KJEE 51(4): 365-372 (2018)
https://doi.org/10.11614/KSL.2018.51.4.365
ISSN: 2288-1115 (Print), 2288-1123 (Online)

Note

Population Trends of Wintering Whooper Swans (*Cygnus cygnus*) in South Korea: Data from the Winter Waterbird Census Program

Choi, Jieun (0000-0002-2367-7028), **Ji Yoon Kim**[1] (0000-0001-5228-4939), **Yuno Do**[2] (0000-0002-0095-7916) **and Gea-Jae Joo**[3,*] (0000-0002-5617-7601)

Department of Integrated Biological Science, Pusan National University, Busan 46241, Republic of Korea
[1]*Department of Environmental Science, Toho University, Funabashi 274-8510, Japan*
[2]*Department of Biological Science, Kongju National University, Gongju 32588, Republic of Korea*
[3]*Department of Biological Science, Pusan National University, Busan 46241, Republic of Korea*

Abstract The Wintering Waterbird Census of Korea was started in 1999 and monitors 200 major migratory sites in South Korea. Waterfowl counts have been undertaken for more than 20 years since; however, a limited number of studies have analyzed the temporal patterns of waterfowl population. In this study, we analyzed population size changes of wintering whooper swan (*Cygnus cygnus*) at 112 monitoring sites from 2001 to 2018. The average number of whooper swans was 4,296±42.66 and there was a trend for an increase in population size across the survey period. We found that the population in the Nakdong River Estuary, one of the major wintering sites over 18 years (26.22% of the national population), had rapidly decreased (−0.77% per year). Conversely, the whooper swan population in the Junam Reservoir and Sihwa Lake increased (+1.64%, +0.54% per year, respectively). Estuaries showed the highest dominance of whooper swans among the five different habitat types, accounting for 32.13% of the population. Reservoir/lakes had 30.60% of the total population and reclaimed lakes (18.24%), river (13.11%), and coast (5.93%) followed. The annual distribution of the whooper swan population in South Korea has been affected by various habitat conditions resulting from human activities and urbanization. To better understand the complex factors that can cause rapid changes in wintering waterfowl populations, it is necessary to integrate the data from the bird census program with environmental conditions to conduct in-depth pattern analyses over longer time periods.

Key words: waterbird census, endangered species, population trend, conservation

INTRODUCTION

Understanding long-term changes in waterbird populations can provide useful information on the current condition of aquatic habitats and other related wildlife living in wetland environments (Park *et al*., 2000; Quan *et al*., 2002). The Christmas Bird Count (CBC) and International Waterbird Census are representative examples of the long-term bird monitoring. The CBC has been conducted by the National Audubon Society (NAS) since 1900. Over 50,000 birdwatchers have participated in the CBC, and 2,000 monitoring sites are maintained (Dunn *et al*., 2005). The CBC is the largest survey in the world (Butcher *et al*., 1990) and has been used as a source of essential data for many conservation studies (Niven *et al*., 2004; Link *et al*., 2006; Link *et al*., 2008). The International Waterbird Census was started in 1967 by Wet-

Manuscript received 22 November 2018, revised 28 December 2018, revision accepted 31 December 2018
* Corresponding author: Tel: +82-51-510-3344, Fax: +82-51-583-0172, E-mail: gjjoo@pusan.ac.kr

lands International, allowing 15,000 researchers from 143 countries to survey waterbird populations and distributions of 30~40 million individual waterbirds recorded every year (Delany, 2005).

South Korea is located in the middle of the East-Asian Australasian Flyway and serves as an important stopover, wintering, and breeding site for a diverse range of migratory birds, particularly for various waterbirds that breed in Siberia, Manchuria, and Mongolia (Crosby and Chan, 2005; Li *et al*., 2009). Wintering waterbirds visiting the Korean peninsula are well documented; however, there have been limited national-wide studies investigating temporal changes on a long-term scale (Choi *et al*., 2012; Yoo *et al*., 2012b; Kim *et al*., 2017). In 1999, the Ministry of Environment and the National Institute of Environmental Research established the Winter Waterbird Census program to collect nationwide occurrence information on migratory birds over a long-term scale (NIBR, 2013). Researchers, local NGOs, and experienced citizens have participated to record the number of wintering waterfowl. The program established fixed monitoring sites and monitoring periods each year (i.e., mostly January). Until now, this program provides the only dataset in South Korea that is surveyed on a national scale spanning decades.

