayed in bold.

	Water Area	Water Length	Water Area/Length	Temperature	Wind Speed	Time of Year
Water length	0.15					
Water Area/Length	0.81	-0.30				
Temperature	-0.29	-0.22	-0.22			
Wind Speed	-0.25	-0.12	-0.14	-0.32		
Time of Year	-0.22	-0.26	-0.09	0.01	0.12	
Disturbance	-0.84	-0.13	-0.63	0.26	0.23	0.14

100m bufferzone from the edge and only used the data inside the zone. The Shrimp Farm 2 was rarely used from shorebirds and little environmental changed occurred during the survey therefore was not included in the analysis. EXCEL was used for calculation of the temperature and the windspeed and ERDAS IMAGINE 9.2 was used for Landsat Image analysis and ARC GIS 10.0 for spatial analysis.

2.4 Statistical Analysis

Only the species that have used the roost site more than 50 individuals and used more than 11 incidents has been analysed; the Eastern Curlew *Numenius madagascariensis*, the Green Shank, the Bar-tailed Godwit *Limosa lapponica*,

the Grey Plover *Pluvialis squatarola*, the Dunlin, the Whimbrel *Numenius phaeopus*, the Terek Sandpiper *Xenus cinereus* and the Eurasian Curlew *Numenius arquata* (Fig. 3). To calculate the number of times use of each species (Shrimp Farm 1 and 2 during the 26 surveys), based on the incidence we used the total number of visits. And to calculate the annual (during 26 surveys) proportion use we divided the value to the total times the species was observed in the southern Kanghwa Island (Table 2). When there were no population during the census, the species value was regarded as null and was not used for analysis. To examine the daily proportion use of the Shrimp Farm we used the total counts of each shorebird species from the 11 sites and the total daily population (Fig. 3).

Table 2. Shorebird species and number of total observations in the Shrimp Farm during the 26 surveys (from September 2011–November 2012) in the southern Kanghwa Island. Also the annual roost use (during 26 surveys) of Shrimp Farm 1 and 2 are presented.

Common Name	Scientific Name	Number of observations	¹⁾ Proportion Use			
			Shrimp Farm 1	Shrimp Farm 2		
Eastern Curlew	<i>Numenius madagascariensis</i>	3625	0.60	(12/20) ²⁾	0.10	(2/20)
Green Shank	<i>Tringa nebularia</i>	2089	0.41	(7/17)	0.47	(8/17)
Bar-tailed Godwit	<i>Limosa lapponica</i>	1030	0.40	(6/15)	0.00	(0/15)
Great Knot	<i>Calidris tenuirostris</i>	853	0.56	(5/9)	0.11	(1/9)
Grey Plover	<i>Pluvialis squatarola</i>	806	0.40	(8/20)	0.05	(1/20)
Dunlin	<i>Calidris alpina</i>	768	0.20	(4/20)	0.00	(0/20)
Whimbrel	<i>Numenius phaeopus</i>	417	0.45	(5/11)	0.09	(1/11)
Black-tailed Godwit	<i>Limosa limosa</i>	285	0.60	(3/5)	0.00	(0/5)
Terek Sandpiper	<i>Xenus cinereus</i>	183	0.15	(2/13)	0.08	(1/13)
Red-necked Stint	<i>Calidris ruficollis</i>	120	0.50	(1/2)	0.00	(0/2)
Eurasian Curlew	<i>Numenius arquata</i>	52	0.31	(5/16)	0.06	(1/16)
Eurasian Oystercatcher	<i>Haematopus ostralegus</i>	4	0.17	(3/18)	0.06	(1/18)
Wood Sandpiper	<i>Tringa glareola</i>	1	0.20	(1/5)	0.00	(0/5)

1) Annual proportion use based on the incidence of the shorebird species using the roost site out of 26 surveys.

2) The number in the parenthesis: number of incidence in the roost site/number of observations in the southern Kanghwa Island during the 26 surveys.

