WINTERING ACTIVITY RANGE AND POPULATION ECOLOGY OF BLACK-FACED SPOONBILLS (*Platalea minor*) IN TAIWAN

A Dissertation

by

LIANG-LI LIU

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2006

Major Subject: Wildlife and Fisheries Sciences

WINTERING ACTIVITY RANGE AND POPULATION ECOLOGY OF BLACK-FACED SPOONBILLS (*Platalea minor*) IN TAIWAN

A Dissertation

by

LIANG-LI LIU

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Approved by:

Chair of Committee, R. Douglas Slack
Committee Members, Keith A. Arnold
Soujin Wang
Roel R. Lopez
Head of Department, Robert D. Brown

May 2006

Major Subject: Wildlife and Fisheries Sciences

ABSTRACT

Wintering Activity Range and Population Ecology of

Black-faced Spoonbills (*Platalea minor*) in Taiwan. (May 2006)

Liang-Li Liu, B.S., National Cheng-Kung University, Taiwan;

M.S., National Taiwan Normal University, Taiwan

Chair of Advisory Committee: Dr. R. Douglas Slack

Black-faced Spoonbill (BFS), *Platalea minor*, numbers during the non-breeding season increased steadily from 1990 to 2004 in Taiwan. Numbers of the BFS in Taiwan accounted for more than 50% of the total population, with 96% of the BFS in southwestern Taiwan at the town of Chi-Ku and Tainan City. The percentage of adult BFS remained constant from 2000-2003. Relatively constant high survey counts, with similar ratios of adult to non-adult birds, suggested that the BFS has a healthy population. With the exception of avian botulism resulting in 73 BFS deaths in the 2002 winter, several other mortality factors were documented with no more than four birds lost in a year from 1849-2004.

I counted numbers of BFS at the town of Chi-Ku and Tainan City almost daily during the winter months from September 1998 to May 2001. Although variable, overall population numbers increased sharply from September to October. From November to February, the BFS maintained a high, stable population-level. Migration began during March, and population numbers decreased from March to May. I used visual observations and radio-telemetry data to locate, count and monitor BFS during the

day and night, respectively, and also to assess nocturnal habitat use. Information obtained through these methods showed that habitat use was not in direct proportion to its availability. Activity ranges obtained from radio tracking and visual observations showed an increase in activity range size by BFS just prior to migration with more of the study area used north of the core-roosting area.

Sizes and weights of potential prey items were measured at fish ponds used by BFS. Available prey in fish ponds was dominated by fish prey less than 5 cm in length and at least 30 gm in size. Similar size classes of prey items were selected by a captive BFS. Biomass of prey in fish ponds around the primary roosting site declined sharply in the pre-migration stage (March-April), compared to the middle winter stage (November-February). I suggest that this low biomass of prey items may have stimulated the northward movement of BFS in the late stage of winter. In addition, the activity range expansion may have related to preparation for migration.

ACKNOWLEDGMENTS

I would like to thank all the members of my committee. I am especially thankful to the Chair of my committee, Dr. R. Douglas Slack. Each time I met with him he made me feel welcome, with kind words and lots of smiles. Without his warm encouragement, I could have not finished my draft as I missed the writing-schedule targets of this dissertation many times. I also appreciated his comments, suggestions and corrections mixed with great patience towards my Chinese-style English sentences.

Dr. Keith Arnold's ornithology class was both a think-tank and a source of inspiration for my research. Dr. Roel Lopez was extremely kind, opening his lab to give me personal tutoring classes for GIS mapping and analyses. Dr. Soujin Wang from the Statistics Department showed me how much he cared about my personal life and professional career by speaking my same language, Chinese.

Many WFSC graduate students in Dr. Douglas Slack's and Dr. William Grant's labs were very friendly and helpful. M. Margarita Mieres helped me by reviewing some parts of the manuscript, both by writing and thinking in scientific terms. April Conkey and Rob Powell were both very good listeners when I felt a little depressed and pressure on my shoulders. Edith González, Marcelo Pisani, and Karine Gil were also preparing their doctoral dissertations at the same time as I, so their assistance and kindness was appreciated. We all encouraged each other, and I am sure we all felt it was really helpful.

I could have not completed my field work without generous funding provided by the Taiwan Cement Corporation. Many volunteers at the study area were excellent helpers in collecting data in the wild. The names of those kind volunteers are Yang-Ming Liu (filmmaker), Jin-Rong Tsu (Cameraman), Collin Chen (field worker, Black-faced Spoonbill Conservation Association, BFSA), Cola Kou (BFSA), Jin-Zhu Tsai (BFSA), Shi-Hong Wu (BFSA), Fu-Xing Huang (BFSA), Zi-Yao Dai (BFSA), Jian-Cheng Chen (BFSA), Wen-Cong Cheng (BFSA), Zong-Xian Lee (BFSA), Su-Ling Yang (BFSA), Ji-Hua Lee (BFSA), Grace Chen (National Cheng Kung University, NCKU), Jun-Yao Wang (NCKU), Edith Chen (NCKU), Chang-Wei Peng (NCKU).

Finally, I would like to thank several professors in Taiwan, because of their kind help and support: Dr. Ying Wang (National Taiwan Normal University) provided me with some radio frequencies of banded Black-faced Spoonbill individuals (BFS). Dr. Kurtis Pei (National Pingtung University) helped me to apply for funding to the Taiwan Cement Corporation. Dr. Yen-Hsin Sun (National Pingtung University) created the traps to catch BFS. Without their kind assistance, I would not have been able to complete my research in Taiwan.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (continued)

LIST OF FIGURES

FIGURE Page

LIST OF FIGURES (continued)

FIGURE Page

LIST OF TABLES

TABLE Page

CHAPTER I

INTRODUCTION

The Black-faced Spoonbill, *Platalea minor*, is one of six species of spoonbills found globally (Del Hoyo et al. 1992, Hancock et al. 1992). They are medium-sized white waterbirds with a long spoon-like bill, and long black legs (Hancock et al. 1992). Their feathers are white, except in breeding season, when spoonbills have yellow plumage around the neck and head (Hancock et al. 1992). Little is known about the status and trends of their population (Severinghaus et al. 1995, Collar et al. 2001). The Black-faced Spoonbill (BFS) is classified as a threatened species (Groombridge 1993, IUCN 1997), and it is likely to continue to decline due to substantial threats to its habitat, qualifying it as endangered (Collar et al. 2001).

The BFS is found only in east Asia, including the Korean Peninsula, Siberia, and the coasts of mainland China in summer (Hancock et al. 1992, Severinghaus et al. 1995, Collar et al. 2001), and southwards to Taiwan, Hong Kong, Vietnam and other places in winter (Kennerley 1990, Dahmer and Felley 1995 and 2000, Anita et al. 1998). Spoonbills use estuarine habitats, especially the intertidal zone, fish ponds, shallow water and lagoons, where small fish are the main food items. Recently, spoonbills bred on cliffs of small islands along with other aquatic birds, such as egrets (*Egretta*

Format and style follow Ecology.

eulophotes), cormorants (*Phalacrocorax carbo*), and gulls (*Larus argentatus*) (Chong 1996, Jung 2005). Spoonbills lay an average of 4 eggs in a nest, with incubation lasting for 26 days, and another 40 days as nestlings. (Chong et al. 1996). However, there was an older report that the normal clutch size was 4-6 eggs before 1960 (Won 1963). After the third year, juveniles exhibit adult plumage, but with ends of the primary flight feathers still showing some black. In the 5th or 6th year, spoonbill feathers will change to all white (Chong et al. 2000).

Spoonbills migrate south to Taiwan in mid-September, or in the beginning of October, from Asian breeding sites, and increase to population peaks in December (Liu 2002 and 2003). Birds return to the breeding sites in the north, from March to May (Tsai 1998, Liu 2003). Few longevity records exist for spoonbills, but at least one bird raised in a zoo lived 14 years (Collar et al. 2001). At present, the longest lived wild Black-faced Spoonbill was 9 years old and was banded in 1995 in North Korea, and was re-sighted in 2004 at Hong Kong (Liu 2004 b, Yu 2005).

BREEDING SITES

The known breeding grounds are on islands around the western coast of the Korean Peninsula, near the demilitarized zone (DMZ) at 38^0N Latitude (Chong and Pak 2000, Ueta et al. 2002), and several islands around the eastern and northern coasts of the Yellow Sea in northeast China (Collar et al. 2001). Only 5 nests were recorded at the South Korean breeding sites (Chong et al. 1996), and 13 nests were found in 1997 and

1998 in North Korea (Chong and Pak 2000). Although some breeding islands have been discovered along the Korean Peninsula and the Yellow Sea (Ding et al.1999, Ueta et al. 2002, Jung 2005), most breeding sites are still unknown.

NONBREEDING SITES

The BFS occurs only in east Asia (Del Hoyo et al. 1992, Hancock et al. 1992), and has major wintering habitats in Taiwan, Hong Kong and Vietnam (Kennerley 1990, Dahmer and Felley 1995 and 2000, Yu 2003b and 2004). The first documented populations in the three areas in 1990 were composed of 150, 50, and 62 birds, respectively (Kennerley 1990). Because of their low population numbers and continued habitat degradation and destruction, the Asian International Program has begun to consider their breeding, nonbreeding and migratory habitats (Severinghaus et al. 1995, Wild Bird Society of Japan 1997) in protection plans.

SPOONBILLS IN TAIWAN

The first record of the BFS in Taiwan was in 1863, when 4 were shot in Tamsuy Harbor (Swinhoe 1864). Sixty-two years later, a bird collector from the Tainan Avian Museum, Taiwan, found over 50 birds around Anping Harbor, in south Taiwan, between 1925 and 1938 (Hachisuka and Udagawa 1951). After the Anping Harbor sittings, it was hard to find any formal records of spoonbills in Taiwan until the 1980s (Kennerley

1990). Kennerley (1990) reported that Taiwan had the largest wintering flock of Black-faced Spoonbills in the world between 1988 and 1990 when over 150 individuals were counted. In 1995, the wintering population in Taiwan increased to 300 (Dahmer and Felley 1995), and the largest winter flock was on the Tseng-Wen estuary at Chi-Ku town located in southwest Taiwan (Jonker and Poorter, 1994).

Prior studies in Taiwan have focused on understanding daily activities and behaviors of spoonbills (Hu and Wang 1995, Wang and Wang 1997, Wang 2001), estimating population size (Ueng and Kuo 1991), describing habitats by compiling location data (Lee et al. 1995), finding distance and home range of spoonbills in the winter season (Wang and Chen 1997), assessing age structure of spoonbills (Jonker and Poorter 1994, Xue 1995), and providing basic ecological data and the strategy for protection (Yen et al. 1994). Although those studies can solve some basic questions about spoonbills wintering in Taiwan, we need to provide direct evidence of habitat use to define protected areas for the species.

OBJECTIVES

My study will emphasize historical populations, age structure, activity ranges, and feeding movements. Data will be used to determine the value of Tseng-Wen River in Taiwan. In addition, data from the study will be used to determine the optimal size for a potential refuge for BFS in the Republic of China, Taiwan.

Specific objectives include:

1) Determine wintering population trends in Tseng-Wen River, Taiwan, and Deep Bay, Hong Kong. Assess adult juvenile ratios in Black-faced Spoonbill populations in Tainan, Taiwan.
2) Identify home range and habitat use pattern of spoonbills in different wintering stages using radio-tracking and visual observations.
3) Measure potential prey at fish ponds used by BFS and evaluate biomass of fish ponds around the core roosting area (primary roosting sites).

CHAPTER II

POPULATION TRENDS OF BLACK-FACED SPOONBILLS IN TAIWAN

INTRODUCTION

The Black-faced Spoonbill (BFS), *Platalea minor*, is one of six species of spoonbills found globally (Del Hoyo et al. 1992, Hancock et al. 1992), and belongs to the family *Threskiornithidae* (Monroe and Sibley 1997, Dickinson 2003). Little is known about the status and trends of the BFS population (Severinghaus et al. 1995, Collar et al. 2001). The BFS is classified as a threatened species (Groombridge 1993, IUCN 1997), and it is likely to continue to decline due to substantial threats to its habitat, qualifying it as endangered (Collar et al. 2001). Black-faced Spoonbills are found only in east Asia, including the Korean Peninsula, Siberia, and the coasts of mainland China in summer (Hancock et al. 1992, Severinghaus et al. 1995, Collar et al. 2001), and southwards to Taiwan, Hong Kong, Vietnam in winter (Kennerley 1990, Dahmer and Felley 1995 and 2000, Anita et al. 1998).

The known breeding grounds are on islands around the western coast of the Korean Peninsula, near the demilitarized zone (DMZ) at 38^{0}N Latitude (Chong and Pak 2000, Ueta et al. 2002), and several islands around the eastern and northern coasts of the Yellow Sea in northeast China (Collar et al. 2001). Only five nests were recorded at the South Korean breeding sites (Chong et al. 1996); and 13 nests were found in 1997 and 1998 in North Korea (Chong and Pak 2000), the major breeding area with the most nests is still unknown (Ueta et al. 2002, Jung 2005).

The BFS found only in east Asia (Del Hoyo et al. 1992, Hancock et al. 1992), has major wintering habitats in Taiwan, Hong Kong and Vietnam (Kennerley 1990, Dahmer and Felley 1995 and 2000). Population numbers of BFS in the three areas in 1990 were 150, 50, and 62, respectively (Kennerley 1990). Because of the low population numbers of spoonbills, and continued habitat degradation and destruction, the Asian International Program has considered their breeding, nonbreeding and migratory habitats (Severinghaus et al. 1995, Wild Bird Society of Japan 1997) for protection.

The first record of the BFS in Taiwan was in 1863, when 4 were shot in Tamsuy Harbor (Swinhoe 1864). Sixty-two years later, a Japanese collector from the Tainan Avian Museum, Taiwan, found over 50 birds around Anping Harbor, in south Taiwan, between 1925 and 1938 (Hachisuka and Udagawa 1951). After the Anping Harbor sitings, few records of spoonbills were recorded in Taiwan until the 1980s (Kennerley 1990). Kennerley (1990) reported that Taiwan had the largest wintering flock of BFS in the world between 1988 and 1990 when over 150 individuals were counted. In 1995, the wintering population in Taiwan increased to 300 (Dahmer and Felley 1995), and the largest winter flock was on the Tseng-Wen estuary at Chi-Ku town located in southwest Taiwan (Jonker and Poorter 1994).

Although the BFS is an endangered species, population information is lacking (IUCN 1997, Collar et al. 2001). As Taiwan has the largest wintering population of BFS (Kennerley 1990, Dahmer and Felley 1995 and 2000), my studies will include counts of breeding-age adults as well as total bird counts. Morphology, which can be used to determine sexual maturity, includes flight plumage with no black-tip showing appearance, banded bills, and yellow breeding plumage (Severinghaus et al. 1995, Tsai 1998, Yu 2003a, Liu 2004a). Flight plumage with black-tipped wings disappears at ages five or six and because adults can reproduce at three years of age (Chong et al 2000), black-tipped wings can not be used to identify adults.

MATERIALS AND METHODS

Study areas

The study areas include Tainan City (17,565 ha) and at the town of Chi-Ku (11,500 ha) (23^{0} 66^{1} N, 120^{0} 88^{1} E). The Tseng-Wen River is the boundary between Tainan City and Ch-Ku town, facing the Taiwan Straits (Fig. 2-1). During the last 10 years, Tainan City and Tainan County included 29.5%-39.1%, respectively, of the total coastal fishing industry in Taiwan, with the largest proportion of the industry in fish ponds in Taiwan (FA 2002, Table 2-1). Tseng-Wen River is the 5th longest river of 21 major rivers of Taiwan (TESRI 2003), and the mouth of the river is used for commercial fishing and oyster cultivation. The BFS population usually occupies a 300-ha artificial lagoon, which is located in the north side of Tseng-Wen River mouth (Ueng and Kou 1991, Yen et al. 1994). This artificial lagoon was identified as a potential protection site for the BFS in November of 2002 (TCG 2002).

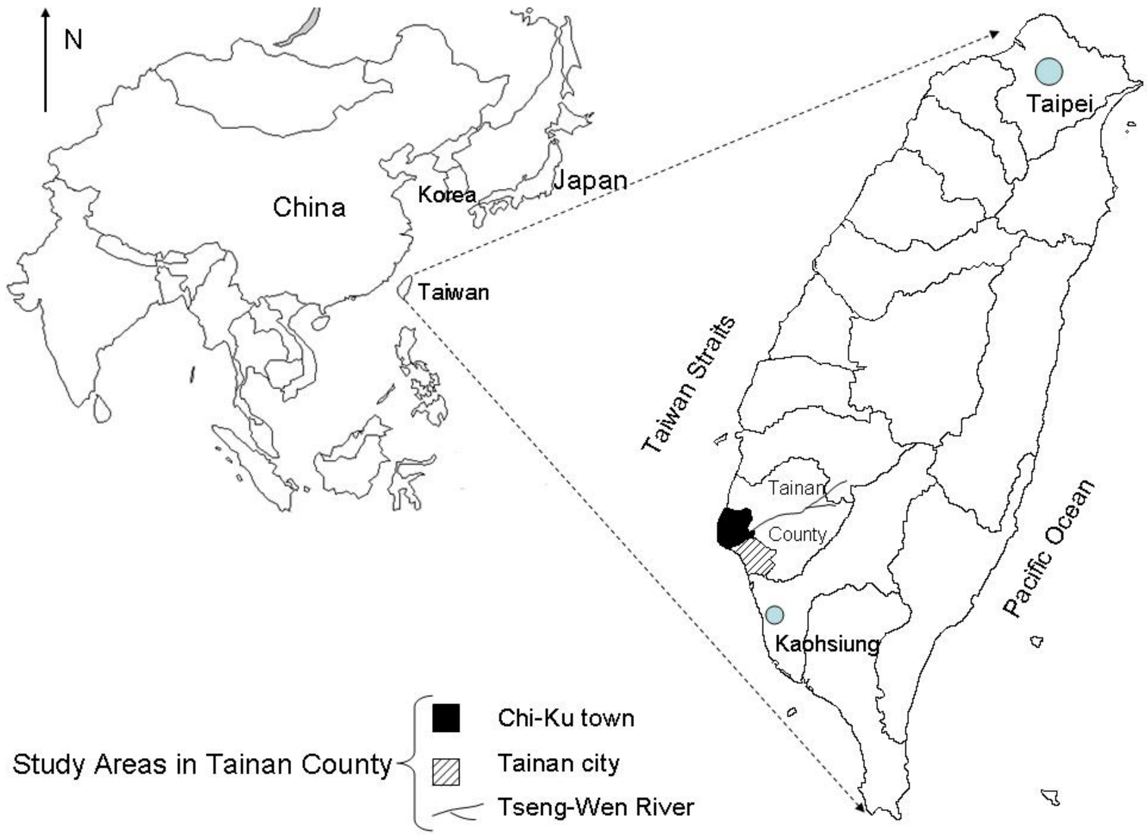

Fig. 2-1. Study areas in Tainan County, Taiwan.