In this study, we focused on the temporal changes and spatial distribution of whooper swans (*Cygnus cygnus*) using 20 years of records from the Winter Waterbird Census program. The total number of whooper swans in the world is known to be approximately 180,000 (Wetlands International, 2015), with 4,000~5,000 individuals known to have visited South Korea in winter. Whooper swans were rated as a species of Least Concern (LC) by IUCN. It is designated as a National Monument (201-2) and an endangered Species Class II in South Korea. Previous studies have focused on temporal changes of whooper swans in local sites, while information on nationwide distribution and temporal trends are not well understood (Won, 1980; Hahm and Kim, 2001; Jeon and Cho, 2006; Hong and Rho, 2016). First, we used the Winter Waterbird Census dataset to identify the annual change in whooper swan numbers over 18 years. Second, we categorized monitoring sites into five types (i.e., river, reservoir/lake, estuary, coast, or reclaimed lake) and analyzed monthly usage patterns for 4 years (November~February, 2014~2018). We further analyzed the temporal pattern of whooper swans at the core wintering sites and discussed the potential cause of population changes.

MATERIALS AND METHODS

We only focused on the occurrence records of whooper swans from Winter Waterbird Census data (NIBR, 2004~2018). We organized the population data of whooper swans (*C. cygnus*) for each monitoring site and analyzed the annual population size change and the characteristics of their distribution. The spatial coverage of monitoring sites in Winter Waterbird Census program was expanded from 69 sites in 1999 to 200 sites in 2014. We analyzed the temporal changes in 112 sites from 2001 to 2018 (Fig. 1). These sites included more than 91.78±2.04% of the total population. We also

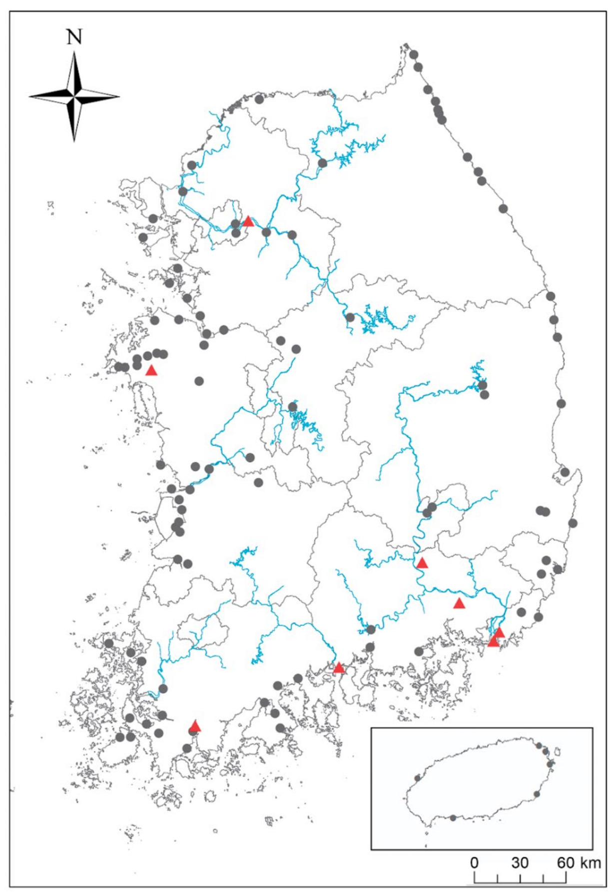

Fig. 1. Monitoring sites of the Winter Waterbird Census program (2001) in the Republic of Korea. Grey circle: Winter Waterbird Census program monitoring sites used in this study, Red triangle: core sites presented in Fig. 4.

selected eight core monitoring sites which constituted more than 70% of the total population size observed across all sites. Population data was merged when a single wetland was divided into sub-regions (e.g., Upo, Mokpo, Sajipo wetland). Annual variation in local population size are affected not only by environmental conditions in the area but also by changes in the size of the global population in the flyway. To compensate for annual fluctuations in the visiting population size, we analyzed the distribution pattern using the ratio of the population at each point to the total number of whooper swans in 112 sites each year. The changes in the population size of whooper swans for 18 years (2001∼2018) were analyzed by linear regression analysis using PASW Statistics 18.0 (SPSS Inc.).

The habitat preferences of the whooper swan were analyzed using the four-year dataset from 2014 to 2018 in 196 sites. We grouped the habitat types of monitoring sites into 5 different types, which includes river, reservoir/lake, estuary, coast, or reclaimed lake (Choi *et al.*, 2012). The spatial pattern of the whooper swan population was represented on the map using ArcMap (ver. 10, ESRI, USA).

RESULTS

1. Temporal change in whooper swan population size

The average number of whooper swans wintering in South Korea was 4,296±42.66 during the 18 years of study (2001∼2018; median: 4,275.5; Fig. 2). The number of whooper swans tended to increase over time (F=9.57, df=17, β=75.02, R^2=0.37, P=0.007). The minimum number was recorded in 2002 (2,961) and the maximum number was recorded in 2015 (5,710).

