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Difference in Black-tailed Gull (*Larus crassirostris*) diet during the breeding season for the last 10 years in the South Sea of Korea

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Abstract

Sea temperature in the South Sea of Korea has been increased over the last decades. Seabirds are sensitive to changes in food availability in marine environment. In this study, we investigate the diet of Black-tailed gulls (*Larus crassirostris*) during the breeding season to identify changes of marine environment and biological response such as breeding performance in the South Sea of Korea. A total of 22 fish species or family (n = 128) from regurgitates by chicks were collected on Hongdo Island in 2002 and 2012. The most important prey item was Japanese anchovies (*Engraulis japonicas*). Proportion of Anchovy in diet increased in 2012 (70.5%) compared to 10 years ago (27.5%). Some species were newly found in 2012: Spotted chub mackerel (*Scomber australasicus*), Pacific sand lace (*Ammodytes personatus*), White ventral goby (*Acanthogobius lactipes*), Silver-strip round herring, Multicolorfin rainbowfish (*Halichoeres poecilopterus*), Silverside (*Hypoatherina tsurugae*), Surfperch (*Neoditrema ransonneti*) and Spotnape ponyfish (*Leiognathus muchalis*), but not in 2002. Especially, sub-tropic fish such as Kammal thryssa (*Thryssa kammalensis*), and Rosefish (*Helicolenus hilgendorfi*) were frequently observed in the diet of 2012. These results might reflect the increase of sea temperature in the South Sea of Korea.

Key words: Black-tailed Gull, diet, fish, Hongdo Island, Sea temperature, South Sea

INTRODUCTION

Marine environment and ecosystem has been affected by global climate change. Sea level and temperature rise have been widely occurred in the world. In Korea, sea temperature has also been increased as much as maximum 1°C for last 40 years (Choi and Choi 2011). This is about two folds higher than global average of sea temperature (Choi and Choi 2011). Sea surface temperature (SST) of the South Sea of Korea has been increased as much as about 0.03-0.05°C per year from 1980 to 2000 (Yoon and Choi 2011). Increasing rate of SST in the South Sea of Korea has got larger since 1994 (Seol 2008). The Intergovernmental Panel on Climate Change (IPCC) expected that SST in the South Sea of Korea may be higher up to 2.3-3.5°C by 2100 (IPCC 2007).

Changes in marine environment probably affect marine ecosystem. Species and population of fish in the South Sea of Korea relate to sea temperature and salinity (Ju 2011). Recently, tropical species which were never found before have been found in the South Sea of Korea. *Halophia nipponica*, a kind of tropical seagrass expanded

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Fig. 1. Study site, breeding colony and diet of Black-tailed Gulls (BTGs). (a) Location of Hongdo Island (★), (b) a photo of breeding colony, and (c) *Halichoeres paecilopterus* and *Helicolenus hilgendorfi* in the diet of BTGs.

through the whole South Sea of Korea. Other subtropical fish are frequently observed (Myoung 2002) while cold water fish population has decreased in the East Sea of Korea.

As a top predator in marine ecosystem, seabirds have been used as an indicator reflecting marine environmental conditions. Breeding season can be the most sensitive period to detect climate change. During the breeding season, initiation of breeding, egg volume and chick and adult survival are affected by availability of fish. Gulls in the northern Japan Sea switched diet depending on food availability which was related to sea temperature (Watanuki and Ito 2012).

Black-tailed gulls (*Larus crassirostris*, hereafter BTGs) are common resident seabirds in South Korea. Because they live in inshore and coastal area during the non-breeding season and breed on remote islands, gulls during the breeding season can reflect the change of food web near breeding colony. Although breeding ecology (Kwon and Yoo 2007), vocal communication (Chung and Park 2006) and contamination (Kim et al. 2013) of BTGs have been studied, their diet was hardly reported in South Korea. In this study, we investigated fish species and its abundance in the diet of BTGs breeding on Hongdo Island and whether diet differed between 2002 and 2012. Causes and effects of the diet change related to marine environmental conditions were discussed.

MATERIALS AND METHODS

Study area and sea temperature

This work was carried out on Hongdo Island (34°32′14.1″N, 128°43′58.6″E) in the Hallyeohaesang National Marine Park, South Korea (Fig. 1a). Hongdo Island is the largest breeding colony of BTGs with more than approximately 10,000 to 30,000 pairs in South Korea (Fig. 1b) (Kwon and Yoo 2007, Kang et al. 2008). It is an uninhabited island approximately 21 km from mainland. To investigate the relationship between marine environmental condition and diet, we used marine environment data of Sea temperature and salinity collected at the Point No. 206-3 by the Korea Oceanographic Data Center around Hongdo Island (DMDB 2013). SST was estimated on 17 April 2002 and 16 April 2012. Because BTGs usually forage on surface water in the sea as other gull species (Burger 1988), salinity and sea temperature were estimated on 0 m and 10 m in water depth.