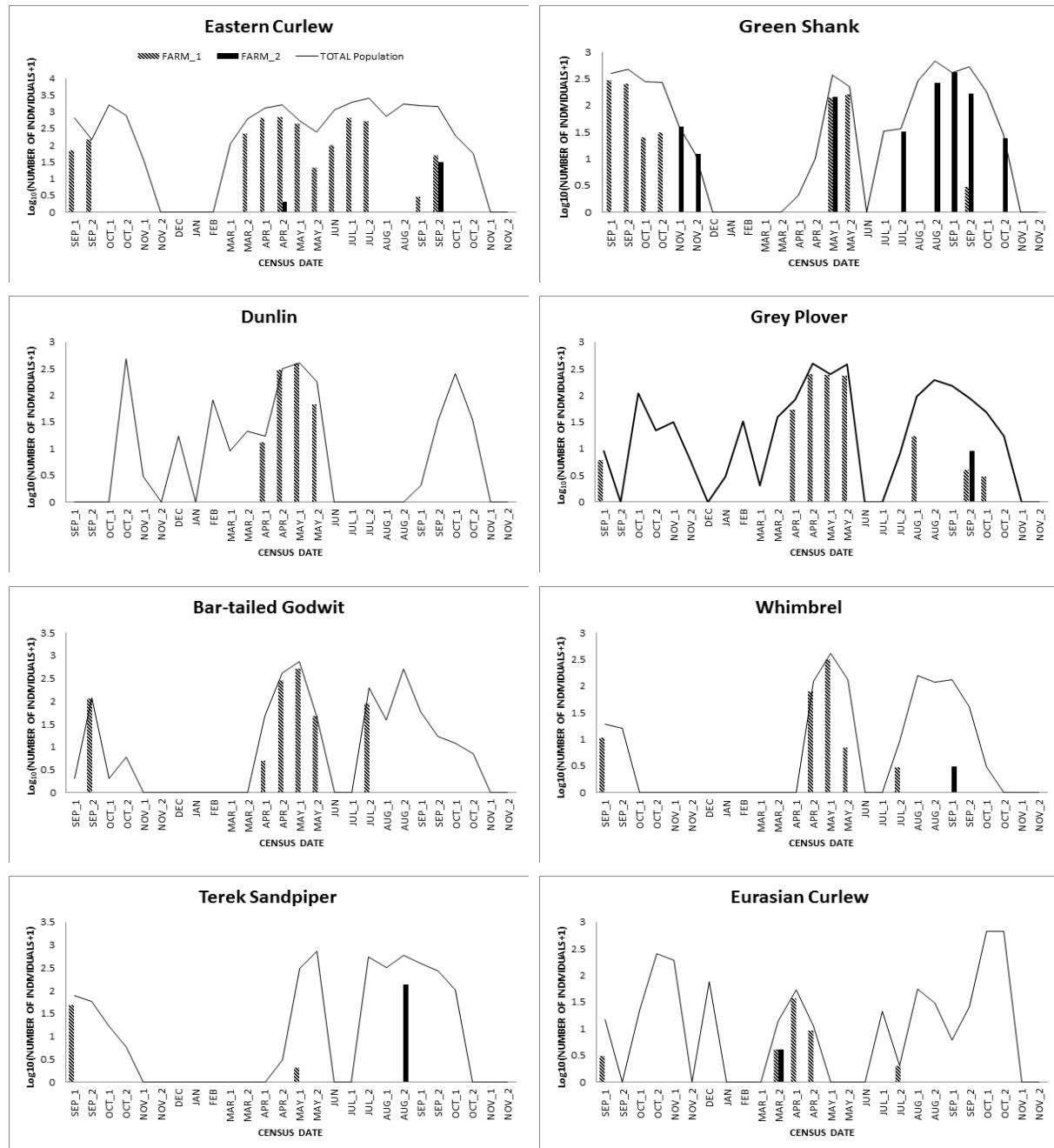


Fig. 3. Daily total number of individuals observed in the southern Kanghwado Island and the number of individuals using the Shrimp Farm 1 and 2 are presented for the eight shorebird species from early September 2011 to late November 2012; marked _1 for the first survey and _2 for the second survey. The number of individuals are log transformed.(Spring:Mar.,Apr.,May, Summer: Jun.,Jul.,Aug., Fall: Sep.,Oct.,Nov.)