2. Spatial patterns and temporal changes in core sites

The highest number of whooper swans were found in the Nakdong River Estuary (26.22% of the total population), followed by the Junam Reservoir (14.87%), Gangjin Bay (8.81%), Ganwol Lake (6.32%), Upo (5.00%), and Geumgang Lake (4.22%; Fig. 3a). Junam Reservoir and Sihwa Lake showed the highest rate of increase in whooper swan numbers (1.64, and 0.54% · $year^{-1}$, respectively; Fig. 3b), while Nakdong River Estuary recorded the highest rate of decrease (−0.77% · $year^{-1}$). The total number of the overall population in core sites have increased from 2001 to 2018 (F=4.70, df=17, β=57.01, R^2=0.23, P=0.0438). Upo, Junam Reservoir, and Nakdong River Estuary constituted 46.09±9.19% of the total population (Fig. 4). Among the southern-most core sites, Nakdong River Estuary was the largest wintering site until 2011, whereas a major part of the whooper swan population stayed in the Junam Reservoir after 2015.

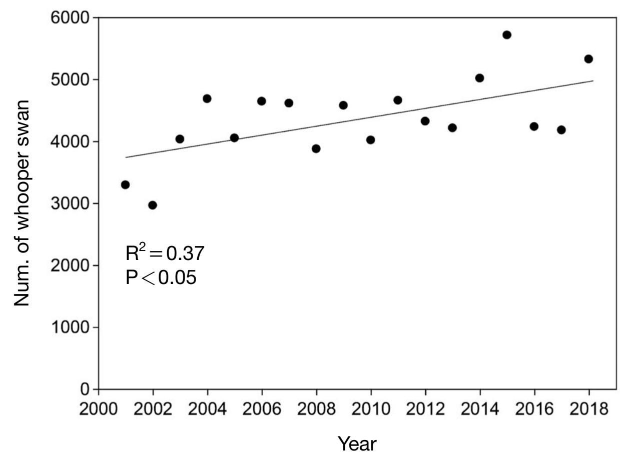

Fig. 2. Population size changes of whooper swans over 18 years (2001∼2018, 112 sites). The number of whooper swans is the sum of the 112 sites, which were constant from 2001 to 2018.

3. Habitat preference

When comparing the numbers of whooper swans based on their habitat preferences, estuaries showed the highest dominance of the 5 different types, accounting for 32.13% of the population (Fig. 5). Reservoir/lakes had 30.60% of the total population and reclaimed lakes (18.24%), river (13.11%), and coast (5.93%) followed. The relative percentage of whooper swans observed in the reclaimed lakes were relatively consistent during winter. The estuary accounted for the highest proportion of swans in November (46.11%); however, the rate declined markedly in December (27.71%). The number of swans in the river and coast habitats were the lowest in November (6.36%, 1.97%) but tended to increase during winter. The number of whooper swans in the reservoir/lake habitats peaked in January (40.77%).