Field survey

We recorded clutch size during the incubation period (mid-May) in 2002 and 2012. Fish samples regurgitated by chicks (2-4 weeks after hatching) of BTGs were collected at visiting nests during the chick rearing period (June to August) in 2002 and 2012. Chicks often regurgitated food when we visited nests. Regurgitated fish were identified as lower taxonomic level as possible. If fish were difficult to identify on the species level, we took several photos of them in the field and kept fish in 70% ethanol until identification in the laboratory. Partially digested fish were identified on the family level.

Statistical analysis

We did t-test to compare clutch size between 2002 and 2012. $P < 0.05$ (two–tailed probabilities) was regarded as significant. All statistical analyses were carried out using SPSS ver. 21 (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Diet of Black-tailed Gulls

We collected 31 regurgitates in 2002 and 32 regurgitates in 2012, in respectively. BTGs fed total 128 individuals of 22 fish species (Table 1). Total 40 individuals of 12 species were collected in 2002 and total 88 individuals of 13 species were collected in 2012.

BTGs mainly fed chicks on small fish species (mostly less than 15 cm in adult body length) such as Japanese anchovies (*Engraulis japonicas*) and Silver-stripe round herrings (*Spratelloides gracilis*). Japanese anchovies were the most frequently used for diet of BTGs during the breeding season in both years (Table 1). Anchovies mainly distribute to the South Sea of Korea through March to August (Cha et al. 2008). In Japan, BTGs fed mainly Japanese anchovy, Japanese sand lance (*Ammodytes personatus*) (Kazama et al. 2007) and Krill (*Thysanoessa inermis*) (Tomita et al. 2009). It might relate to food availability near breeding colony. In South Sea of Korea, Japanese anchovy is the most dominant fish (Ju 2011).

Species and dependence of fish in the diet of BTGs varied between years. First of all, proportion of Japanese anchovies in regurgitates was more than two times higher in 2012 (70.5%) than in 2002 (27.5%; 40% including fish of Engraulidae) (Table 1). It may reflect the increase of anchovy population near breeding colony, Hongdo Island. BTGs like other gulls are opportunistic predators which select preys depending on food availability. In the South Sea of Korea, amount of catching anchovy has been increased since 1970 and proportion of anchovies in a total caught fish has also increased from 21% in 1990 up to 54% in 2005 (Jang et al. 2009). Anchovies are warm-water

Table 1. Fish from the diet of Black-tailed Gulls in 2002 and 2012 on Hongdo Island, South Korea

Species /Family name (Korean name)	Scientific name	2002	2012	Total
		N (%)	N (%)	N (%)
Spotted chub mackerel (망치고등어)	*Scomber australasicus*	-	3 (3.4)	3 (2.3)
Pacific sand lance (까나리)	*Ammodytes personatus*	-	1 (1.1)	1 (0.8)
Callionymidae sp.(돛양태과)	-	1 (2.5)	-	1 (0.8)
Gobiidae sp. (망둑어과)	-	3 (7.5)	-	3 (2.3)
Finespot goby (쉬쉬망둑)	*Chaeturichthys stigmatias*	1 (2.5)	-	1 (0.8)
White ventral goby (흰발망둑)	*Acanthogobius lactipes*	-	1 (1.1)	1 (0.8)
Engraulidae sp. (멸치과)	-	5 (12.5)	-	5 (3.9)
Japanese anchovy (멸치)	*Engraulis japonicus*	11 (27.5)	62 (70.5)	73 (57.0)
Kammal thryssa (청멸)	*Thryssa kammalensis*	-	5 (5.7)	5 (3.9)
Sciaenidae sp.(민어과)	-	6 (15.0)	-	6 (4.7)
Silver-stripe round herring(샛줄멸)	*Spratelloides gracilis*	-	1 (1.1)	1 (0.8)
Multicolorfin rainbowfish(용치놀래기)	*Halichoeres poecilopterus*	-	1 (1.1)	1 (0.8)
Silverside(은줄멸)	*Hypoatherina tsurugae*	-	3 (3.4)	3 (2.3)
Surfperch(인상어)	*Neoditrema ransonneti*	-	1 (1.1)	1 (0.8)
Stichaeidae sp.(장갱이과)	-	1 (2.5)	1 (1.1)	2 (1.6)
Konoshiro gizzard shad(전어)	*Konosirus punctatus*	2 (5.0)	1 (1.1)	3 (2.3)
Korean rockfish(조피볼락)	*Sebastes schlegelii*	3 (7.5)	-	3 (2.3)
Rosefish(홍감펭)	*Helicolenus hilgendorfi*	-	7 (8.0)	7 (5.5)
Leiognathidae sp.(주둥치과)	-	4 (10.0)	-	4 (3.1)
Spotnape ponyfish(주둥치)	*Leiognathus nuchalis*	-	1 (1.1)	1 (0.7)
Hexagrammidae sp.(쥐노래미과)	-	2 (5.0)	-	2 (1.6)
Fat greenling(쥐노래미)	*Hexagrammos otakii*	1 (2.5)	-	1 (0.8)
No. of species (including Family)		12	13	22
No. of individuals		40	88	128