Table 2-1. Areas (ha) and proportion of coastal fish ponds in fishing culture* in Tainan City/County and in Taiwan.

	Tainan County (include Chi-Ku town)		Tainan City		Taiwan	
Year	in use (ha)	ponds not used (ha)	in use (ha)	ponds not used (ha)	in use (ha)	ponds not used (ha)
1993	15418.1	1335.2	5473.4	239.2	70684.5	5218.3
	(21.8%)**	(25.6%)	(7.7%)	(4.6%)	(100%)	(100%)
1994***	--	--	--	--	--	--
1995	15565.8	1945.7	5193.7	180.9	69797.3	6232.0
	(22.3%)	(31.2%)	(7.4%)	(2.9%)	(100%)	(100%)
1996	14252.2	3238.1	5861.8	203.0	67349.4	9488.7
	(21.2%)	(34.1%)	(8.7%)	(2.1%)	(100%)	(100%)
1997	14266.4	2632.4	5016.4	114.3	62917.5	7519.5
	(22.7%)	(35.0%)	(8.0%)	(1.5%)	(100%)	(100%)
1998	17560.6	1352.6	4672.7	117.1	62928.8	6004.1
	(27.9%)	(22.5%)	(7.4%)	(2.0%)	(100%)	(100%)
1999	17100.1	466.6	4943.0	154.9	63214.7	5147.9
	(27.1%)	(8.1%)	(7.8%)	(3.0%)	(100%)	(100%)
2000	17271.6	698.0	4582.6	225.7	62344.1	4554.2
	(27.7%)	(15.3%)	(7.4%)	(5.0%)	(100%)	(100%)
2001	13700.1	889.5	4321.2	128.2	57078.6	5203.2
	(24.0%)	(17.1%)	(7.6%)	(2.5%)	(100%)	(100%)
2002	13619.2	977.8	4314.0	129.3	56415.7	5364.6
	(24.1%)	(18.2%)	(7.6%)	(2.4%)	(100%)	(100%)

* Marine fishing cultures are not included
** Percent of Taiwan fish ponds
*** No data in 1994

Population estimation

Surveys of spoonbills were conducted at roosting sites or fish ponds with binoculars and telescopes. Population count data from1990 to 2004 were used to identify trends. Counts included data from the Wild Bird Federation Taiwan (WBFT), publications by Hong Kong Ecosystem Limited Company and Hong Kong Bird Report before 1996 (Kennerley 1990, Dahmer and Felley 1995, WBFT 2004a and 2004b), and data from an international survey conducted every January from 1997 to 2004 (Dahmer and Felley 2000, Yu 2003b and 2004). Survey participants included more than 21 wild bird societies of the WBFT league and Black-faced Spoonbill Conservation Association.

Adult determination

Although horizontal bands on the upper mandible can be used to age birds, these are hard to observe, whereas yellow feathers indicative of adult birds can be found easily (Chen 2003, Liu 2004c). Therefore, I used the presence of yellow feathers to identify adults of breeding age (Fig. 2-2). The date at which the first spoonbill molted to yellow plumage was recorded until the last BFS molted to yellow.

Historical mortality

I recorded known mortality factors from data sources, such as museums and documents, from Europe, Japan, Taiwan, S. Korea, and Hong Kong. These mortality data were used to further understand population trends.

Fig. 2-2. Morphological methods to determine adult and non-adult status of Black-faced Spoonbills. (A). comparison with primary black-tip plumage (although some adults will continue to have black-tipped primaries until six years old). (B). comparison with banded bill. (C). comparison with yellow breeding plumage. (photo courtesy of J. R. Hsu and Y. M. Liu)

Analysis

Total population counts in Taiwan and Hong Kong from 1990-2004, and proportion of yellow-plumage every week over the winters, 2000-2003, were evaluated using regression analysis by SPSS (Ott 1993, Daren and Paul 2001). The regression analyses were used to determined significant population trends, and to determine if the ratios of juveniles to total population changed.

RESULTS

Population trends of Black-faced Spoonbill

Although no spoonbill records were available in Taiwan and Asia in 1991-1992, and Hong Kong in 1991-1993, known population numbers for 13 years (1990-2004) exceeded 50% of the total population remaining in Taiwan for the entire winter (Fig.2-3 and Table 2-2). Taiwan was thought to be the most important wintering area in the range of the BFS. In particular, numbers of birds in Tainan areas were more than 96% (Table 2-2) of total numbers found each year in Taiwan. The Tainan areas include Tainan City and Ch-Ku town, which has the most concentrated wintering area in far Asia.

I found that Hong Kong, Taiwan and Asian population numbers increased from 1990-2004; in Hong Kong: linear Regression: $Y = 11.05 X + 8.5$, $R^2 = 0.712$, $P = 0.001$ (Fig. 2-4); in Taiwan: linear Regression: $Y = 35.31 X + 53.77$, $R^2 = 0.952$, $P < 0.001$ (Fig. 2-5); in Asia: linear Regression: $Y = 65.87 X + 65.35$, $R^2 = 0.899$, $P < 0.001$ (Fig. 2-6). Growth curves have high correlation coefficients with the population steadily increasing.

Table 2-2. The population of Tainan areas and Taiwan (International synchronized census started in 1997).

year	1990	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Tainan Areas						298	321	364	380	402	583	580	628
% of Taiwan number						(97.4)	(98.2)	(98.9)	(96.0)	(98.5)	(99.1)	(99.1)	(99.4)
Taiwan	150	206	286	300	320	306	327	368	396	408	588	585	632
% of global number	(52.1)	(60.8)	(64.7)	(65.4)	(54.2)	(57.2)	(53.3)	(62.7)	(59.5)	(50.2)	(59.2)	(54.7)	(52.4)
Global number	288	339	442	459	590	535	613	587	666	812	993	1069	1206
1% of RAMSAR Requirement*	3	3	4	5	6	5	6	6	7	8	10	11	12

*RAMSAR Convention requirement for endangered wetland birds: wetland habitat with 1% of total population of birds should be protected (UNESCO 1971 and 1999).

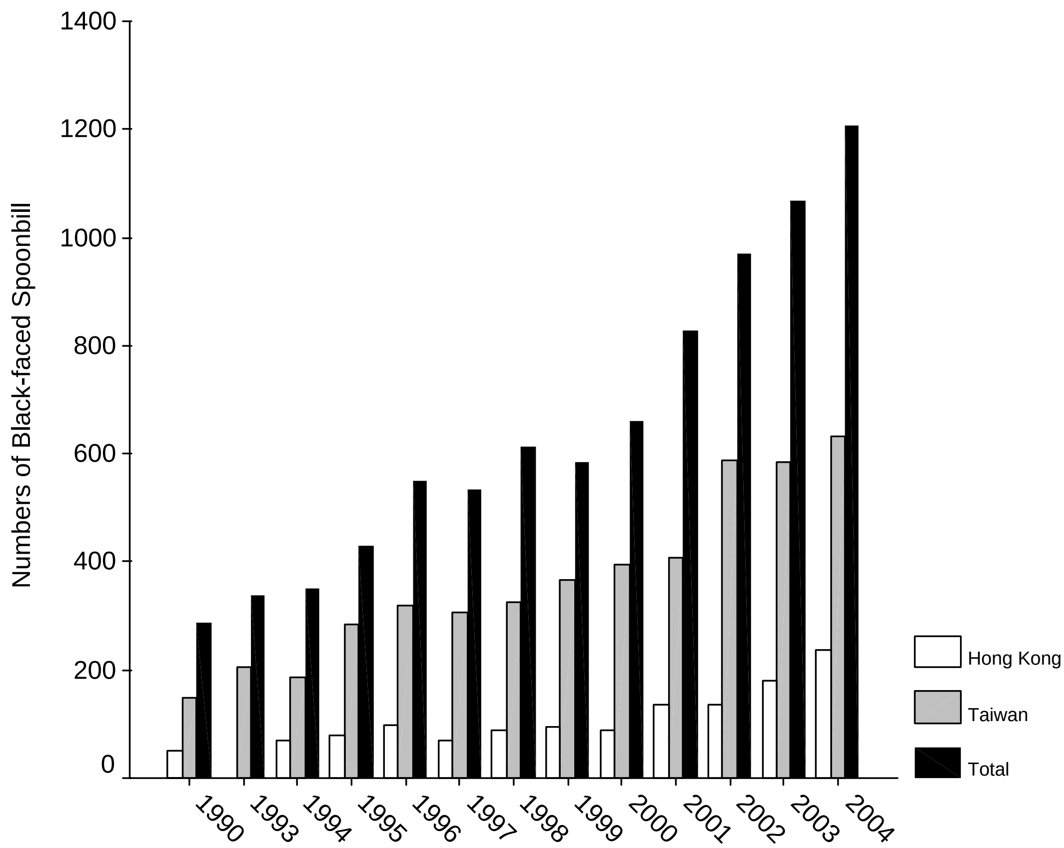

Fig. 2-3. Population numbers of Black-faced Spoonbills in Taiwan, Hong Kong, and total winter range.

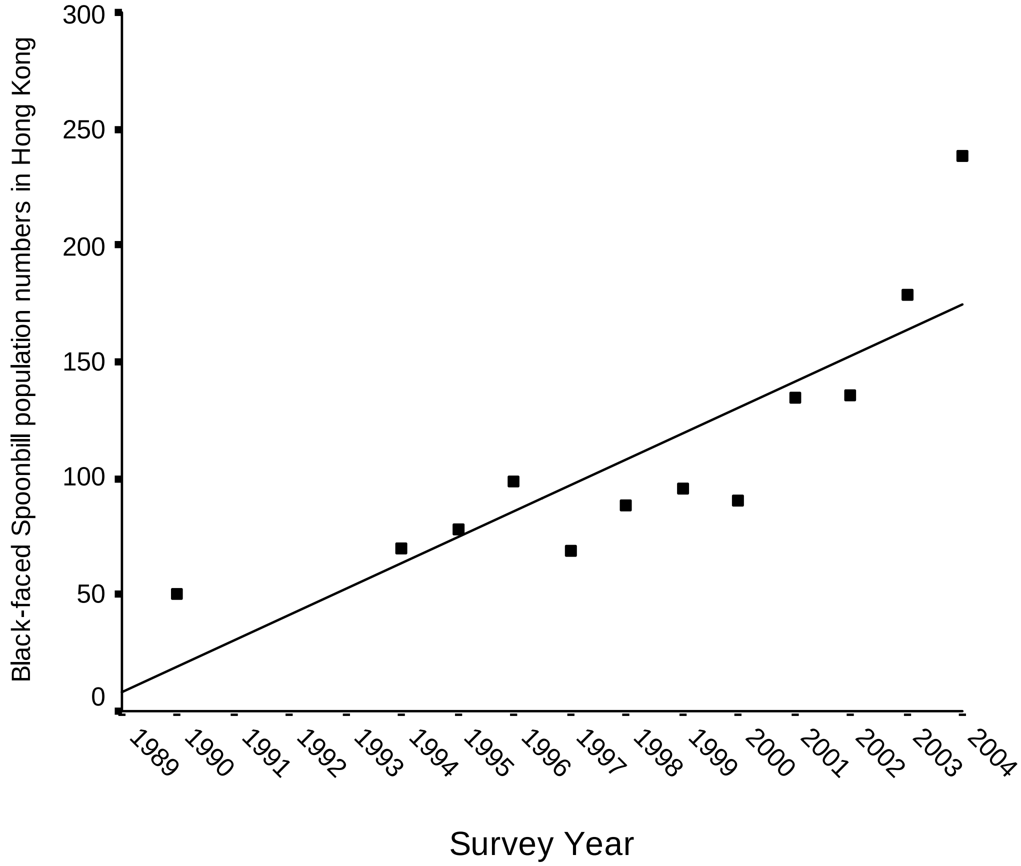

Fig. 2-4. Population trends from 1990 to 2004 in Hong Kong. There were no data from 1991, 1992, and 1993. (Linear Regression: Y = 11.05 X + 8.5, R^2 = 0.712, P = 0.001)

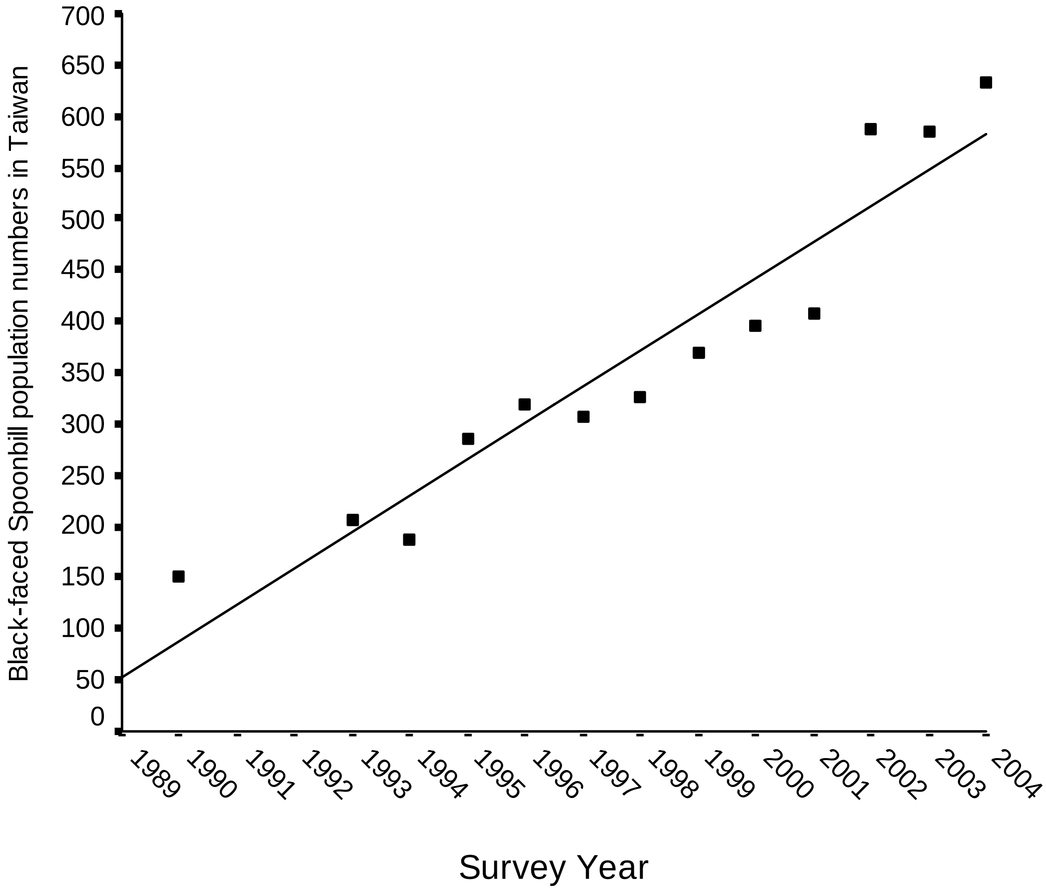

Fig. 2-5. Population trends from 1990 to 2004 in Taiwan. There were no data from 1991 to 1992. (Linear Regression: Y = 35.31 X + 53.77, $R^2 = 0.952$, $P < 0.001$)

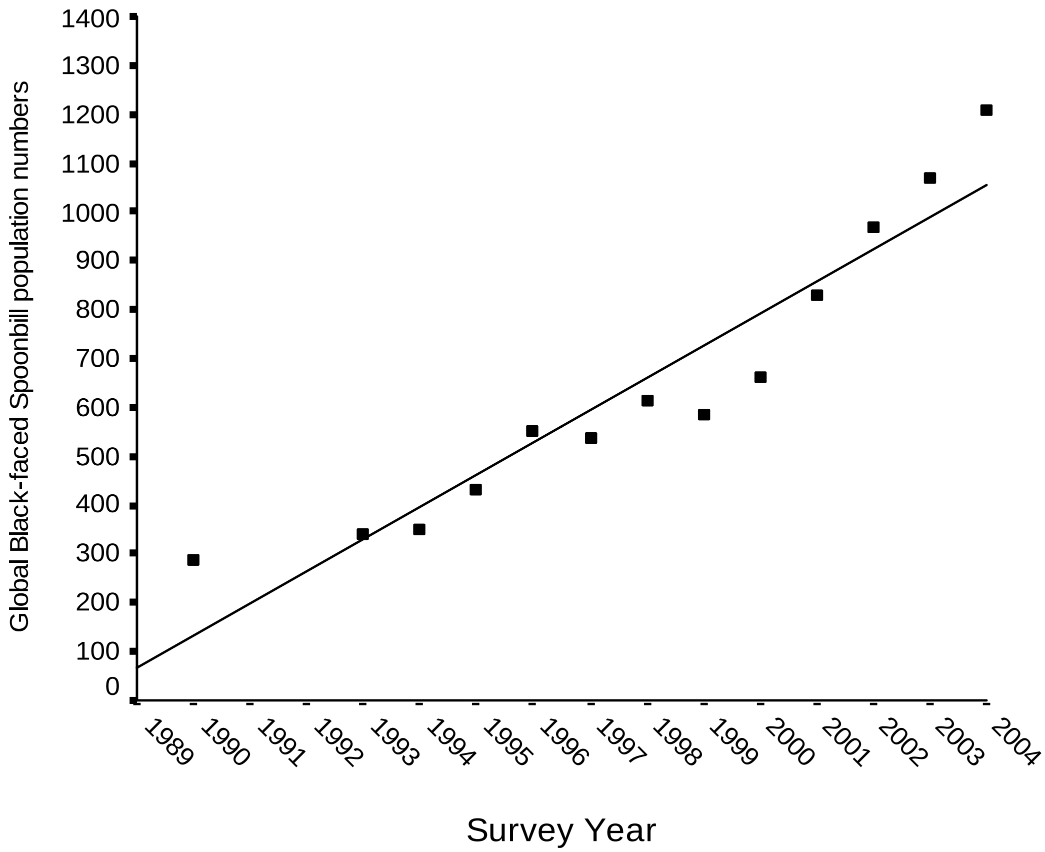

Fig. 2-6. Population trends from 1990 to 2004 in Asia. There are no data from 1991 to 1992. (Linear Regression: Y = 65.87 X + 65.35, $R^2 = 0.899$, $P < 0.001$)

Global population numbers ranged from 288 in 1990 to 1206 in 2004, having increased 4.19 times in 15 years, while the population of BFS in Taiwan rose from 150 to 632, increasing by 4.21 times in the same period.

Known mortality factors

Because population numbers of BFS are small, only a few anthropocentric death records can be found. Twenty-nine records have been confirmed in relevant documents from various countries (Table 2-3), with some records omitted because documented causes of mortality were lacking. For instance, Collar et al. (2001), quoted in the Red Data Book of Birdlife International, reported that some BFS were shot in Russia, and in Hainan island, China, but they gave no numbers and dates.

Similarity, Chong et al. (2000) mentioned five BFS had been caught in the field and were placed in the zoo of Japan for breeding and one bird died unexpectedly. Therefore, one bird was recorded dying with unknown reasons in Table 2-3. In addition, unknown numbers of eggs were collected and eaten by fishermen at breeding islands around the Yellow Sea (Collar et al. 2001), or were eaten by gulls (Chong et al. 1996).