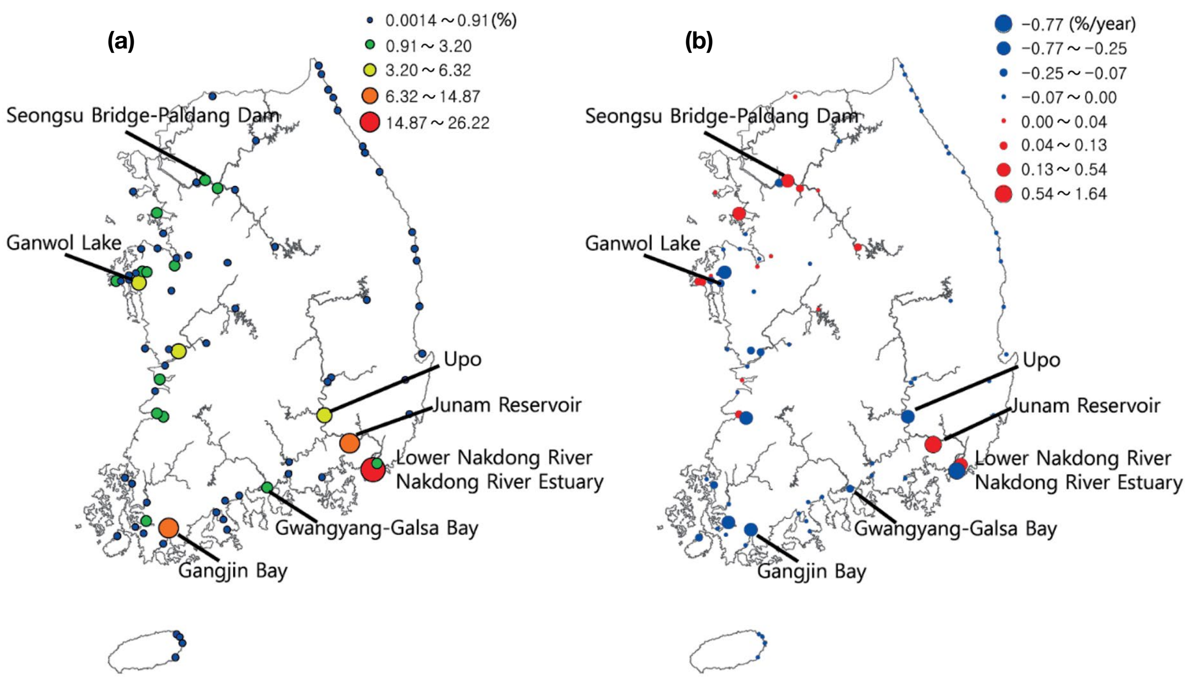

Fig. 3. Spatial patterns of whooper swan population (a, the relative percentage of total population in each year) and (b) the annual trend of population change. Temporal trend of population size was calculated using 18 years of monitoring data.

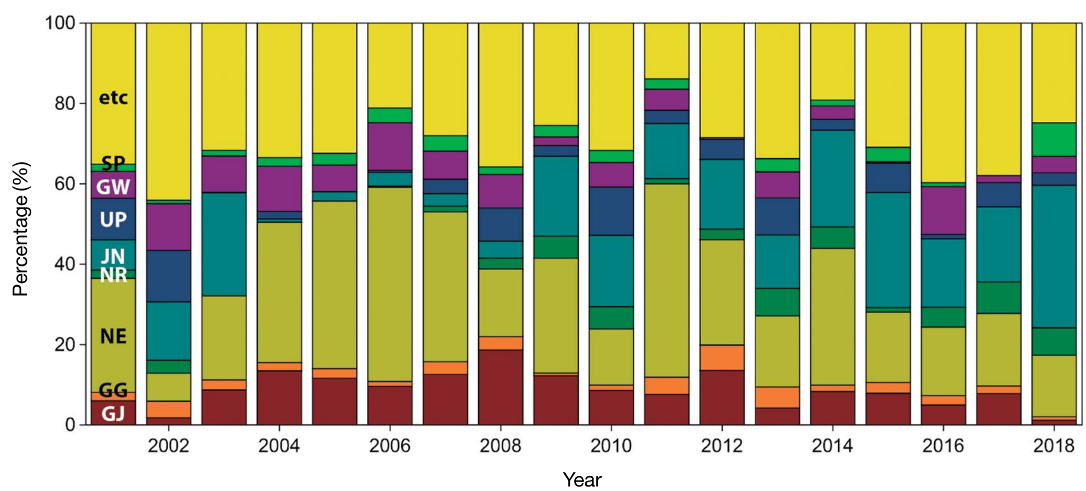

Fig. 4. Temporal changes in whooper swan numbers at 8 core wintering sites (2001～2018). The size of bar represents relative percentage of total number of individuals. The sites were arranged with the order of latitude of the sites. SP: Seongsu Bridge-Paldang Dam, GW: Ganwol Lake, UP: Upo, JN: Junam Reservoir, NR: Lower Nakdong River, NE: Nakdong Estuary, GG: Gwangyang Bay, Galsa Bay, GJ: Gangjin Bay, etc: others.

4. Population changes in the lower Nakdong River

Estuaries were used as major stopover sites by the swans (Fig. 5) and the Nakdong River Estuary held more than 70.49 ±16.51% of the total population found in estuaries (Fig. 6a). The sum of the population sizes in Upo and Junam Reservoir constituted 78.97±18.50% of the total population in the lake and reservoir habitat (Fig. 6b). The number of the whooper swan population in Upo and Junam Reservoir tended to be opposite to the number in the Nakdong River Estuary (Fig.

