Acta zool. cracov. **38**(3): 399-460, Kraków, 29 Dec. 1995

Distribution, abundance and biology of the Antarctic Tern *Sterna vittata* GMELIN, 1789 on King George Island (South Shetland Islands)

Bolesław JABŁOŃSKI

Received: 19 July 1994
Accepted for publication: 31 May 1995

JABŁOŃSKI B. 1995. Distribution, abundance and biology of the Antarctic Tern *Sterna vittata* GMELIN, 1789 on King George Island (South Shetland Islands). Acta zool. cracov. **38**(3): 399-460.

Abstract. A total of 3518 pairs of Antarctic Terns nested on King George I in the 1980/81 season. In the region of Admiralty Bay the numbers ranged from 652 to 1828 pairs (7.2-20.1 pairs per 1 km of coastline). Most pairs nested on rock-rubble heaps void of vegetation and on moraines. On the average 1.45 eggs, 0.46 newly hatched chick and 0.22 young bird leaving the colony fell to one pair. Mean dimensions calculated from 498 eggs were 44.8 × 33.5 mm. Single eggs and the first ones of two-egg clutches were longer. The first chicks grew faster. The diet od adult and young birds consisted of *Euphausia*, Amphipoda and Pisces. Their proportions in the food of the young changed with age. The total consumption of krill by Antarctic Terns in the region of Admiralty Bay was 4.69-4.93 tons in the 1980/81 season, which makes 0.60-0.78% of its biomass. A relatively small amount of faeces excreted on land and the considerable scattering of nests cause that the role of Antarctic Terns in the formation of ornithogenic soils is of minor significance, whereas the presence of their colonies may be important to the development of associations of nitrophilous lichens.

Key-words: *Sterna vittata*, biology, nests, eggs, breeding success, diet, Antarctica.

Bolesław JABŁOŃSKI, Toeplitza 2A, 05-805 Otrębusy, Poland.

I. INTRODUCTION

Sterna vittata GMELIN, 1789, inhabits the circumpolar regions on the Australian (starting from Stewart I – 47°00' S), African (from Bird I – 33°49'S) and South Atlantic sides (from Tristan da Cunha – 37°05'S) up to Stonington I (68°11'S) off the Antarctic Peninsula Fig. 1 (MURPHY 1936; FALLA 1964; STONEHOUSE 1964; VOOUS 1965; PREVOST, MOUGIN 1970; WATSON et al. 1971; WATSON 1975). No breeding sites were observed on the coast of the so-called western part of Antarctica, i.e. the part facing the Pacific (KOROTKEVICH 1959, 1964).

The nesting of birds on islands far removed from each other and providing diverse climatic and biotopic conditions and their keeping to areas not very distant from the breeding colony caused their biometrical differentiation. In MURPHY'S (1938) opinion, these differentiations constituted the basis for the isolation of subspecies (Fig. 1). The type form *S. v. vittata* GMELIN, 1789, inhabits the islands in the Indian Ocean (from the Heard Is, Kerguelen Is and Amsterdam I to the Crozet Is and Marion), *S. v. tristanensis* MURPHY, 1938 – Gough I (SWALES 1965) and Tristan da Cunha (ELLIOTT 1957) in the Atlantic, *S. v. bethunei* BULLER, 1896 – the islands of New Zealand (Bounty, Antipodes, Campbell, Auckland, Steward, Macquarie), *S. v. georgiae* REICHENOV, 1904 – from South Georgia to the South Orkney Is, and *S. v. gaini* MURPHY, 1938 from the South Shetlands to the Archipelago of the Antarctic Peninsula (Fig. 2). The nesting of terns on Bouvet I, difficult of access, needs explaining and determining their subspecific membership. SOLYANIK (1964) found the presence of 2 colonies there, whereas HOLGERSEN (1960), LUNDE (1963), WINSNES (1965), MÜLLER el al. (1967) and FELVOLDEN & SØMME (1977) did not mention S. vittata in their lists of birds observed.

The distribution and size of the colonies of the above-named subspecies are not equally well known. The most data we have at our disposal come from the New Zealand Antarctic Sector and

Fig. 1. Breeding ranges of particular subspecies of Antarctic Terns.

concern *S. v. bethunei* (EDGAR, WHITE 1909; FALLA 1937; STEAD 1948; WESTERKOV 1960; BAILEY, SORENSEN 1962; SAGAR 1978; WARRHAM, BELL 1979; ROBERTSON, VAN TETS 1982; SADLER et al. 1986), which occurs north of the Antarctic convergence, and *S. v. vittata* on the Indian Ocean side (CRAWFORD 1952; PAULIAN 1953; RAND 1954; DOWNES et al. 1959; SEGONZAC 1972; PREVOST, MOUGIN 1970; DESPIN et al. 1972; BERRUTI, HARRIS 1976; THOMAS 1983; WEIMERSKICH et al. 1988; SAGAR 1991). In the areas of the Antarctic convergence this subspecies nests only on the Heard Is (which are howeever very distant from the limit of pack ice in summer), whereas its most closely studied population from the Kerguelen Is lives at the boundary of the Antarctic convergence. The sympatric species *Sterna virgata* also occurs on these last islands, which, according to BERRUTI and HARRIS (1976), led to the formation of many mechanisms separating these two species. The remaining islands inhabited by *S. v. vittata* and *S. v. tristanenis* have climatic conditions resembling those prevailing in the New Zealand Sector or considerably milder (e.g. Gough I 40°20'S and 10°00'W, Tristan da Cunha 36°51'S and 12°17' – 12°30'W, Bird I 33°51'S and 26°17'E).

The above-mentioned works however give only fragmentary information concerning phenology and reproduction biology. The reproductive season was studied more closely only in 10 pairs of *S. v. bethunei* from the Snares Is (48°02'S and 166°36'E) and in 29 pairs of *S. v. vittata* from the Kerguelen Is (49°15'S and 69°10'E) by SAGAR (1978 and 1991, respectively).

S. v. georgiae from South Georgia I (CLARKE 1906, 1913; MATTHEWS 1929; LOVE, KINNEAR 1930; MURPHY 1936; PRINCE, PAYNE 1979) and from the South Orkney Is (CLARKE 1906; ARDLEY 1936; TICKELL 1962) nests in the Antarctic convergence area affected by pack ice only in winter. The data concerning distribution and abundance and the fragmentary information regarding phenology and reproduction biology are available for these regions.

The bulk of the western population of *S. vittata*, i.e. *S. v. gaini* occupies the terrains from Elephant I and Bridgeman I (FURSE, BRUCE 1975; FURSE 1979) through King George I (GAIN 1914; KRYLOV 1968; ARAYA, ARRIETA 1971; SIMONOV 1975; JABŁOŃSKI 1980, 1986; BANNASCH, ODENING 1981; PETER et al. 1988; SIERAKOWSKI 1991; MYRCHA 1992), Robert I (PEFAUR, MURUA 1972), Nelson I (ARAYA, ARAVENA 1965), Livingston I (HOLGERSEN 1957) and Deception I (GAIN 1914) to the Antarctic Peninsula and its Archipelago (MENEGAUX 1907; GAIN 1914; HOLDGATE 1963; PARMELEE, MAXON 1975). These regions are characterized by the occurrence of pack ice in the summer season (Fig. 1). The hard conditions of field work caused that most observation had been made in the neighbourhood of polar stations and consequently the distribution and abundace of birds were still poorly known. Many data have been added since then (WATSON et al. 1971; WATSON 1975), but numerous areas have not been investigated yet. That is why the estimates of the size of this population given in literature are very various. And so, e.g., according to PREVOST (1976), the size of the population of *S. vittata gaini* in the Antarctic region is 11 500 pairs (50 000 in the subantarctic area), whereas PETER et al. (1988) estimated it at 35 000 on the South Shetlands alone.

It seems therefore expedient to present the results of the survey of breedidng colonies all over King George I and to sum up the past studies, because this island has been as yet given the most publications.

Studies on breeding biology carried out by PARMELEE and MAXSON (1975) on Anvers I (64°45'S, 64°05'W) in 1973, by CORDIER et al. (1983) in the Antarctic Peninsula (Esperance, 63°24'S, 56°59'W) in 1979/80 and on King George I by PETER et al. (1988) on the Fildes Peninsula (62°09'S, 58°54'W) in 1983-85 and by me in the region of Admiralty Bay (62°09'S, 58°28'W) in 1978-1981 (JABŁOŃSKI 1986 and pres. publ.) permit a synthetic presentation of the biology of *S. v. gaini*, seeing that the most abundant documentary material collected from various regions of its occurece, characterized by different local climatic conditions, is available. This summing-up seems necessary also because in the last ten years an increase in the temperature has been observed on King George I as compared with preceding decades (1948-1987); it brings about an apparent process of deglaciation on land and a regression of the ice barriers (RAKUSA-SUSZCZEWSKI et al. 1992a). As a result of that warming the biotopic conditions are changing for *S. vittata* in this region. The spontaneous setting up of polar stations has also been observed lately and the activity connected with them may negatively influence the effectiveness of breeding in regions intenselty penetrated by people (RAKUSA-SUSZCZEWSKI 1992a, b).

A c k n o w l e d g m e n t s. I wish to express my thanks to the chiefs of successive Antarctic Expeditions organized by the Polish Academy of Sciences: Prof. S. RAKUSA-SUSZCZEWSKI, Prof. A. MYRCHA and Prof. K. BIRKENMAJER for making it possible for me to participate in them and to Assist. Prof. W. KRZEMIŃSKI, Dr W. NURKIEWICZ, Dr J. ROŻYŃSKI, Assist. Prof. A. ŁUKOWSKI, Prof. A. WASILEWSKI, Prof. K. ZDZITOWIECKI, Dr R. WHITE and Assist. Prof. J. PIASECKI for helping me to collect materials. I extend my thanks to the skippers A. CIEŚLAK and B. DIBOWSKI, the helicopter pilots J. LITWIN, W. KURZYŃSKI and E. BIENIASZEWICZ and a group of geologists under Prof. K. BIRKENMAJER for assinstance in my field work. I owe my heartfelt gratitude to the members of other expeditions on King Georege I, from Base Frey (Chile), Bellingshausen (Russia), Refugio Teniente, Belleve and Jubany (Argentina) for their help with the field work and hospitality.

My thanks go to Dr H. JACKOWSKA, Prof. K. JAŻDŻEWSKI, Assist. Prof. T. LINKOWSKI, Assist. Prof. P. PRESLER, Dr M. RĘBISZEWSKI and Dr R. STĘPNIK for their carrying out identifications of food items.

I also thank Prof. Z. BOCHEŃSKI and Dr T. TOMEK for help with the preparation of materials and Prof. D. F. PARMELLE, Prof. G. F. WATSON, Dr P. M. SAGAR, Dr G. L. HUNT and Prof. J. P. CROXALL, and the British Antarctic Survey for their kind contributions to the completion of the literature.

II. STUDY AREA AND METHODS

King George I (Fig. 2 & 3) extends from 61°50' to 62°15' S lat. and from 57°30' to 59°00' W long (BIRKENMAJER 1980a), its area amounting to 1338 km^2. Places free from ice form only 1.9% of the area (or about 21 km^2). The climate is oceano-antarctic (RAKUSA-SUSZCZEWSKI et al. 1992), influenced chiefly by cyclonic centres connected with the atmospheric pressure system. Remarkable differences were found in the mean air temperature (both monthly and daily) and in the numbers of cloudy days with precipitation and strong winds between the region of Admiralty Bay and the Fildes Peninsula in the western part of the island (RAKUSA-SUSZCZEWSKI et al. 1992; PETER et al. 1988). Frequent melting and freezing result in the intense frost weathering of rocks.

An investigation of the changes in the abundance of *S. vittata* in the annual cycle and its biology was carried out in the region of Admiralty Bay (Fig. 4), 388 km^2 in area, whose part free from ice was 19 km^2 (RAKUSA-SUSZCZEWSKI 1980). The total length of the coastline (from Red Hill to Chabrier Rock) was 91 km.

In connection with the great skittishness of the Antarctic Tern the estimation of its numbers was performed in two phases: (1) the indication of the colony area or the location of single birds in a field sketch in the course of observations made with the help of field glasses and (2) searching for nests on the basis of the sketch. This method besides allowed the determination of the number of birds without nests, staying in the colony area. In the Admiralty Bay region in the breeding sites where I did not carry out a regular investigation of the biology of the birds, they were counted 2-3 times in the 1978/79 season, 3-4 times in 1979/80 and once or twice in 1980/81 – between 10 Dec. and 5 Jan. (i.e. in the period of mass egg-laying). In the season 1980/81 an inventory of breeding sites all over King George I was taken only once (exceptions were the Barton Peninsula – 3 times and Stranger Pt – twice) because of the grat length of the coast line (about 365 km). Naturally, the appraisal of abundance is not very exact, because no nests abandoned after the loss of the brood before our counts were taken into account.