N, number of fish; %, the percentage of all fish; sp., species.

fish and mainly distribute in the southwest of Geojaedo Island, Yokjido Island, and Komundo Island with higher chlorophyll and warm streamer (Choo 2002). According to Kim and Kwoun (2003), amount of a catch anchovy decreased when sea temperature at 0 to 20 m in depth was lower than average temperature. Anchovy mainly ranges between 0 m and 25 m in depth and require 17-22°C for laying eggs and more than 23°C for growing (Lee et al. 1977). Zooplankton which is a prey of anchovy grows depending on sea temperature. It is already known that anchovy population also increased in the Southern Sea of Korea as zooplankton biomass increases, (Park et al. 2004). SST of April at 0 m and 10 m was slightly higher in 2012 than 2002 near Hongdo Island (Table 2). Higher SST of April in 2012 may influence Zooplankton biomass and anchovy population as well.

Composition of fish species in the diet of BTGs also differed between years. In 2002, fish of Family Callionymidae, Finespot goby (*Chaeturichthys stigmatias*), fish of family Sciaenidae, Korean rockfish (*Sebastes schlegelii*), fish of Family Hexagrammidae and Fat greenling (*Hexagrammos otakii*) were found in the diet of BTGs. While Spotted chub mackerel (*Scomber australasicus*), Pacific sand lace (*Ammodytes personatus*), White ventral goby (*Acanthogobius lactipes*), Kammal thryssa (*Thryssa kammalensis*), Silver-strip round herring, Multicolorfin rainbowfish (*Halichoeres poecilopterus*) (Fig. 1c), Silverside (*Hypoatherina tsurugae*), Surfperch (*Neoditrema ransonneti*), Rosefish (*Helicolenus hilgendorfi*) (Fig. 1c) and Spotnape ponyfish (*Leiognathus muchalis*) were found in the diet of 2012 but not in 2002. Three species such as Japanese anchovy, fish of Stichaeidae, and Konoshiro gizzard shad (*Konosirus punctatus*) were commonly fed by BTGs in both years. Kammal thryssa, Siver-stripe round herring, Silverside and Rosefish which were found only in 2012 are known as sub-tropic or warm-water fish (Choi et al. 2002, Kim et al. 2005). Recently, a catch of sub-tropical or tropical species has been increased in the Southern Sea of Korea (Kwon et al. 2011). Tropical species such as Seagrass (*Halophila nipponica*), Blueline Angel (*Chaetodontoplus septentrionalis*), White coral (*Antipathes japonica*), Putter's giant sea anemone (*Dendronephthya putteri*) and Blue-ring sea squirt (*Clavelina coerulea*) have been frequently found in Hongdo Island (Kwon et al. 2011). Subtropic fish in the diet of BTGs may reflect change of fish population near Hongdo Island in terms of fish distribution and/or population size.

Last decades, change in the diet of Seabirds has been observed in Japan. Rhinoceros auklets switched their diet from sardine *Sardinops melanostictus* (cold-water fish) in 1980s to anchovy (warm-water fish) in 1990s according to change of current. Watanuki and Ito (2012) expected that BTGs might not change their diet because of their narrow ranged diet. In Korea, the diet of BTGs seems to be affected by food availability near breeding colony.

Diet change and clutch size

Food availability is a main factor affecting breeding performance in seabirds (Crawford et al. 2009). Sea surface temperature can affect the distribution and abundance of prey and this induces a mismatch between prey abundance and timing of breeding in gulls (Tomita et al. 2009). In Glaucous-winged gulls (*L. glaucescens*), mean egg size increased with sea temperature (Hipfner 2012).

We compared the SST at Survey site No. 206-3 (DMDB 2013), the closest survey site to Hongdo-Island, before laying eggs between two years. Mean sea temperature in April was lower as 0.15°C in 2002 and was higher as 1.36°C in 2012 than mean SST in April for last 47 years (Table 2). Higher sea temperature in 2012 may increase food availability in mainly anchovies which may affect breeding performance of BTGs. In our results, clutch size was slightly higher in 2012 comparing to 2002 although it did not statistically significant (Table 2).

In conclusion, diet of BTGs changed last 10 years in terms of fish composition and dominance. Larger proportion of sub-tropical fish such as anchovies in the diet of BTGs may reflect increased sea temperature in the South Sea of Korea. Occurrence of sub-tropic fish in the diet may present changes of marine environment.

Table 2. Clutch size (mean ± SE) of BTGs and sea temperature (°C) at 0 m (SST) and 10 m of April in 2002 and 2012, and mean SST of April (mean ± SE) from 1961 to 2012

	Mean SST (1961-2012)	2002	2012	t-test
Clutch Size (n)	-	1.89 ± 0.04 (127)	1.99 ± 0.02 (527)	*P* = 0.087
SST	14.06 ± 0.15	13.91	15.42	
Sea temp. at 10 m	13.85 ± 0.16	13.92	15.31	

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