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Ecological differences of south polar skua populations from Fildes Peninsula of King George Island and eastern Larsemann Hills, Antarctica

Wang Zipan(王自磐)[1] and Hans-Ulrich Peter[2],

1 Second Institute of Oceanography, SOA, Hangzhou 310012 China

2 Ecology Institute of Jena University, Jena D-07743, Germany

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Abstract A study has been done on the comparison of nesting and feeding behavior, population variances as well as breeding success between two populations of south polar skua *(Catharacta maccormicki)* from near Great Wall station on Fildes Peninsula and near Zhongshan station in Eastern Larsemann Hills, Antarctica. There are evident differences in their population ecology. The foraging habit is much related to regional ecosystem and food resources near their territorial area. Dependence on human food waste influences skua's diet, which considerably affects their behavior even population variation in both areas. The skuas in Zhongshan Station, could shorten and/or regulate the timing for their egg laying and hatching, and take precedence of one chick brooding, for keeping their breeding success and subsequent species continuation.

Key words south polar skua, population ecology, Antarctica

1 Introduction

South polar skua *(C. maccormicki)* is the most important carnivore sea bird species in the Antarctic area. Its breeding ranges overlap in continental coast areas, as well as the region of the Antarctic Peninsula and South Shetland Islands. It extends more into marginal areas around the eastern Antarctic continent, such as at Ross Island (Young 1963a, b) and the Larsemann Hills(Wang & Norman 1993a, b). In the regions of the Antarctic Peninsula and sub-Antarctic islands, the south polar skua can have mixed pairs with Brown skua *(C. antarctic lonnbergi)* in breeding, for example near the Palmer Station, as well as in King George Island (Peitz 1984, 1987; Peter et al. 1990), but not the case in eastern Antarctica like Larsemann Hills. Marine fishes, zooplankton species such as krill and amphipods, and even some smaller birds are the most important foraging resources for south polar skua. They play an important role in food web of Antarctic marine ecosystem.

South polar skuas also swarm frequently near research stations in Antarctica. Human food waste is a part of their food, which is more related to natural food resources (Peitz 1987; Trivelpiece & Volkman 1982; Wang & Norman 1993a). It has been reported that south polar skua's habit is related closely to human activities, which remarkably affects to

the dynamics of skua population (Hemmings 1990; Wang & Norman 1995, 1996). So far, there are many studies of skua ecology, but very few dealing with populations comparison. The present study presents the differences in ecology of two south polar skua populations in their nesting, feeding behavior, population variances and breeding success from the areas of the Antarctic peninsula and eastern continental Antarctica.

2 Study area and Methods

The study was carried out on Mirror and Broknes Peninsulas in the eastern part of the Larsemann Hills (ELH), east Antarctica, during the period of 1989/90 to 1993/94, and on the Fildes Peninsula (FP) of the King George Island during the period of 2000/01 to 2002/03.

2.1 *Study area*

Great Wall Station (GW) (62°13′S, 58°58′W) is located at the FP, King George Island, South Shetland Islands, north of the Antarctic Circle. Regional characteristics in meteorology and natural environmental background have been published by many articles (Bian and Xiu 1989; Zhao 1991; Xie 1993). The peninsula consists mainly of hills under the elevation of 200 m, with a coastal plateau of < 50 m. The mean annual temperature is −2.1℃ in this area and, the highest temperature was 5.4℃ and the lowest −4.6℃. It is about 1~3.5℃ from December to February. Mean annual precipitation is 634.9 mm. It is much warmer and wetter than the Antarctic continent areas. The summer season is considerably longer with 110 days of snow and ice melting, typical of the sub-Antarctic climate with much cloudy and snowy weather.

Zhongshan Station (ZS) (69°22′S, 76°22′E) is located in Mirro Peninsula of ELH, in which the south-east coast of the Prydz Bay is one of the larger ice-free areas in continental Antarctica. In contrast to GW, it is typically windy and dry Antarctic weather. The mean annual temperature is −9.8℃, mean monthly temperature is 0℃ in December ~ February. In the summer, it has less than 50 days of snow and ice melting. It has < 250 mm of precipitation. The surface of bedrock is entirely bare and eroded severely with very few plants due to the extreme environment.