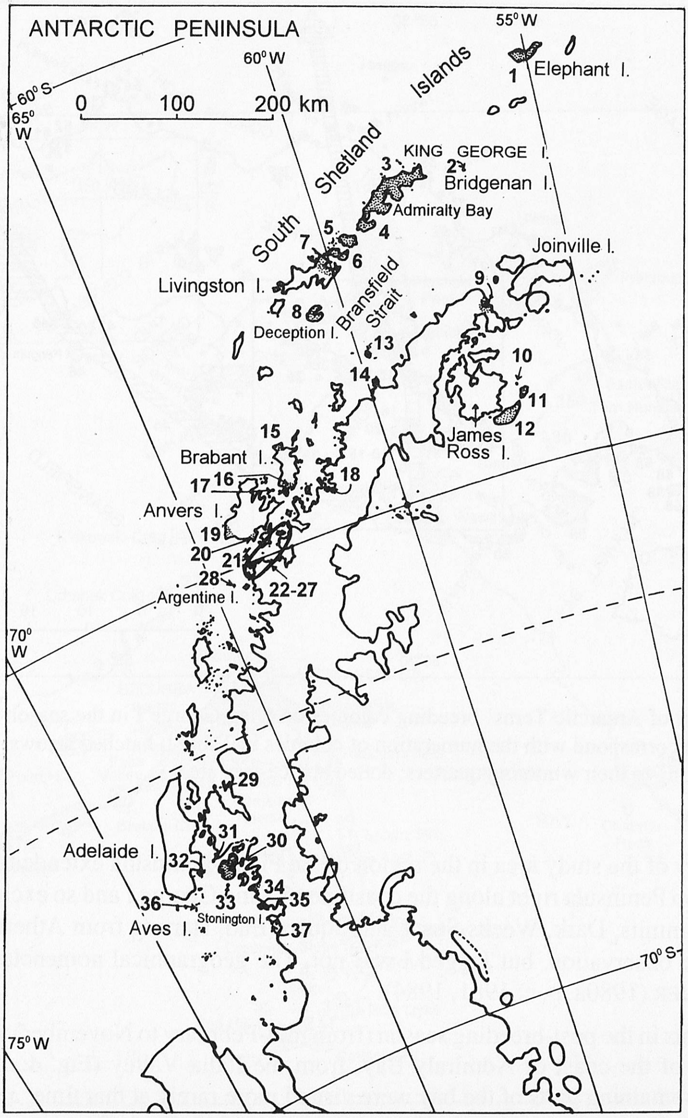

Fig. 2. Distribution of Antarctic Terns in the area of the South Shetlands and the Antarctic Peninsula with the Archipelago. Breeding regions: 1 – Elephant I., 2 – Bridgeman I., 3 – King George I. – 62°00'S 58°15'W, 4 – Nelson I. – 62°18'S 59°03'W, 5 – Robert I. – 62°24'S 59°30'W, 6 – Greenwich I. – 62°31'S 59°47'W, 7 – Livingston I. – 62°36'S 60°30'W, 8 – Deception I. – 62°57'S 60°38'W, 9 – Hope Bay – 63°24'S 56°59'W, 10 – Cockburn I. – 64°12'S 56°51'W, 11 – Seymour I. – 64°17'S 56°45'W, 12 – Snow Hill I. – 64°28'S 57°12'W, 13 – Tower I. – 63°33'S 59°51'W, 14 – Kater Cape – 63°46'S 59°54'W, 15 – Brabant I. (Metchnikoff Pt) – 64°15'S 62°32'W, 16 – Brabant I. (Bulls Bay) – 64°23'S 62°15;W, 17 – Melchior I. – 64°19'S 62°57'W, 18 – Gaston I. – 64°28'S 61°50'W, 19 – Anvers I. (Monaco Cape) – 64°43'S 64°18'W, 20 – Anvers I. (Bonaparte Pt) – 64°47'S 64°05'W, 21 – Joubin I. – 64°47'S 64°27'W, 22 – Cormorant I. – 64°48'S 63°58'W, 23 – Wiencke I. – 64°50'S 63°25'W, 24 – Doumer I. – 64°51'S 63°35'W, 25 – Booth I. – 65°05'S 64°00'W, 26 – Hovgaard I. – 65°08'S 64°08'W, 27 – Petermann I. – 65°10'S 64°10'W, 28 – Argentine I. – 65°15'S 64°16'W, 29 – Detaille I. – 66°52'S 66°48'W, 30 – Webb I. – 67°27'S 67°56'W, 31 – Leonie I. – 67°36'S 68°21'W, 32 – Horseshoe I. – 67°51'S 67°12'W, 33 – Lagotellerie I. – 67°53'S 67°24'W, 34 – Antarctic Peninsula (Calmette Cape) – 68°04'S 67°13'W, 35 – Debenham I. – 68°08'S 67°07'W, 36 – Avian I. 67°46'S 68°54'W, 37 – Stonington I. – 68°11'S 67°00'W.

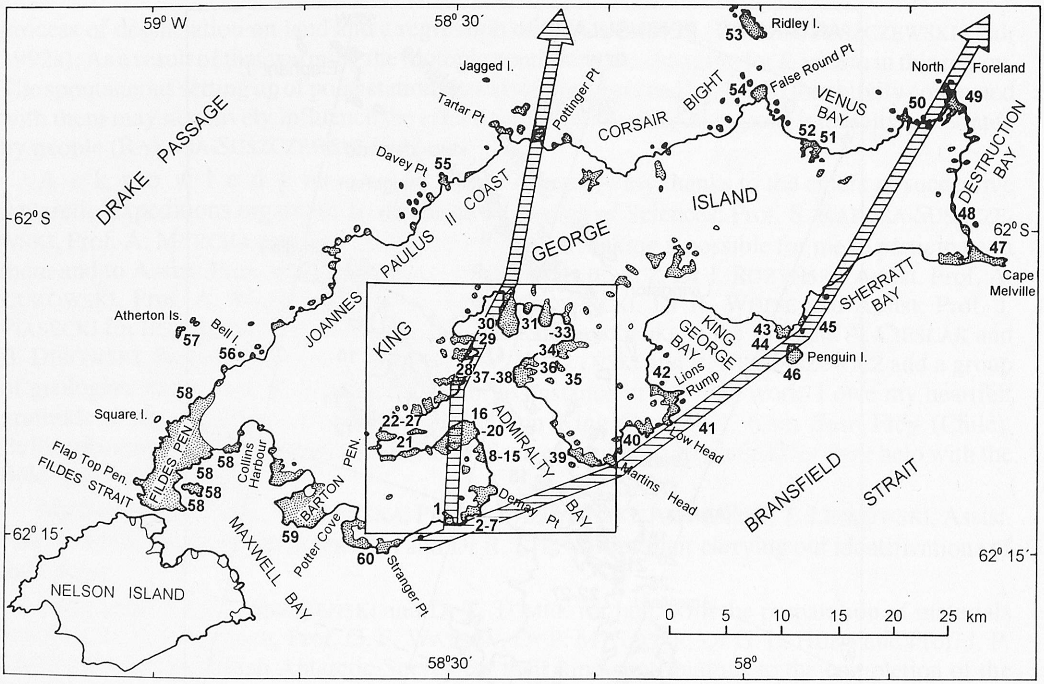

Fig. 3. Distribution of Antarctic Terns' breeding colonies on King George I in the season 1980/81. Arabic numerals (1-60) correspond with the numeration of colonies in Table I; hatched arrows – flight direction of flocks migrating to their wintering quarters; dotted are ice-free areas.

The boundary of the study area in the region of the Fildes Peninsula extended from Half Tree Pt to the Flap Top Peninsula right along the coastline of King George I and so excluding the small islands: Two Summits, Dark, Weeks Stack and Square End; starting from Atherton, the islands were included in observation, but Jegged I was not. The geographical nomenclature is adopted after BIRKENMAJER (1980a, b, c; 1981, 1984).

Regular counts in the post-breeding season (from mid-February to November) were made over a 20 km length of the coast of Admiraly Bay, from the Italia Valley (Fig. 4: 19) to Red Hill (Fig. 4: 1). The remaining parts of the bay were visited more rarely at that time; a survey of these counts was presented in an earlier paper (JABŁOŃSKI et al. 1987: Table I).

To determine the losses in eggs and chicks I marked the nests and eggs (successive numbers) and young (symbols on legs and plumage) with varnich. A two-grade appraisal was: (1) general – consisting in taking down only the numbers of eggs, newly hatched chicks and fledglings (without taking into consideration the causes of losses); I utilized these data in analysing the phenology of breeding in consecutive seasons; (2) particular – including the causes of losses.

The following method was applied to study the food nass: in the case of the young neck rings were used and emetic (1% ammonium tartrate in doses of 3-4 cm^3 for chicks up to about 10 days and above 10 days as for adults, i.e. 6-8 cm^3); adults were caught in small folding frame-traps, with *Euphausia* used as bait, and given emetic, which was injected into their gullets with the help of a tube. This method was time-consuming and provided a small number of food samples. Neither were there any samples showing the presence of food in the alimentary canal of terns after the emetic stopped acting. However, experiments made on penguins showed that only 0.86-4.35% of the food remained in the stomach (JABŁOŃSKI 1985). This method, after all, allowed me to avoid

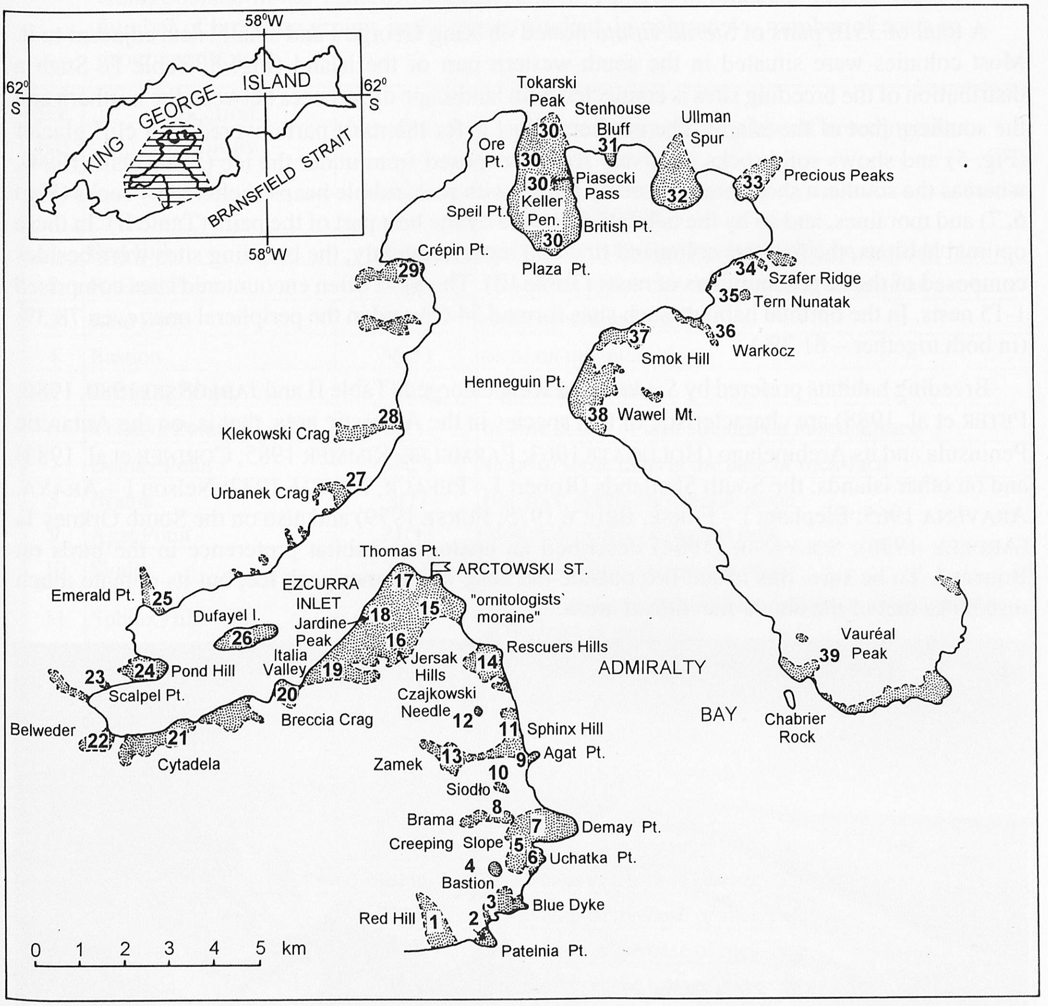

Fig. 4. Distribution of Antarctic Terns' breeding colonies in the Admiralty Bay region on King George I in season 1978/79 – 1980/81. Dotted areas free from ice; Arabic numerals indicate the location of particular colonies (corresponding with Fig. 3 and Table I).

killing the birds and that was a sine qua non of conducting this study. The inquiry into the food composition was complemented by noting down the prey brought to the nest in their beaks by the adults during the 24-hour observation of their activity.

Excrement of adults and chicks (at the time of their stay in the nest) was gathered on the underlying plastic film. The application of the film was necessary because of the penetration of faeces into the substratum. Older chicks were reared in an aviary with the floor lined with plastic film as well. The excrement was dried, because the method employed made it impossible to estimate their wet mass under the conditions prevailing during field work at the time of rainy weather.

III. DISTRIBUTION AND ABUNDANCE

A. Distribution and size of breeding colonies in 1980/81

A total of 3518 pairs of *Sterna vittata* nested on King George I and small islets adjacent to it. Most colonies were situated in the south-western part of the island (Fig. 3, Table I). Such a distribution of the breeding sites is connected with landscape differences between the northern and the southern part of the island. The northern coast is for the most part covered by a cliff glacier (Fig. 5) and shows solid rocks relatively freshly exposed from under the ice (JABŁOŃSKI 1984), whereas the southern shore presents many places with rock-rubble heaps sheltered by rocks (Figs 6, 7) and moraines, and so by the habitats occupied by the best part of the pairs (Table II). In these optimal habitats, the habitats colonized first and most frequently, the breeding sites were besides composed of the largest numbers of nests (Table III). The most often encountered sites comprised 1-15 nests. In the optimal habitats such sites formed 54.6% and in the peripheral ones even 78.3% (in both together – 61.7%).