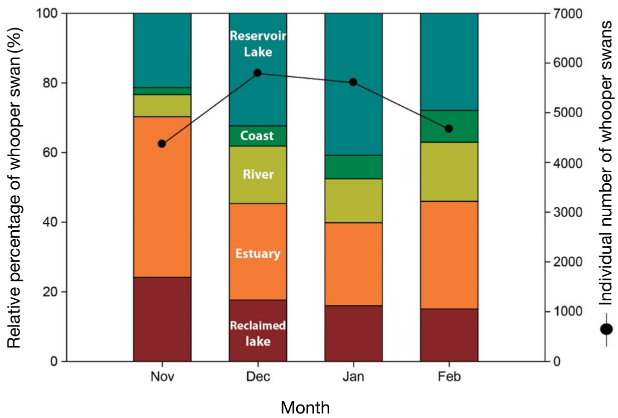

Fig. 5. Temporal changes in whooper swan numbers in different habitat types (November~February, 2014~2018, 196 sites). Individual number of whooper swans represents monthly averages of four years.

6c). From 2014 to 2017, the number of whooper swans in the Nakdong River Estuary peaked in November and decreased in December and January. However, in Upo and Junam Reservoir, the highest number of whooper swans were observed from December to January (Fig. 6c). This temporal pattern among the three sites was not observed in 2018. In 2018, the highest number of whooper swans was observed in Junam Reservoir and the number of whooper swans kept increased during the wintering season.

DISCUSSION

We identified that the population size of whooper swans has increased over the last 18 years. In the freshwater habitat, a topology of shallow habitat and level of artificial disturbance seem to be related to the increase in the whooper swan population (Choi *et al*., 2015). In the Seongsu Bridge-Paldang Dam region, Dangjeong Island has been used as a major feeding site managed by Hanam City and the Swan School. Because of sand mining in Dangjeong Island in the 1980s and 1990s, the island itself disappeared. A rapid recovery of migratory birds was observed as sand deposition recovered from 2000 (Hanam City, 2018). Changwon City prohibited fishing during the visiting periods of the migratory birds (i.e., November to January) from 2009 (Junam Wetlands Park, 2008, 2016), and a rapid expansion of emergent aquatic plants has been observed concurrently in Junam Reservoir. It is necessary to study vegetation change in the reservoir and the relative effect of environmental changes on the swans since the distribution of food resources may also influence their habitat choice (Chisholm and Spray, 2002).

Temporal changes in the reclaimed lake provided indirect evidence for the importance of seawater circulation on swan numbers. Water circulation in the Sihwa Lake had been limited because of the construction of the seawall in 1999. Seawater circulation has since been enhanced by opening the sea walls and by constructing a tidal power plant (Lee, 2012). After recovering the circulation between reclaimed lake and coast, the number of waterbirds has increased by 20% (40,000 individuals) compared with numbers from the uncirculated conditions (Park *et al*., 2016).

In the estuarine environment, the annual fluctuation of food sources and the increase of urban infrastructure in the tidal habitats were suggested as the main cause of the change in the local whooper swan population (Choi *et al*., 2015; Kim, 2016). Relative proportion of whooper swans arriving in the Nakdong River Estuary has recently been decreased. On the contrary, the number of visiting whooper swans in nearby sites, including the lower Nakdong River and Junam Reservoir, have been continuously increasing. Based on the monthly visiting patterns from the lower Nakdong River, whooper swans first arrived in the Nakdong River Estuary at the beginning of the migratory season and moved to proximal habitats (Lee, 2007). Several studies have identified there is a shortage of food in the Nakdong River Estuary following the recent development of the tidal flat due to urbanization (Kim *et al*., 2005; Choi *et al*., 2015). In order to recover the population of whooper swan visiting Nakdong River Estuary, it is necessary to solve the problems caused by reclamation of the tidal flats and the decrease in food sources caused by the fluctuation in the freshwater discharge from the estuarine barrage (Lee, 2000; Kim, 2016).

It seems that the nationwide trend in increased swan population size was partly related to the expansion of the Biodiversity Management Contract Scheme (Yoo *et al*., 2012a). Biodiversity Management Contracts recommend retaining grains and stacks of rice straw in the paddies to provide feeding areas for migratory birds. This program began with three lake or reservoir sites (Junam Reservoir, Geumgang Lake, Yeongam/Gocheonam/Geumho Lakes) in 2002. It has expanded to 24 regions in 2016. Since Busan Metropolitan City (Gangseogu, lower Nakdong River) suspended this program