The FP is rich with lichens. More then 100 marine species have been found in tidal zones near the coast of the Peninsula. Invertebrate animal species live in the mid-tidal zone. They are mostly limpets *(Nacella concinna)*, polar capulidae *(Laevilittorina antarctica)*, little red clam *(Margarilla antarctica)* and polychaets *(Capilla* sp.). Sea stars, sand dollars, and nematodes are also common species of the sea shore (Yang *et al.* 1992). In the tidal zone, limpets are the most important foraging food for many sea birds living in this area. Marine species, such as Amphipoda, krill and small fishes are main food resources for south polar skua as well as other birds here (Huang and Wu 1992). Penguin – Skua – Gull as breeding birds populations in the Peninsula include the species as Adelie penguin *(Pygoscelis adeliae)*, Chinstrap penguin *(Pygoscelis antarctic)*, and Gentoo penguin *(Pygoscelis papua)*, South polar skua and Brawn skua, Antarctic tern (*Sterna vittata)*, Wilson′

s storm petrel *(Oceanites oceanicus)* and Giant petrel *(Macronectes giganteus)*.

In the LH, mosses and lichens are less common. Penguins are uncommon with very small numbers of Adelie penguin seen here, mainly two colonies on two small islands about 10 km away from Mirror Peninsula. Bird populations in the Larsemann Hills are restricted both in numbers and in breeding species. No surface-nesting petrels breed there and only the snow petrel *(Pagodrama nivea)* and Wilson's storm petrel *(Oceanites oceanicus)* occur in relatively large numbers, nesting (usually cryptically) in areas of eroded bedrock, in crevices, under boulders and in rock falls. About 60 benthic marine species were found in the tidal zone, fewer than other areas of the Peninsula and sub-Antarctic regions. Polycheats *(Lepidonotinae* sp.) and Gastropod mollusc *(Neoduccinum eatoni)*, Amphypoda *(Paramoera* sp.), as well as Echinoidea *(Sterechinus* sp.), Asteroidea *(Odontaster* sp.), mostly live in the waters under low tidal zone.

Table 1. Comparison of natural conditions of skua habitat between GreatWall and Zhongshan Stations

	GreatWall	Zhongshan
Location	Antarctic Peninsula	Antarctic continent
Latitude	62°13′S	69°76′S
Mean temp. / y ℃	– 3~ 0℃	– 10~ – 5℃
Mean temp. ℃ Dec.-Feb.	> 1	< 0
Ice melting (d)	> 100	40~ 60
Topography	Surface with much crumbling rock	Surface with much eroded rock
Vegetation	Rich mosses and lichens; wide in distribution	Less mosses and lichens; sparse in distribution
Sea birds	7 families, 18 species	4 family, 8species
Intertidal zone	> 100 species	< 65 species
Mean biomass of Inter-tidal zone	1658 g/m^2 (GW ㊣, gravel)	590 g/m^2 (near the Hart Lake, gravel)

2.2 *Methods*

We collected the regurgitated pellets and food remains as well as population ecological data from 17 pairs of breeding south polar skua in the areas near Zhongshan Station (Wang 1991; Wang and Norman 1995). Materials and population ecological data were obtained from 18 breeding pairs of south polar skua near GreatWall Station in the south part of the Fildes Peninsula (FP) in Antarctic seasons respectively. Skua breeding territories were mapping by GPS in the breeding season. Masses were determined by means of a spring balance. Regurgitated pellets and remains were collected from above territories in every 10 days throughout the breeding season. Food components of those pellets and remains were

analysed in the laboratory (see Wang and Norman 1993a; Peter *et al.* 1990).