Breeding habitats prefered by *S. vittata* on King George I (Table II and JABŁOŃSKI 1980, 1986; PETER et al. 1988) are characteristic of this species in the Antarctic area, that is, on the Antarctic Peninsula and its Archipelago (HOLDGATE 1963; PARMELEE, RIMMER 1985; CORDIER et al. 1983) and on other islands: the South Shetlands (Robert I – PEFAUR, MURUA 1972; Nelson I – ARAYA, ARAVENA 1965; Elephant I – FURSE, BRUCE 1975; FURSE 1979) and also on the South Orkney Is (ARDLEY 1936). SOLYANIK (1964) described an analogous habitat preference in the birds on Bouvet I. To be sure, this island lies outside the zone of summer pack ice, but its climate much resembles that of the above-mentioned areas.

Fig. 5. Typical appearance of the shore-line in the northern part of King George I: Davey Pt (cf Fig. 3: 55). Phot B. JABŁOŃSKI.

Table I

Distribution and abundance of Antarctic Terns in different regions of King George Island in the 1980/81 breeding season. Figures in brackets: in column 3 – number of breeding groups in the region studied, in column 4 – number of nests in group mentioned

Ser. No	Location of colony	No of nests	Description of the place of breeding sites
1	2	3	4
	Admiralty Bay Region		
1	Red Hill	6(6)	nests scattered on barren rock rubble on raised terrace
2	Patelnia Point	30(2)	12 nests on barren moraine, 18 on fine debris of lava streams
3	Blue Dyke	16(1)	scree on mountain slope
4	Bastion	36(1)	scree on mountain slope
5	Creeping Slope	138(2)	on barren moraines
6	Uchatka Point	6(1)	on fine debris of lava streams on raised terrace
7	Demay Point	30(5)	slope of loose talus at the base of rock-face
8	Brama	8(1)	fine rock debris on nunatak slope
9	Agat Point	21(1)	rock slab debris on coastal rock
10	Siodło	6(1)	fine rock debris on nunatak slope
11	Sphinx Hill	36(2)	20 nests on fine debris of lava stream on slope; 16 talus at the base of rock-face
12	Czajkowski Needle	13(1)	nunatak slope with fine debris of lava stream
13	Zamek	6(1)	nunatak slope with fine debris of lava stream
14	Rescuers Hills	2(2)	single nests on fine debris of lava stream
15	"ornithologists' moraine"	32(1)	moraine poorly overgrown with *Usnea*
16	Jersak Hills	5(5)	single nests on fine rock debris
17	Thomas Point	13(1)	loose talus at the base of rock-face
18	Jardin Pk.	8(1)	loose talus at the base of rock-face
19	Italia Valley	20(1)	loose talus at the base of rock-face
20	Breccia Crag	4(1)	loose talus at the base of rock-face
21	Cytadela	48(1)	loose talus at the base of rock-face
22	Belweder	10(1)	loose talus at the base of rock-face
23	Skalpel Point	16(1)	loose talus at the base of rock-face
24	Pond Hill	62(3)	loose talus at the base of rock-face
25	Emerald Point	58(3)	two groups (50 nests) on rock debris poorly overgrown, one group of 8 nests on debris devoid of vegetation
26	Dufayel I.	12(12)[1]	single nests on loose and barren scree on steep rock-slope
27	Urbanek Crag	2(2)	single nests on moraine amidst glacier
28	Klekowski Crag	42(1)	stone heaps on glacier at the base of rock-face
29	Crepin Point	56(4)	3 breeding groups on poorly overgrown moraine (8), 8 single nests on gravel beach with moss tufts
30	Keller Peninsula[2]		
	– on Visca Anchorage side	58(6)	3 breeding groups (38 nests) on poorly overgrown moraines, 2(15) on loose stone talus at the base of rock, 1(5) on gravel beach with moss tufts

Table I ctd

1	2	3	4
30	– above British Station	25(5)	stony area with moss tufts
	– Plaza Point	6(1)	scree of fine debris of lave streams on rock slopes
	– Harpoon Point	3(1)	scree of fine debris of lave streams on rock slopes
	– between Speil Point and Ore Point	244(9)	5 breeding groups (72) on poorly overgrown storm-water ridges, 2 groups (118) on poorly overgrown stony slopes, 2 groups (54) on loose talus at the base of rocks
	– from Ore Point to Tokarski Point	192(6)	2 breeding groups (108) on slopes of loose tail at the base of rocks, 2 (22) on storm-water ridges overgrown with vegetation (one of them in the association *Deschampsia antarctica*), one (20) in poorly overgrown rock debris heap, one (42) on rock debris heap on glacier
31	Stenhouse Bluff	30(1)[1]	loose talus at the base of rock-face
32	Ullman Spur	15(10)	stony slope of rock
33	Precious Pk.	75(2)[1]	63 nests on slope covered with fine rock debris and 12 on gravel beech
34	Szafer Ridge	4(4)[1]	single nests on stony slope below rock-face
35	Tern Nunatak	10(1)[1]	single nests on stony slope below rock-face
36	Warkocz	25(2)	moraine in glacier (18 nests), on barren moraine (7)
37	Smok	40(2)	scree on rocky slope (32), on poorly overgrown rock debris (8)
38	Henneguin Pt. – Mt. Wawel	26(6)	5 groups on banks rocky debris (20), one on overgrown storm-water ridge (6)
39	Vauréal Pk.	78(6)	5 groups on slopes of loose scree (39 nests), one on barren moraine
	Legru Bay Region		
40	Cinder Spur	6(1)	loose talus at the base of rock
	King George Bay Region		
41	Low Head	7(1)	thinly overgrown moraine
42	Lions Rump	15(2)	barren moraine (12 nests), slope of talus (3)
43	Sukiennice Hills	16(1)	talus of lava debris at the base of rock
44	Turret Point	14(2)	thinly overgrown moraine
45	Three Sisters	1(1)[3]	thinly overgrown moraine
46	Penguin I.	3(2)[4]	2 nests on fine debris at crater, 1 inside crater
	Destruction Bay Region		
47	Melville Peninsula	49(4)	on thin weathered layer of slates of cliff shore
48	Wrona Buttress	12(1)	moraine in glacier on its beach side
49	North Foreland	8(2)	on slope with fine rock debris
	Emeral Cove Region		
50	Brimstone Pk.	74(3)	two groups on loose stone heaps at the base of rock-face (40), one on slope of moraine in glacier (34)
	Venus Bay Region		
51	Bolinder Bluff	239(4)	loose stone talus at the base of rock
52	Pyrites I.	6(1)	thin layer of weathered debris on cliff shore
53	Ridley I.	218(2)	loose stone talus at the base of rock

Table I ctd

1	2	3	4
Corsair Bight Region			
54	False Round Pt. (western side)	387(9)	7 breeding groups on barren moraines (362), 2 groups on loose talus at the base of rock (25)
Joannes Paulus II Coast			
55	Davey Point	24(1)	debris heap on glacier
56	islet west of Bell I.	84(1)	islet west of Bell I slope with thin layer of rock debris
57	Atherton I.	16(1)	slope with thin layer of lava debris
58	Fildes Peninsula Region[2]		
	– West Foreland	21(1)[5]	on barren moraine close to glacier
	– Suffield Pt.	32(4)[6]	on poorly overgrown moraines covered with fine rock debris
	– Ostrov Geologov	39(2)[7]	slope of mountainous island with fine rock rubble
	– Ardley I.	12(2)[8]	in fine rock debris on cliffy shore
	– Ostrov Albatros	8(1)[9]	slope of island with fine rock rubble
	Nebles Point	+[10]	
59	Barton Peninsula	32(4)[11]	2 breeding groups on thinly overgrown moraines on raised terrace near glacier (17), one group on loose rock rubble (3), one group on gravel beach overgrown with *Xantaria elegans* (12)
60	Potter Peninsula Region[2]		
	– of Teniente Jubany to Three Brothers	369(8)[12]	6 breeding groups on barren moraines on raised terrace near glecier (231), one on moraine on ice (10), one on loose rock rubble at thr foot of Three Brothers rock-face (128)
	– Stranger Point	2(1)[13]	cliff with fine rock debris

[1] In the breeding season 1978/79 did not occur.

[2] The colonies on Keller Peninsula, Fildes Peninsula and Potter Peninsula were often almost fused together and so they were difficult to separate.

[3] 16 pairs nested there in the 1978/79 season.

[4] In January 1979 18 pairs nested on the layers of loosely bound scoria at the foot of the crater in the NW part of the island (groupings of 6, 3, 6 and 2 nests) and one nest on the debris heap of the crater (JABŁOŃSKI 1980)

[5] In the 1979/80 -34 pairs (BANNASCH et al. 1981); in 1984/85 – from November and in Jaunuary – 7 breeding groups from 1 to 9 and two from 10 to 24 pairs (PETER et al. 1988).

[6] In the 1984/85 season – 10-24 – pairs (PETER et al. 1988).

[7] In the 1979/80 season – 34 pairs (BANNASCH et al. 1981); in 1984/85 – 10-24 pairs (PETER et al. 1988).

[8] In the 1979/80 season – 4-10 pairs (BANNASCH et al. 1981); in 1984/85 from November and in Jaunuary – 7 breeding groups of 1-9 and 10-24 pairs (PETER et al. 1988).

[9] In the 1979/80 season – the presence of breeding pairs was reported but no numbers given (BANNASCH et al. 1981), in 1984/85 from 10 to 24 pairs (PETER et al. 1988).

[10] I was at Nebles Point only on 22 and 26 Feb 1981, and so after the breeding season and for that reason I did not give any figures. At the time of my visit there were about 150 individuals of *S. vittata* there PETER et al. (1988) estimated the size of this colony at 100-300 pairs.

[11] Acc to PETER et al. (1988), 10-24 pairs nested on the Barton Peninsula. In 1966/67 season – 50 pairs in the three Brothers Region (ARAYA & ARRIETA 1971).

[12] Acc to PETER et al. (1988), in 1984/85 from 50 to 90 pairs.

[13] In the 1984/85 season from 1 to 9 pairs (PETER et al. 1988).

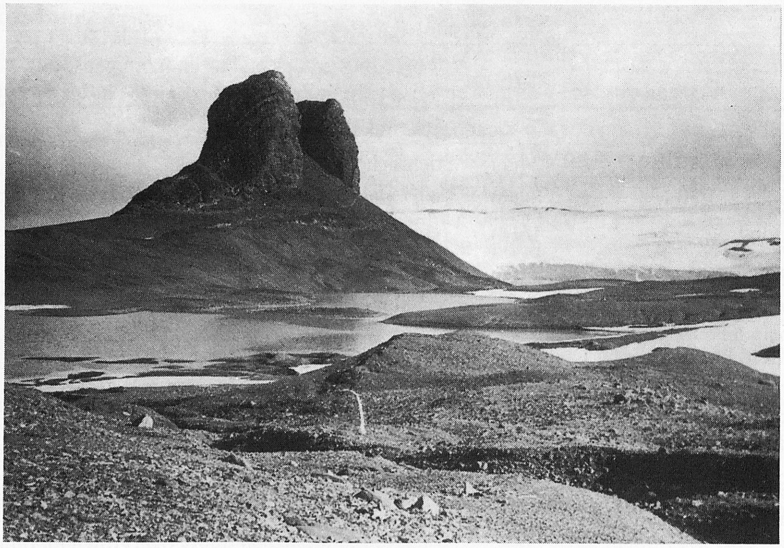

Fig. 6. Breeding environment of the Antarctic Tern on the southern coast of King George I: Three Brothers region (Fig. 3 and Table I: 60). Phot. B. JABŁOŃSKI.

Fig. 7. Breeding environment of the Antarctic Tern in the region of its most abundant occurrence on King George I in the surroundings of Admiralty Bay: moraines at Demay Pt (Fig. 3 and Table I: 7). Phot. B. JABŁOŃSKI.

Table II

Preference of Antarctic Terns for breeding sites on King George Island

Ser. No	Habitat	No of breeding pairs	%
	Optimal habitats:		
1	Rock-rubble not overgrown with *Usnea* sp and fine weathering debris on raised terraces and rocky slopes	1932	54.9
2	Moraines not overgrown with *Usnea* sp.	826	23.5
3	Slopes with rock-rubble thinly overgrown with *Usnea* sp.	275	7.8
	Peripheral habitats:		
4	Rock-rubble heaps and morains on glaciers	142	4.0
5	Moraines poorly overgrown with *Usnea* sp.	109	3.1
6	Storm-water ridges thinly overgrown by *Usnea* sp. and mosses [1]	100	2.8
7	Fine weathering waste on nunantak slopes	97	2.8
8	Gravel beaches (often with lichens)	37	1.1
	Total	3 518	100.0

[1] including a case of 18 nests amid *Deschmpsia antarctica* .

I found a high percentage of single breeding sites on King George I, both in the optimal and in the peripheral habitats (Table III). The nests were about 50-150 m apart, but this notwithstanding, these distances did not prevent the birds from raising alarms in the whole group, including the birds from distant nests, and undertaking collective defence whenever a Skua or Kelp Gull appeared. Such breeding sites with scattered nests occur in the Subantarctic (SAGAR 1978), where the pressure of predators is much smaller than in the Antarctic Region (SAGAR 1978; PARMELEE, MAXSON 1975).