I found that 11 of 29 literature recorded deaths were from gunshots, with 3 collected by scientists (Swinhoe 1864, Ogilvie-Grant 1889). Records showed that mortality in fish ponds included two birds deaths of intestinal damage due to swallowed fishhooks and one death from entanglement with a fish net. Some records of deaths included necrosis, three deaths after broken-wing bones, and two birds with injured feet.

Table 2-3. Known mortality factors for Black-faced Spoonbills from 1849-2004.

year	Mortality Factor	Number	Place of death	Body collection	Literature Source
1849	gunshot	1	Japan	Netherlands*	(Ogilive-Grant 1889)
1863	gunshot	4	Taipei, Taiwan	U.K.	(Swinhoe 1864)
1863	gunshot	1	S. China	Netherlands	(Swinhoe 1864)
1876	gunshot	1	Japan	U.K.	(Hancock et al. 1992)
1898	gunshot	1	unknown	U.K.	(Sharpe 1898)
1912-1921	unknown	2	unknown	Germany	(Harter 1912-1921)
1931	gunshot	2 (at least)	Tainan, Taiwan	Japan	(Hachisuka 1931-1932)
1951	gunshot	2 (at least)	Tainan, Taiwan	Japan	(Hachisuka 1951)
1950s	gunshot	1	Tainan, Taiwan	Taiwan	skin in high school (Liu 2004d)
1959	gunshot	1	S. Korea	S. Korea	(Fennell and King 1964)
1966	unknown	2 (at least)	S. Korea	S. Korea	(Won 1966)
1990s	unknown	1	Tainan, Taiwan	Taiwan(bill remained)	bill remained (Liu 2004d)
1992	unknown	1	Sogamdo, Japan	Japan	(Chong et al. 2000)
1992	gunshot	2	Tainan, Taiwan	Taiwan	(UDN 1992)
1993	wing bone fracture	1	Tainan, Taiwan	Taiwan	(Hu and Wang 1995)
1995	gunshot	1	Tainan, Taiwan	unknown	(Yao et al. 1997)
1997	electrical shock	1	Tainan, Taiwan	unknown	local people interviewed (Liu 2004d)
1998	drowned	1	Tainan, Taiwan	Taiwan	banding stress (Liu 2004d)
1998	one foot lost	1	unknown	unknown	local people interviewed (Liu 2004d)

Table 2-3. Continued.

year	Die of	Died number	Place of death	Body collection	Literature
1999	fishhook in intestine	1	Tainan, Taiwan	Taiwan	(Shen 2000)
1999	one foot seriously injured	1	unknown	unknown	observed in field (Liu 2004d)
2000	wing bone fracture	1	Tainan, Taiwan	Taiwan	skin remained (Liu 2004d)
1998	drowned	1	Tainan, Taiwan	Taiwan	banding stress (Liu 2004d)
2001	poisoned (avian botulism)	3	Mai-Po, Hong Kong	Hong Kong	Hong Kong Bird Watching Society (Liu 2004d)
2002	wing bone fracture	1	I-Lan, Taiwan	Taiwan	captive in zoo** (Liu 2004d)
2002-2003	poisoned (avian botulism)	73	Tainan, Taiwan	Taiwan (49 skins, 8 skeleton)	(Shiau et al. 2003)***
2003	unknown	1	Tainan, Taiwan	Taiwan	local people interviewed (Liu 2004d)
2004	2 feet twined by fish net	1	Tainan, Taiwan	Taiwan	local people interviewed (Liu 2004d)
2004	unknown	1	Tainan, Taiwan	Taiwan	local people interviewed (Liu 2004d)

* Species type of Black-faced Spoonbill
** Bird lost flight ability: is still alive, can not be released
*** Botulism disease caused 73 BFS died, and 17 BFS sick

In addition, two records were found of avian botulism disease, one bird died by drowning during the banding process, and one bird died of an electric shock. Also, I found six records listed for unknown causes (Table 2-3, Shen 2000, Collar et al. 2001, Liu 2004d).

With one exception for over 155 years from 1849 to 2004 I found no more than five birds mortalities in any one year. The one recorded exception was from December of 2002 to February of 2003 when avian botulism occurred at Chi-Ku in Taiwan. Botulism resulted in 73 spoonbill mortalities plus 17 spoonbills suffering prolonged illness (Chaung et al 2003, Shiau et al. 2003). In January of 2003, the total surveyed numbers of spoonbills was 1069, hence the botulism losses in 2003 accounted for 6.4% of the total population.

Adult ratio in wintering population

From year 2000 to year 2003, the first spoonbill with yellow plumage was found in the 3rd week in January (Table 2-4). In 2000, adult spoonbills with yellow plumage peaked at 63.1% in the 8th week, from February 20 to February 26. In 2001, the peak percentage of adult-plumaged birds was 57.1% in the 9th week, from February 25 to March 3. In 2002, the peak of adult-plumaged birds (66.1%) occurred in the 10th week, from March 4 to March 10, while in 2003, the peak of adult birds (54.7%) occurred in the 9th week, from February 23 to March 1 (Fig. 2-7). After peak adult populations were reached, migration began and adult-plumaged bird numbers declined. For four years all adults left Taiwan (Table 2-4) at the 16th week (last two weeks of April).

Table 2-4. Percentage of sexually-mature adults (with yellow plumage) to total birds in Tainan area, Taiwan.

Weeks (Jan.1-Apr.30)	Year 2000		Year 2001		Year 2002		Year 2003	
	Yellow/total	(%)	Yellow/total	(%)	Yellow/total	(%)	Yellow/total	(%)
1	0/406	0.0	0/380	0.0	0/375	0.0	0/400	0.0
2	0/399	0.0	0/420	0.0	0/381	0.0	0/408	0.0
3	5/370	1.4	10/410	2.4	10/324	3.1	9/356	2.5
4	8/380	2.1	16/407	3.9	25/359	7.0	12/350	3.4
5	65/330	19.7	28/332	8.4	34/394	8.6	33/362	9.1
6	90/356	25.3	99/332	19.8	148/355	41.7	62/314	19.7
7	206/360	57.2	138/394	35.0	168/351	47.9	86/286	30.0
8	218/345	63.1	165/387	42.6	153/332	46.1	120/299	40.1
9	200/360	55.6	200/350	57.1	151/312	48.4	144/263	54.7
10	145/293	49.4	145/313	46.3	160/242	66.1	152/301	50.5
11	79/226	35.0	105/239	43.9	120/218	55.0	114/243	46.9
12	35/199	17.6	38/156	24.4	40/141	28.4	30/141	21.3
13	6/131	4.6	20/153	13.1	27/104	26.0	5/25	20.0
14	3/96	3.1	6/135	4.4	27/141	19.1	9/90	10.0
15	1/80	1.3	1/81	1.2	12/164	7.3	9/132	6.8
16	0/112	0.0	0/61	0.0	0/100	0.0	1/106	0.9
17	0/26	0.0	0/38	0.0	0/64	0.0	0/64	0.0

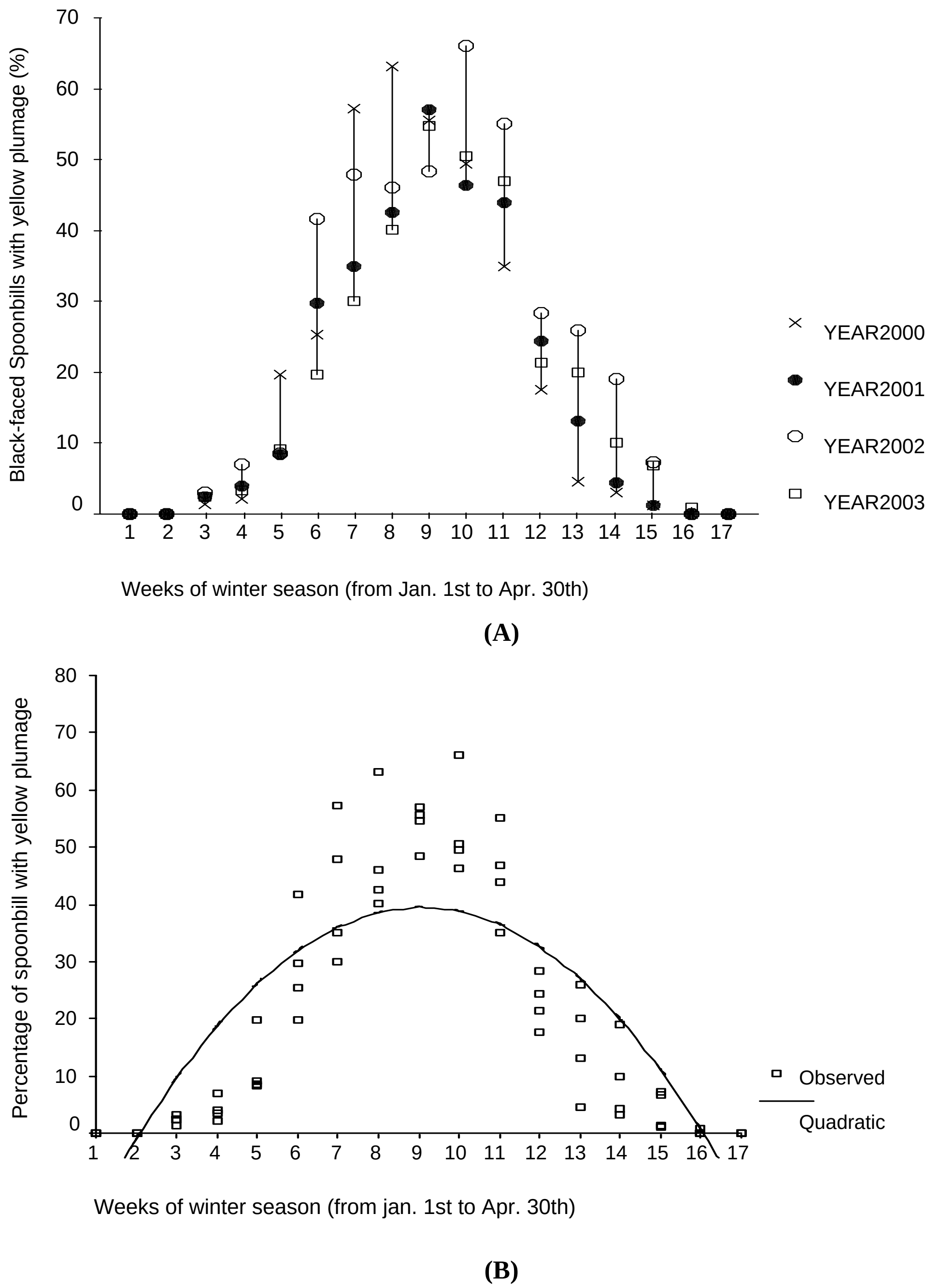

Fig. 2-7. The percentage of adults in Taiwan during 4 years (2000-2003).
(A) BFS with yellow adult plumage
(B) the quadratic regression curve: $Y= - 0.81x^2+ 14.69x -27.07$, $R^2 = 0.686$, $P < 0.001$.

The combination of 4 years of data showed that the increase, peak and decline of adult birds fits a quadratic equation (Percent of adult birds = $-0.81x^2 + 14.69x - 27.07$, $R^2 = 0.686$, $P < 0.01$) (Fig. 2-7).

DISCUSSION

Population levels of Black-faced Spoonbill

Populations of BFS in Taiwan and Hong Kong increased steadily over 15 years. During this period Taiwan accounted for more than 1/2 of the total population each year (1990-2004) with 96% of spoonbills in Taiwan found in Chi-Ku town and Tainan City. Continued growth of BFS populations in Taiwan suggested that populations have not yet reached the carrying capacity. As a result, the continued increase in numbers suggested that dangers to the population have declined. In addition, adult to non-adult bird ratios during the migration to Taiwan were similar for the 4 year period (2000-2003). The proportion of breeding aged adults (54.7%-66.1%) has remained relatively constant during the winter season. It appeared that given the trend of increasing numbers and similarity in adult to non-adult, the population of BFS was healthy.

Factors that affect the growth and decline of populations include natality, mortality, emigration, immigration, food, and climate (MacArthur and Connell 1966, Newton 1998, Kransman 2002, Sibly et al. 2003). The growth curves I determined (Fig. 2-4, Fig. 2-5, Fig. 2-6) from wintering-ground counts did not include natality and mortality. Unfortunately, production of young at breeding sites on islands around the Yellow Sea in northeast Asia, were not known because of the paucity of research on breeding ground. But some of mortality factors, including fishermen collecting eggs and Herring Gulls predation, were certainly of concern (Chong et al. 1996, Collar et al. 2001). Chong et al. (1996) referred to 2 nests of BFS which laid a second clutch immediately after gulls had destroyed the first brood. Re-nesting suggested that the reproductive system of spoonbills can respond to egg predation.

Mortality by disease

The summary of recorded deaths of spoonbills since 1849 showed both deaths from natural causes and deaths from humans (Table 2-3). Among them, the recorded mortality factors included 11 by gunshots, three deaths in fish ponds (where birds had swallowed fishhooks or were entwined by fishnets). Most of these mortality factors can be avoided. Generally, anthropocentric mortalities each year accounted for less then five mortalities, mostly one-two per year. But in the winter of 2002- 2003, avian botulism killed 73. If antitoxin had not been available from U.S. Wildlife Health Center in time, more birds would likely have died. After cleaning the infected fish ponds and removing dead fish, losses were minimized (Chaung et al. 2003, Shiau et al. 2003).

Because of the BFS's endangered status (Red Data Book of IUCN and Bird International), spoonbill populations should be protected from human caused losses. Infectious diseases caused particular problems with two avian mortality events known to be significant to BFS in Asia. These diseases include toxin in avian botulism; that was potentially a problem in fish ponds (Chaung et al. 2003), and secondly, avian flu which has been found throughout Asia and is difficult to control (Terakado et al. 2004). The deadly H5N1 virus has been found recently in Asia, and has caused Anseriform birds to die, and could cause Ciconiiform birds, egrets and storks, to die (Sturm-Ramirez et al. 2004, Terakado et al. 2004). The BFS is a potential victim because they live with egrets and are taxonomically in the same avian order (Dickson 2003).

Maintain habitats at Chi-Ku for protected area

Increasing population numbers for BFS may reflect the stable environment of Tainan area and suggest sufficient space and food resources for spoonbills. The fishing culture of the Tainan area has not changed much in the past 10 years (1993-2002) (Table 2-1), and nearby marsh environments have not changed either. However, a technologically-based industrial complex developed in Tainan City in 1996 in close proximity to 750 ha of sites that were previously fish ponds. Besides Tainan industrial complex, Chi-Ku industrial complex (300 ha, proposed in 1986) and Bin-Nan industrial complex (1100 ha, proposed in 1993) in Ch-Ku town have been scheduled for development by the Tainan County government. Both sites were major roosting and feeding grounds of spoonbills at Chi-Ku (Liu 2002). Once the scheduled development has occurred, spoonbill habitat will be reduced by 1400 ha.

Two Black-faced Spoonbills were shot at the end of 1992 at the scheduled Chi-Ku industrial complex (UDN 1992). After that incident, local residents petitioned for a protected area at Chi-Ku for spoonbills. Not only Taiwanese, but also many international friends from the United States, United Kindom, Japan, Hong Kong, Australia, South Korea and North Korea supported the protected area. On 1 November 2002 the Tainan County Government announced that 300 ha on the north side of the Tseng-Wen River and surrounding shore banks will be the BFS protected area (TCG 2002). Because of severe protests by local residents for 8 years, another planned Bin-Nan Industrial Complex was suspended (CNT 2001).

Although habitats were not destroyed at Chi-Ku, BFS habitats still have other potential environmental hazards, including avian botulism and avian flu. Problems of habitat destruction and avian disease have become international issues, not just a Taiwan problem. Because the BFS annual cycle includes several countries, international cooperation is necessary to ensure continued availability of habitat for BFS.

CHAPTER III

CHANGES IN ACTIVITY RANGES OF WINTERING BLACK-FACED SPOONBILLS IN TAIWAN

INTRODUCTION

The endangered black-faced spoonbill (BFS) is distributed in east Asia, with major wintering sites in Taiwan, Hong Kong and Vietnam (Kennerley 1990, Dahmer and Felley 1995). Recent records show that more than 50% of the total population winters in Taiwan. In Taiwan, 96% of wintering BFS are found in Tainan City and Chi-Ku town. The concentration of BFS in southern Taiwan is the most concentrated aggregation of BFS in Asia (Chapter II).

There has been little research about habitat use by BFS on wintering sites. Lee et al. (1995) reported sites at Chi-Ku town were used by spoonbills for 50 years. They found spoonbills mainly used the tidal mudflat, shallow water, lagoons, and fish ponds. Wang and Chen (1997) evaluated the home ranges and habitats in Chi-Ku town by tracking the locations of 3 spoonbills with radio transmitters. However, the Wild Bird Federation Taiwan (WBFT) database reported that many spoonbills frequently moved to Tainan City on the south side of Tseng-Wen River, and along the Tseng-Wen River for roosting and foraging in 2001-2002.

Behavioral studies have shown that the BFS spent 60-80% of daytime resting, while the proportion of foraging time was less than 6% (Hu and Wang 1995, Wang and

Wang 1997, Wang 2001). Similarly, Hu and Wang (1995) reported that BFS foraged at night using moonlight for 64% of the observed time. These earlier reports (Hu and Wang 1995, Wang and Wang 1997, Wang 2001) have documented that BFS foraged primarily at night.

Observations of BFS in daylight hours were easily accomplished as most spoonbills concentrated in shallow water, artificial lagoons, and fish ponds on the north side of the Tseng-Wen River (Yen et al. 1994, Wang and Chen 1997). In addition, Bray et al. (1975), Wanless et al. (1985), Kenward (1987), White and Garrott (1990) monitored movements with radio transmitters to determine activity patterns, habitat use, and activity ranges.

Therefore, this study will observe spoonbills in daylight hours, and also track the birds with radio-transmitters at night. I will evaluate the changes of BFS numbers in different periods of the winter, identify habitat use, and determine activity ranges of BFS in different stages of winter seasons.