We used a Generalized Linear Model (GLM, logit link function and quasibinomial error structure to account for overdispersion) to examine the relationship between the number of individuals out of the total population (daily) using the Shrimp Farm 1, the response variable, and the changing environmental variables, the explanatory variables (Table 2). Previous studies using logistic regression method used the presence/absence as the response variable

(Colwell and Dodd 1997, Danufsky and Colwell 2003) therefore couldn't define the cause of the increase or decrease of the number of individuals but only were informed of what variables are related to its presence/absence. We wanted to look for the variables which could explain the change in the number of individuals' use of the shorebirds therefore, instead of binary numbers we used the actual numbers into account

(Crawley 2013). We applied log transformation to the time of year (Julian Date), area of water, circumference of the water and to prevent multicollinearity among variables, we tested the Spearman Correlation (Table 1) and eliminated the area of water variable for a reason of high correlation between another variable and instead inserted the area/length of the water variable which includes both area and the circumference values and had less correlation effects (Table 3). The area/length variable explains the shape and the distribution of the standing

water regarding the flooded area as a circle. Higher value means the standing water is close to one whole area and lower value means it has an irregular shape. Furthermore, to prevent multicollinearity we checked the Variance Inflation Factor (VIF) when selecting explanatory variables in the model and only used the variables smaller than 10 (Danufsky and Colwell 2003). We used statistical program R (R Core Team 2012) for GLM analysis and considered results significant when P values were smaller than 0.05.

Table 3. Analysis on the change in the proportion using the Shrimp Farm 1 in relation to the environmental factors. (GLM analysis based on Quasi binomial error structure and logit link function)

Species	Variables	N	Beta coefficient	SE	P
Eastern Curlew	Area/Length of water	20	0.32	0.30	0.29
	Time of year		-2.51	0.80	< 0.01
	Disturbance		0.68	1.12	0.55
	Temperature		0.09	0.09	0.32
	Wind Speed		0.19	0.37	0.63
Green Shank	Area/Length of water	17	1.52	0.23	< 0.001
	Time of year		-3.89	0.72	< 0.001
	Temperature		0.06	0.06	0.34
	Wind Speed		0.06	0.30	0.84
Bar-tailed Godwit	Time of year	15	-4.39	1.33	< 0.01
	Disturbance		-5.31	2.44	0.05
	Wind Speed		-0.28	0.68	0.69
Grey Plover	Area/Length of water	20	-1.86	0.56	< 0.01
	Time of year		-3.59	1.18	< 0.01
	Disturbance		3.31	1.16	< 0.05
	Temperature		0.19	0.06	< 0.01
	Wind Speed		1.02	0.44	< 0.05
Dunlin	Area/Length of water	14	-0.84	2.32	0.73
	Time of year		-3.13	2.23	0.19
	Temperature		0.42	0.26	0.13
	Wind Speed		2.03	1.47	0.19
Whimbrel	Area/Length of water	11	2.27	11.49	0.85
	Time of year		-0.15	47.22	1.00
	Wind Speed		2.17	3.49	0.55
Terek Sandpiper	Disturbance	13	-7.22	2.71	< 0.05
	Temperature		-0.63	4.50	0.89
	Wind Speed		-2.83	27.37	0.92
Eurasian Curlew	Area/Length of water	16	1.09	1.50	0.48
	Time of year		-6.03	1.78	< 0.01
	Disturbance		3.01	8.02	0.71
	Wind Speed		-0.38	3.45	0.91