Table III

Number of breeding sites in successive classes of Antarctic Terns in optimal and peripheral habitats (criterion of the assessment of habitats was fixed on the basis of the global number of pairs breeding in the habitats listed in Table II)

Habitat		Division into classes according to numbers of nests									
		1	2-5	6-10	11-15	16-20	21-30	31-50	51-100	100<	Total
Optimal (1-3 in Table II)	No of sites	19	8	16	16	13	7	11	15	3	108
	%	17.6	7.4	14.8	14.8	12.0	6.5	10.2	13.9	2.8	100
Peripheral (4-8 in Table II)	No of sites	11	3	9	13	5	1	4	–	–	46
	%	23.9	6.5	19.6	28.2	10.9	2.2	8.7			100
Total	No of sites	30	11	25	29	18	8	15	15	3	154
	%	19.5	7.1	16.2	18.8	11.7	5.2	9.7	9.7	2.0	99.9

In the subantarctic region of the Atlantic (on Gough I) SWALES (1965) found that the most frequent size of colony lay within a range of 5-10 pairs and, he noted only 1 colony numbering 100 pairs (among all the 500 colonies). CORDIER et al.(1983) reported from Esperance (on the Antarctic Peninsula, 63°24'S) that 3 pairs nested at each of two sites and at the remaining two sites: 10 and 43 pairs (then the mean size of those colonies was 14.7 pairs). In the season 1980/81 I found 3 518 pairs at 181 sites and so the mean colony size was 19.4 pairs. According to PETER et al. (1988), in the seasons 1983/84 and 1984/85 the most frequently observed colonies on the Fildes Peninsula numbered 10-50 pairs, while the colonies of 50-300 pairs formed 12.0% (in the period of my investigation – 11.7%). Those authors mentioned also a very big colony of about 9 000 pairs existing on Livingston I. It may therefore be supposed that the tendency to create larger breeding groupings in the Antarctic Region than in subantarctic areas is one of the asaptations of the species to life in the polar zone. This may be connected with limited ice- and snow-free areas suitable for nesting and with a greater density of predators.

Literature concerning King George I published so far shows that Anatarctic Terns occupy the same breeding areas for many years. In 1908-1911 some French investigators explored, among others, the region of Jardin Pk (Fig. 4, Table I: No 18) and it was probably there that GAIN (1914) came across the breeding sites that have persisted, in dispersion, till today. The colonies on the screes of Three Brothers (Fig. 3, Table I: No 60) numbered 50 pairs in 1966/1967 (ARAYA, ARRIETA 1971), 128 pairs in 1980/81 and 50-99 in 1983 (PETER et al. 1988). These last authors also confirmed the presence of small breeding sites at Strange Pt (Fig. 3, Table I: No 60): in the season 1980/81 – 2 pairs and in 1983-1985 from 1 to 9 pairs. Similar quantitative fluctuations at one and the same site could be observed in the region of the Fildes Peninsula (Fig. 3, Table I: No 58) in 1978-1985 (BANNASH, ODENING 1981; PETER et al. 1988 and the author's own materials – Table I), at Patelnia Pt (Fig. 4, Table I: No. 2) and on the coast between Sphinx and Thomas Pt in 1978-1990 (Fig. 4, Table I: Nos 11-17) (JABŁOŃSKI 1986; SIERAKOWSKI 1991; MYRCHA 1992). The differences between the assessments of abundance and exact situations can be accounted for not only by the fluctuations in the size of population and local microclimatic conditions (differences in the occurrence of snow cover) but also by the time of counting, which in the case of polar investigations is not always dependent on the investigator; it can be seen from the findings presented by PETER et al. (1988) that the results of counts in November and January differed somewhat from each other. In my opinion, this is due to the changing level of losses in consecutive phases of the process of reproduction. The losses in the regions adjacent to the polar stations may be caused, among other things, by frequent penetrations of the area by people and the aggression of predators facilitated at that time. It is significant that, according to PETER et al. (1988), there were no breeding colonies in the neighbourhood of the station in January, whereas some new ones appeared in less frequented areas.

B. Changes in the abundance of terns in the Admiralty Bay region in the successive breeding seasons 1978-1981

I assessed the changes in the abundance of the breeding colonies in the Admiralty Bay region in three sucessive breeding seasons. The area was situated in the close nethbourhood of the Henryk Arctowski Station and included only 91 km of the coastline, which made the inspection of the colonies easier. Besides, the most sites occurred here (81 in the 1980/81 season, that is, 58.9% of the whole population of King George I).

The number of pairs in successive breeding seasons ranged from 652 to 1826 (Table IV). Calculated for the lenght of the coastline (91 km), it was 7.2-20.1 pairs/km (on the average 14.0 pairs/km). I found the dependence of the size of a colony upon the surface area of the existing snow cover till 15 Dec, or the time of mass egg-laying (Table V). That was mainly connected with blizzards at the onset of summer (i.e. between mid-November and the begining of December). The

Table IV

Abundance of Antartic Terns in the Admiralty Bay region (from Red Hill to Martins Head) in 1978-1981

Location of colony (colony Nos from Table I and Fig. 4 in brackets)	Numbers of pairs in successive seasons		
	1978/79	1979/80	1980/81
Red Hill (1)	4	3	6
Patelnia (Telephone Pt – (2))	20	39	30
Bastion, Creeping Slope, Uchatka Pt, Demay Pt, Brama (4-8)	311	363	512
Siodło, Agat Pt, Sphinx Hill, Czajkowski Neadle, Zamek (9-13)	8	62	82
Rescures Hills (14)	4	2	2
"ornitologists moraine", Jersak Hills, Thomas Pt, Jardin Pk, Italia Valley (15-19)	53	129	78
Breccia Crag (20)	18	7	4
Cytadela, Belweder (21-22)	8	36	58
Scalpel Pt, Pond Hill (23-24)	9	13	78
Emeral Pt (25)	5	78	58
Dufayel Island (26)	–	8	12
Urbanek Crag, Klekowski Crag (27-28)	1	43	44
Crepin Pt. (29)	6	41	56
Keller Peninsula (30)	146	67	503
Stenhouse Bluff (31)	–	26	30
Ullman Spur (32)	3	28	15
Precious Pk. (33)	–	11	75
Szafer Ridge, Tern Nunatak (34-35)	–	–	14
Warkocz, Smok, Hennequen Pt., Mount Wawel (36-38)	20	25	91
Vauréal Pk. (39)	36	362	78
Total (1-39)	652	1343	1826

thick snow layer blown at the time of hurricanes thawed considerably more slowly than did the snow fallen while there were no strong winds blowing. The very various directions of foehn winds and so the directions the snow was drifted in particular regions of the bay produced various conditions for breeding even in places not very distant from each other. That induced changes in the abundance of particular breeding groups irrespective of the general tendency shown by the changes in abundace in the whole population inhabiting the Admiralty Bay region (cf. the data from the Keller Peninsula and Vauréal Pk – Tables IV and V). In some places (e.g. Italia Valley – Fig. 4, No 19) the colony size depended upon the amount of snow falling both in winter and in spring and the temperatures in these seasons, because they decided how long the snow cover lingered (Tables IV and V – data from 1978/79 and 1980/81: frosty winters, and from 1979/80: mild winter, the bay unfrozen).

C. Changes in abundance in the Admiralty Bay region in course of the year

Summer (December, January, February)

The presence of breeding birds caused that the quantitative level of the population was stable for 60 days. They formed 81.4-99.5% of the size of the whole population in the egg-laying season (December, January – Table VI). After the loss of their broods the parental birds led a nomadic

Table V

The dependence of the colony size upon the size of the snow-covered part of its territory in the Admiralty Bay region (the area of the colony was fixed in the season of the greatest abundance of birds and snow cover at that time is assumed to be 0%)

Colony location (figures in parentheses same as in Table I, Fig 4) and area in m^2	Breeding season	Approx. area of colony territory part covered with snow till 15 Dec (%)	No of nests
Italia Valley (19) ± 20 m^2	1978/79	41	19
	1979/80	0	39
	1980/81	58	20
Keller Peninsula (30) – talus at the foot of Tokarski Pk. ± 2125 m^2	1978/79	60	36
	1979/80	88	10
	1980/81	0	68
– rubble heaps above British Station ± 420 m^2	1978/79	75	4
	1979/80	90	2
	1980/81	0	18
– western slopes of Piasecki Pass ± 1785 m^2	1978/79	58	24
	1979/80	77	11
	1980/81	0	42
– valley below Piasecki Pass ± 165 m^2	1978/79	64	28
	1979/80	81	9
	1980/81	0	76
Vauréal Pk (39) – rubble heap on top ± 1250 m^2	1978/79	96	0
	1979/80	0	180
	1980/81	78	9

life in the colony area for 7-14 days. They abandoned it definitively when unfavourable weather conditions set in (snow-storms, foehn winds). I noted the smallest changes in abundace during summer in the 1978/79 season (Table VI), when the weather conditions were favourable and the period of egg-laying and incubation was still in full swing in February (the last fledgling was observed on 19 March – K. ZDZITOWIECKI oral comm). That year the losses in eggs were also the smallest (31.9%).

In the summer 1979/80 many broods were destroyed in the period of incubation of eggs and young chicks. As early as the end of December 69.2% of the nests had been destroyed on the slope of Vauréal Pk (Fig. 4, No 39). After 19 Jan in the Italia Valley 56.5% of the nests were occupied (Fig. 4, No 19) and in the remaining regions of Ezcurra Fiord (Fig. 4, Nos 20-28) only 17%, whereas between Blue Dyke, Bastion, Uchatka Pt. and Demay Pt (Fig. 4, Nos 3,4,6,7) the occupied nests constituted 33.3%. After the snow storm on 8 Feb *S. vittata* was absent in the area of the largest colony (i.e. Vauréal Pk – observation on 12 Feb, Demay Pt and Blue Dyke on 16 Feb). In February only 174 individuals of *S. vittata* stayed in the Bay region (6.4% of their number in December – Table VI).

The breeding season of 1980/81 was characterized by the greatest losses in eggs (85.9%). In this connection the nomadizing flocks appeared as early as the third decade of January. After a heavy gale on 7 Feb hardly 137 individuals remained (3.5% of the breeding population – Table VI).

Table VI

Changes in the numbers of *Sterna vittata* in the Admiralty Bay region in summer in three breeding seasons. A – No of nonbreeders, B – No of breeders (in February in the 1979/80 season and throughout the 1980/81 season pairs that had lost their broods most probably stayed among nonbreeders at their roosts)

Breeding season		Numbers in successive months		
		December	January	February
1978/79	A	299 (18.6%)	299 (18.6%)	299 (18.6%)
	B	1304	1304	1304
	Total	1603 (100%)	1603 (100%)	1603 (100%)
1979/80	A	49 (1.8%)	14 (0.5%)	174
	B	2686	2686	–
	Total	2735 (100%)	2700 (100%)	174
1980/81	A	275 (6.9%)	590 (13.9%)	137
	B	3652	3652	–
	Total	3927 (100%)	4242 (100%)	137

Autumn (March, April)

The abundance of birds and the frequency of encounters with them in March were various in successive years: in 1979 K. ZDZITOWIECKI (oral comm) came sporadically upon 1-25 individuals; along the coastline from Vauréal Pk (Fig. 4, No 39), Hennequen Pt (Fig. 4, No 38) to the Keller Peninsula (Fig. 4, No 30) I observed single birds or group of 2,4,6,8 till 16 March 1980 (the largest number of 20 on 12 March). The mean number per count was 8.5 individuals, the frequency 35.7% whereas in 1981 the mean number for the Bay region was 92.7 (70-119) individuals and the frequency 58.6%. That was 2.5% of the population size in the breeding season. On 28 March I saw 3 migrating flocks over the Brandsfield Strait (75, 57 and 123 individuals) heading for Penguin I (Fig. 3, No 46) and further towards North Foreland (Fig. 3, No 49).

In April 1979 *S. vittata* was not seen in the Bay region, whereas on 3 Apr 1980 I observed 19 birds flying at a great height from the Bransfield Strait side over Emerald Pt (Fig. 3,4 No 25) towards the northern part of King George I.

Winter (May, June, July, August)

In this season of the year the abundance depended on weather conditions. In 1979 Admiralty Bay did not freeze and regularly 5 to 100 terns stayed in this region; on 16 July 1979 flights of flocks numbering obove 100 individuals were observed (altogether about 3000 bird flew over) along the line marked out by Blue Dyke and Penguin I (Fig. 3, Nos 3 and 46). In 1980 I regularly came upon terns only in May (frequency – 83.9%). The mean calculated on the basis of many observations was 231.2 (179-345) individuals, 2.6 individuals per 1 km of the coastline. The largest feeding flocks occurred between Blue Dyke and Agat Pt (Figs 3,4 Nos 3 and 9) and on the Keller Peninsula (Figs 3,4 No 30). Having finished foraging many birds rested at the sites of breeding colonies. I noted down the following migrating flocks: 12 May 1980 – 76 individuals; 17 May – 71; 19 May – 51; 20 May – 10; 21 May – 83; 25 May – 28; 26 May – 80; 27 May – 84 (altogether 483 migrating birds).

In June and July 1980 I encountered *S. vittata* only as follows: on 11 June – 1 bird (thaw after severe frost), 28 June – 3 birds (onset of snow-storm), 1 July - 1 bird and next 5 (before snow-storm), on 5 July one bird and one on 11 July. Starting from 15 July, nearly whole Admiralty Bay and Bransfield Strait were already covered with ice and there were no terns present.

Spring (September, October, November)

In consequence of the regular occurrence of *S. vittata* in the winter of 1979 it was found present at the sites of colonies as early as 13 Sep (K. ZDZITOWIECKI – oral comm). Towards the end of October most of the last year's nests were occupied. Heavy snow-fall, accompanied by strong winds (11 Nov 1979) made it however impossible for the birds to rebuild the nests and lay eggs. In the first-formed colonies the number of breeding pairs did not get stabilized at the old level until 20 Nov and then egg-laying was started.