MATERIALS AND METHODS

Traps and banding

Black-faced Spoonbills were trapped in shallow fresh water with modified Bal-chatri noose traps (McClure 1984). I put the traps under the surface of the water, and used nylon ropes with iron bars to hold the trap array steady (Fig. 3-1). A

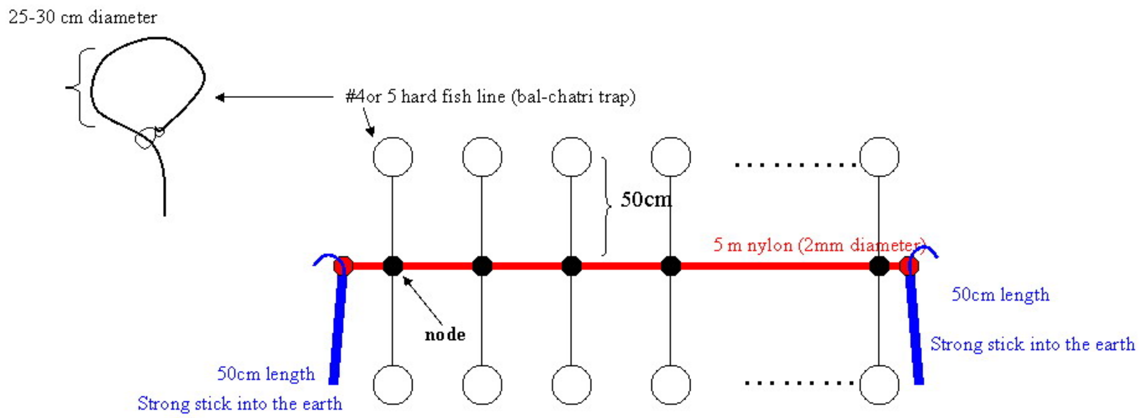

Fig. 3-1. The modified Bal-chatri traps made of fish lines set under water in shallow ponds.

camouflaged tent was used to conceal researchers monitoring the traps. Once the BFS stepped into the traps, a team of researchers controlled the bird, assessed health status of the bird, and took morphological measurements. If birds were in good health, color bands were placed on the tarsus, and a transmitter harness package with Teflon broad cloth was attached to the birds. We used the Amlaner-style, figure-eight pattern with neck and body loop meeting at the breast area, to harness the transmitters on BFS backs (Amlaner et al. 1978, Anderka and Angehrn 1992).

Receiver and transmitter

The radio transmitters were made by ATS INC. (Advanced Telemetry System , Inc.). The total transmitter package (harness and radio) weighed 30 gm, and had a launch frequency between 164.000-165.000, and 180 days battery life. Harness materials were made of Teflon cloth which minimized abrasion, and cotton thread was used for tying end nodes which allowed the transmitter package to break naturally. I used a Yagi-type antenna produced by Telonics Company with a Telonics receiver.

Study area

The primary study area covered 22,508 ha and was located west of provincial highway No.17, north of the Yen-Shui River, and south of the Jiang-Jun River. Land use within the study area included: agriculture, channel (seawater for fish ponds), estuary, fish ponds, industrial, lagoons, wildlife reserve, salt ponds, shallow lagoons (artificial), and trees. In all, I identified 11 different habitat types (Fig. 3-2).

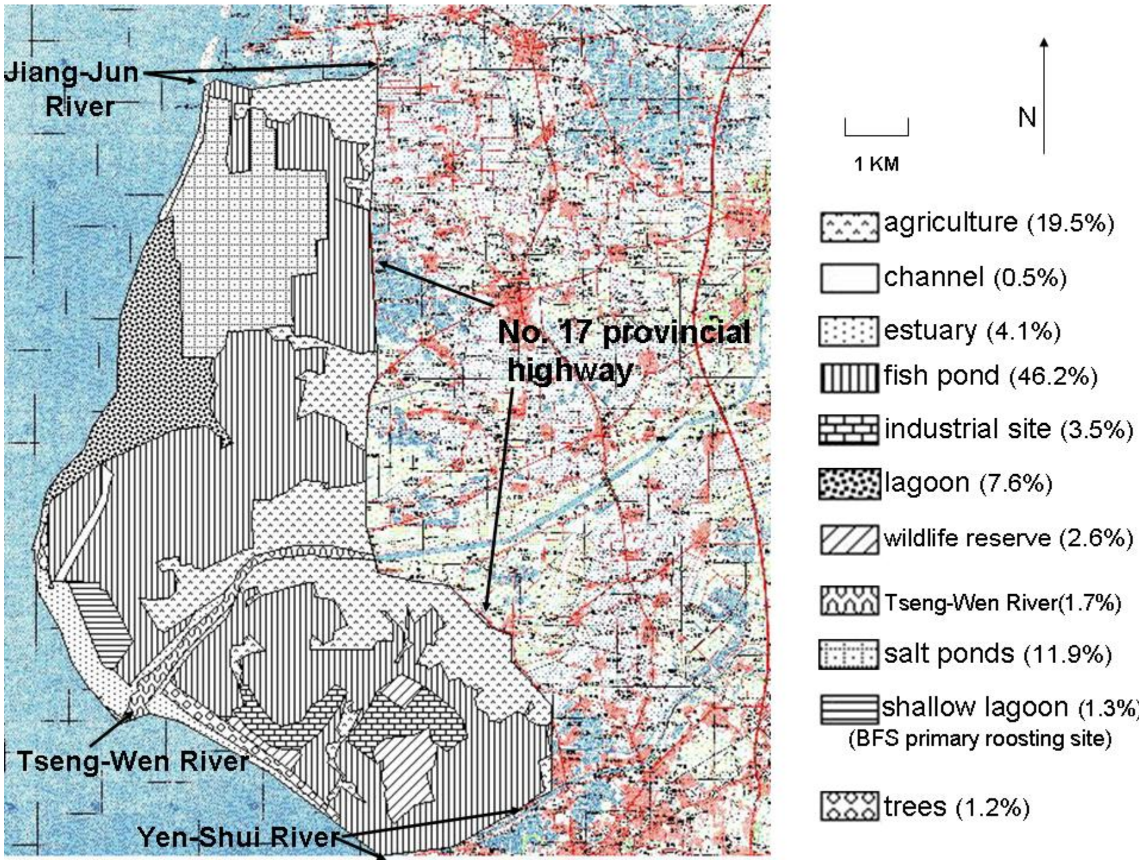

Fig. 3-2. Study areas and habitat types which include north and south sides of the Tseng-Wen River in Tainan areas.

Population counts

I used a telescope to count BFS primarily in the artificial shallow-water lagoons almost daily for 4 consecutive years (1998- 2001). I averaged the number of observed individuals for several surveys conducted at each site each day. I randomly surveyed different areas of the primary study area in order to find the largest aggregation of BFS.

Habitat use

Both diurnal visual observations and nocturnal radio-tracking were conducted. During the daylight hours in the winter seasons of 1998, 1999, and 2000, I identified habitat types used by BFS. Because I could not accurately count birds at night, I only recorded habitat types used by birds with radios. In the winter seasons of 1997 and 1998, I used the Telonics TDP-2 radio receiver on birds. Birds were located and habitats used were identified. In addition, I determined how nocturnal locations differed from daytime use areas. On some occasions, birds were located with triangulation (Kenward 1987, White and Garrott 1990), but in most instances locations of birds could be found directly. I also determined the number of times each of the 11 different habitat types was used by spoonbills.

Activity ranges

Locations by visual observations were conducted 5-10 times each week and radio-tracking was conducted 2-3 times a week. Points of bird locations were processed into digital maps using ArcView GIS software, where the “animal movement” function was used to calculate the activity ranges during the winter period. These calculations of spoonbill home ranges included the Minimum Convex Polygon method (MCP) and Kernel method (Fuller et al. 2005). Kernel density levels (50%, 90%, 95%) were computed and the smooth parameter, H, was defaulted as 1000.

RESULTS

Three stages of the wintering season

Spoonbill arrived in Taiwan each year from the end of September to the beginning of October (Table 3-1, Fig. 3-3). The population increased sharply until the end of November where population numbers remained effectively stable until March. Beginning in early March the population declined sharply until all birds were gone from Taiwan by late March.

Average population counts were compared for the months November-February by using one-way ANOVA (Lehner 1979, Norušis 1982, Ott 1993). I found the mean comparison of these 4 months did not show differences in the winter of 1998-1999, ($P = 0.473$). Also, there were no significant differences in 2000-2001, ($P = 0.061$), and in 2001-2002, ($P = 0.002$). But, there were significant differences among these 4 months in 1999-2000, $P < 0.001$. Although the middle stage (November- February) were not the same for the 4 years, this stage had a stable population-level compared to early (September-October) or late (March-May) stages.

Table 3-1. Mean number of wintering Black-faced Spoonbills at Tainan areas for 4 consecutive years.

Months	Mean number in 1998-1999	Mean number in 1999-2000	Mean number in 2000-2001	Mean number in 2001-2002 ***
September	-	1.67 (N=3)	1 (N=1)	-
October	76.9 (N=10)	77.7 (N=27)	97.5 (N=29)	125.4 (N=31)
November**	305.6 (N=22)	396.4 (N=30)	388.8 (N=30)	474.0 (N=30)
December**	298.8 (N=13)	434.7 (N=31)	413.4 (N=31)	442.9 (N=31)
January**	304.2 (N=13)	383.6 (N=31)	404.1 (N=31)	431.9 (N=31)
February**	281.4 (N=12)	343.0 (N=29)	394.7 (N=28)	395.4 (N=28)
March	200.3 (N=19)	287.3 (N=31)	267.3 (N=31)	232.0 (N=31)
April	103.6 (N=18)	95.1 (N=30)	98.2 (N=30)	-
May	44.7 (N=17)	39.5 (N=19)	31.3 (N=5)	-

* N : counting days in each month

** Stable population-level stages of wintering season in November, December, January, and February.

*** Data collected from BFSA (Black-faced Spoonbill Conservation Association)

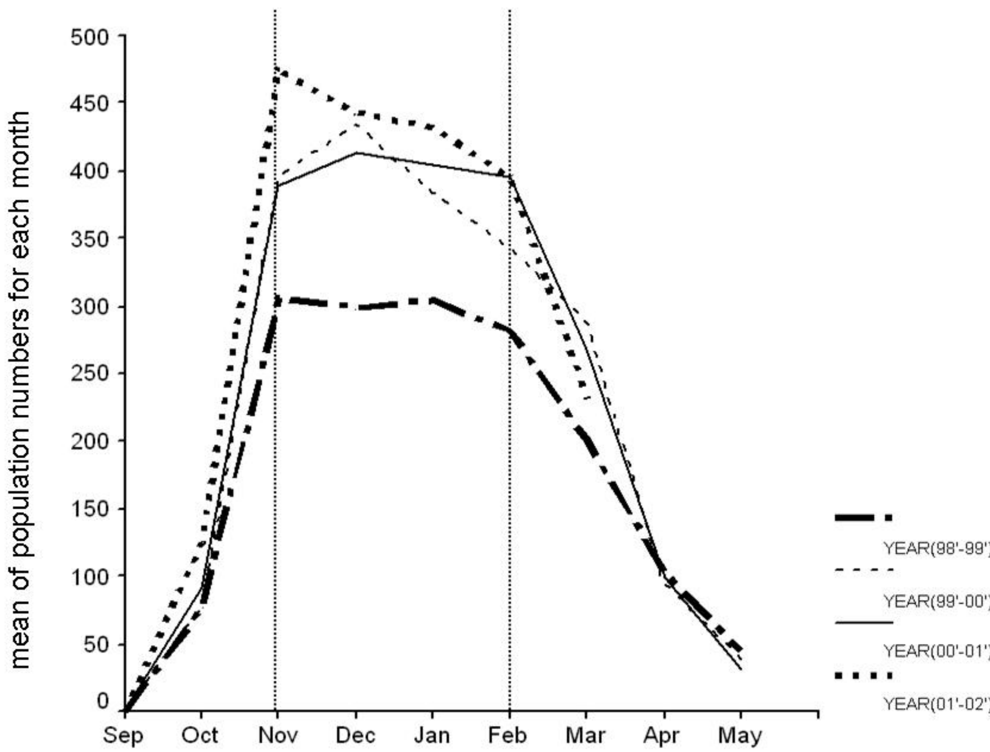

Fig. 3-3. The mean value of wintering Black-faced Spoonbills in Tainan areas.

Radio-tracking at daytime

In the winter of 1997-1998, I captured 4 Black-faced Spoonbills in January. In 1998 -1999 winter, eight BFS were captured after December. I tracked them in February and March in 1997-1998 and 1998-1999 to determine daytime movements. I found most BFS roosted in shallow-water habitats in daylight hours, only birds164.554, 164.774, 165.435, and164.206 had slight movement (Table 3-2).

Activity ranges based on visual observations and radio telemetry at night

All visual locations were integrated for the 3 winters (1998-1999, 1999-2000, 2000-2001) and nocturnal tracking locations were integrated for the 2 winters (1997-1998, 1998-1999) (Fig. 3-4). The activity ranges for the two time periods were 13,092 ha and 13,023 ha, respectively, using the Minimum Convex Polygon (MCP) computing method. Although the activity ranges appeared to be similar in size, they exhibited different shapes (Fig. 3-5, Fig. 3-6). Using the Kernel method to compute activity ranges for 3 levels of coverage (50%, 90%, and 95%), all ranges from the Kernel method were smaller than MCP method; even the 95%-level home range was smaller than the half of the MCP area (Table 3-3).

Spoonbills located by daytime observations concentrated on three circle areas by the Kernel method (Fig. 3-5), and located by radio tracking, spoonbills centralized in two circle areas by the Kernel method (Fig. 3-6). In addition, the Kernel-50% areas were only located inside the shallow lagoon (primary roosting site) habitat type (Fig. 3-5, Fig. 3-6).

Table 3-2. Radio tracking of Black-faced Spoonbills in daylight hours.

Frequency of radio transmitters	Tracking hours/days in February	Tracking hours/days in March	Percentage of stands without movement (February/March)	Date of capture
164.554*	19/112.7	10/47.7	99.6/100	12/22/97
164.614*	19/112.7	10/51.2	100/100	12/22/97
164.774*	19/112.7	10/51.2	100/97.1	12/27/97
164.294*	no signal	no signal	no signal***	01/04/98
164.295**	4/13.5	11/37	100/100	12/07/98
165.435**	4/13.5	11/37	100/98.6	12/07/98
164.206**	4/13.5	11/37	100/97.3	12/07/98
164.979**	4/13.5	11/37	100/100	12/07/98
164.103**	4/13.5	11/37	100/100	12/21/98
164.064**	4/13.5	11/37	100/100	12/21/98
164.153**	1/4	no signal***	100	01/13/99
164.180**	not captured yet	1/3, no signal***	100	03/12/99

* Tracking from1998 February to 1998 March.
** Tracking from 1999 February to 1999 March.
*** Transmitters malfunctioned.

Fig. 3-4. Locations of visual observations for the 3 winters (1998, 1999, and 2000), and locations of radio-tracking for the 2 winters (1997 and 1998).

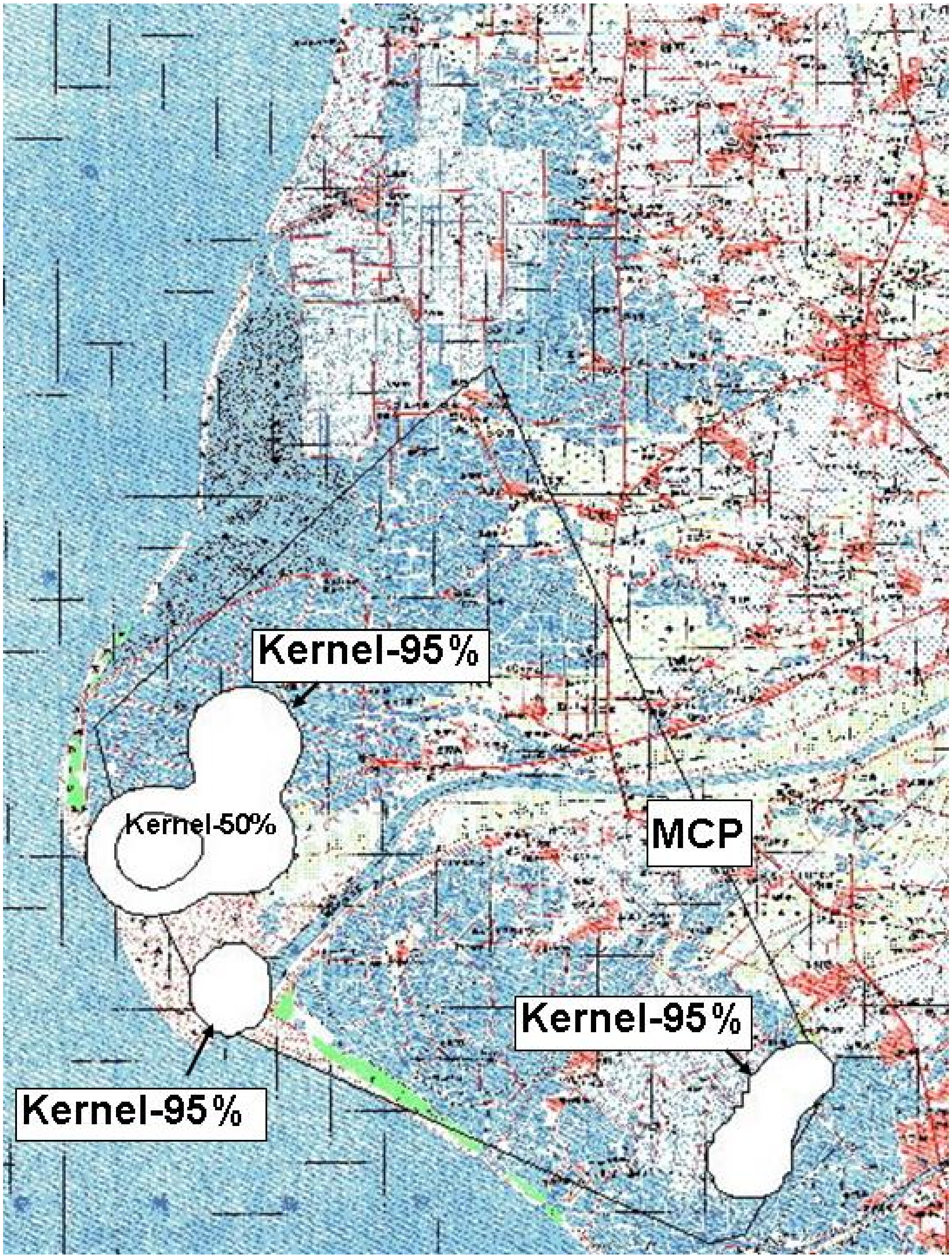

Fig. 3-5. Activity ranges of Black-faced Spoonbills for 3 years of daylight observations. Polygon areas were drawn by the Minimum Convex Polygon method, and white areas were drawn by the Kernel method. The small circle inside a larger one is calculated by Kernel-50%; other white areas are calculated by Kernel-95%.