3. Results

3.1 Shorebird observation and the annual use of the Shrimp Farms

During the 26 surveys, 13 shorebird species were observed using the Shrimp Farm 1 and 2. 3,625 individuals of Eastern Curlews, 2,089 individuals of Green Shanks, 1,030 individuals of Bar-tailed Godwits, 853 Great Knots and 2,636 other 9 species were observed (sum of 26 surveys) (Table 2, Appendix). The annual use of the roost site fluctuated by species (Table 2 and Fig. 3). The Eastern Curlew used the Shrimp Farm 1 as much as the proportion of 0.6 during the 26 surveys and Terek Sandpipers used only twice out of 13 visits (0.15) in the southern Kanghwado Island. However, compared to Shrimp Farm 1, most of species rarely used the Shrimp Farm 2. Bar-tailed Godwits, Dunlins, Black-tailed Godwits, Red-necked Stints and Wood Sandpipers did not use the Shrimp Farm 2 at all. However, Green Shanks, exceptionally, used the Shrimp Farm 2, eight times out of 17 visits (0.47) in the southern Kanghwado Island. Seasonally, the Shrimp Farm 1 was used highly in the Spring (March to May) 2012 (except for the Terek Sandpiper) and in the Fall (September to November) of 2011 except for the Dunlins (Fig. 3). In the Fall of 2012 however, number of individuals using the Shrimp Farm 1 varied among species. Eastern Curlews, Green Shanks and Grey Plovers roosted in the Shrimp Farm 1, however Bar-tailed Godwits, Dunlins, Whimbrels, Terek Sandpipers and Eurasian Curlews did not use the site at all. Shrimp Farm 2 wasn't used throughout the survey until the Fall of 2012 with some exceptions of Eastern Curlews, Green Shanks and Eurasian Curlews. However, the Eastern Curlew and the Eurasian Curlew used only once before the Fall 2012. In a whole, from September 2011 to July 2012 Shrimp Farm 1 was highly used and after July 2012 Shrimp Farm 2 was used by some of the species (Fig. 3).

3.2 Change in the daily number of individuals using the roost site and the environmental factors

Except for the Dunlin and the Whimbrel, there were significant variables that explained the change in the number of individuals roosting on Shrimp Farm 1 (Table 3). The proportion using the Shrimp Farm 1 correlated negatively with the time of year ($N=20$, $P<0.01$, Table

3) in Eastern Curlews. A higher proportion used the Shrimp Farm 1 in the earlier times based on the Julian date. The proportion of roosting Green Shanks had a positive correlation with the area/length of water variable ($N=17$, $P<0.001$, Table 3) and a higher proportion were found in Spring ($P<0.001$, Table 3). Bar-tailed Godwits ($N=15$, $P<0.01$) and Eurasian Curlews ($N=16$, $P<0.01$) also highly used the Shrimp Farm 1 in the Spring. The proportion using the roost in Grey Plovers had significant correlation with every variables (Table 3). The proportion negatively correlated with the area/length of water ($N=20$, $P<0.01$) and the time of year ($P<0.01$), positively with the disturbance ($P<0.05$), temperature ($P<0.01$) and wind speed ($P<0.05$). The proportion using the roost site in Terek Sandpipers had a negative correlation with the disturbance variable ($N=13$, $P<0.05$) having lower proportion of use in higher disturbance situations.

4. Discussion

4.1 Annual use of the Shrimp Farms

There had been a fluctuation in the proportion of shorebirds using the roost and a fluctuation in the migration cycle among species (Fig. 3). And, there have been periods when there were no individuals observed (Fig. 3). During the 26 surveys the annual use of the Shrimp Farm 1 was less than or equal to 0.6 and less than or equal to 0.47 in the Shrimp Farm 2 (Table 2) which coincides with other research results which has seen a fluctuation in number of shorebirds using the roost site (Peters and Otis 2007). The shorebirds in Kanghwado Island used the dredged soil reclamation area, another roost site in the Yeongjongdo Island (pers.obs.). Therefore, shorebirds in the southern Kanghwado Island are currently roosting on Shrimp Farms and a dredged soil reclamation area. However, with previous studies this study has proved that there is a selective force affecting the use of the roost site (Peters and Otis 2007) which will eventually change the number of individuals as well as the proportion using the Shrimp Farm 1 (Table 3).

4.2 Daily number of individuals using the roost site in relation to the environmental factors

A variety of variables associated with the change in the proportion in using the Shrimp Farm 1 and were species-specific (Table 3). Time of year influenced the