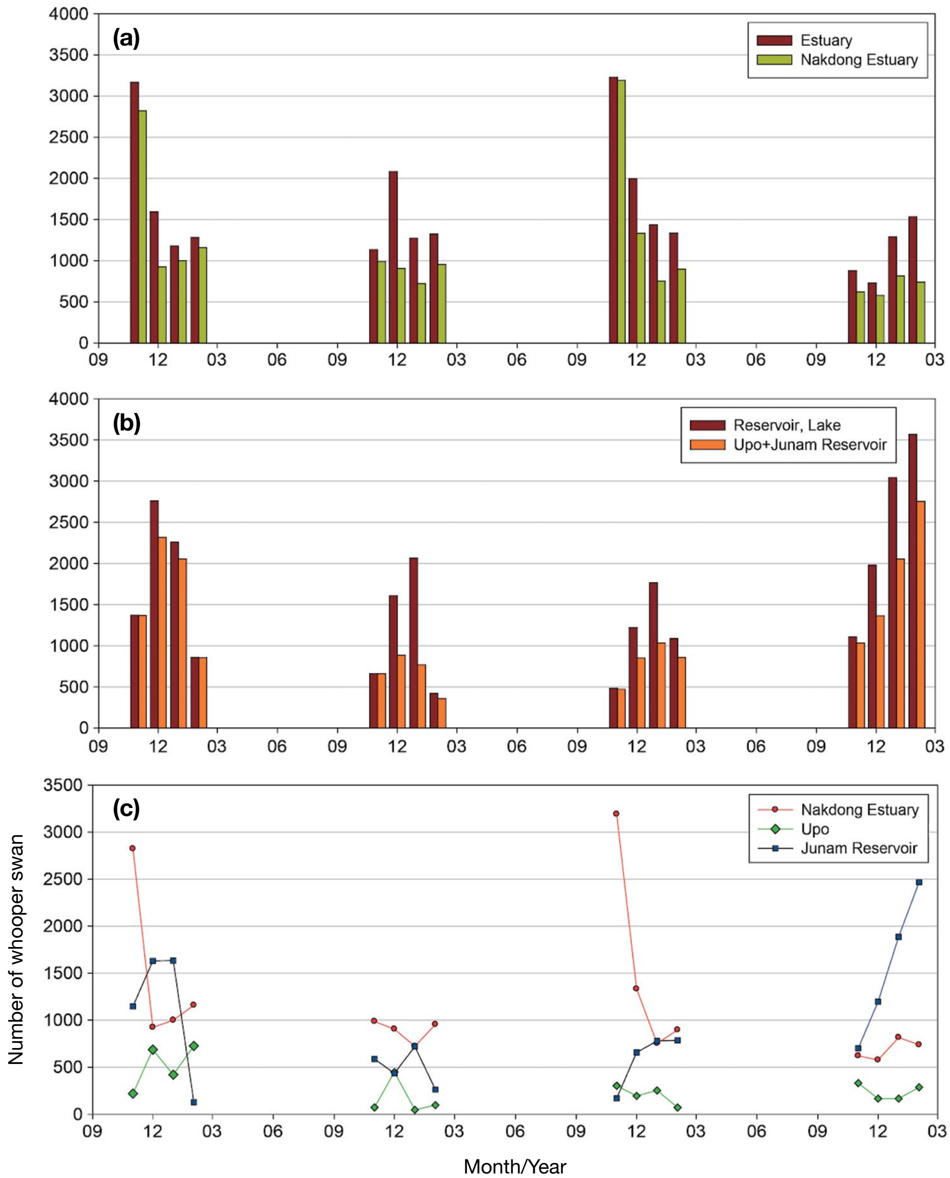

Fig. 6. Changes in whooper swan population size in the Nakdong Estuary, Upo, and Junam Reservoir (2014∼2018). Total population of estuary habitat and Nakdong Estuary (a), total population of reservoir/lake habitat and sum of population of Upo and Junam Reservoir (b), temporal population change in Nakdong Estuary, Upo, and Junam Reservoir (c).

in 2010, the number of migratory birds has tended to decrease in the Lower Nakdong River. Ganwol Lake is one of the regions where the feeding program is active. Whooper swans mainly foraged in the feeding site, but also in the neighboring reservoirs (Jeon and Cho, 2006). This implies the importance of considering dispersal pattern of waterfowl in Biodiversity Management Contracts, as the government should encourage participation from the regions surrounding the main feeding site. The Biodiversity Management Contract program would seem to be an appropriate tool to promote biodiversity and support farmers to contribute to conservation activities. Yoo *et al.* (2012a) noted some negative aspects of the Biodiversity Management Contract related to the lack of economic compensation for conversion to environmentally-friendly agriculture. However, we expect active participation and expansion of the Biodiversity Management Contract when an appropriate compensation system is suggested.