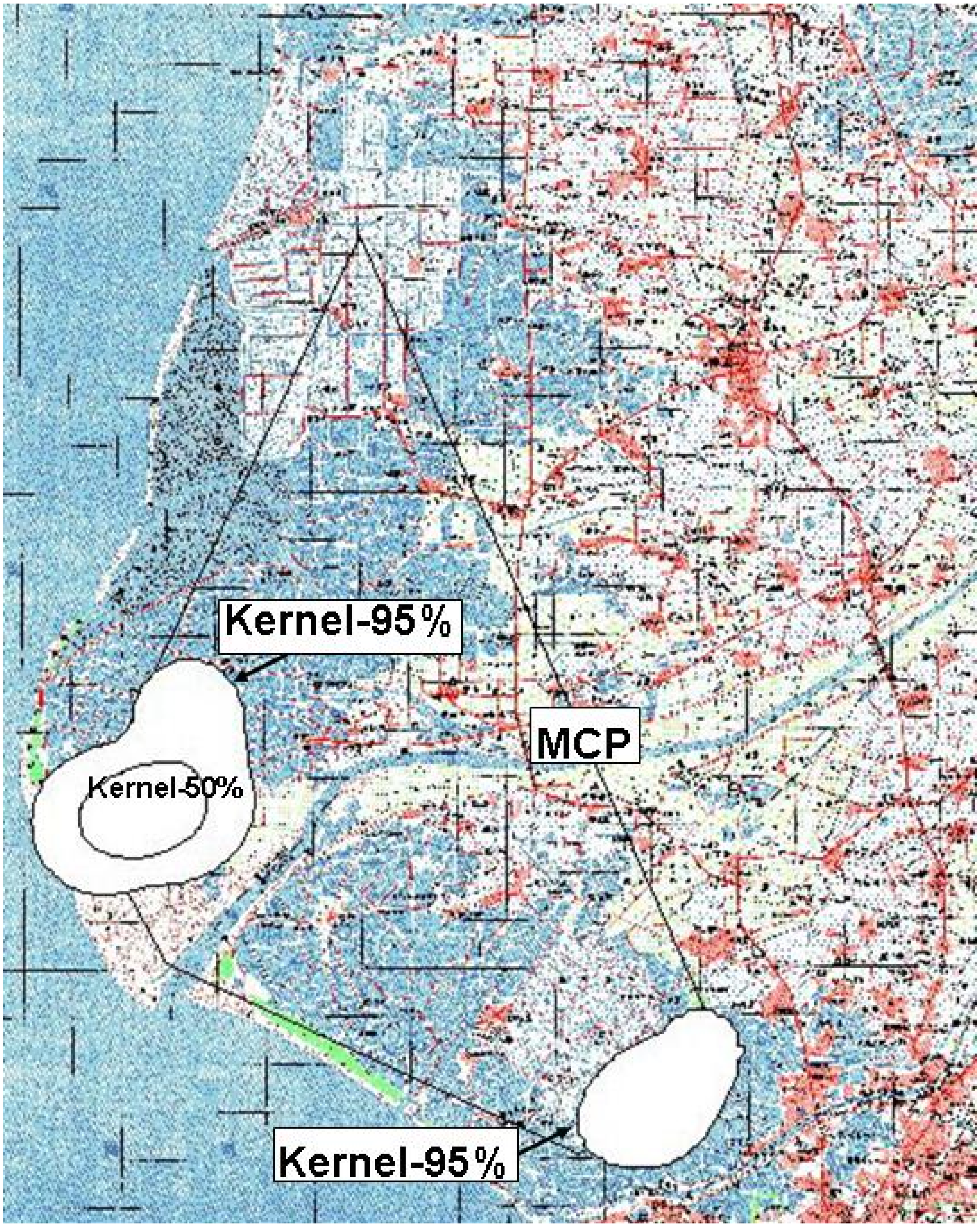

Fig. 3-6. Activity ranges of Black-faced Spoonbills for 2 years of radio-tracking. Polygon areas were drawn by the Minimum Convex Polygon method, and white areas were drawn by the Kernel method. The small circle inside the big one was calculated by Kernel-50%; other white areas were calculated by Kernel-95%.

Table 3-3. Activity ranges (ha) of Black-faced Spoonbills in different winter seasons.

BFS located	winter season	MCP*	Kernel **		
			50%	90%	95% (proportion of MCP)
observation	1998.9-1999.5 (N=338)	11572	188	951	1178 (0.10)
	1999.9-2000.5 (N=484)	9208	206	1448	1989 (0.22)
	2000.9-2001.5 (N=434)	9451	401	2021	2793 (0.30)
	locations of 3 years	13092	190	998	1816 (0.14)
radio-tracking	1997.12-1998.5(N=142)	11886	793	3913	5152 (0.43)
	1998.12-1999.5(N=328)	11444	364	1137	1824 (0.16)
	locations of 2 years	13023	420	1699	2409 (0.18)

* Activity ranges calculated by Minimum Convex Polygon method.
** Activity range areas calculated by Kernel method via 3 levels (50%, 90%, 95%).

Regardless of the method of calculation, the activity ranges size were larger in the latter period of the winter, than the initial months and from the peak stages from November to February (Table 3-4, Fig. 3-7, Fig. 3-8). Because I attached radios to birds after December, the locations were recorded only from December to May. Using the Kernel-95 calculation (Fig. 3-9) I also found that birds moved northwards at night in the later stage of the winter. However, the same trend of northward movement during daylight observations was not discernible (Fig. 3-10).

Use of habitat types

I used the Chi-square to test the frequency of spoonbills in each habitat type (Neu et al. 1974, Ott 1993). Although some of the habitat types, agriculture, channel, and lagoon, didn't have any spoonbill records, they do exist in our study area (Table 3-5). Therefore, I didn't exclude them from my calculations. After the calculations, spoonbill locations of visual observations in each habitat type differed significantly from the occurrence of habitat categories within the study area ($df = 10$, $P > 0.05$).

I found similar results regarding habitat use with radio-tracking ($df = 10$, $P > 0.05$). I found the fish pond habitat, composing 46.2% of study area, was the major area spoonbills used with 49.5% of observations during daylight hours and 71.9% at night. It is obvious that spoonbills used fish ponds frequently at night. But the most important habitat were the shallow lagoons, comprising only 1.3% of study area, but spoonbills frequency of use was 48.3% in daylight hours and 25.1% at night (Table 3-5). Other habitat types of the study areas were rarely used by BFS during daytime, such as 2.3% of

Table 3-4. Activity ranges (ha) of Black-faced Spoonbills in different winter stages.

BFS located	winter season	MCP** (ha)	Kernel*** 50%(ha)	Kernel*** 90%(ha)	Kernel*** 95% (proportion of MCP)(ha)
Observation (1998-2000)	early stage (Sep.- Oct.)	3904	127	552	722 (0.18)
	stable stage (Nov.- Feb.)	10578	207	1241	1994 (0.19)
	late stage (Mar.- May)	11690	414	1837	2612 (0.22)
Radio-tracking (1997-1998)	stable stage (Dec.- Feb.)*	10225	401	1327	2191 (0.21)
	late stage (Mar.- May)	12864	639	2744	4277 (0.33)

* Radio-tagging Black-faced Spoonbills were all banded after December. There were no data for radio tracking in early stages.

** MCP: Minimum Convex Polygon method.

*** Kernel probability density method can be computed by 3 levels (50%, 90%, 95%)

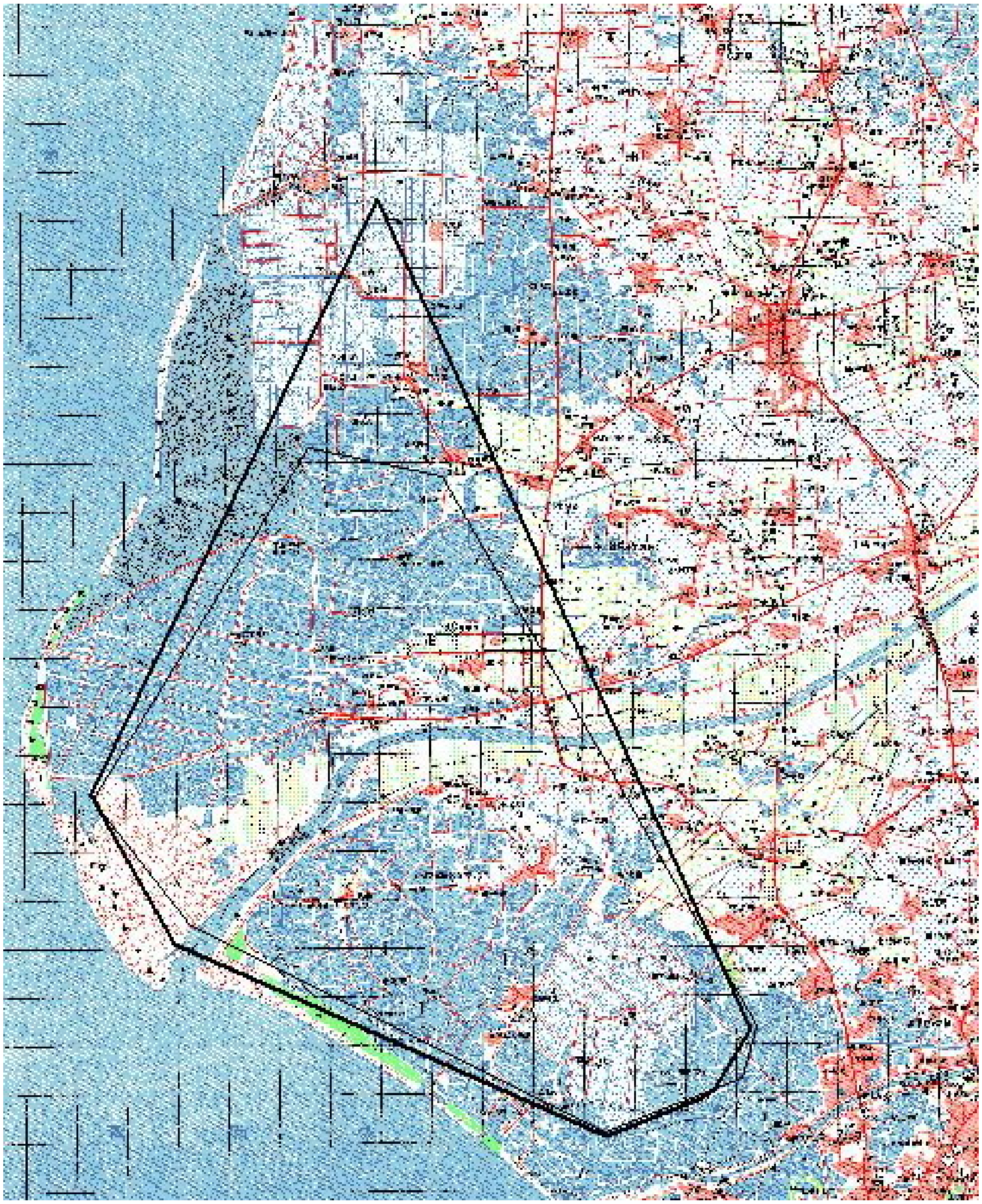

Fig. 3-7. Activity ranges of late stages (thicker line polygon) and stable stages (thinner line polygon) in wintering season from two years of radio telemetry. The activity ranges were calculated by the Minimum Convex Polygon method.

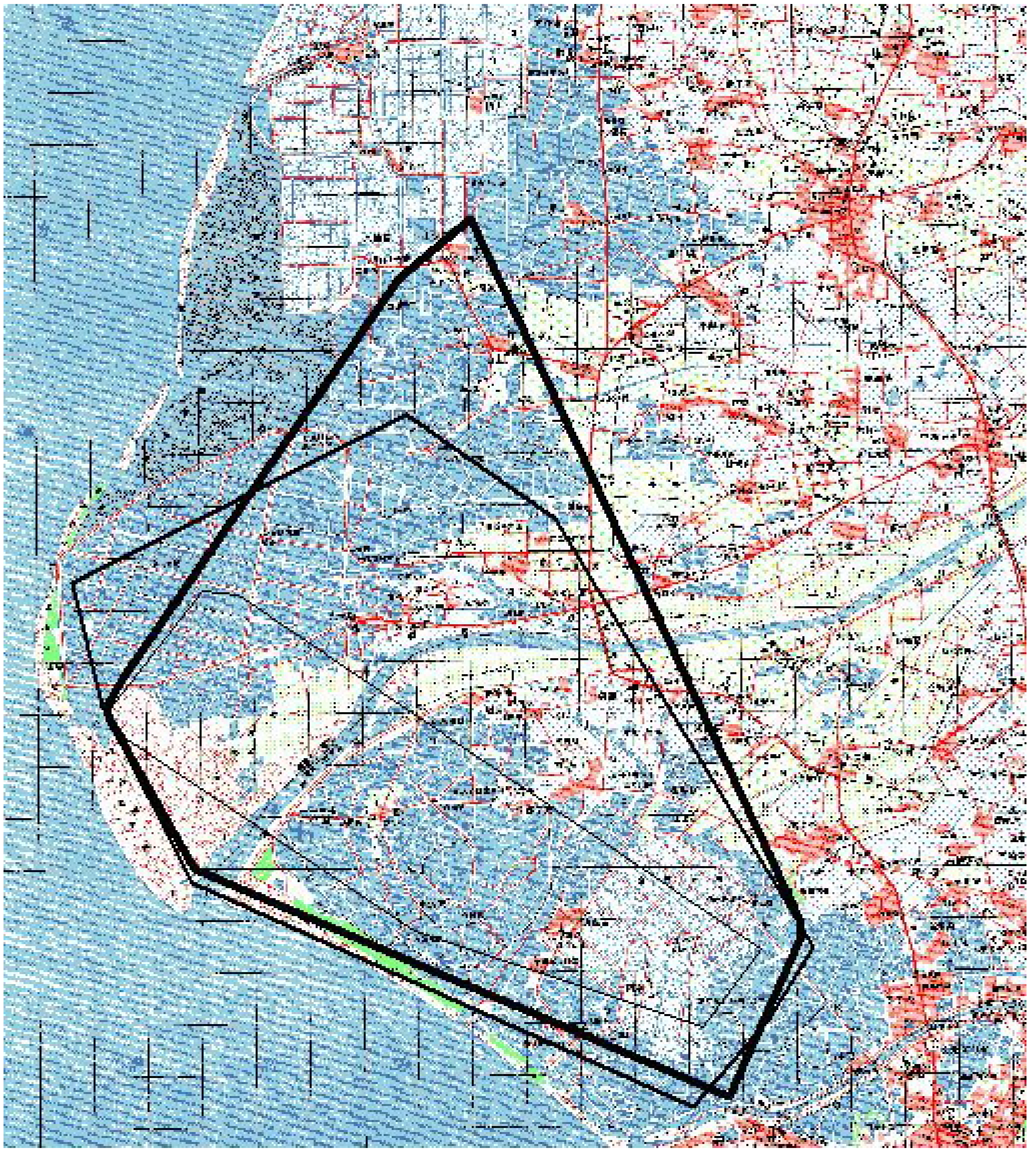

Fig. 3-8. Activity ranges of early stages (thin-lined polygon), stable stages (thick-lined polygon), and late stages (bold polygon) for the wintering season from three years of daylight observations. Activity ranges were calculated by the Minimum Convex Polygon method.

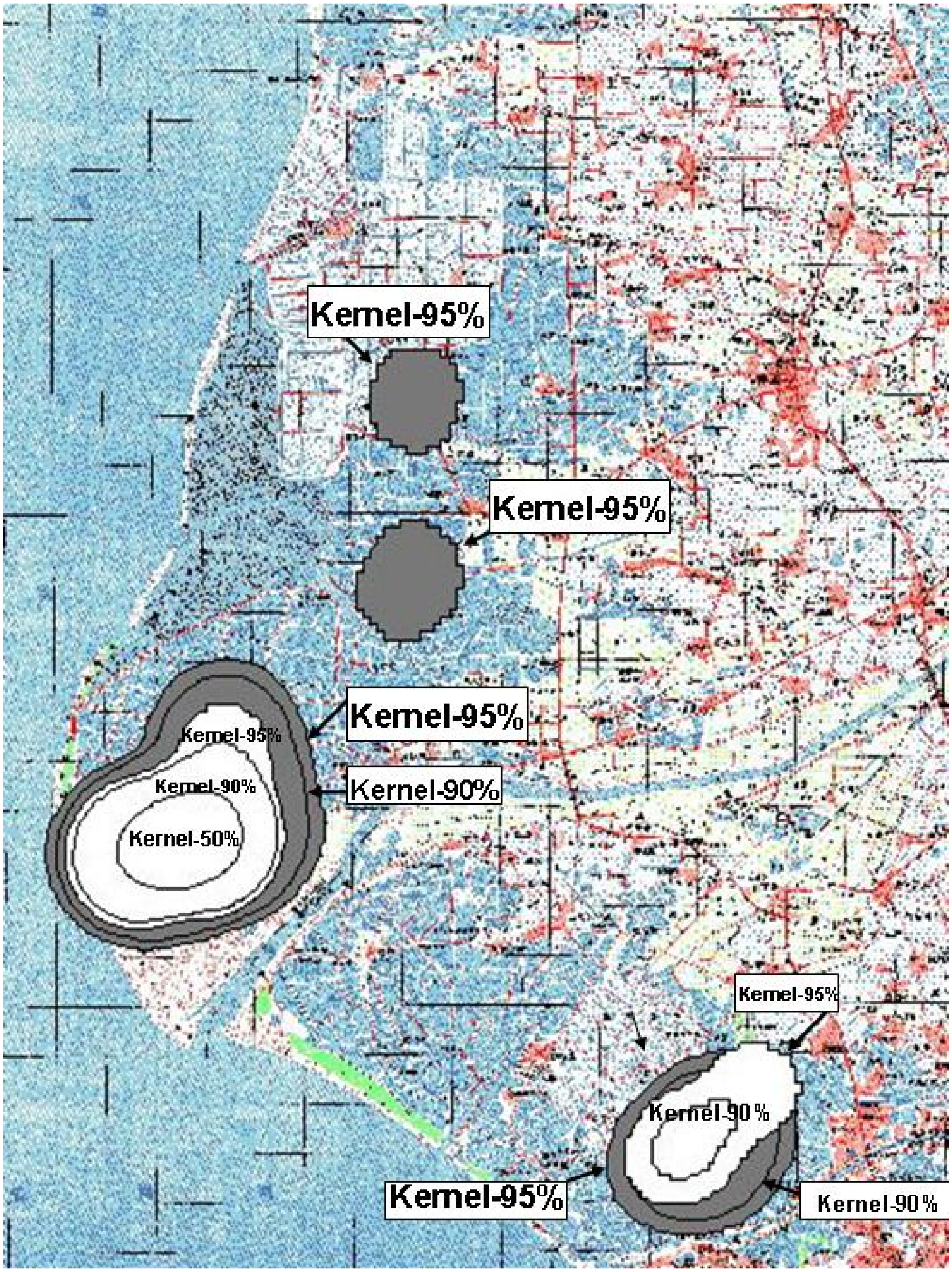

Fig. 3-9. Activity ranges of late stages (gray areas) and stable stages (white areas) in wintering season from two years of radio tracking at night. Two gray circles indicated that spoonbills moved north during late winter using 95%-Kernel method. The concentric circles were calculated by different Kernel levels (50%, 90%, 95%).