3 Results and discussion

3.1 *Nesting and territory*

Skuas return to their original breeding sites from the north in the Antarctic warm season. The differences of return time of different locations are probably because of the situation in snow and ice melting within different latitude. However, skuas mostly start to move in the beginning of October to the middle of November. Young (1963a) considered that return of the south polar skua in Ross Island was related to less covering of sea ice for foraging. In the ELH, fast ice covers the surface of most waters near the coast in October, and the ice edge is located about 50 km away from the shore. That is just the peak time of seals (*Leptonychotes weddellii*) breeding on the ice, which is good for south polar skuas to forage seals' placental remains (Wang 1991). South polar skuas near the GW Station also return to their original breeding sites in early October. However, sea surface is mostly open, but the land is still covered by snow. It is earlier to skuas for their nesting, but is good for skuas to forage sea food, as well as seals placentas (Trivelpiece & Volkman 1982). They start to nest in early November, and select their nesting sites near the top of small hills, where usually lichens are present. Lichens are most common materials for their nesting. The nests are mostly established far from penguin colonies. There are generally no feeding territories in south polar skua breeding area here, even it is close to the colonies of cape pigeon (*Daption capense*) or Wilson's storm petrel (*Oceanites oceanicus*) and Black-bellied storm petrel (*Fregetta tropica*). Comparison with this, in the ELH, mostly the nests of south polar skua are established completely on erotic and rocky ground, and on higher position (normally not on the top) of small hills, where there is no any vegetation can be used as nesting material. Some of south polar skua near ZS Station also have feeding territories with snow petrels (Wang and Norman 1993a). In Ross Island, it has penguin colonies as feeding territories (Young 1963a), and Antarctic petrels in Hop Island (Norman and Ward 1990).

Table 2 Comparison of south polar skua nesting strategy between Great Wall and Zhongshan Stations, Antarctica

	Great Wall					Zhongshan				
	Item	Mean	Std. D	Factor	Cont. (%)	Item	Mean	Std. D*	Factor	Cont. (%)
1	HE	60.94 m	32.82	Topography	42.38	SPD	267.00 m	108.58	Food1 Human	35.18
	SED	510.00 m	244.70	Food1		STD	1024.50 m	815.95		
2	STD	754.50 m	266.68	Human	31.56	HE	45.51m	15.40	Topography	28.96
	ND	155.95m	65.41	Density		SED	455.33 m	430.03	Food2	
3	LM	869.75 d/m^2	235.51	Nesting material	14.35	SL	146.33°	29.06	Climate	18.68
	SL	153.80°	56.57	Climate						

HE: elevation of nest above sea level; SED: distance of nest to the beach; STD: distance of nest to the Station; SPD: distance of nest to Snow Petrel colonies; ND: nearest distance between two skua nests; LM: Lichen density in skua territory; SL: slope direction (E$\rightarrow$W); Std. D: standard deviation; Cont.: contribution to nesting steategy.

The comparison of compositional analysis (Wang and Peter 2002) for environmental factors of affecting skuas nesting strategy in breeding habitat between GW and ZS is given in Table 2. There are evident differences in sequencing by comparison on six related factors between two habitats. The topographic factor (HE) as well as food factor (SED) are the most important factors that affect nesting strategy near the GW Station. Higher nesting location may allow adults to overlook and protect their territory, which is very important for brood safety and territory security. HE is at the first of sequence (see Table2) in GW Station. This is probably because of that the skua population has high nest density (7 pairs/km^2), which means of high press to birds in survival space there. In contrast, HE is at the second of sequence in ZS Station, where is much less of competition in survival space with lower nest density(0.8 pairs/km^2). Since natural food resources is more scarcity in eastern Antarctica, food should be most important requirement for survival of the skuas there, therefore, colonies of snow petrel as feeding territories for South Polar skua in ELH are necessary. It is reasonable that SPD (snow petrel) occupies the first of sequence near ZS Station (see Table 2). Secondly, part of the skuas have their nests close to station can easier obtain some food remains from the stations. So that STD could be significant factor for their feeding activities (see following pages). This also means impact of human activities, mainly as the medium of food remains affects of nesting (and of their breeding success late) of south polar skuas here, partly by changing in foraging habit and their diet(Wang and Norman 1993b, 1996). Thus, STD and SPD presented together at the first of nesting sequencing is quite corresponding the environmental conditions of the habitat(Wang and Norman 1993a). Sea food is regarded as additional food resource for south polar skuas in ZS Station, therefore, the SED here drops as the second of sequencing of nesting strategy.