In summary, the annual distribution of the whooper swan population in South Korea has been affected by various habitat conditions resulting from human activities and urbanization. Although feeding activities have been undertaken in major wintering sites (e.g., Ganwol Lake, Upo, Junam Reservoir, Nakdong River Estuary etc.), feeding activities will not be a long-term solution, as this supplemental practice can only provide a small part of the total food needed by migratory birds. It is known that the major food source of whooper swans is aquatic plants, and if the amount of the aquatic food source is limited, they frequently eat grains from agricultural land (Rees *et al*., 1997; Chisholm and Spray, 2002). The management plan needs to focus on the recovery of the habitat of their major food source and broad participation in the Biodiversity Management Contract of the surrounding agricultural lands. It is also necessary to accumulate high-resolution data such as on migration routes and the daily utilization patterns (Nolet *et al*., 2002; Dirksen *et al*., 2013) in order to understand the specific cause of population changes.

ACKNOWLEDGEMENTS

This work was supported by a 2-Year Research Grant of Pusan National University.

REFERENCES

Butcher, G.S., M.R. Fuller, L.S. McAllister and P.H. Geissler. 1990. An evaluation of the Christmas bird count for monitoring population trends of selected species. *Wildlife Society Bulletin (1973-2006)* **18**(2): 129-134.

Chisholm, H. and C. Spray. 2002. Habitat usage and field choice by mute and whooper swans in the tweed valley, Scotland. *Waterbirds* **25**(Special Publication 1): 177-182.

Choi, Y.E., S.J. You, S.R. Kang, B.K. Choi and J.H. Con. 2015. Management plan of whooper swan (Cygnus cygnus) habitat using causal loop analysis: Focused on Eulsukdo. *Korean Journal of Environment and Ecology* **29**: 353-367.

Choi, Y.S., W.H. Hur, S.H. Kim, S.G. Kang, J.H. Kim, H.J. Kim, J.S. Son, J.Y. Park, J.Y. Yi, C.H. Kim, J.H. Kang and S.H. Han. 2012. Population trends of wintering ducks in Korea. *The Korean Journal of Ornithology* **19**(3): 185-200.

Crosby, M.J. and S. Chan. 2005. Important bird areas and potential Ramsar sites in Asia. Cambridge, UK.

Delany, S. 2005. Guidelines for participants in the international waterbird census (IWC). Wetlands International, Wageningen.

Dirksen, S., J.H. Beekman and T.H. Slagboom. 2013. Bewick's Swans Cygnus columbianus bewickii in the Netherlands: Numbers, distribution and food choice during the wintering season. *Wildfowl* **1**: 228-237.

Dunn, E.H., C.M. Francis, P.J. Blancher, S.R. Drennan, M.A. Howe, D. Lepage, C.S. Robbins, K.V. Rosenberg, J.R. Sauer and K.G. Smith. 2005. Enhancing the scientific value of the Christmas bird count. *The Auk* **122**(1): 338-346.

Hahm, K.H. and T.J. Kim. 2001. Population fluctuations of Cygnus cygnus and C. columbianus during 11 years, on Junam reservoir of Kyungsangnam-do (1989-1999). *The Korean Journal of Ornithology* **8**(1): 47-53.

Hanam newsletter. http://mbook.newstool.co.kr/hanam.

Hong, S.B. and P. Rho. 2016. Temporal and spatial distribution characteristics of Swans (Cygnus spp.) in the Nakdong estuary, Busan, Republic of Korea. *The Korean Journal of Ornithology* **23**(1): 33-40.

Jeon, K.H. and S.R. Cho. 2006. A studies on the wintering distribution of the whooper swan (Cygnus cygnus) within the Seo-san area, Korea. *The Korean Journal of Ornithology* **13**(2): 97-104.

Junam Wetlands Park. http://junam.changwon.go.kr.

Kim, G.Y., C.W. Lee, H.S. Yoon and G.J. Joo. 2005. Changes of distribution of vascular hydrophytes in the Nakdong River Estuary and growth dynamics of Schenoplectus triqueter, waterfowl food plant. *Korean Journal of Ecology* **28**(5): 335-345.

Kim, H.N., J.W. Lee and J.C. Yoo. 2017. Population fluctuation of wintering Great Cormorants (Phalacrocorax carbo) and its potential impact in Hangang. *The Korean Journal of Ornithology* **24**(2): 25-40.

Kim, J.Y. 2016. The role of hydrological regime in the distribution and abundance of aquatic plants across diverse hydroscapes. Ph.D. thesis, Pusan National University, Busan.

Lee, C.W. 2007. Usage patterns and management of waterbird habitat in the lower Nakdong River. Ph.D. thesis, Pusan National University, Busan.

Lee, H.K. 2012. Shihwa regional reclamation development project and the changes in the environmental management policy. *Environmental Law and Policy* **9**: 153-173.

Lee, K.S. 2000. Feeding ecology of migratory waders in relation to the preys on the southern tidal flat of Kanghwa Island in the west coast of Korea. Ph. D. Dissertation, Univ. of Kyunghee, Seoul.