In 1980 I observed the first two individuals on "ornithologists' moraine" (Fig. 4, No 15) on 26 Sep. From 1 to 3 Oct 3 individuals stayed between Jardin Pk and Belweder (Fig. 4, Nos 18 and 22). Afterwards they left the region of the still frozen Admiralty Bay for several days. The gradual occupying of the colony site did not begin until 8 Oct and on 16 Oct I found 8 freshly rebuilt nests on "ornithologists' moraine". The mean abundance over a 20 km length of coastline from the Italia Valley to Red Hill (Fig. 4, Nos 19 and 1), where after the arrival of terns their concentration was the highest, came to 105.8 individuals in October or 3.2% of their number in summer (frequency in October – 48.4%). Such low numbers were due to the occurrence of a thick snow cover at the colony sites on the Keller Peninsula (Fig. 4, No 30), Vauréal Pk (Fig. 4, No 39) and from Demay Pt to Blue Dyke (Fig. 4, Nos 7-3), and to the freezing-over of the Bay. A small space of unfrozen water (about 50 × 150 m) did not appear between Thomas Pt and Urbanek Crag (Fig. 4, Nos 17 and 27) until 25 Oct 1980. Antarctic Terns foraged there together with other species of birds. In the biggest group on water there were 84 *S. vittata*, 136 *Larus dominicanus*, 52 *Phalacrocorax atriceps*, about 300 *Pygoscelis adeliae* and 52 *Pygoscelis papua*.

In 1980 the formation of colonies was for the first time interrupted by snow-storms and snowfalls on 3 and 6 Nov 1980. On 8 Nov all the breeding grounds were covered by a thick layer of snow; only on "ornithologists' moraine" (Fig. 4, No 15) the snow was partly blown off and 8 *S. vittata* were sitting on nests built on 16 Oct (no eggs). The settling of the colony area was restrained for the second time on 18-19 Nov because of strong winds (in gusts up to 63 m/sec.), which produced new snow drifts. From 23 Nov 40.9% of the breeding population stayed in the region of Sphinx, Agat Pt, Czajkowski's Needle and Zamek (Fig. 4, Nos 9-13) and 20.5% on "ornithologists' moraine" and in the Jersak Hill - Jardin Pk region. From 23 Nov to 29 Nov there were on the average 1055 individuals of *S. vittata* or 28.9% of the summer population in the area of Admiralty Bay.

D. Comments

In summer the numbers of *S. vittata* are stable in different Antarctic regions. This is true of both the breeding population and the non-breeders. In OLROG's (1963) opinion, Antarctic Terns are inshore birds in summer. That is indicated by the lack of observations of this species at a distance from the shore (SIPLE, LINDSEY 1937; BIERMAN, VOUS 1950; TICKELL, WOODS 1972; ERIKSON et al. 1972, 1974; LINKOWSKI, REMBISZEWSKI 1978; GRIFFITHS 1982; HUNT et al. 1990; VEIT, HUNT 1991). According to HOLDGATE (1963), the occurrence and abundance of *S. vittata* in the Antarctic area in the post-breeding season is determined by the degree of freezing of the inshore waters, where they have their feeding places. On the other hand, according to PEFAUR & MURUA (1972) terns fly away from Robert I as early as after 15 Feb (and so before ice had flown in). To be sure, the results of my studies from 1979 and 1980 and those obtained by PRESLER (1980) and PETER et al. (1988) confirm HOLDGATE's (1963) opinion on the effect of freezing on the abundance of *S. vittata* in the post-breeding period; it seems however that in certain circumstances PEFAUR & MURUA's (1972) view may also be justifiable, for I found a relationship between the period of occupation of the colony sites by birds after the breeding season and the size of losses they had suffered in the breeding season. In the seasons of exceptionally great losses in eggs and chicks, *S. vittata* left the region of Admiralty Bay before the appearance of pack ice and the freezing of the Bay. The numbers of birds increased again towards the end of March and in April (in 1980 also in

May), which was caused by migrations of individuals from areas situated further to the south - some migrating flocks could be seen flying over at a great height at that time. My observations of a second wave of migration, i.e. on 16 July and from 13 to 17 May in 1981, a high frequency in May (83.9%), and sporadic observations (PETER et al. 1988) of large flocks (150-400 individuals) in July and August 1984, in the periods of worsening weather conditions, seem to have been caused by the movements of the population form Deception I. On this volcanic atoll with active geysers suitable feeding conditions last much longer than in other Antarctic regions and for this reason it is a concentration place of *S. vittata* from areas situated further to the south. Sailing from the Esperance Station to the Mirny Station (27 Feb - 16 March 1979), no longer did I meet with any Antarctic Terns, whereas on 19 March 1980 I saw a grouping of 358 adult and 98 young birds capable of flying, even though there were no longer any Antarctic Terns on Livingston I at that time. And so, probably, these birds do not undertake an autumnal migration before the sea around Deception I begins to freeze over.

In 1979-1981 I made 11 observations of autumnal flights of *S. vittata*: 10 times the flocks headed to the north of King George I (between Tartar Pt and Pottinger Pt – Fig. 3), which agreed with OLROG'S (1963) statement that *S. v. gaini* winters on the Chilean coast. The flights on 16 July 1979 (altogether about 3000 individuals) were directed along the coastline of King George I on its Bransfield Strait side towards Penguin I – North Foreland (Fig. 3). Therefore, the eastern coast of South America may also provide wintering places for part of the *S. v. gaini* population on the assumption that the flight direction taken by the flocks observed on 17 July 1979 was maintained (i.e., the Scotia Sea between the Falkland Is and South Georgia).

In literature there are some contradictory items of information about the winter ground of *S. v. georgiae*. According to OLROG (1963), this subspecies migrates in the direction of Buenos Aires and Brazil, whereas the findings of MATTHEWS (1929) and PRINCE and PAYNE (1979) indicate that Antarctic Terns occur on South Georgia all the year round. It is interesting that JEHL et al. (1979), who carried out their observations on the sea in the season of autumnal migrations (from 26 March to 19 Apr 1977), did not encounter any Antarctic Terns at all between Ushuaia and South Georgia. On the other hand, according to ARDLEY (1936), this species only exceptionally spends winter on the South Orkney Is. CLARKE (1906) also observed autumnal migrations in that region on 25 March. The problem of the sedentary or migratory ways of living of the western part of population remains open and seems to be independent of weather conditions.

The eastern part of the population (on the Indian Ocean side) fly off after fledging in April and May. According to the data published by DOWNES et al. (1959), *S. vittata* was absent from Heard I in the following periods: 1949: 30 June – 30 Nov; 1950: 18 Aug – 31 Oct; 1951: after the completion of breeding only 2 individuals were seen in October; 1953: 8 Aug – 24 Nov. In winter this island becomes encompassed by pack ice. On the other hand, the population of the Kerguelen Is (out of the range of pack ice) covers a distance of 4581 km to South Africa, where these birds arrive in March and the abundance of the flocks wintering there was estimated by SAGAR (1991) at about 13 500 individuals. Observations made by STAHL et al. (1985) point also at migrations of the population inhabiting the Crozet Is.

The manner in which Antarctic Terns move to their winter grounds also needs explaining. Their migrations begin perhaps with northward movements of small groups in the nature of nomadic roamings in different parts of the area. This supposition seems to be supported by the data presented by JOHNSTONE & KERRY (1976) from the Australian Sector and by BROWN et al. (1975) and STARCK & WYRZYKOWSKI (1982) from the South Shetland region up to the Patagonia Shelf. On the other hand, later observations show already long-distance migrations.

IV. BREEDING BIOLOGY

A. Breeding sites (biotope, nests)

1. Material from King George I

2758 pairs of Antarctic Terns or 78.4% of the pairs observed during three breeding seasons, nested on rock rubble without any growth of *Usnea* sp. and on plant-less moraines (Table II). In such stony areas there was a large amount of weathering waste in the form of small flat fragments and of fine gravel. Preference for these habitats was mainly connected with the fact that after frequent rainfalls the water percolates into deeper layers of the substratum sooner in the unbound rock rubble on the slopes and moraines than in other places. The choice was also prompted by the availability of building material (small pebbles) within the limits of the defended territory (within a radius of 3-5 m from the nest), which also provided the possibility of sheltering the nest (Fig. 8) and the young (Fig. 9) against the wind.

Fine rocky material gathered by birds inside their territories and used to pad the nest up to three-quarters of its height, forms a layer permeable to rain water and water from melted snow at the time of above-zero temperatures. Sometimes, however, this layer fails to protect the brood from flooding with muddy water of abundant surface run-off, especially when the bottom part of the nest is still cemented with ice.

The following measurements of the wind velocity taken in three places on 29 Jan 1979 indicate the effectiveness of the protection of nests from the wind: 1) at the top of Jardin Pk, where the terns did not nest, it was 20-23 m/sec and in gusts reached 35 m/sec (dr J. SPEIL), 2) in the area of the Antarctic Terns' colony on the slope of Jardin Pk – at the edge of each of 10 nests – 1-5 m/sec (mean speed 2.8 m/sec) and at a height of 1.5 m above the nests 10-12 m/sec, in gusts up to 15 m/sec (dr J. PIASECKI) and 3) in the colony on "ornithologists' moraine" the speed of the wind measured at the edges of 14 nests was 1-8 m/sec (mean 3.6 m/sec) and at a height of 1.5 m above the nests 8-12 m/sec, in gusts up to 15 m/sec. In the nests built for the second time (17 Dec 1978), after the first ones had been covered by snow, the greatest speed of the wind that I measured at the edges of 2 nests was 4 and 5 m/sec.

Stony areas overgrown by thick patches of lichens of *Usnea* sp. and mosses were more rarely used for setting up a colony (cf Table II), since the fine rocky material indispensable to nest building was covered by vegetation. In the 1980/81 season 18 pairs exceptionally nested on the Keller Peninsula amidst the patches of *Deschampsia antarctica*; there was however some gravel between them.

Before setting to egg laying the Antarctic Terns built new nests of rebuilt the last year's ones. The building of new nests began with warming and thawing the ground by birds sitting on it and next deepening the defrosted substratum with their feet. Having made a pit, the terns brought pebbles and laid them in layers in the pit; then turning round in it they gave the nest its final shape. On the bottom of the pit there was a layer of gravel and rock waste about 1-1.5 cm thick and another layer on that base, consisting of flat pieces, 0.5-1 cm long, of rock waste. Such pebbles, sometimes cemented with mud, formed also the internal layer of the side wall of the nest. In the colonies located in the neighbourhood of lakelets with adjoining raised bog communities, I also observed "bands" of mosses or single tufts of mosses on the surface of the side walls of nests. Small covert feathers of gulls and skuas were exceptionally present in the building material. A scheme of the arrangement of materials in the nest of an Antarctic Tern is shown in Fig. 10. In 42 nests measured the inner diameter ranged from 9 to 17 cm (mean dia. 11.5 cm) and the depth from 1.5 to 3.2 (mean – 2.3 cm). The building of a new nest usually took 3 to 10 days, according to weather conditions (thawing of the ground) and phenology (later-started nests were built faster).

Fig. 8. Typical situation of an Antarctic Tern's nest among stones. Phot B. JABŁOŃSKI.

Fig. 9. A chick Antarctic Tern after leaving the nest. Rock rubble shelters it against high winds and impedes attacks of skuas. Phot B. JABŁOŃSKI.

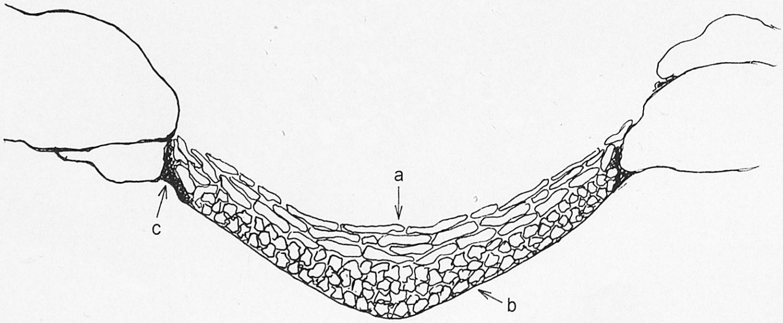

Fig. 10. Construction diagram of the Antarctic Tern's nest on King George I. a – pad of flat pieces of rock-waste (sometimes cemented with mud on sides), b – layer of gravel or small rock pieces, c – moss (only in nest located near the lakelets).

If at the beginning of December last year's sites were covered with snow, some of the birds sat down on the old nests to accelerate the melting of snow. The rebuilding of an old nest usually consisted of mending the pit and rearranging the flat pebbles, and this took 1-4 days.

2. Comparisons and comments

On the Antarctic Peninsula CORDIER et al. (1983) found nests placed so as to be protected by stones, similarly to those observed on King George I (Fig. 11). Such location of nests also often occurs with other species of Antarctic birds. Its purpose is to counteract not only the chilling but also the mechanical action of the wind, for, according to SYROYECHKOVSKIY (1959), the wind with a speed of, say, 25 m/sec is able to blow adult birds off their nests and to scatter the eggs. On islands situated in the transition zone of Antarctic and sub-Antarctic climates, e.g. on the Heard Is and South Georgia, the Antarctic Tern nests mainly on moraines (DOWNES et al. 1958; MATTHEWS 1929; MURPHY 1936). On South Georgia nests were found also in places overgrown by *Poa* sp. (LOVE, KINNEAR 1930; MURPHY 1936). The location of breeding sites on peatbogs with decayed tussocks of *Poa* on the substratum of lava streams on cliffs can be observed in the sub-Antarctic region on the New Zealand side (Snares Is – STEAD 1948; SAGAR 1978). Next on the islands in the Indian Ocean (from the Kerguelen Is to the Crozet and Prince Edward Is) *S. vittata* occupies mainly stony habitats in the upper parts of cliffs and small rocky slopes (FALLA 1937; SEGONZAC 1972; BERRUTI, HARRIS 1976; SAGAR 1991), whereas the sympatric species *Sterna virgata* nests in plant communities with *Poa*, *Azorella* and *Acaena*. It may be supposed that this difference in habitats is brought about by the competitive interactions between these species. On Tristan da Cunha many pairs of Antarctic Terns nested also on sandy beaches (ELLIOTT 1957), which widens the spectrum of biotopic requirements of this species.