use of the five species and conveys that roost use is related to the migration cycle of the species which matches with the work of Peters and Otis (2007). The birds significantly used more in the Spring. Area/length of water influenced the roost use of the Green Shanks and the Grey Plovers, whereas the proportion of the Green Shanks in the roost site correlated positively ($P<0.001$) and the Grey Plovers correlated negatively ($P<0.01$). Such result comes from each species' ecological behavior where Green Shanks used the lower part of the dyke in September 2011 when the area/length was relatively high however, Grey Plovers used the roost site in spite of how low the area/circumference ratio was, during the Spring and Fall, 2012. As in the case of the Terek Sandpiper, shorebirds consider disturbance as a factor when selecting roost sites. In this study however, the disturbance factor correlated with just Grey Plovers and Terek Sandpipers. This results from the discordance between the migration period and the time of harvesting, which prevented other species from being disturbed by harvesting. In the case of the Grey Plover, which used the roost even in the harvesting period, we could assume that more than a certain level of disturbance is needed to force the shorebirds away from the roost as in the case of Peters and Otis (2007). Grey Plovers used the roost in spite of the change in surface from harvesting, roosting in the edge of the harvesting points where the visual appearance had not changed. In high ambient temperatures, shorebirds could end up in a loss of energy (Rogers *et al.* 2006b). Instead of flying to a far distant roost and risking heat stress from flying (Rogers *et al.* 2006a, Rogers *et al.* 2006b, Peters and Otis 2007), Grey Plovers could have preferred the Shrimp Farm. As in the case of the temperature, wind speed could also be a factor when selecting the roost sites as "energy requirements will increase rapidly on windy days" (Evans, P. R. 1976). Dunlins (Handel and Gill 1992), Whimbrels (Peters and Otis 2007) and other species (Peters and Otis 2007) are already known to consider wind speed however, in our study the three species were not related to the wind speed.

4.3 Conservation Implications

The two Shrimp Farms are the major coastal inland roost sites currently in the southern Kanghwa Island and the shorebirds in Kanghwa Island roost on a dredged soil reclamation area, which is 10km away in the Yeongjong

Island. A conservation plan is inevitable in this area and a construction of an artificial roosting site or a shorebird ecology-based management of the Shrimp Farm 1 should be considered.

Artificial roost sites should be based on scientific knowledge, including this study, of the shorebirds reflecting the species' ecology. However, Rogers *et al.* (2006a) insisted that "shorebirds make decisions based on thresholds rather than on probability algorithms that are much more information and computationally demanding." Therefore, although significant variables from this study are considered in the construction of an alternative roost site in the southern Kanghwa Island, the shorebirds might not prefer the newly constructed site to the traditional roost site as in the case of Zhijun Ma *et al.* (2004) resulting in a loss of biodiversity. Instead, there are literatures and a long time experience that shorebirds use traditional roost sites (Rehfisch *et al.* 2003 Zhijun Ma *et al.* 2004). So in shorebird conservation, better management in the Shrimp Farm 1 could be more effective than constructing a new roost site. And Kim (2003a) had described that the shorebirds have used the Shrimp Farm 1 which conveys that the shorebirds in the southern Kanghwa Island could have the site fidelity for a long period. Rogers *et al.* (2006a) mentioned that at nights shorebirds rely on memory to find a roost. Which further strengthens the idea that the shorebirds would prefer the Shrimp Farm 1 and as a result managing the traditional roost would be more effective. The suggesting management implication for the Shrimp Farm 1 is to regulate the area/length of water, control the farmwork time and eliminate the disturbance factors as in the result of this study (Table 2). In summer drought, opening the sluice valve in the range which the *S. herbacea* doesn't get inundated will help the shorebirds to thermoregulate (Rogers *et al.* 2006b) as well as provide a suitable area/circumference of flooded habitat. A little disturbance, farmers sowing seeds and thinning out once in a while, does not bother some shorebird species (Fig. 3). However, the result does not imply that the shorebirds will roost in spite of the farmers inside the Shrimp Farm. The farm work and providing shorebirds a roost site could be concurrently achieved when working time is slightly modified. Therefore, we propose the farmwork to be done before four hours to high tide, when the shorebirds start to look for the coastal inland roost sites (Kim 2003c), or work on a neap tide day when the high tide leaves the intertidal mudflat unflooded where the shorebirds could

roost. And it would be better to move the agricultural machines placed in the dyke where Terek Sandpipers and Green Shanks usually use, to a place inside the bufferzone. Finding a resolution for the juxtaposition of shorebirds and men are vital and this research was in the middle of such circumstances. Therefore, we encourage others to refer to this study in protecting the shorebirds in the southern Kanghwado Island.