The characteristics of climate in both areas of GW and ZS Stations are generally snowy and windy from eastern and/or south-eastern. The SL means that weather does affect skua's nesting in both areas near GW and ZS Stations. This could be beneficial to the breeding or exactly to the earlier chick growing of both skua populations. Lichen (LM, in table 2) actually is the material for south polar skua's nest building only in area near GW Station, it as one of nesting factors should be not the case in Eastern Antarctica.

3.2 *Foraging strategy*

Young(1963a) reported that south polar skua hunted in Adelie colonies as main food resources in Ross Island in continental Antarctica. Maher(1966) regarded that there was a special prey-preyer relationship between skua and penguin as food model. Fredrickson (1971) also suggested that a "penguin-skua system". However, in the area near GW Station, skuas return generaly in the early of October. Brown skuas return to their breeding grounds about one or two weeks earlier than south polar skua. The former can occupy some feeding territories in the penguin's colonies. In contrast, most of south polar skuas prefer to forage marine small animals as food (Trivelpiece & Volkman 1982). South polar skuas in King George Island forage mainly sea food (Amphipods and fishes) which could be as high as 79% in their food contents (Peter *et al* 1990). They also pray other small sea birds, such as Wilson's storm petrel nesting in rocky beach. While Brown skuas pray mostly pen-

guin's eggs, chicks, and seal's corpses. In the area near ZS Station, south polar skuas pray mainly snow petrels and additionally small marine fishes and shrimps. Meanwhile, they forage human food remains as necessary compensation (Wang and Norman 1993a). Nesting factors in the above such as SED, STD, and SPD, all are actually related to utilization of food resources. For example, skuas select their nest sites close to the sea, it can probably forage sea food easier and return to their nests and territories as soon as possible after foraging. This is much beneficial to their chicks feeding and protecting. Furthermore, because of nesting at the sites close to stations skuas could easily find human food remains. In table 2, SET, SPD and STD both in GW and ZS Stations occupy different position in compositional analysis respectively. Thus, nesting strategy reflects that the skuas have stronger adaptation of using food resources in their habitat by different forage strategy. We think that south polar skua characteristics a random foraging strategy.