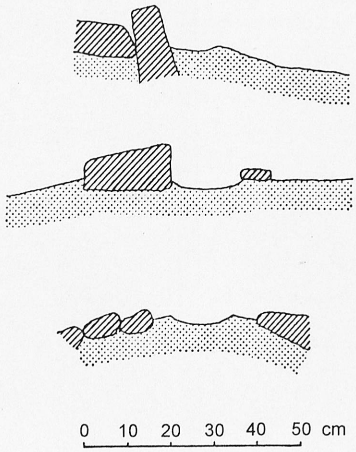

Fig. 11. The location of nests of Antarctic Terns on the Antarctic Peninsula (after CORDIER et al. 1983).

B. Eggs

1. Clutch size

The full clutch consisted of 1 or 2 eggs. One nest found in the Creeping Slope region on 5 Jan 1979 exceptionally contained 3 eggs. The mean number of eggs in a clutch was 1.45, which mean however underwent fluctuations in successive breeding seasons (Table VII).

The second egg was laid 48 hours after the first, but incubation began with the first egg.

Table VII

Numbers of eggs in nests of *Sterna vittata* in three breeding seasons on King George Island

Breeding season	No of eggs	No of nests	Mean number of eggs per nest	Range of mean numbers of eggs per nest in particular breeding groups
1978/79	184	134	1.37	1.21–1.65
1979/80	383	274	1.40	1.33–1.67
1980/81	325	205	1.58	1.48–1.65
Total	892	613	1.45	1.21–1.67

2. Colour and shape of eggs

The diversity of eggs of *Sterna vittata* in respect of colour and shape is exemplified by 9 selected eggs (Fig. 12). The ground colour is more often than not dark with different greenish brown shades (eggs 4, 5, 6), more rarely in a light tonality (egg 8). The other sort of the ground colour (about 30% of eggs) shows different dominant shades of brown, from light to darker (egg 1, 2, 3), the variant represented by egg 3 prevailing among them.

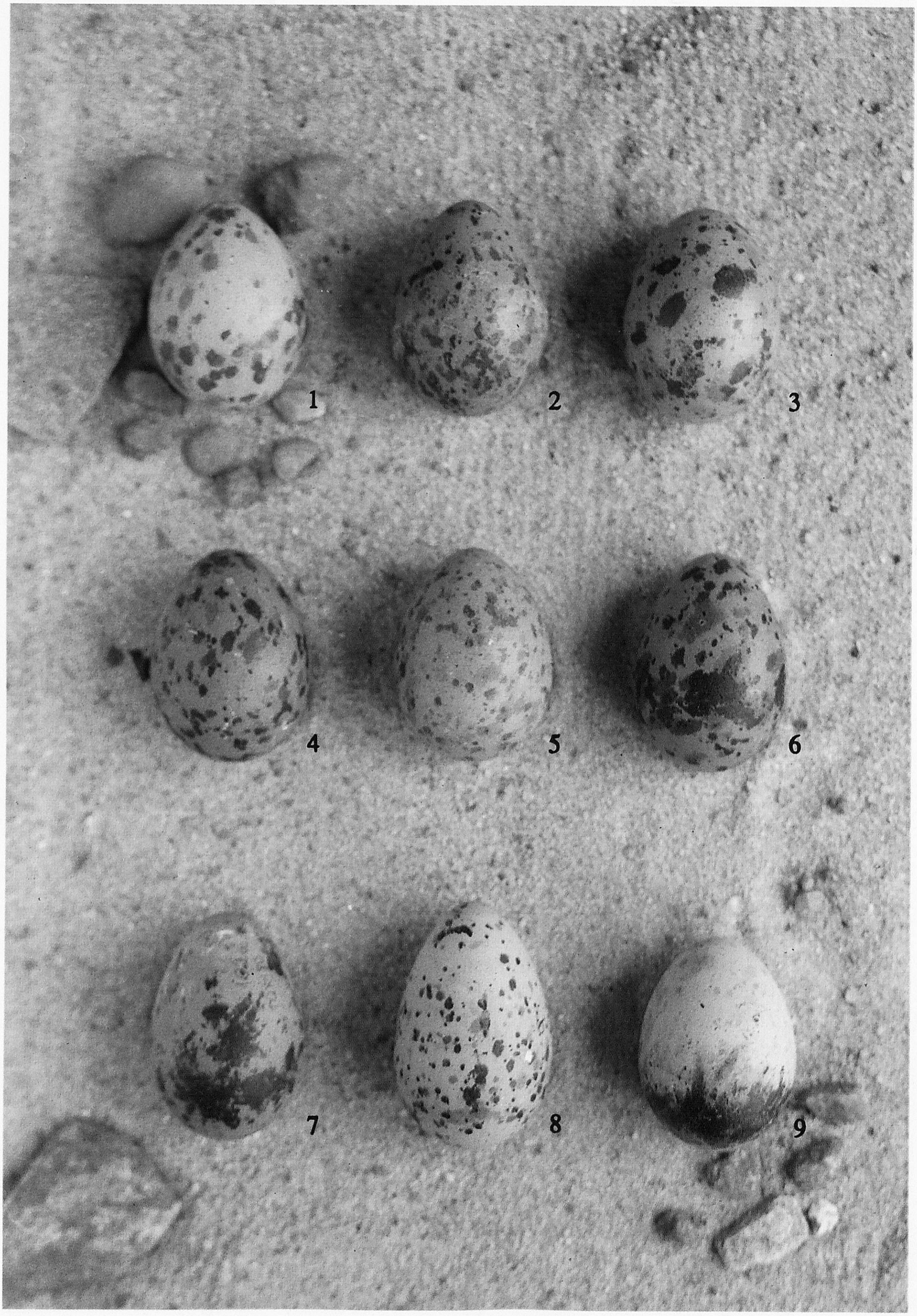

Fig. 12. Types of coloration of eggs of Antarctic Terns on King George I. The numbers of eggs are quoted in the text. Phot T. PŁODOWSKI.

Deep spots are grey-brown, pale, usually smaller than surface spots. They are mostly regularly distributed, more rarely larger and concentrated at the broad end of the egg.

The surface spots are generally dark brown, less frequently somewhat lighter, as on egg 6. Their size and arrangement are various: from fine, more or less regularly scattered (egg 8) to large patches forming a wreathe at the broad end (eggs 6, 7, 9). The rarest type of coloration is represented by egg 9.

Dumpy eggs with gently rounded small ends (eggs 1 and 3) are most often encountered. Remarkable differences in colour and shape occur even between eggs in one and the same clutch: eggs 2 and 3, 5 and 6, 7 and 8.

3. Measurements and weight of eggs

A total of 498 eggs were measured in three breeding seasons; 344 of these eggs were single or first laid in many-egged clutches and 154 second eggs.

The mean length calculated from all eggs measured was 44.8 mm (41.5-51.5 mm). The single and first eggs were longer, 80.5% of them ranged from 44.0 to 46.9 mm, and 76% of the second eggs from 43.0 to 45.9 mm (Fig. 13).

The mean width from all the eggs measured was 33.5 mm (31.1-35.9 mm, exceptionally 39.2 mm in one egg considerably departing from the rest – cf Fig. 14). In the graph the peaks of the curves of both groups overlap: 64.2% of the single and first eggs and 56.5% of the second eggs lie within limits from 33.0 to 33.9 mm. 37.3% of eggs had a width between 33.0 and 33.4 mm, while

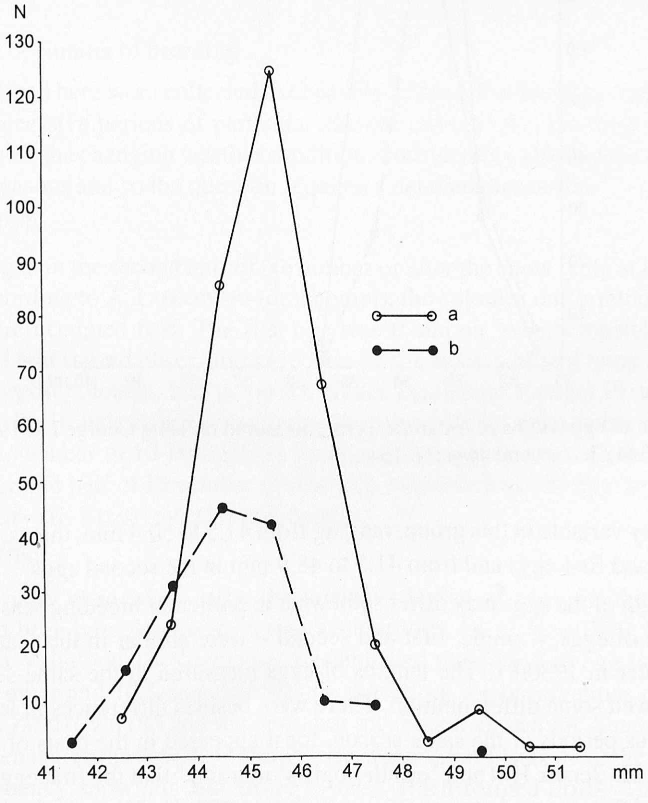

Fig. 13. Distribution of egg lengths in Antarctic Terns, measured on King George I in 1978-1981. a – single or first eggs (N=344), b – second eggs (N=154).

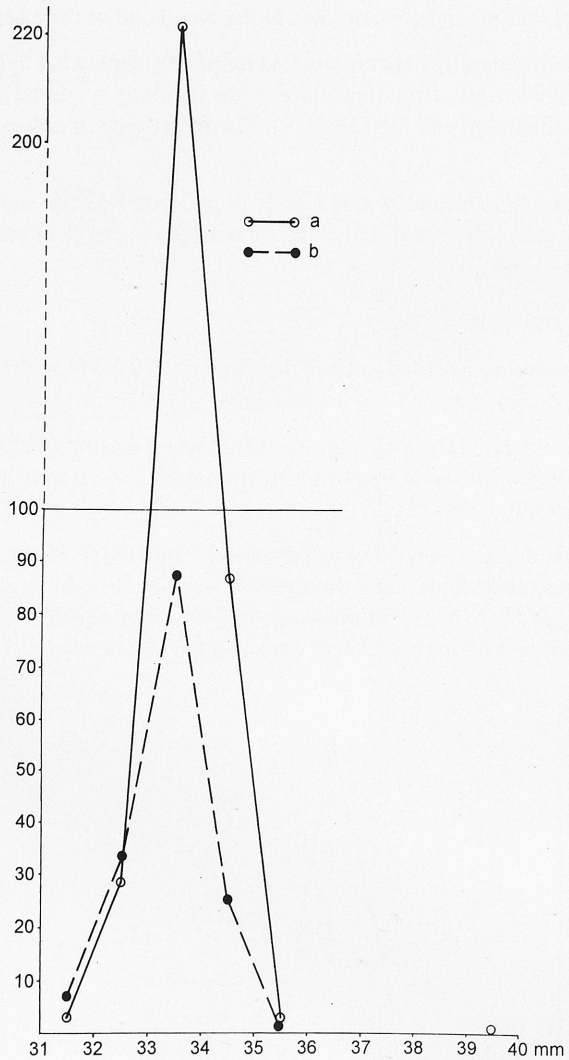

Fig. 14. Distribution of egg widths in Antarctic Terns, measured on King George I in 1978-1981. a – single or first eggs (N=344), b – second eggs (N=154).

the length was very variable in this group, ranging from 41.5 to 50.4 mm, that is, from 42.5 to 50.4 mm in the single and first eggs and from 41.5 to 48.9 mm in the second eggs.

The mean length of the eggs may differ somewhat in particular breeding seasons. Its values for all the three sorts of eggs, – single, first and second – were similar in the seasons 1978/79 and 1979/80 and greater in 1980/81. The lengths of eggs measured in the same season in different colonies also showed some differentiation. There were besides differences in length between the eggs laid in various periods of the same season, for it appeared in the basis of the data from the colonies in Jardin Pk, Jersak Hill and "ornithologists' moraine" that the first eggs laid in old nests at the beginning of the season, between 25 and 30 Nov 1979 (N=51) were the longest: 45.0-51.5 × 32.5-34.2 mm (on the average 46.7 × 33.1 mm), the eggs from the same colony laid between

26 Dec 1979 and 3 Jan 1980 (N=28) were shorter, 44.0-44.8 × 31.9-33.7 mm, (averaging 44.5 × 33.5 mm), whereas the last eggs, in half the cases single, most probably from repeated clutches, laid between 9 and 14 Jan 1980 (N=17), were the shortest: 42.9-44.3 × 33.3-34.1 mm (on the average 43.0 × 33.5 mm).

The weight of 308 fresh eggs of Antarctic Terns from King George I ranged from 23.5 to 30.0 g, the mean value being 26.4 g (Table VIII). Most of the eggs, i.e. above 60%, weighed 27-28 g. From among these 308 eggs, 87 were weighed again at the moment of hatching and they showed mass decrements of 27.2-44.3%.

Table VIII

Distribution of weights (in g) of fresh eggs of *Sterna vittata* on King George Island (x = 26.4 g)

Egg weight in g	23	24	25	26	27	28	29	30	Total
No of eggs	6	18	25	55	93	92	14	5	308
%	1.9	5.8	8.1	17.9	30.2	29.9	4.5	1.6	99.9

4. Time of the beginning of breeding

The data presented here were collected exclusively in the Admiralty Bay region. The numbers of eggs laid in successive periods of particular seasons indicate that the most eggs were laid in December. However, the changing weather conditions considerably affected the period of egg-laying in particular seasons and so the question requires a detailed discussion.