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Appendix. Environmental variables measured during the 26 surveys on the southern Kanghwa Island, South Korea. The Temperature and the Wind Speed is calculated as mean of the values(N=13) from two hours to high tide. And the species total population and the number of individuals using the Shrimp Farm 1 and Shrimp Farm 2, respectively inside the parentheses, are presented.

	Survey Time								
	Sep_1_2011	Sep_2_2011	Oct_1_2011	Oct_2_2011	Nov_1_2011	Nov_2_2011	Dec_2011	Jan_2012	Feb_2012
Environmental variables									
Area/Length of Water	2166	735	398	247	162	107	110	113	115
Disturbance	0	0	0	0	0	0	0	0	0
Temperature(°C)	24.6	26.1	20.0	13.0	17.2	8.9	-3.2	4.0	4.8
(SD)	(0.6)	(0.9)	(0.7)	(0.3)	(0.5)	(0.3)	(0.2)	(0.2)	(0.3)
Wind Speed(m/s)	1.5	3.8	2.2	6.6	1.9	3.8	6.6	4.0	2.0
(SD)	(0.7)	(0.8)	(1.0)	(0.8)	(0.8)	(0.6)	(0.9)	(0.8)	(0.5)
Area of Water(m ²)	179767	159975	140183	120391	100599	80809	95444	110076	124708
Length of Water(m)	83	217.8	352.6	487.4	622.2	757	865.5	974	1082.5
Species									
Eastern Curlew	643(72,0)	147(147,0)	1584(0,0)	755(0,0)	36(0,0)	0	0	0	0
Green Shank	394(295,0)	462(259,0)	276(25,0)	264(31,0)	38(0,38)	11(0,11)	0	0	0
Bar-tailed Godwit	1(0,0)	114(112,0)	1(0,0)	5(0,0)	0	0	0	0	0
Great Knot	8(8,0)	9(9,0)	121(0,0)	3(0,0)	0	0	0	0	0
Grey Plover	8(5,0)	0	109(0,0)	21(0,0)	30(0,0)	5(0,0)	0	2(0,0)	32(0,0)
Dunlin	0	0	0	487(0,0)	2(0,0)	0	16(0,0)	0	82(0,0)
Whimbrel	18(10,0)	15(0,0)	0	0	0	0	0	0	0
Black-tailed Godwit	76(75,0)	20(20,0)	190(190,0)	0	0	0	0	0	0
Terek Sandpiper	77(47,0)	58(0,0)	16(0,0)	5(0,0)	0	0	0	0	0
Red-necked Stint	0	0	0	0	0	0	0	0	0
Eurasian Curlew	14(2,0)	0	21(0,0)	250(0,0)	192(0,0)	0	76(0,0)	0	0
Eurasian Oystercatcher	3(0,0)	0	44(0,0)	22(0,0)	64(0,0)	0	0	0	11(0,0)
Wood Sandpiper	0	0	0	0	0	0	0	0	0