Li, D.Z.W., A. Bloem, S. Delany, G. Martakis and O. Quintero. 2009. Status of waterbirds in Asia. Results of the Asian waterbird census: 1987-2007. Wetland international.

Link, W.A., J.R. Sauer and D.K. Niven. 2006. A hierarchical model for regional analysis of population change using Christmas bird count data, with application to the American Black Duck. *The Condor* **108**(1): 13-24.

Link, W.A., J.R. Sauer and D.K. Niven. 2008. Combining breeding bird survey and Christmas bird count data to evaluate seasonal components of population change in northern bobwhite. *Journal of Wildlife Management* **72**(1): 44-51.

Lu, L., B.P.L. Goh and L.M. Chou. 2002. Effects of coastal reclamation on riverine macrobenthic infauna (Sungei Punggol) in Singapore. *Journal of Aquatic Ecosystems Stress and Recovery* **9**(2): 127-135.

NIBR. 2004. '99-04 winter migratory bird census. National Institute of Biological Resources, Incheon.

NIBR. 2005. 2005 winter migratory bird census. National Institute of Biological Resources, Incheon.

NIBR. 2006. 2006 winter migratory bird census. National Institute of Biological Resources, Incheon.

NIBR. 2007. 2007 winter migratory bird census. National Institute of Biological Resources, Incheon.

NIBR. 2008. 2008 winter migratory bird census. National Institute of Biological Resources, Incheon.

NIBR. 2009. 2009 winter migratory bird census. National Institute of Biological Resources, Incheon.

NIBR. 2010. 2010 winter migratory bird census of Korea. National Institute of Biological Resources, Incheon.

NIBR. 2011. 2011 winter migratory bird census of Korea. National Institute of Biological Resources, Incheon.

NIBR. 2012. 2012 winter migratory bird census of Korea. National Institute of Biological Resources, Incheon.

NIBR. 2013. 2013 winter migratory bird census of Korea. National Institute of Biological Resources, Incheon.

NIBR. 2014. 2014 winter migratory bird census of Korea. National Institute of Biological Resources, Incheon.

NIBR. 2015. 2014-2015 winter migratory bird census of Korea. National Institute of Biological Resources, Incheon.

NIBR. 2016. 2015-2016 winter migratory bird census of Korea. National Institute of Biological Resources, Incheon.

NIBR. 2017. 2016-2017 winter migratory bird census of Korea. National Institute of Biological Resources, Incheon.

NIBR. 2018. 2017-2018 winter migratory bird census of Korea. National Institute of Biological Resources, Incheon.

Niven, D.K., J.R. Sauer, G.S. Butcher and W.A. Link. 2004. Christmas bird count provides insights into population change in land birds that breed in the boreal forest. *American Birds* **58**: 10-20.

Nolet, B.A., R.M. Bevan, M. Klaassen, O. Langevoord and Y.G.J.T. Van der Heijden. 2002. Habitat switching by bewick's Swans: Maximization of average long-term energy gain? *Journal of Animal Ecology* **71**(6): 979-993.

Park, C.Y., M.S. Shin, H.J. Kim, W.K. Paek and J.W. Lee. 2016. Study on the influence of waterbirds distribution according to the restoration of intertidal zone. *Korean Journal of Environment and Ecology* **30**(5): 837-847.

Park, S.G., K.S. Lee and J.C. Yoo. 2000. Effect of the hunting activities on wintering waterbird population. *Korean Journal of Ornithology* **7**(2): 55-62.

Quan, R.C., X. Wen and X. Yang. 2002. Effects of human activities on migratory waterbirds at Lashihai Lake, China. *Biological Conservation* **108**(3): 273-279.

Rees, E.C., J.S. Kirby and A. Gilburn. 1997. Site selection by Swans wintering in Britain and Ireland; the importance of habitat and geographic location. *Ibis* **139**(2): 337-352.

Sato, S. 2006. Drastic change of bivalves and gastropods caused by the huge reclamation projects in Japan and Korea. *Plankton and Benthos Research* **1**(3): 123-137.

Wetland International. 2015. http://wpe.wetlands.org.

Won, P.O. 1980. Present status of the swans wintering in Korea and their conservation. Proceeding of 2nd International Swan Symposium: 15-18.

Yoo, J.C., S.S. Yeo and K.S. Kong. 2012a. Economic evaluation on the biodiversity management contract scheme. *Korean Journal of Agricultural Management and Policy* **39**(2): 297-319.

Yoo, S.H., K.S. Lee and C.H. Park. 2012b. Raptor's community changes in Cheorwon, Korea. *The Korean Journal of Ornithology* **19**(2): 133-140.