Season 1978/1979

Egg-laying began in the second half of November or after the snow lying at breeding sites had melted away. According to A. ŁUKOWSKI (oral comm), the colonies on "ornithologists' moraine" and Jersak Pk were occupied first. The first egg was found on "ornithologists' moraine" on 18 November. After I had started observation (10 Dec 1978), snow was still lying in many places in the areas of the largest colonies, that is, on the Keller Peninsula, Vaureal Pk and between Blue Dyke and Demay Pt; It may therefore be generally assumed that the number of eggs laid early (second half of November to 10 December) was small in comparison with the total. Most eggs were laid in the second half of December (Table IX). Nevertheless, the egg-laying period lasted throughout February (K. ZDZITOWIECKI oral comm).

Season 1979/1980

Although the nests were taken early, the intensive laying of eggs was belated because the breeding sites had been buried in snow during a snowstorm on 11 Nov 1979. The first egg was found in the Italia Valley on 18 November. I established the period of egg-laying indirectly at between 21 November and 10 December, basing myself on the observations of hatching in the nests found by K. ZDZITOWIECKI and the period of incubation known for Antarctic Terns. 28.8% of the eggs had been laid in these nests (Table X). Between 1 and 3 December the rate of egg-laying was hindered by heavy snowfalls and strong winds, which formed drifts. These unfavourable weather conditions however did not destroy the eggs of those early clutches. 52.8% of all the eggs were laid between mid-December and the first days of January.

Table IX

Breeding phenology of Antarctic Terns in the Admiralty Bay in the 1978/79 season and the fates of broods from particular time intervals

Egg laying			Hatching of chicks			Readiness for flight	
Time interval	No of eggs laid	%	Eggs	Time interval	Chicks (pull.)	Time interval	Fledglings (juv.)
21 Nov – 5 Dec	?[1]		No records	No records	No records	No records	No records
6-10 Dec	8	4.3	Total: 90 eggs, 65 nests $\bar{x}$ = 1.38 eggs/nest	30 Dec – 3 Jan	Total: 62 pull. $\bar{x}$ = 0.95 pull./nest	30 Jan – 3 Feb	Total: 20 juv $\bar{x}$ = 0.31 juv./nest
11-15 Dec	12	6.5		4-8 Jan		4-8 Feb	
16-20 Dec	30	16.3		9-13 Jan		9-13 Feb	
21-25 Dec	40	21.7		14-18 Jan		14-18 Feb	
26-30 Dec	32	17.4	Total: 88 eggs, 65 nests $\bar{x}$ = 1.35 eggs/nest	19-23 Jan	Total: 59 pull. $\bar{x}$ = 0.91 pull./nest	19-23 Feb[3]	No records
31 Dec-4 Jan	6	3.3		24-28 Jan		24-28 Feb[3]	
5-9 Jan	8	4.3		29 Jan – 2 Feb		1-5 March[3]	
10-14 Jan	17	9.2		2-7 Feb		6-10 March[3]	
15-19 Jan	15	8.1		8-12 Feb		11-15 March[3]	
20-24 Jan	10	5.4		13-17 Feb		16-20 March[3]	
25-29 Jan	5	2.7	6 eggs, 4 nests[2]	18-22 Feb[3]	No records	21-25 March[3]	No records
30 Jan-3 Feb	1	0.5		23-27 Feb[3]		26-30 March[3]	
Total	184	99.7					

[1] first egg on 18 Nov – dates of the laying of next eggs not recorded (A. ŁUKOWSKI – oral comm)

[2] No calculations because of a small number of records

[3] Dates of hatches calculated theoretically; own field study only till 16 February

Season 1980/81

The beginning of egg-laying was preceded by frequent snowfalls and high winds bringing about the formation of drifts and burying very many nests in snow. That was why the first egg was not noted before 28 November on the Keller Peninsula and the intensive egg-laying was not observed until 4 Dec 1980. Above 57% of the eggs were laid in a short period from 6 to 18 December (Table XI).

The numbers of eggs laid in successive day pentads in 5 breeding seasons, worked out on the basis of own data and those published by PETER et al. (1988) are given in Table XII.

5.Incubation period

The period of incubation of 495 eggs (Table XIII) oscillated between 22 and 26 days; it amounted to 24 days for 412 eggs (mean – 24.1).

After the hatching of chicks the adult birds carried the egg-shells away out of the territory of the colony.

Temperature was not taken in nests at the time of incubation. The results presented by other authors differ: from 39.4°C (GAIN 1914) to 42.2°C (MURPHY 1936).

Table X

Breeding phenology of Antarctic Terns in the Admiralty Bay in the 1979/80 season and the fates of broods from particular time intervals[1]

Egg laying				Hatching of chicks		Readiness for flight	
Time interval	No of eggs laid	%	Eggs	Time interval	Chicks (pull.)	Time interval	Fledglings (juv.)
21 Nov-25 Nov[2]	25	4.6	Total: 155 eggs[3], 110 nests $\bar{x}$ = 1.41 eggs/nest	15-19 Dec	Total: 101 pull. $\bar{x}$ = 0.92 pull./nest	15-19 Jan	Total: 65 juv. $\bar{x}$ = 0.59 juv./nest[2]
26-30 Nov[2]	57	10.6		20-24 Dec		20-24 Jan	
1-5 Dec[2]	16	3.0		25-29 Dec		25-29 Jan	
6-10 Dec[2]	57	10.6		30 Dec-3 Jan		30 Jan-3 Feb	
11-15 Dec	48	8.9	Total: 212 eggs, 151 nests $\bar{x}$ = 1.40 eggs/nest	4-8 Jan	Total: 69 pull. $\bar{x}$ = 0.46 pull./nest	4-8 Feb	Total: 36 juv. $\bar{x}$ = 0.24 juv./nest
16-20 Dec	68	12.6		9-13 Jan		9-13 Feb	
21-25 Dec	96	17.8		14-18 Jan		14-18 Feb	
26-30 Dec	60	11.1	Total: 171 eggs, 123 nests $\bar{x}$ = 1.39 eggs/nest	19-23 Jan	Total: 28 pull. $\bar{x}$ = 0.23 pull./nest	19-23 Feb[3]	Total: 6 juv. $\bar{x}$ = 0.05 juv./nest
31 Dec-4 Jan	59	11.0		24-28 Jan		24-28 Feb[3]	
5-9 Jan	40	7.4		29 Jan-2 Feb		29 Feb-4 March	
10-14 Jan	12	2.2		3-7 Feb		5-9 March	
Total	538	99.7					

[1] extremal weather conditions in the breeding season:

- snowstorm on 11 Nov 1979 (breeding sites buried in snow)
- heavy snowfalls between 1 and 3 Dec 1979 and high winds (snowdrifts, egg-laying stopped)
- heavy rainfalls on 6 and 12 Jan 1980 (losses in eggs and chicks) rain and sleet between 18 and 22 Jan 1980 (washing out of eggs, rock falls)
- 3 Feb 1980 heavy snow, 4-6 Feb 1980 rains, 7 Feb 1980 rain and gale (40 m/sec), 8 Feb 1980 blizzard (losses in eggs and chicks).

[2] dates of egg laying fixed on the basis of the dates of hatches.

[3] number of eggs on the basis of estimates before hatches.

6. Comparisons and comments

The phenology of the occupation of breeding colonies varies markedly from region to region in Antarctica. According to VALETTE (1906 – after MURPHY 1936), in the South Orkneys the occupation of colonies occurs in October. On the other hand, CLARKE (1906) observed spring migrations in that region still in October (21-25 Oct 1903). However, these may have been flocks colonizing the breeding grounds lying further to the south or having been hindered by particularly frosty winter weather. In the same years MENEGAUX (1907) noted the arrival of Antarctic Terns on Booth I (65°05'S) as early as September. Also in September HOLDGATE (1963) saw the return of Antarctic Terns to Anvers I (64°33'S): from 12 to 16 Sep 1955, from mid-September to 26 Sep 1956 and on 19 Sep 1957. My observations from King George I are similar: 18 Sep 1978, 18 Sep 1979 and 26 Sep 1980. In following years the sea around King George I did not freeze and, in consequence, PETER et al. (1988) heard call display (tooting) in the colony area as early as 21 July

Table XI

Breeding phenology of Antarctic Terns in the Admiralty Bay in the 1980/81 season and the fates of broods from particular time intervals[1]

<table>
<tr><th colspan="4">Egg laying</th><th colspan="2">Hatching of chicks</th><th colspan="2">Fledging capable of flight</th></tr>
<tr><th>Time interval</th><th>No of eggs laid</th><th>%</th><th>Eggs</th><th>Time interval</th><th>Chicks (pull)</th><th>Time interval</th><th>Juveniles</th></tr>
<tr><td>26-30 Nov[2]</td><td>1</td><td>0.3</td><td rowspan="4">Total: 208 eggs, 131 nests $\bar{x}$ = 1.59 eggs/nest</td><td>20-24 Dec</td><td rowspan="4">Total: 30 pull. $\bar{x}$ = 0.23 pull./nest</td><td>20-24 Jan</td><td rowspan="4">Total: 21 juv. $\bar{x}$ = 0.16 juv./nest</td></tr>
<tr><td>1-5 Dec</td><td>20</td><td>6.1</td><td>25-29 Dec</td><td>25-29 Jan</td></tr>
<tr><td>6-10 Dec</td><td>120</td><td>36.9</td><td>30 Dec-3 Jan</td><td>30 Jan-3 Feb</td></tr>
<tr><td>11-15 Dec</td><td>67</td><td>20.6</td><td>4-8 Jan</td><td>4-8 Feb</td></tr>
<tr><td>16-20 Dec</td><td>30</td><td>9.2</td><td rowspan="6">Total: 117 eggs, 74 nests $\bar{x}$ = 1.58 eggs/nest</td><td>9-13 Jan</td><td rowspan="6">Total: 16 pull. $\bar{x}$ = 0.22 pull./nest</td><td>9-13 Feb</td><td rowspan="6">Total: 11 juv. $\bar{x}$ = 0.15 juv./nest</td></tr>
<tr><td>21-25 Dec</td><td>25</td><td>7.7</td><td>14-18 Jan</td><td>14-18 Feb</td></tr>
<tr><td>26-30 Dec</td><td>26</td><td>8.0</td><td>19-23 Jan</td><td>19-23 Feb</td></tr>
<tr><td>31 Dec-4 Jan</td><td>30</td><td>9.2</td><td>24-28 Jan</td><td>24-28 Feb</td></tr>
<tr><td>5-9 Jan</td><td>5</td><td>1.5</td><td>29 Jan – 2 Feb</td><td>1-5 March</td></tr>
<tr><td>10-14 Jan</td><td>1</td><td>0.3</td><td>3-7 Feb</td><td>6-10 March</td></tr>
<tr><td>Total</td><td>325</td><td>99.8</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

[1] The least propitious weather conditions for successful breeding occurred in this season. Heavy snowfalls preceded egg-laying (3, 6 and 15 Nov 1980); on 18 Nov 1980 the max. wind speed came up to 63 m/sec and on 19 Nov 1980 to 30 m/sec, whereas on 23 and 26 Dec 1980 exceptionally abundant rainfalls were accompanied by the wind with a speed of 30 m/sec.

[2] On the basis of the hatching of young at Hennequen Pt.

1984, met with first pairs on 9 August and fresh nests on 11 September. In the same breeding season SADLER et al. (1986) noted call display on the sub-Antarctic Campbell I (52°33'S) from 2 to 4 Sep 1984.

The collected documentation concerning the dates of egg-laying in different parts of the breeding range of the Antarctic Tern (Table XIV) permits the following generalizations:

(1). In the region of the Indian Ocean breeding begins latest at higher latitudes, e.g. on the Heard Is (53°06'S) from the second half of the January to the second half of February and most early in the regions more distant from the Antarctic convergence, e. g. on St Paul I (38°44'S) or New Amsterdam (37°52'S) towards the end of October and in November. Many years' investigations carried out by FALLA (1937), PAULIAN (1953), THOMAS (1983) and SAGAR (1991) on the Kerguelen Is in the proximity of the zone of Antarctic convergence show that despite the most frequent dates of the laying of the first eggs range between 20 and 27 December, distinct fluctuations can be observed in the phenology of breeding; for example, in 1987 egg-laying did not begin until the first week of January (WEIMERSKIRCH et al. 1989).

(2). Most differentiated are the findings concerning the dates of egg-laying on the islands of the Pacific Ocean, which is most probably so because the observations of eggs come upon were only sporadic, the stage of eggs was not determined, and also because of a large number of second clutches. Many a time nests with eggs were found still on March. Both OLIVER (1955) and SADLEIR

Table XII

Intensity of egg-laying of the Antarctic Tern on King George Island in 1978-1985 (author's own materials; data from 1983-1985 acc to PETER et al. 1988)

Dates of egg-laying	Successive breeding seasons									
	1978/79		1979/80		1980/81		1983/84		1984/85	
	N	%	N	%	N	%	N	%	N	%
16-20 Oct									2	0.8
21-25 Oct									2	0.8
26-30 Oct									16	6.5
31 Oct-4 Nov									30	12.2
5-9 Nov									33	13.4
10-14 Nov									4	1.6
15-19 Nov	?[1]						2	2.9	10	4.1
20-24 Nov	?		21	3.9			2	2.9	9	3.7
25-29 Nov	?		61	11.3	1	0.3	1	1.5	14	5.7
30 Nov-4 Dec	?		16	3.0	17	5.2	3	4.4	20	8.1
5-9 Dec	5	2.7	55	10.2	120	36.9	6	8.8	19	7.7
10-14 Dec	14	7.6	50	9.3	70	21.5	11	16.2	21	8.5
15-19 Dec	31	16.8	69	12.8	30	9.2	15	22.0	15	6.1
20-24 Dec	38	20.6	95	17.7	24	7.4	12	17.6	16	6.5
25-30 Dec	34	18.5	60	11.1	27	8.3	9	13.2	14	5.7
31 Dec-4 Jan	6	3.3	59	11.0	30	9.2	6	8.8	7	2.8
5-9 Jan	8	4.3	40	7.4	5	1.5	1	1.5	6	2.4
10-14 Jan	17	9.2	12	2.2	1	0.3			4	1.6
15-19 Jan	15	8.1							2	0.8
20-24 Jan	10	5.4							2	0.8
25-29 Jan	5	2.7								
30 Jan-3 Feb	1[2]	0.5								
No of eggs	184	99.7	538	99.9	325	99.8	68	99.8	246	99.8

[1] First egg on 18 Oct 1978, but no observations were made as to the quantitative distribution of egg-laying until the pentade 5-9 Dec 1978.