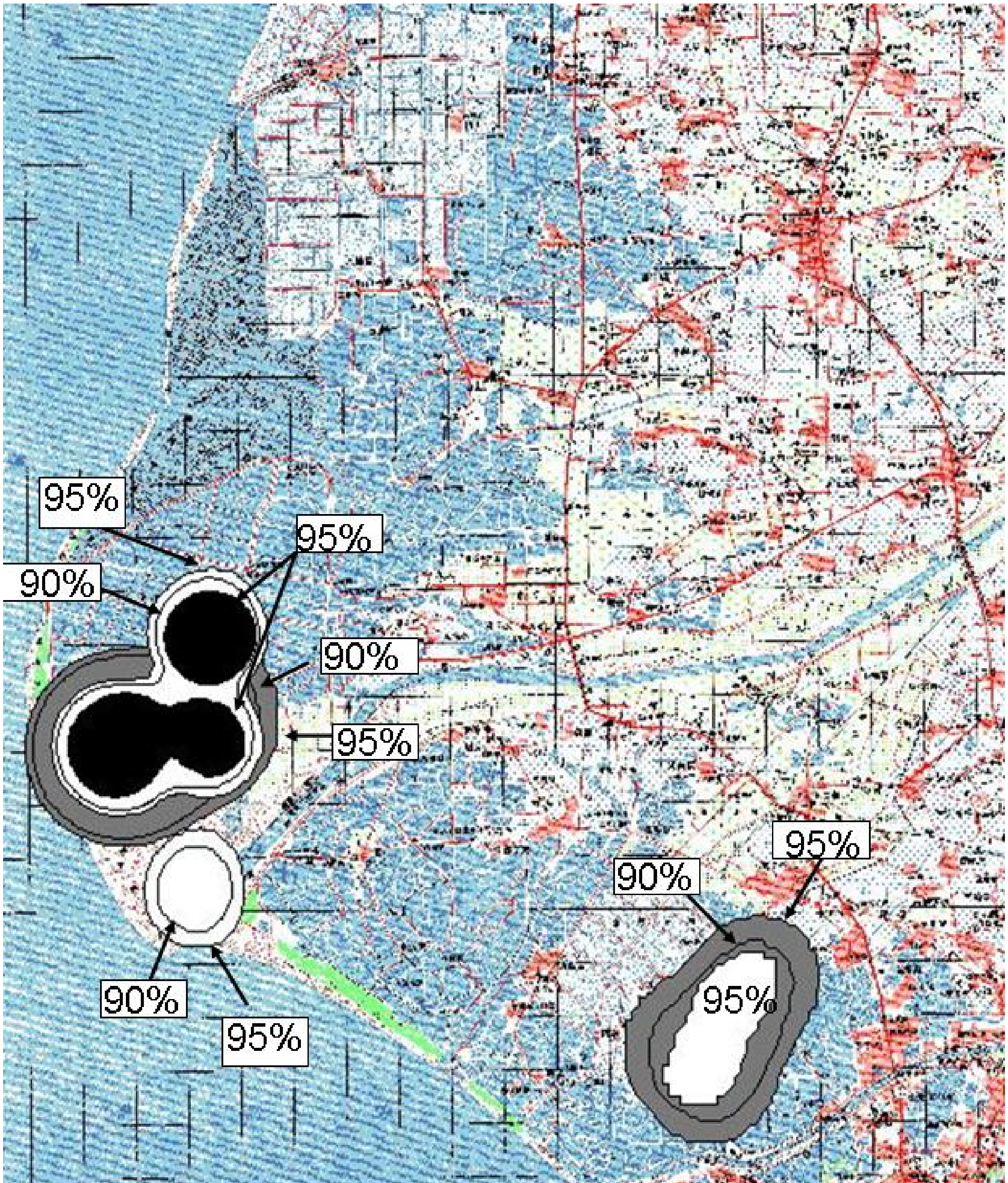

Fig. 3-10. Activity ranges of early stages (black areas), stable stages (white areas), and late stages (gray areas) in wintering season from three years of daylight observations. The concentric circles were calculated by different Kernel levels (50%, 90%, 95%).

Table 3-5. Habitat types and frequency of visual observations and radio-tracking locations of Black-faced Spoonbills.

Habitat types		Observation frequency (1998, 1999, and 2000 winter seasons)		Radio-tracking frequency (1997 and1998 winter seasons)	
types	percentage	frequency	percentage	frequency	percentage
agriculture	19.5	0	(0)	0	(0)
channel	0.5	0	(0)	0	(0)
estuary	4.1	29	(2.3)	3	(0.6)
fish pond	46.2	622	(49.5)	338	(71.9)
industrial site	3.5	4	(0.3)	0	(0)
lagoon	7.6	0	(0)	0	(0)
wildlife reserve	2.6	24	(1.9)	4	(0.9)
river(Tseng-Wen River)	1.7	18	(1.4)	0	(0)
salt pond	11.9	0	(0)	6	(1.3)
shallow lagoon (primary roosting site)	1.3	549	(43.8)	118	(25.1)
trees	1.2	10	(0.8)	1	(0.2)
Total frequency	(100)	1256	(100)	470	(100)
Total area (ha)	22508				

*Chi-square analysis,
habitat use by BFS (visual observation frequency) was not in proportion to its availability (df =10, P > 0.05)
habitat use by BFS (radio-tracking frequency) was not in proportion to its availability (df=10, P > 0.05)

total visual locations in the estuary, 0.3% on the industrial site, 1.9% in the wildlife reserve, 1.4% in the river, and 0.8 in trees. And similarly some habitat types were rarely used by BFS at night, such as 0.6% of total radio-tracking locations in estuary, 0.9% in wildlife reserve, 1.3% in salt ponds, and 0.2% in trees (Table 3-5).

DISCUSSION

Monthly changes of Black-faced Spoonbill populations in the winter season

Black-faced Spoonbills increased in numbers on the study area in September and October as birds arrived from their breeding grounds on the small islands of Yellow Sea and the Korean Peninsula. Peak numbers were reached and were relatively stable beginning with the period, November-February. For the 4 years of the study, November-February represented the most stable stage in terms of variation in population numbers. As a result of stable population-levels, the international synchronized survey was held in middle January (Dahmer and Felley 2000, Yu 2003b, Yu 2004). Furthermore, from March to May population numbers declined sharply until all birds left for the breeding areas (Chen 2003).

Differences between MCP and Kernel methods

Activity ranges calculated by Minimum Convex Polygon (MCP) and Kernel methods were different for determining the scope of spoonbill activities. Because the

Minimum Convex Polygon method links all outermost locations, activity ranges were larger than actual activities of animals (Bray et al. 1975, White and Garrott 1990). The Kernel method estimated home ranges by calculating the probability of a given density of locations. As the locations become more centralized, use circle areas became smaller (Worton 1989, Seaman and Powell 1996). In this study, the locations of visual observations were concentrated in 3 areas, primary roosting site, estuary, and wildlife reserve (Fig. 3-5), and the locations of nocturnal radio-tracking were centralized in 2 areas, primary roosting site and the wildlife reserve (Fig. 3-6). Therefore, activity ranges calculated by MCP did not focus on the most frequently used habitats.

I found that spoonbills in late stages of the winter season had larger activity ranges than middle and early stage using either visual observations or nocturnal radio-tracking (Fig. 3-7, Fig. 3-8). I also found that locations of spoonbills changed in late winter, with nocturnal movements taking place further north (Fig. 3-9). Wang and Chen (1997) also mentioned that spoonbills moved northward from fish ponds after February. It appears from this study that spoonbills become more active in late season while preparing to migrate north for the coming breeding season.

Most radio-tagged spoonbills stayed in one habitat during daylight hours, with occasional movement to other habitats (Fig. 3-2). Previous studies have arrived at similar conclusions that spoonbills spent 80%- 93% of daytime resting (Wang and Wang 1997, Wang 2001). Hence land protection should ensure that habitats for resting during daylight hours should be included for protection as well as areas used for foraging.

With three years of visual observations, I found that 43.8% of total locations were at a roost on the north side of the Tseng-Wen River, an artificial shallow lagoon. Similarly, two years of radio telemetry locations indicated 25.1% of total locations were at the shallow lagoon used for roosting. The shallow lagoon, also known as the primary roosting site, was important for spoonbills primarily in daylight hours. The local government-sponsored BFS Protection Area includes areas of roosting (TCG 2002). However, the protected area was the principal site for resting, not particular for foraging.

Fish ponds around the primary roosting site and wildlife reserve

Mudflats and fish ponds were the major habitats identified in historical records (Yen et al. 1994, Lee et al. 1995). My data supported their conclusion. In this study, the shallow lagoon and fish ponds occupied 93.3% (daytime observation) and 97.0% (nocturnal radio-tracking) of habitats used (Fig. 3-2). There was no doubt that spoonbills depend on fish ponds and shallow lagoons, also the primary roosting site, during their stay in Taiwan.

Furthermore, nocturnal tracking for fish-pond use accounted for 71.9% of locations and 49.5% of visual locations in daylight hours. Hu and Wang (1995) reported that spoonbills spent 64% of their time feeding at night using moonlight in fish ponds. Using the Kernel-95% home ranges, I found that two major fish pond areas around the primary roosting site and wildlife reserve were used (Fig. 3-2, Fig. 3-9, Fig. 3-10). I suggest that further feeding studies should focus on these two protected areas.

CHAPTER IV

FOOD ABUNDANCE OF FISH PONDS USED BY BLACK-FACED SPOONBILLS AT CHI-KU, TAIWAN

INTRODUCTION

Black-faced Spoonbill (BFS), *Platalea minor*, is one of six species of spoonbills found globally (Del Hoyo et al. 1992, Hancock et al. 1992), and is distributed in east Asia, with Taiwan serving as a major wintering site (Kennerley 1990, Dahmer and Felley 2000, Yu 2004). Because of low population size, the BFS was regarded as threatened or endangered species (Groombridge 1993, IUCN 1997, Collar et al. 2001). Recent records show that more than 50% of the total BFS population winters in Taiwan (Yu 2003b and 2004) with 96% of wintering BFS in Taiwan found in Tainan City and Chi-Ku town. The concentration of BFS in southern Taiwan is the most concentrated aggregation of BFS in Asia (Table 2-2).

Many studies have reported that the BFS feeds on fish as do other species of spoonbill of the genus *Platalea* (Hu and Wang 1995, Severinghaus et al. 1995, Collar et al. 2001). For example, fishes are the major food items of Roseate Spoonbills, *Platalea ajaja*, (Allen 1942, Kushlan 1978, Lewis 1983, Hancock et al. 1992) and the Eurasia Spoonbill, *Platalea leucorodia* (Kemper 1985 and 1995, Van Wetten et al. 1986, Aguilera et al. 1996). However, there has been little research about the food of BFS in its wintering areas. One record of BFS stomach material was collected from a spoonbill killed by gunshot (Hsueh et al. 1993), and other stomach materials were checked from over 40 spoonbills that died of botulism (Shiau et al. 2003). In these analyses, fish bones were the most prominent remains.

Electro-fishing in shallow waters such as that where spoonbills forage has been used to evaluate the availability of potential prey (Kolz and Reynolds 1989). Electro-fishing has been shown to be an effective method to harvest shrimp as well as fish (Hu and Wang 1995). Other methods for collecting fish have been also reported, such as small sample nets, 80x40 cm^2 (Kemper 1985 and1995), or fish sample traps, $1m^2$- $4m^2$ (Kushlan 1974). Electro-fishing and use of small nets have both been used for small water impoundments. The average size of fish ponds used by BFS ranged from 0.5 ha to 10 ha (Wang and Chen 1997).

Black-faced Spoonbills feed in shallow water areas (Young and Chan 1997) with water depth ranging between 1 and 30 cm (Hu and Wang 1995, Yu and Swennen 2004). Wang and Chen (1997) reported that BFS at Chi-Ku, Taiwan, might have moved northward for foraging at night after January. Similarly, in another study, the BFS had larger activity ranges and moved northward in late stages of wintering seasons (Chapter III). In this study, fish biomass and body size of prey were collected in different stages to estimate the food abundance at Chi-Ku fish ponds.

METHODS

Fish sampling in ponds used by Black-faced Spoonbills

The RAMSAR Wetland Convention mentioned that habitats used by one percent of the population of an endangered species of wetland birds should be protected (UNESCO 1971). The BFS was regarded as a threatened or endangered species (Groombridge 1993, IUCN 1997, Collar et al. 2001). And because global numbers of BFS were 613 and 587 in 1998 and 1999, respectively (Chapter II), the RAMSAR one percent criterion for the BFS population was easily surpassed (criterion level equals six or more). Therefore, fish ponds used for foraging by at least six BFS were selected to collect fish samples during these two winter seasons. A bag seine fishing net, 11 m x 11 m, was designed for collection of from fish ponds at Chi-Ku, with 0.2cm x 0.2cm mesh to capture small fish, and with four steel poles on the corners to hold the net steady (Fig. 4-1). This method sets the fish net on to the bottom of the shallow-water impoundment. During the process of setting the net in place, prey species were potentially disturbed. After the turbidity of the water column subsided, or at least one hour later, four research assistants walked slowly toward the net poles and pulled up on the fish net simultaneously (Fig. 4-2), thus capturing potential prey items.

Measurement of prey items

All fish ponds used by BFS were harvested by fishermen during the winter season at Chi-Ku when the water depth was suitable for foraging of long-legged waders

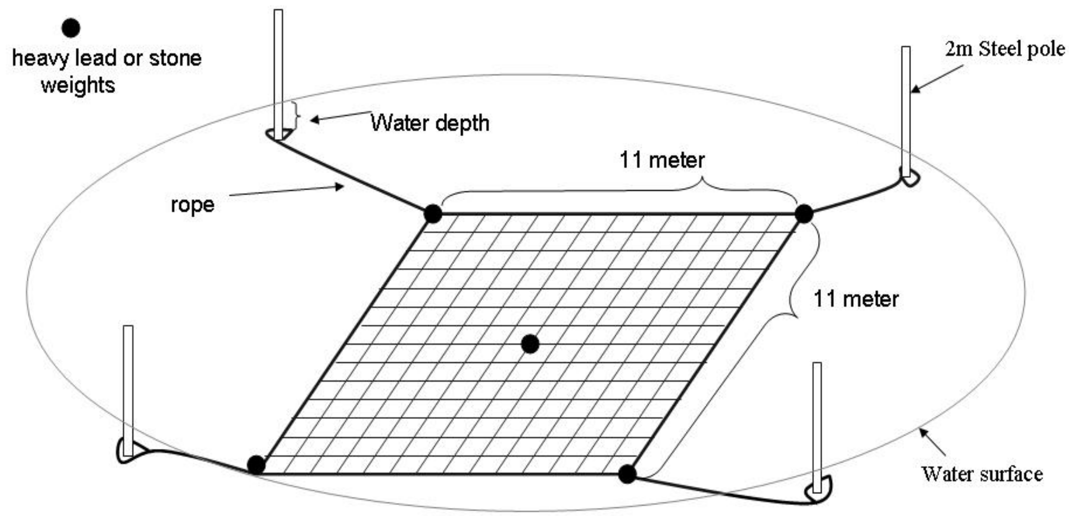

Fig. 4-1. Net used for capture of fish in shallow fish ponds (area of fish net = 121 m^2 ; mesh cell= 0.2 cm x 0.2 cm).

Fig. 4-2. Collecting prey items in BFS feeding ponds. 1. setting nets 2. collecting. (photo courtesy of J. Z. Tsai)

(Hu and Wang 1995). Body size and weight of fish were measured in middle and late stages of winter seasons, and similar size of prey items were put together to obtain total biomass in all potential prey fish ponds. I used six size classes of potential prey based on data (<10 cm, 10-12 cm, 12-14 cm, 14-16 cm, >16 cm) from a wounded, captive spoonbill (Yao et al. 1995), and the sizes classes of potential prey (ranging from 2 cm to 10 cm observed in the field by Huang (2000). The six size classed used in this study were < 5 cm, 5-10 cm, 10-12 cm, 12-14 cm, 14-16 cm, and >16 cm. I also classified fish weight into 8 categories(<5 gm, 5-10 gm, 10-20 gm, 20-30 gm, 30-40 gm, 40-50 gm, 50-60 gm, and > 60 gm) following work by Yao et al. (1995). Therefore, I could understand the size of potential prey at fish ponds compared to the size of prey selected by the captive bird.

I separated all potential food items into 4 major groups following Chen (2003), Shao (2004), and the experience of fishermen at Chi-Ku town. Fish species in ponds included tilapia (*Tilapia* spp.), mosquitofish (*Gambusia affinis*), shrimps (*Palaemon carincauda*, *Penaeus monodon*), and gobies (Gobiidae family, *Rhinogobius* spp.).

Biomass of fish and analysis

To evaluate the change of prey biomass around the primary roosting site (shallow lagoon, BFS protection area), shallow fish ponds were chosen randomly for biomass assessment (per fish net) by month in the winter of 1998.

Middle wintering stage, November-February, in Taiwan was regarded as the stable population-level stage compared to early, September-October, and late stage, March-May. The late stage reflected dramatic changes in numbers of spoonbills as birds departed Taiwan for migration to breeding areas (Chapter III). A T-test was used to analyze differences between stable and late stages in this winter. Comparisons of mean biomass were tested in the stable and late stages.

RESULTS

Sizes of prey at Chi-Ku fish ponds

I measured the length and weight of all prey items of 30 fish sampling nets, 15 in late stage and 15 in the stable stage, of 1998 and 1999 winters. The 2 smallest category sizes (< 5 cm and 5-10 cm) occurred in the highest proportion, 95.5%, during the stable stage, while 97.6% of the same categories were present during the late season (Table 4-1). These category sizes did not represent the highest biomass during the stable stage. However, they did represent the highest biomass during the late stage (Table 4-1). During the stable population-level stage, the main components were the 4 smallest categories of prey items (weighing less than 30 gm) which made up 56% of the potential diet (Table 4-2). The same categories represented even a higher proportion of the diet (93.7%) during the late stage (Table 4-2).

Four prey items found at Chi-Ku fish ponds were used by BFS. Data from 30 fish sampling nets, mosquitofish had the highest frequency of occurrence (6882) and Tilapia made up the greatest biomass (92.9% in late, and 75.4% in stable) (Table 4-3).

Table 4-1. Numbers and biomass of BFS prey categorized by length at fish ponds in two winter periods (1998 winter and 1999 winter) at Chi-Ku.

	Stable population-level stage of BFS wintering * (November-February)				Late stage of BFS wintering ** (March-May)			
length categories (cm)	prey numbers	(%)	prey biomass (gm)	(%)	prey numbers	(%)	prey biomass (gm)	(%)
<5	5279	(68.9)	1879.5	(7.7)	3921	(81.3)	1839.6	(22.4)
5-10	2041	(26.6)	8326.9	(34.2)	784	(16.3)	3994.3	(48.8)
10-12	154	(2.0)	3305.6	(13.6)	94	(1.9)	1681.1	(20.6)
12-14	84	(1.2)	2995.5	(12.3)	17	(0.4)	544.0	(6.7)
14-16	53	(0.7)	2770.0	(11.4)	3	(0.1)	121.0	(1.5)
>16	49	(0.6)	5096.0	(20.8)	0	(0)	0.0	(0)
total	7660	(100)	24374.5	(100)	4819	(100)	8180.0	(100)

* Stable population-level stage: fishnet sampling at 15 fish ponds in 1998 and 1999 winters.