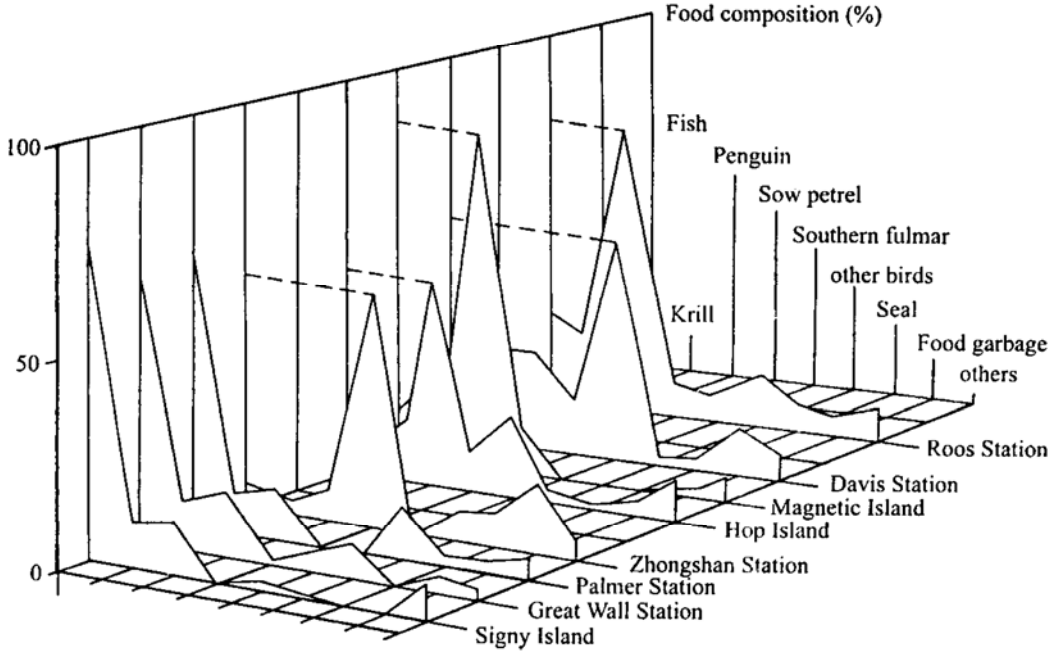

Fig. 1 Comparison of food composition by south polar skuas in GW and ZS stations and other Antarctic sites. Data by: this study and Young 1963a, Hemmings 1984, Peitz 1987, Green 1986 and Norman and Ward 1990.

3.3 *Numbers of breeding pair and Breeding success*

Table 3 shows the change of breeding pairs of south polar skua around the GW and ZS in different years. In the area near ZS, it had basically slight change during the period of 1988/89 — 1993/94, except the years of 89/90 and 92/93, when it was increasing because of more garbage and waste materials around there from the station (Wang and Norman 1996). In the GW, the number of breeding pairs of south polar skua markedly increased as high as 81.8% during 1984/85 — 2000/01. Even in the plateau (a small area) south to GW Station, it increased from 10 pairs of 1984/85 to 20 pairs of 2000/01. Number of skua breeding pairs generally increased sharply in the peninsula area. There are so many bases and stations in the King George Island, such a small area, and human activities are so frequent including scientific research, tourists, other visitors, as well as much traffic by aircraft flight and vehicles here. So far, regional environmental manage by station is not so

well, and visitors coming from different countries are not controlled. It usually happened here that the ecological species were interfered by people severely, even the wildlife, such as skuas, fed by kitchen food. All of these could be considered as one of the important reasons to change natural populations. Numbers of skua club used to be decreased by the activities of Antarctic Environmental Year in ZS station, which was stronger clean up garbage around the station during the years of 1992/93 and 1993/94. Changing of the number of skua club related to the condition of waste management in the stations.

Table 3. Comparison of breeding pairs and club of south polar skua near the Great Wall and Zhongshan Station

Year	GW			ZS	club	
	breeding pairs	club	& date	breeding pairs	club	& date
86/87	21	12-22	16. Feb-25. Feb			
88/89				10	9-14	19. Jan-22. Feb
89/90				15	16-28	21. Nov-10. Feb
92/93				13	11-23	25. Dec-18. Feb
93/94				10	7-11	10. Jan-20. Feb
00/01	56	21-39	21. Dec-20. Feb	11	15-24	12. Jan-15. Feb
01/02	47	22-47	29. Jan-22. Feb			
02/03	43	20-35	25. Dec-19. Feb			

Breeding success could be another important factor to affect the populations. Table 4 shows the timing of egg laying, hatching and chicks out and fledging of south polar skua at different areas in Antarctica. In table 4, 25– 30 days are regarded as skua incubation period time from different regions with slight difference depending on egg volume and the hatching strength (Yong 1963b). Thus, the date of chick hatched is directly relative to the date of egg lying. It is clear that the last date of egg laying in high latitude like in ZS, is earlier than that in low latitude like GW (Table 4). The timing of egg laying from the first egg to the last egg is about one month in ZS and in Ross Is., but as long as two month in GW. This is because of severe climate conditions, which could be the shorter of warm season the higher latitude. Thus, the earlier and shorter timing of egg laying means that the chicks could have the longer warm time during their growth in higher latitude areas.