Appendix. Extended

	Survey Time							
	Mar_1_2012	Mar_2_2012	Apr_1_2012	Apr_2_2012	May_1_2012	May_2_2012	Jun_2012	Jul_1_2012
Environmental variables								
Area/Length of Water	117	121	126	134	134	134	0	22
Disturbance	0	0	1	1	1	1	1	1
Temperature(°C)	6.2	7.4	11.9	8.7	21.5	22.2	25.6	23.3
(SD)	(0.9)	(0.8)	(0.6)	(0.1)	(1.6)	(0.3)	(0.9)	(0.7)
Wind Speed(m/s)	3.7	5.0	4.5	5.0	5.3	3.7	5.2	4.1
(SD)	(0.6)	(0.4)	(1.2)	(0.9)	(0.4)	(0.8)	(0.5)	(1.1)
Area of Water(m ²)	139335	121689	104046	86407	57609	28807	0	6642.4
Length of Water(m)	1191	1009	827	645	430	215	0	296.8
Species								
Eastern Curlew	110(0,0)	614(226,0)	1282(653,0)	1603(710,1)	526(440,0)	242(21,0)	1153(100,0)	1840(642,0)
Green Shank	0	0	1(0,0)	9(0,0)	366(140,140)	218(160,0)	0	31(0,0)
Bar-tailed Godwit	0	0	46(4,0)	408(280,0)	729(500,0)	46(46,0)	0	0
Great Knot	0	0	0	500(500,0)	312(310,0)	6(6,0)	0	0
Grey Plover	1(0,0)	38(0,0)	83(52,0)	392(250,0)	253(240,0)	388(230,0)	0	0
Dunlin	8(0,0)	20(0,0)	16(12,0)	314(300,0)	406(390,0)	180(66,0)	0	0
Whimbrel	0	0	0	118(80,0)	401(317,0)	127(6,0)	0	0
Black-tailed Godwit	0	0	0	0	0	76(0,0)	20(0,0)	190(0,0)
Terek Sandpiper	0	0	0	2(0,0)	306(1,0)	740(0,0)	0	0
Red-necked Stint	0	0	0	0	(120,0)	0	0	0
Eurasian Curlew	0	13(3,3)	52(35,0)	10(8,0)	0	0	0	20(0,0)
Eurasian Oystercatcher	3(0,0)	4(0,0)	1(0,0)	1(1,0)	3(1,0)	5(0,0)	0	2(1,1)
Wood Sandpiper	0	0	0	4(0,0)	11(0,0)	0	0	0

Appendix. Extended

	Survey Time									
	Jul_2_2012	Aug_1_2012	Aug_2_2012	Sep_1_2012	Sep_2_2012	Oct_1_2012	Oct_2_2012	Nov_1_2012	Nov_2_2012	
Environmental variables										
Area/Length of Water	22	22	22	22	19	13	18	26	31	
Disturbance	1	1	1	1	1	2	2	2	2	
Temperature(°C)	25.3	31.6	27.9	26.5	21.5	21.2	16.4	9.6	4.8	
(SD)	(0.2)	(1.2)	(0.4)	(0.7)	(0.2)	(0.4)	(0.4)	(0.2)	0.4	
Wind Speed(m/s)	1.9	2.8	2.7	4.0	3.2	4.3	5.7	6.3	2.7	
(SD)	(0.9)	(0.5)	(0.3)	(1.0)	(0.7)	(0.6)	(0.9)	(0.8)	0.8	
Area of Water(m ²)	13284.6	19926.8	26569	33211	22782	12353	4731	9576	14421	
Length of Water(m)	593.6	890.4	1187.2	1484	1205.5	927	267	365	463	
Species										
Eastern Curlew	2455(530,0)	735(0,0)	1733(0,0)	1498(2,0)	1426(51,30)	190(0,0)	55(0,0)	0	0	
Green Shank	35(0,31)	286(0,0)	664(0,262)	411(0,411)	512(2,160)	175(0,0)	27(0,23)	0	0	
Bar-tailed Godwit	192(88,0)	38(0,0)	492(0,0)	56(0,0)	16(0,0)	11(0,0)	6(0,0)	0	0	
Great Knot	0	0	0	20(0,20)	1(0,0)	0	0	0	0	
Grey Plover	7(0,0)	95(16,0)	195(0,0)	152(0,0)	88(3,8)	48(2,0)	16(0,0)	0	0	
Dunlin	0	0	0	1(0,0)	33(0,0)	251(0,0)	34(0,0)	0	0	
Whimbrel	8(2,0)	156(0,0)	115(0,0)	128(0,2)	39(0,0)	2(0,0)	0	0	0	
Black-tailed Godwit	1(0,0)	0	0	0	0	18(0,0)	0	0	0	
Terek Sandpiper	543(0,0)	312(0,0)	589(0,135)	391(0,0)	271(0,0)	104(0,0)	0	0	0	
Red-necked Stint	0	0	0	0	0	0	0	0	0	
Eurasian Curlew	1(1,0)	55(0,0)	29(0,0)	5(0,0)	24(0,0)	654(0,0)	668(0,0)	0	0	
Eurasian Oystercatcher	3(0,0)	0	35(0,0)	22(0,0)	21(0,0)	26(0,0)	5(0,0)	0	0	
Wood Sandpiper	0	0	0	1(1,0)	5(0,0)	0	7(0,0)	0	0	