** Late stage: fishnet sampling at 15 fish ponds in 1998 and 1999 winters.

Table 4-2. Numbers and biomass of BFS prey categorized by weight at fish ponds in two wintering stages (1998 winter and 1999 winter) at Chi-Ku.

	Stable population-level stage of BFS wintering * (November-February)				Late stage of BFS wintering** (March-May)			
weight categories (gm)	prey numbers	(%)	prey biomass (gm)	(%)	prey numbers	(%)	prey biomass (gm)	(%)
<5	6678	(87.2)	4459.2	(18.3)	4345	(90.2)	2701.5	(33.0)
5-10	481	(6.3)	3499.1	(14.4)	254	(5.3)	1779.2	(21.8)
10-20	220	(2.9)	3193.9	(13.1)	161	(3.3)	2126.8	(26.0)
20-30	101	(1.3)	2485.7	(10.2)	45	(0.9)	1057.0	(12.9)
30-40	59	(0.8)	2000.1	(8.2)	9	(0.2)	301.0	(3.7)
40-50	40	(0.5)	1767.0	(7.2)	5	(0.1)	214.5	(2.6)
50-60	20	(0.2)	1087.5	(4.5)	0	(0)	0.0	(0.0)
> 60	61	(0.8)	5881.0	(24.1)	0	(0)	0.0	(0.0)
Total	7660	(100)	24374.5	(100)	4819	(100)	8180.0	(100)

* Stable population-level stage: fish sampling at 15 fish ponds in 1998-1999 winters.
** Late stage: fish sampling at 15 fish ponds in 1998-1999 winters.

Table 4-3. Numbers and biomass of 4 prey items in wintering, Chi-Ku, Taiwan.

Prey items*	Stages of winter**	numbers	(%)	Biomass (gm)	(%)	Mean±S.D. (length)	Mean±S.D. (weight)	T-test*** (mean of length)	T-test*** (mean of weight)
Mosquitofish	Stable	3020	39.4	785.1	3.2	3.84±0.80	0.35±0.16	P=0.024	P<0.001
	Late	3862	80.1	1944.9	23.8	3.76±1.40	0.72±1.82		
Goby	Stable	1746	22.8	614.0	2.3	2.83±0.77	0.26±0.47	P=0.001	P<0.001
	Late	27	0.6	19.4	0.1	3.00±0.87	0.50±0.54		
Shrimp	Stable	712	9.3	357.1	1.6	4.03±1.07	0.50±0.27	P=0.896	P=0.725
	Late	86	1.8	57.7	0.7	4.19±1.19	0.67±0.68		
Tilapia	Stable	2182	28.5	22617.3	92.9	6.95±3.08	10.37±18.51	P=0.383	P<0.001
	Late	844	17.5	6158.0	75.4	6.34±2.98	7.30±7.19		

* Mosquitofish (*Gambusia affinis*), Goby (Gobiidae family, *Rhinogobius* spp.), Shrimp (*Palaemon carincauda, Penaeus monodon*), Tilapia (*Tilapia* spp. and *Oreochromis hybrids*).

** Stable stage: November-February. Late stage: March-May.

*** T test was used to compare means of length and weight between stable and late.

Three categories of prey items, excluding the shrimp category, had significant differences in mean weight comparisons (T-test, $P< 0.001$) between stable and late stages (Table 4-3). However, I found no significant differences in comparisons of mean prey length in all prey categories (Table 4-3). I also found that the relation between weight and length of prey at wintering Chi-Ku fish ponds fitted the quadratic equation. ($Y = 0.445 X^2 -3.083 X + 5.411$, $P < 0.001$, $R^2 = 0.963$) (Fig. 4-3).

Biomass of prey around primary roosting site

Prey biomass of 28 fish ponds was measured (Fig. 4-1) during November of 1998 to February of 1999. In late stage of BFS wintering population from March to April in 1999, biomass was counted with the same fish net in 13 fish ponds. The biomass was relative low in late stage compared to the stable population-level stable in November to February (Fig. 4-4). Although the biomass ranged widely at fish ponds, monthly mean differences of biomass between the stable population-level stage and the pre-migration stage produced significant differences (t-test, $P = 0.005$, Table 4-4).

DISCUSSION

Fishing net and body size of prey items

The fish-capture method used in this study minimized the disturbance to fish and shrimp in the water. Not only did the fish net have a larger catching area than other methods,

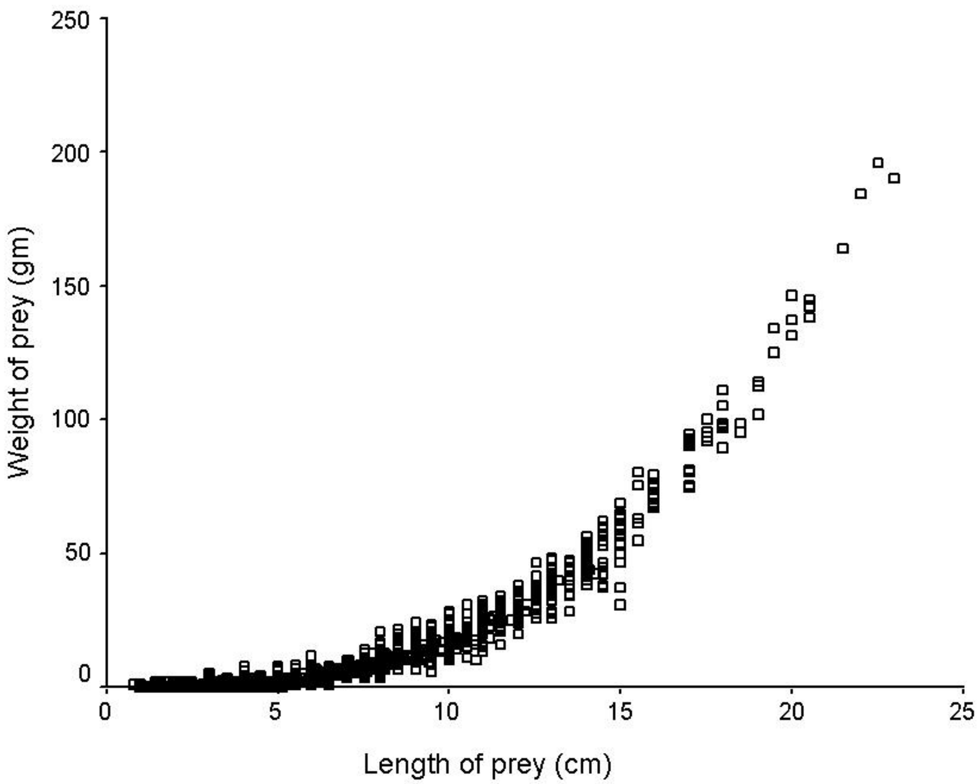

Fig. 4-3. Correlation between potential prey weight and prey length of Black-faced Spoonills in the winter seasons of 1998 and1999, Chi-Ku, Taiwan. (N=12,479) (quadratic equation: $Y = 0.445 X^2 - 3.083 X + 5.411$, $P < 0.001$, $R^2 = 0.963$).

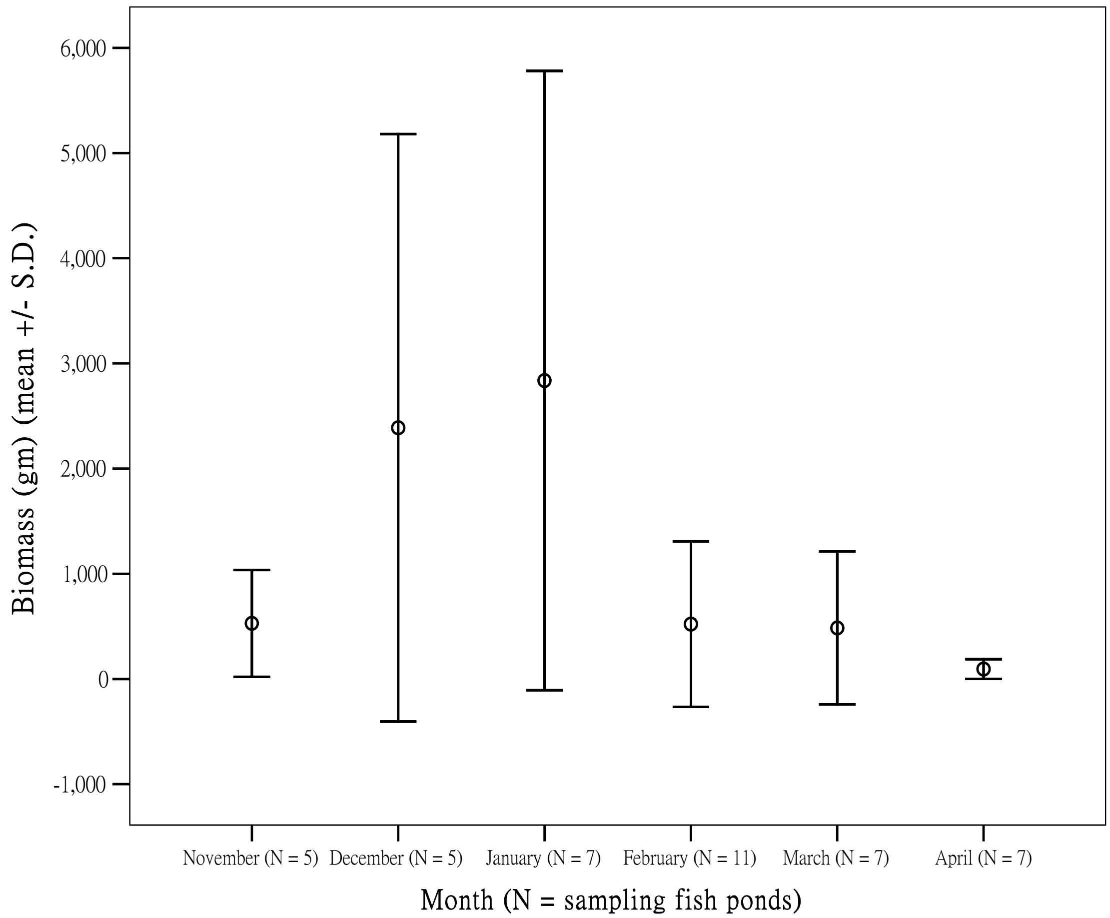

Fig. 4-4. Biomass of fish sampled in fish ponds adjacent to core roosting site at Chi-Ku in different months in the winter season of 1998.

Table 4-4. Means (Standard Deviation S.D.) of biomass at fish ponds located adjacent to BFS core-roosting site (primary roosting site) of Chi-Ku town in 1998.

wintering stage	Sampling fish ponds	means of biomass per fish net (gm)*	S.D.
Stable population-level (November-February)	28	1434.9	2125.6
Late (March-April)	13	304.9	556.7

*T-test used to compare means of biomass in different stages, P = 0.005.

but also I could use the method on flats throughout fish ponds of Taiwan. Although the electro-fishing and small fish traps (sampling) may collect prey items at small areas (Kolz and Reynolds 1989, Hu and Wang 1995), these methods can not quantify the biomass in large fixed areas.

According to the records of a captive BFS (Yao et al. 1995), fish with less than 10 cm length and less than 30 gm were the primary sizes and weights selected by this bird. My sampling results showed that more than 95% of prey were in the two smallest size categories (<5 cm and 5-10 cm), and more than 56% of prey during stable population-level stage and 93.7% of prey during late stage within the four smallest weight categories (< 5 gm, 5-10 gm, 10-20 gm, 20-30 gm). During the 15 most recent years (1990-2004) more than 50% of the global BFS population remained in Chi-Ku and Taiwan, each year (Table 2-2). It appears that optimal food size and weight of fish in the selected foraging ponds may account for the choice wintering spoonbills at Chi-Ku, Taiwan.

Proportion of prey items

The four categories of potential prey items were defined based on experiences of local fishermen and exotic species fish research (Chen 2003). Tilapia made up the largest biomass of potential prey during the entire season, while mosquitofish became more important in the pre-migratory season (3.2%-23.8%). These two prey items represented 96.1% (stable wintering stage) and 99.2% (late wintering stage) of total biomass in the fish ponds. Although the remaining two prey items, shrimps and gobies, were minimal in weight at fish ponds, their numbers represented 32.1% of total items in the stable population period. Future research should evaluate the diet of the BFS by collecting droppings of BFS in dried fish ponds and evaluate the droppings for fish bones or fish scales similar to the research conducted in breeding birds of the DMZ on the Korean Peninsula (Kim 2005). Although the species of BFS food may not be the most important in numbers or biomass, the energy intake and biomass of prey might be important for migratory birds (Van Wetten and Wintermans 1986, Kersten et al. 1991, Alerstam 1993).

Biomass of fish around the core roosting site

The biomass of fish ponds around BFS primary roosting site changed during different months of the winter at Chi-Ku (Table 4-4). The late stage, March-April, had less food compared to the stable population period in November to February at the core area which is the primary roosting site. As birds need more food to store energy by fat accumulation prior to migration (Alerstam 1993, Whittow 2000), the decline in food in this pre-migratory period might account for the movement of spoonbills further away from the roosting site for foraging. The decline in food available in the study ponds is supported by this study (Chapter III) in which the activity ranges of wintering BFS at Chi-Ku, Taiwan became larger in late stages.

CHAPTER V

CONCLUSIONS

Population numbers of BFS in Taiwan and Hong Kong have increased steadily over the 15-year period 1990-2004. Taiwan accounted for more than 50% of the total non-breeding population of BFS each year (1990-2004) with 96% of spoonbills in Taiwan found in Chi-Ku town and Tainan City. Continued growth of BFS populations in Taiwan suggests that populations have not reached carrying capacity yet. As a result, the growing numbers of BFS in Taiwan suggests continued pressure to protect quality spoonbill foraging and roosting habitats in the vicinity of Chi-Ku town and Tainan.

Spoonbills molt to yellow plumage around the head and neck when sexually mature. This molt occurs annually prior to migration back to the breeding grounds. The percentage of birds exhibiting the sexually mature yellow plumage within any one year was described by the quadratic regression curve with high a correlation coefficient. Because the proportion of breeding-aged adults remained relatively constant during the non-breeding season and the trend of increasing numbers with similar ratios of adult to non-adult birds, the population of BFS appears to be healthy.

I evaluated the known mortality factors of BFS using historical documents from 1849 to 2004. During this 155-year period, several mortality factors were documented and with the exception of the 73 spoonbill deaths associated with avian botulism in 2002, no more than four birds were lost to known mortality factors in any one year. Because of the potential toxic effects of avian botulism, factors favorable to the growth of botulism should be minimized in fish ponds. Avian flu is another potential disease of birds currently found throughout Asia and it is difficult to control. The H5N1 virus has been found recently in Asia, and the virus has caused mortality in Anseriforms and domestic chickens, and could cause mortality in Ciconiiform birds, includes egrets, storks, and spoonbills. The BFS is a potential victim because spoonbills associate with egrets and other Ciconiiform birds.

Black-faced Spoonbill population numbers increased sharply from September to October. From November to February, population numbers remained stable as peak numbers are reached. Migration began during March and the numbers of BFS declined sharply with birds disappearing by late May. My three winter stages included early (September-October), stable population-level (November-February), and late (March-May) stages. I located and counted BFS by visual observation during daylight hours where observations were conducted using telescopes. In addition to visual observations, radio-tagged BFS were tracked to locate habitat types used by the birds and assess the extent of the activity ranges at night. Information obtained from both visual observations and radio telemetry showed that habitat use was not in direct proportion to its availability. Mudflats and fishponds were the major habitats identified in historical records and my data supported this conclusion.

The GIS software mapped BFS locations during the winter in Taiwan and computed activity ranges of BFS during stable and late stages. Visual observations as well as radio-tracking data, computed by both Kernel and MCP drawing methods, showed that spoonbills have larger activity ranges during the late stage (pre-migration period) when compared to the size of stable population-level stage activity ranges. The MCP method consistently produced a larger activity range which did not represent the core area or or areas of high density use by spoonbills. Changes in fish biomass in spoonbills habitats showed that the abundance of small prey around the roost site and core area decreased significantly during the late stages of winters (March-May).

Biomass of prey was measured after capture by a fish net (121 m^2). This technique was effective in habitats over large areas, produced minimal prey disturbance, and was easy to quantify. Four primary food items existed in fish ponds used by fishermen. Tilapia made up the largest biomass throughout the entire winter. Prey items less than 5 cm in length and less than 30 gm in weight were found in the highest proportion at fish ponds of Chi-Ku town where BFS form large feeding aggregations. Indoor observations of a captive spoonbill found similar sized (length and weight) categories were preferred (Yao et al. 1997). Because fish ponds located in Chi-Ku support quantities of fish throughout the winter compared to fish ponds of other wintering places, I believe that spoonbills will come back to Chi-Ku every winter.

LITERATURE CITED

Aguilera, E., C. Ramo, and C. Court. 1996. Food and feeding sites of Eurasian spoonbill (*Platalea leucorodia*) in southwestern Spain. Colonial Waterbirds **19** (special Publ 1):159-166.

Alerstam, T. 1993. Bird migration. Cambridge University Press, Cambridge, UK.

Allen, R. P. 1942. The roseate spoonbill. National Audubon Society, New York, New York, USA.

Amlaner, C. J., R. Jr. Sibley, and R. McCleery. 1978. Effect of transmitter weight on breeding success in herring gulls. Biotelemetry **5**:154-163.

Anderka, F.W., and P. Angehrn. 1992. Transmitter attachment methods. Pages 135-145 *in* I. G. Priede and S. M. Swift, editors. Wildlife telemetry: Remote monitoring and tracking of animals. Ellis Horwood Limited, Chichetser, England.

Anita, P., N. S. Schnell, T. L. Dien, and T. L. Trong. 1998. The status and conservation of threatened and near-threatened species of birds in the Red River Delta, Vietnam. Bird Conservation International **8**:31-51.

Bray, O. E., K. H. Larsen, and D. F. Mott. 1975. Winter movements and activities of radio-equipped starling. Journal of Wildlife Management **39**:795-801.

Chaung, H. B., C. Weng, S. C. Wu, R. M. Hsui, and T. J. Tzen. 2003. The process of dealing with botulism intoxication of Black-faced Spoonbills in Tainan. Pages 11-17 *in* the International Symposium on Black-faced Spoonbill

Conservation. Taiwan Endemic Species Research Institute, Nantou, Taiwan.

Chen, C. 2003. Re-sightings of color-banded black-faced spoonbill at the estuary of Tseng-Wen River. Pages 25-38 *in* the International Symposium on Black-faced Spoonbill Conservation. Taiwan Endemic Species Research Institute, Nantou, Taiwan.

Chen, R. C. 2003. The distribution of exotic fish and shrimp species in Taiwan rivers. Taiwan Endemic Species Research **3**:33-46.

Chong, J. R. 1996. Breeding introduction of black-faced spoonbill. Rao Bei **11**:18-20.