42– 59 days are generally needed for south polar skua chicks from hatching to fledging. There are several factors to influence this processes, and it could be mainly the eggs volume, fed by adults, food structure, as well as the weather. 50 days(or a few days more) is generally regarded as timing for chicks fledging in higher latitude, but it will be less in the areas of lower latitude (see table 4). It will be much unfavorable to chick growth that the weather becomes cold and snowy, particularly the blizzard much threat chick's survival. Also it will be the colder and the less of valuable food, generally in March of the year in high latitude such as in ZS, where, the last chick must be hatched out before mid-January.

In contrast, the situation could be better in sub-Antarctic areas like GW. The timing of breeding generally is relatively longer.

Table 4 Timing of egg laying and hatching chick hatched and fledging of South Polar skua from different sites

	Egg laying (day)	Hatching (day)	Chick out (day)	Fledging (day)	resource
Signy Is.	05/12–13/01	27/30	02/01–10/02	47	Hemmings 1990
Great Wall	12/11–15/01	27–31	13/12–12/02	48	this study
Palmer	04/12–10/01	28–30	03/01–09/02	–	Peitz 1987
Zhongshan	18/11–18/12	25/27	13/12–11/01	53.5	Wang & Norman 1993b
Roos Is.	27/11–27/12	27–29	25/12–31/01	54	Young 1963b

Table 5 Breeding success (%) of the south polar skua in different sites

Sites	Latitude	Breeding success (%)	references
Signy Is.	60°42′	71	Hemmings 1990
Great Wall	62°12′	40	this study
Palmer	64°46′	36	Peitz 1987
Zhongshan	69°22′	29.6	Wang & Norman 1993b
Ross Is.	77°33′	23.2	Young 1963b

Table 5 shows the comparison of breeding success of south polar skua in GW, ZS and other different sites in Antarctica. There is evident negative relationship between the rate of breeding success and the latitude (Reinhardt 1997). The severe natural conditions could be the reasons for lower breeding success. However, egg missing as well as second chick loss should be one of main reason directly to affect breeding success in higher latitude areas (Young 1963; Wang & Norman 1993b). The relative factors should be some others, like food available, weather, capability of chick protecting by their parents, the capability of chicks to resistant bad status, such as snow and frost, wind, starvation and disease and so on. The first chick generally has much superiority in timing of egg laying, larger egg volume (normally) and body mass. Particularly, the body of the first chick is usually more weight and stronger then the second when it is just hatched. Body mass of the first chick was heavier than the second of in first day of coming out being as 8-61 g in ZS and 12-54 g in GW respectively (Wang and Norman 1993b; Wang and Peter unpublished data). The second chick is usually in an inferior status in consequent survival. They mostly get less of food than the first. Therefore, it grows up slowly and weaker to against the predator and the disease as well as cold condition. In sub-Antarctica, because it is richer in food resources for the birds, the second chick could have more food from their parents. This should be benefi-

cial to enhancing survival rate, as compared with that in continental Antarctica. In the other, internecine carnivore also could be an important reason to cause low breeding success to the species. Based on the investigation *in situ*, chicks were directly preyed by the other adults, the ratio was as high as 33% of total chicks near ZS during the breeding season of 1989/90. While it was 51.4% in 2000/01 near the GW. Despite of this, still it kept a higher breeding success in GW, because of higher population density, which is supported by adventure climate and food conditions here.

4 Summary

(1) There are evident differences in nesting and foraging of south polar skua between two populations from GW station and ZS station. It reflects that skuas have much dependence on natural environment and food resources in their habitat, and the birds have very stronger adaptability to rigorous Antarctic conditions.

(2) South polar skuas in ZS station surviving in severer weather condition and food shortage, could shorten the timing of their egg laying and hatching, regulate chicks fledging days, and take precedence of one chick brooding, for keeping their breeding success, and subsequent species continuation.

(3) Both of south polar skua populations dependent more or less on human food remains, someway, it influences animal's ecological habit and variance of population numbers. Therefore, it is important to enhance ecological protection attending to waste management and decrease of human activities, which could interfere the birds life in field.

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