Chong, J. R., U. I. Pak, C. Y. Rim, and T. S. Kim. 1996. Breeding biology of black-faced spoonbill, *Platalea minor*. Strix **14**:1-9.

Chong J. R., I. Tsuchiya, and H. Sugita. 2000. Captive breeding of Black-faced Spoonbills. Pages 43-53 *in* M. Ueta, R. Kurosawa, and D. Allen, editors. Conservation and research of Black-faced Spoonbills and their habitats. Wild Bird Society of Japan, Tokyo, Japan.

Chong, J. R., and U. Pak. 2000. The breeding sites and distribution of Black-faced Spoonbills *Platalea minor* in the Democratic People's Republic of Korea (DPRK). Pages 5-9 *in* M. Ueta, R. Kurosawa, and D. Allen, editors. Conservation and research of Black-faced Spoonbills and their habitats. Wild Bird Society of Japan, Tokyo, Japan.

CNT (China Night Times). 2001. Bin-Nan industrial complex will be suspended (Dec. 16th). China Night Times, Taipei, Taiwan.

COA (Council of Agriculture). 2002. Wildlife conservation law and related laws. Council of Agriculture, Taipei, Taiwan.

Collar, N. J., A.V. Andreev, S. Chan, M. J. Crosby, S. Subramanya, and J. A. Tobias 2001. Threatened birds of Asia: The BirdLife International red data book. BirdLife International, Cambridge, UK.

Dahmer, T. D., and M. L. Felley. 1995. Report on winter range survey of black-faced spoonbill, 1994-1995. Ecosystems, Ltd., Hong Kong.

Dahmer, T. D., and M. L. Felley. 2000. Winter census of Black-faced Spoonbill *Platalea minor*, 1996-1998. Pages. 55-62 *in* M. Ueta, R. Kurosawa, and D. Allen, editors. Conservation and research of black-faced spoonbills and their habitats. Wild Bird Society, Tokyo, Japan.

Darren, G.., and M. Paul. 2001. SPSS for Windows Step by Step: A simple guide and reference, 10.0 Update. Boston, Massachusetts, USA.

Del Hoyo, J., A. Elliot, and J. Sargatal. 1992. Handbook of the birds of the world, Volume 1: Ostrich to Ducks. Lynx Editions, Barcelona, Spain.

Dickinson, E. C. 2003. The Howard and Moore complete checklist of the birds of the world. Princeton University Press, Princeton, New Jersey, USA.

Ding, W., F. Lei, Z. Yin, R. Liu, R. 1999. The breeding sites of the Black-faced Spoonbill *Platalea minor* have been discovered in Northern China. Bird Conservation International **9**:284.

FA (Fisheries Administration). 2002. Fisheries Year Report (1993-2002). Fisheries Administration, Council of Agriculture, Tainan, Taiwan.

Fennell, C. M., and B. F. King. 1964. New occurrences and recent distributional records of Korean birds. Condor **66**:239-246.

Fuller, M. R., J. J. Millspaugh, K. E. Church, and R. E. Kenward. 2005. Wildlife Radiotelemetry. Pages. 377-406 *in* C. E. Braun, editor. Techniques for wildlife investigations and management. The Wildlife Society, Bethesda, Maryland, USA.

Groombridge, B. 1993. 1994 IUCN red list of threatened animals. IUCN Gland, Switzerland.

Hachisuka, M. 1931-1932. The birds of Philippine Islands, vol.1. H.F. and G. Witherby, London, UK.

Hachisuka, M., and T. Udagawa. 1951. Contribution to the ornithology of Formosa, part II. Quarterly Journal Taiwan Museum **9** (1&2):1-180.

Hancock, J. A., J. A. Kushlan, and M. P. Kahl. 1992. Storks, ibises and spoonbills of the world. Academic Press, Ltd., London, UK.

Harter, E. 1912-1921. Die Voegel der Palaearktischen Fauna, vol. 2. R. Friedlaender, Berlin, Germany.

Hsueh, P.W., C.W. Yen, and W.H. Chou. 1993. Food habits of Black-faced Spoonbill *Platalea minor* wintering in Taiwan. Bulletin of National Museum of Natural Science **4**:87-90.

Hu, C.H. and Y. Wang. 1995. Study on foraging behavior and ecology of the Black-faced Spoonbill at Chi-Ku, Tainan. National Taiwan Normal University, Taipei.

Huang, C.Z. 2004. Conservation issue: black-faced spoonbill. Council of Agriculture, Taipei, Taiwan.

IUCN. 1997. 1996 IUCN Red list of threatened animals. IUCN Gland, Switzerland and Cambridge, UK.

Jonker, J., and E. P. R. Poorter. 1994. Black-faced Spoonbills in Taiwan, results of the research in the Tseng-Wen River estuary during January and early February, 1994. Foundation for Spoonbill Research, Amsterdam, Netherlands.

Jung, J. M. 2005. Black-faced Spoonbill's breeding site distribution and status in Korea. Page 5 *in* Conference of Black-faced Spoonbill between Korea and Taiwan. National Cheng-Kung University, Tainan, Taiwan.

Kemper, J. H. 1985. Foraging strategy in the spoonbill (*Platalea leucorodia*). Institute for Taxonomic Zoology, Amsterdam University, Amsterdam, Netherlands.

Kemper, J. H. 1995. Role of the three-spined stickleback *Gasterosteus aculeatus L.* in the food ecology of the spoonbill *Platalea leucorodia*. Behaviour **132**:15-16.

Kennerley, P. R. 1990. A review of the status and distribution of black-faced spoonbill. Hong Kong Bird Report 1989:116-125.

Kenward, R. E. 1987. Wildlife radio tagging. Academic Press, London, UK.

Kersten, M., R.H. Britton, P.J. Ducan, and H. Hafner. 1991. Flock feeding and food intake in little egrets: the effects of prey distribution and behaviour. Journal of Animal Ecology **60**:241-252.

Kim, I. C. 2005. Feeding Ecology of Black-faced Spoonbills during their breeding season in South Korea. Black-faced Spoonbill meeting in National Cheng-Kung University, Tainan, Taiwan.

Kolz A. L., and J. B. Reynolds. 1989. Determination of power threshold response curves. Pages 15-24 *in* electrofishing, a power related phenomenon. U.S. Fish and Wildlife Service, Technical Report. 22. Kearneysville, West Virginia, USA.

Kransman, P. R. 2002. Introduction to wildlife management. Prentice Hall, Upper Saddle River, New Jersey, USA.

Kushlan, J. A. 1974. Quantitative sampling of fish populations in shallow, freshwater environments. Transactions of the American Fisheries Society. **103**:348-352.

Kushlan, J. A. 1978. Feeding ecology of wading birds. Pages 249-297 *in* Sprunt IV, A., J. C. Ogden, and S. Winckler, editors. Wading birds. National Audubon Society, New York, New York, USA.

Jung, J. M. 2005. Black-faced Spoonbill's breeding site distribution and status in Korea. The BFS meeting at National Cheng-Kung University, Tainan, Taiwan.

Lee, P. F., J. E. Sheu, and B. W. Tsai. 1995. Wintering habitat characteristics of black-faced spoonbill (*platalea minor*) at Chi-Ku, Taiwan. Acta Zoologica Taiwanica **6**:67-78.

Lehner, P. N. 1979. Handbook of ethological methods. Garland STPM Press, New York, USA.

Lewis, T. C. 1983. Habitat suitability index model: roseate spoonbill. The Fish and Wildlife Service vi:1-16. The Wildlife Society, Washington D. C., USA.

Liu, L. L. 2002. Wintering activity of black-faced spoonbill by radio-tracking in Tainan, Taiwan. Pages. 40-50 *in* the International Conference of Black-faced Spoonbill Conservation, Tainan. Tainan County Government and Black-faced Spoonbill Conservation Association, Tainan, Taiwan.

Liu, L. L. 2003. Wintering macro-habitats of Black-faced Spoonbills in Taiwan. Pages100-104 *in* the International Symposium on Black-faced Spoonbill Conservation. Taiwan Endemic Species Research Institute, Nantou, Taiwan.

Liu, L. L. 2004a. How to identify the age of black-faced spoonbills. Institute of Environment and Ecology, National Tainan University. Class files: no 28, Tainan, Taiwan.

Liu, L. L. 2004b. The oldest Black-faced Spoonbill in the world. Institute of Environment and Ecology, National Tainan University. Class files: no 29, Tainan, Taiwan.

Liu, L. L. 2004c. Comparison among estimating age-structured methods for black-faced spoonbill population in wintering sites. Institute of Environment and Ecology, National Tainan University. Class files: no 6, Tainan, Taiwan.

Liu, L. L. 2004d. Accidental death of Black-faced Spoonbills from 1849 to 2004. WBFT Flight **17**:8-11.

MacArthur, R. H., and J. H. Connell. 1966. The biology of populations. John Wiley & Sons, Inc., New York, New York, USA.

McClure, E. 1984. Bird banding. The Boxwood Press, Pacific Grove, California, USA.

Monroe, B. L., Jr. and C. G. Sibley. 1997. A world checklist of birds. Yale University Press, New Haven, Connecticut, USA.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A Technique for analysis of utilization availability data. Journal of Wildlife Management. **38**:541-545.

Newton, I. 1998. Population limitation in birds. Academic Press, San Diego, California, USA.

Norušis, M. J. 1982. SPSS introductory guide: basic statistics and operations. McGraw-Hill Book Co., New York, New York, USA.

Ogilvie-Grant, W. R. 1889. On the genus *Platalea*, with a description of a new species from New Guinea. Ibis (ser.6) **1**:32-38.

Ott, R. L. 1993. An introduction to statistical methods and data analysis. Duxbury Press, Belmont, California, USA.

Seaman, D. E., and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology **77**:2075-2085.

Severinghaus, L. L., K. Brouwer, C. Y. Chen, J. R. Chong, P. R. Poorter, and Y. Yang. 1995. Action plan for the Black-faced Spoonbill *Platalea minor*. Wild Bird Federation Taiwan, Taipei, Taiwan.

Sharpe, R. B. 1898. Catalogue of the birds in the British Museum. British Museum (Natural History) **26**:51

Shen, C. C. 2000. Black-faced Spoonbill. Mikado-Pheasant **5**:72. Wild Bird Federation Taiwan.

Shiau J. R., M. C. Chen, M.S. Lee, Y. P. Chen, Y. T. Liu, Y. S. Wu, S. H. Lee, W. H. Lin, Y. C. Hsieh , and X. Y. Lin. 2003. Diagnostic report on type C botulism infection on Black-faced Spoonbills in Taiwan. Pages 75-80 *in* the International Symposium on Black-faced Spoonbill Conservation. Taiwan Endemic Species Research Institute, Nantou, Taiwan.

Sibly, R. M., J. Hone, and T. H. Clutton-Brock. 2003. Wildlife population growth rates. The Royal Society, London, UK.

Sturm-Ramirez, K. M., T. Ellis, B. Bousfield, L. Bissett, K. Dyrting, J. E. Rehg, L. Poon, Y. Guan, M. Peiris, and R. G. Webster. 2004. Reemerging H5N1 influenza viruses in Hong Kong in 2002 are highly pathogenic to ducks. Journal of Virology **78**:4892-4901.

Swinhoe, R. 1864. Description of four new species of Formosan birds; with further notes on the ornithology of the island. Ibis **6** (23,24):361-370.

TCG (Tainan County Government). 2002. The announcement of Black-faced Spoonbills' Protection Area of north side of Tseng-Wen River. Tainan County Government, Tainan, Taiwan.

Terakado, N., T. Ito, Y. Kanai, K. Tsukamoto, T. Tsutsui, T. Nakanishi, T. Mizuhara, M. Yoshitake, and K. Yoneda. 2004. Routes of infection of highly pathogenic avian influenza in Japan. Food Safety and Consumer Bureau, and Ministry of Agriculture , Forestry & Fisheries, Tokyo , Japan.

TESRI. 2003. 21 major rivers in Taiwan: river length and their areas. Taiwan Endemic Species Research Institute, Nantou, Taiwan.

Tsai, C.C. 1998. Chi-Ku, spoonbill, home feeling. Tainan Black-faced Spoonbill Conservation Association, Tainan, Taiwan.

UDN (United Daily News). 1992. Two Black-faced Spoonbills have been shot at Chi-Ku (Dec. 1st). United Daily News, Taiwan.

Ueng, Y. T., and C. C. Kou. 1991. The report of the Black-faced spoonbill staying at the north side of Tseng-Wen River, Taiwan, R. O. C. from August 1991 to May 1992. Wild Birds **2**:59-68.

Ueta, M., D. S. Melville, Y. Wang, K. Ozaki, Y. Kanai, P. J. Leader, C. C. Wang, and C. Y. Kuo. 2002. Discovery of the breeding sites and migration routes of black-faced spoonbills *Platalea minor*. Ibis **144**: 340-343.

UNESCO. 1971. The Ramsar Convention on Wetland. International Conference on the Wetlands and Waterfowl at Ramsar, Iran, 2 February 1971.

UNESCO. 1999. The criteria for identifying wetlands of international importance. The Ramsar Convention Bureau, Switzerland.

Van Wetten J. C. J., and G. J. M. Wintermans. 1986. The food ecology of the spoonbill *Platalea leucorodia* . Institute for Taxonomic Zoology, Amsterdam University, Netherlands.

Wang, C. C., and Y. Wang. 1997. A preliminary study on preening behavior of Black-faced Spoonbill (*Platalea minor*). Biology Bulletin, NTNU, **32**:19-24.

Wang, C. C. 2001. The daily active pattern of black-faced spoonbill at Chi-Ku. M.S. thesis of National Taiwan Normal University, Taiwan.

Wang, Y., and S.C. Chen. 1997. Wintering habitat use in black-faced spoonbill.

Pages 33-41 *in* Education and Management Conference of Wildlife Conservation. Council of Agriculture, Taipei, Taiwan.

Wanless, S., M. P. Harris, and A. Morris. 1985. Radio-monitoring as a method for estimating time budgets of Gullemots *Uria aalge*. Bird Study **32**:170-175.

WBFT (Wild Bird Federation Taiwan). 2004a. The synchronized survey for black-faced spoonbills in Taiwan, 2004. Wild Bird Federation Taiwan, Taipei, Taiwan.

WBFT (Wild Bird Federation Taiwan). 2004b. Black-faced Spoonbill records from data base (1985-2004). Wild Bird Federation Taiwan, Taipei, Taiwan.

White, G. C., and R. A. Garrot. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

Whittow, G. C. 2000. Avian physiology. Academic Press, San Diego, California, USA.

Wild Bird Society of Japan. 1997. Asian International Conference of Black-faced Spoonbill in Tokyo, Japan. Wild Bird Society of Japan, Tokyo, Japan.

Won. H. G. 1963. Black-faced Spoonbill. Birds of Korea **1**:55-58. Academy of Science Press, D.P.R. Korea.

Won, H. G. 1966. Black-faced Spoonbill and its protection. Korean Nature 1966:8-11.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology **70**:164-168.

Xue, T. D. 1995. The population structure of black-faced spoonbill. Rao Bei **8**:

12-16.

Yao, C. T., W. I. Jen, H. J. Huang, C. F. Cheng, and C.G. Lin. 1997. Ecological study of Black-faced Spoonbill (*Platalea minor*) ---behavior in captive environment. Pages130-140 *in* the Conference of Designing the Principles of Black-faced Spoonbill Protection Area. Wetland League, Tainan, Taiwan.

Yen, R. D., K. C. Liao, L. J. Chen, C. Y. Liu, Y.S. Jeng, Y. Wang, C. S. Chen, H. M. Chang, J. Jonker, and E.P.R. Poorter. 1994. The ecological study of black-faced spoonbills (*Platalea minor*) in Taiwan-I. Council of Agriculture, Taipei, Taiwan.

Young, L., and G. Chan. 1997. The significance of drained fish ponds for wintering waterbirds. Ibis **139**:694-698.

Yu, Y. T. 2003a. Age structure assessment of wintering black-faced spoonbill in Hong Kong 2002-2003. The Hong Kong Bird Watching Society, Hong Kong.

Yu, Y. T. 2003b. The international black-faced spoonbill census: 24-26 January 2003. The Hong Kong Bird Watching Society, Hong Kong.

Yu, Y. T. 2004. The international black-faced spoonbill census: 16-18 January 2004. The Hong Kong Bird Watching Society, Hong Kong.

Yu, Y.T., and C. Swennen. 2004. Habitat use of the Black-faced Spoonbill. Waterbirds **27**:129-134.

Yu, Y. T. 2005. Longevity record of a color-ringed Black-faced Spoonbill *Platalea minor*. Forktail **21**:176.

APPENDIX

Body measurements of Black-faced Spoonbills in Tainan, 1997-1999

frequency of radio-transmitter	adult/ juvenile	bill (cm)	wing (cm)	tail (cm)	tarsus (cm)	tibia (cm)	weight (gm)	Total (cm)	Date of being captured
164.554	A	16.8	34.5	11.0	17.3	12.3	1620	74.0	12/22/97
164.774	J	19.8	37.0	11.0	19.3	14.1	1943	83.0	12/22/97
164.614	J	19.0	34.0	10.5	19.6	14.4	U*	79.0	12/27/97
164.294	J	15.0	35.5	10.5	20.6	13.2	U	80.0	01/04/98
164.295	J	19.5	34.0	11.5	18.3	13.6	1570	79.0	12/07/98
195.435	A	20.4	34.4	12.0	19.6	13.8	1620	83.0	12/07/98
164.206	J	19.1	33.2	11.0	19.0	13.1	1850	80.0	12/07/98
164.979	J	16.4	33.0	11.0	17.4	11.7	1520	73.0	12/07/98
164.103	A	18.6	35.5	12.0	17.0	11.3	1428	74.5	12/21/98
164.064	J	16.7	34.0	11.7	18.0	12.3	1442	75.5	12/21/98
164.153	J	18.7	38.8	11.0	18.6	13.1	1687	80.3	01/13/99
164.180	J	15.7	32.5	12.2	17.2	12.1	1295	73.0	03/12/99

* U - no data .

VITA

Name: Liang-Li Liu

Permanent Address:

189, Hsin-Hwa 2nd Village,

Jhong-Li, 32039, Taiwan

Education:

B.S. Biology. 1989. National Cheng-Kung University, Taiwan

M.S. Biology. 1991. National Taiwan Normal University, Taiwan

Ph.D. Wildlife and Fisheries Sciences. 2006. Texas A&M University, USA

Professional Experience:

Webmaster. 2001-2005. Black-faced Spoonbill Communication, Taiwan. (http://home.kimo.com.tw/lapueekou/)

Coordinator. 2002. International Conference of Black-faced Spoonbill Conservation in Taiwan. Tainan County.

Researcher and Co-founder. 1998-2001. Black-faced Spoonbill Conservation Association, Tainan.

Research Assistant. 2000-2001. Taiwan Cement Corporation (sponsor).

Research Assistant. 1995-1996. National Taiwan University.

Research Assistant. 1993-1995. National Taiwan Normal University.

Graduate Research Assistant. 1990-1991. Yushan National Park (sponsor).