[2] K. ZDZITOWIECKI (oral comm) however used to find eggs till the end of February.

Table XIII

Period of egg incubation (in days) by the Antarctic Tern on King George Island in the seasons 1978/79 – 1980/81

Duration of incubation	No of eggs	%
22	1	0.2
23	3	0.6
24	412	83.2
25	77	15.5
26	2	0.4
Total	495	99.9

Table XIV

Periods of egg-laying in Antarctic Terns in various regions of the breeding range

Location of colony	Author	First eggs	Periods of egg-laying	
1	2	3	4	
Indian Ocean				
New Amsterdam I. (37°52'S)	Segonzac (1972)	–	End of October, November	(ca 30-40 days)
St. Paul I. (38°44'S)				
Crozet Is. (46°00'S)	Despin et al. (1972)	–	Second half of Dec and 1st half of Jan	(ca 25-30 days)
Marion I. (46°54'S)	Rand (1941)	–	From mid-January	Length of egg-laying period needs further study
	Berruti, Harris (1976)	–	21-22 Jan and 2-3 Feb 1975 (based on dates of hatching of 2 chicks)	
Kerguelen I. (48°27-50'sS)	Falla (1937)	–	January, February	(ca 56 days)
	Paulian (1953)	–	From mid-December till mid-February	
	Thomas (1983)	20 Dec 1977	–	
	Weimerskich et al. (1988)	The first week of February 1987	–	
	Sagar (1991)	27 Dec 1985	2nd half of December and 1st half of January	
Heard Is. (53°06'S)	Downes et al. (1959)	17 Jan 1951[1]	From 2nd half of January to 6-15 February 1952 (data from 1951-1954)	(ca 30-35 days)
Pacific Ocean				
Bounty I. (47°42'S)	Oliver (1955)	–	Still in February (on the basis of observations from April 1927)	(ca 75-85 days)
	Robertson, van Tets (1982)	18 Nov 1978	–	
Snares Is. (48°36'S)	Sagar (1978)	27 Dec 1976	From the end of October throughout November	(ca 35 days)
Antipodes I. (49°41's)	Warham, Bell (1979)	–	From the beginning of December throughout January (exceptionally to 10 March 1969)	(ca 60-95 days)
	Sadleir et al. (1986)			
Auckland I. (50°40'S)	Oliver (1955)	–	From the end of November till mid-February	(ca 60-85 days)
	Sadleir et al. (1986)			
Campbell I. (52°33'S)	Bailey, Sorensen (1962)	20 Nov 1941	From the end of November throughout January	(ca 70-75 days)
	Sadleir et al. (1986)	13 Oct 1984[1]	From mid-October till 2nd half of February (21 Feb 1985)	(ca 131 days)

Table XIV ctd

1	2	3	4	
Atlantic Ocean (beyond Antarctic Convergence zone):				
Tristan da Cunha I. (37°05'S)	ELLIOTT (1957)	Exceptionally at the end of Nov 1955	December to the end of January (second broods to the beginning of March)	(ca 35-45 days to 90-100 days)
Gough I. (40°20'S)	SWALES (1965)	From the 1st week of December	January to the beginning of March (later broods most probably repetitions after the loss of the firt ones)	(ca 35-45 days to 90-100 days)
Atlantic Ocean (Antarctic Convergence zone):				
South Georgia I. (54°15'S)	MATTHEWS (1929)	–	From the 2nd half of November till the 2nd half of December	(ca 35 days)
South Orkney Is. (60°61'S)	CLARKE (1906)	14 Nov 1903 27 Nov 1904	From mid-November till mid-January	(ca 52 days)
	ARDLEY (1936)	–	1st half December till mid-January	(ca 30-35 days)
Elephant I. (61°10'S)	FURSE (1979)	ca 19 Nov 1970[2]	December, beginning of January	(ca 40 days)
King George I. (62°09'S)	SIMONOV (1975)	–	November – December	(ca 60 days)
	JABŁOŃSKI	18 Nov 1978 18 Nov 1979 28 Nov 1980	Usually most abundant from 5 December to 4 January (Table XIII); in the 1978/79 season to the end of February (K. ZDZITOWIECKI oral comm) (75-100 days)	(ca 106 days and even up to 125-130 days)
	PETER et al. (1988)	16-17 Nov 1983 20-21 Dec 1984	Most abundant between 10-25 Dec and 10 Jan, Two peaks: 25 Oct – 10 Nov and 5-31 Dec to 25 Jan	
Robert I. (62°24'S)	PEFAUR, MURUA (1972)	–	From the beginning of December throughout February	(ca 60-65 days)
Antarctic Peninsula with Archipelago				
Esperance (63°24'S)	CORDIER et al. (1983)	ca 21 Nov 1979[2]	15 Dec 1979 – 4 Jan 1980	(ca 44-45 days)
Anvers I (64°46'S)	HODGATE (1963)	25 Nov 1955 20 Nov 1956	–	
	PARMELEE, MAXSON (1975)	11 Nov 1973	Climax of November egg-laying: 14-18 November	
	PARMELEE et al. (1977)	13 Nov 1975	To 2nd half of January (fixed on the basis of the development of flight capability – 1974, 1975)	
	PARMELEE (1988)	–	11 Nov – 25 Feb (data from 1973-1978)	
Peterman I (65°10'S)	LOVE, KINNEAR (1930)	14 Nov 1910	–	

[1] An observation of a juvenile showing a poor flight capability on 24 March 1953 suggests an earlier date of the laying of the egg, namely, before 10 January

[2] Date calculated on the basis of the hatching of young.

et al. (1988) think that such late clutches follow the loss of the first broods that have fallen prey to rats or skuas. An adult bird was seen with a fish brought for the young on Campbell I still on 1 July 1984 (SADLEIR et al. 1986), which indicates that the eggs had been laid in May (!). The long period of egg-laying seems to be an adaptation which makes up for the exceptionally strong pressure of predators. SAGAR (1978) suggests that, to be sure, on Snares I (48°02'S) *Catharacta antarctica lonnbergii* and *Larus dominicanus* are potential predators and yet it was only after high winds that he found losses in broods.

(3). On Tristan da Cunha (37°05'S) and Gough I (40°20'S) in the South Atlantic nests with eggs were most frequently encountered from late January to the beginning of March. Single observations of volant fledglings at the beginning of February (SWALES 1965) evidence their hatching from the eggs about the first week of December. This estimate is supported by the data presented by ELLIOTT (1957), who saw nests destroyed by high winds as early as November.

(4). Because of very variably weather conditions and organizational difficulties in conducting long-lasting studies the data about the time of egg-laying in the regions from South Georgia to the Antarctic Peninsula and Archipelago are incomplete. Nonetheless, they show that this process begins in mid-November (exceptionally about 20 October) and lasts till February. On King George I (Table XIV) the egg-laying season goes on for about 105 days. Similarly it continues for 106 days on Anvers I (PARMELEE 1988). It may therefore be supposed that such a long egg-laying season is an adaptation of the population inhabiting the Antarctic regions, creating greater possibilities of survival of their progeny, for at least some of the eggs will hit upon favourable weather conditions. That regularity was also found in other species in that region (WASILEWSKI 1986).

The findings concerning the number and biometry of eggs laid by *S. vittata*, collected on King George I, are compared with those obtained from many colonies situated at various latitudes in Table XV.

According to the data from the sub-Antarctic areas (Table XV), *S. vittata* usually lays one, rarely two eggs there; in most cases however the authors (except SAGAR 1978, 1991) do not give the numbers of the nests examined. That tendency is confirmed by the data – not included in Table XV – published by SADLEIR et al. (1983) from the sub-Antarctic islands: Antipodes, Bounty, Campbell and Auckland, where the mean clutch size from 47 nests was 1.17 eggs/nest. In the Antarctic regions however the mean clutches are higher, averaging 1.35-1.73 eggs/nest (Table XV). Even three-egg clutches were sporadically found there: King George I (this study, Table XV), Deception I (GAIN 1914), Booth I (MONEGAUX 1907) and Peterman I (LOVE, KINNEAR 1930). And so it may be supposed that larger clutches in the Antarctic regions are an adaptation that makes up for greater losses caused by weather conditions and predation. SALOMONSEN (1972) found a reverse tendency in *Sterna paradisea* occurring in the northern hemisphere, namely, the mean clutch size of 2.4 eggs/nest in the Boreal zone, 2.1 in the low-Arctic zone and 1.5 eggs/nest in the high-Arctic zone. USPENSKIY (1964) treats this phenomenon more broadly, claiming outright that the species typical of the polar zone are characterized, among other things, by inferior egg-laying ability at higher latitudes. In the light of the above-quoted data on Antarctic Terns this rule does not hold water for all species.

As I have stated in the section on the biometry of eggs, their size on King George I varied somewhat with successive breeding seasons. The dimensions of the eggs measured in 1979/80 turned out very similar to the egg dimensions received in the same season by CORDIER et al. (1983) near the Esperance station on the Antarctic Peninsula.

In spite of differences found in egg-size between particular colonies and seasons, the mean lengths of eggs from King George I come very close to those measured by GAIN (1914) from Deception I and by NOVATTI (1978 after CORDIER et al. 1983) from the Antarctic Peninsula. The

Table XV

Measurements, weights and number of eggs in the nests of Antarctic Terns in various regions of the breeding range. 1 – eggs/nest; 2 – number of eggs checked; 3 – number of nests inspected

Colony location	Author	Measurements			Fresh weight		Eggs/ /nest	No of eggs	No of nests	Losses in eggs (No of eggs = 100%)
		N	Length in mm	Width in mm	in g	N				
1	2	3	4	5	6	7	8	9	10	11
Tristan da Cunha I. (37°05'S)	HAGEN (1952)	10	45.7	31.5			1	?	?	
Crozet Is. (46°00'S)	DESPIN et al. (1972)	5	43.8 (40.6-48.1)	31.8 (31.3-32.3)			1	?	?	
Marion I. (46°54'S)	BERRUTI, HARRIS (1976)	2	48.1 (45.8-50.4)	34.0 (33.7-34.3)			1	2	2	
Snares Is. (48°02'S)	STEAD (1948)	2	46.0 (45.5-46.5)	31.2 (30.5-33.2)						
	SAGAR (1978)	14	46.2 (41.2-49.2)	32.1 (30.5-33.2)			1.40	14	10	28.6% (N=14)
Kerguelen Is. (48°27-50'S)	FALLA (1937)	1	48.4	33.6			1	?	?	
	SAGAR (1991)	19	46.7 (44.0-50.5)	(31.3-34.6)	24.0	6	1	?	?	
Enderby I. (50°30'S)	OLIVER (1955)	2	43.0 (40.8-45.3)	31.6 (31.5-31.6)			1 occasionally 2	?	?	
Campbell I. (52°35'S)	OLIVER (1955)	3	44.1 (42.6-46.4)	33.0 (32.0-33.5)			1 occasionally 2	?	?	
South Georgia I. (54°15'S)	MURPHY (1936)	3	45.8 (44.4-48.5)	31.0 (30.5-31.4)			1-2	?	?	
	ARDLEY (1936)	?					1	?	?	
South Orkney Is. (60°61'S)	CLARKE (1906)	?	47.3	33.4			1-2	?	?	
King George I. (62°09'S)	JABŁOŃSKI (this study)	498	44.8 (41.5-51.5)	33.5 (31.1-39.2)	26.1 (23-30)	308	1.45[1] (1.37-1.58)	892	613	70.2% (N=887) (31.9-86.3%)
	PETER et al. (1988)	86	44.7 (40.9-48.5)	32.9 (30.3-35.1)	26.0 (23.1-29.8)	28	1.47	650	441	52.1% (N=650) (36.9-53.4%)
Deception I. (62°57'S)	GAIN (1914)	4	44.5 (43.0-47.5)	32.9 (32.0-33.5)						
Antarctic Peninsula: Esperance (63°24'S)	CORDIER et al. (1983)	69	46.0 (41.8-52.8)	32.8 (31.5-35.2)	26.9 (25-28)	11	1.35	73	54	91.8% (N=73)

Table XV ctd

1	2	3	4	5	6	7	8	9	10	11
Cap Printemps (64°10'S)	NOVATTI (after CORDIER et al. 1983)	15	44.2 (42.0-47.5)	32.3 (32.5, 35.0)			1.66 ±0.47	15		
Brabant I. (64°15'S)	PARMELEE, RIMER (1985)						1.45 ±0.44	16	11	
Anvers I. (64°46'S)	PARMELEE, MAXSON (1975)						1.73	64	37	40.4% (N=57)[2]
Booth I. (65°05'S)	GAIN (1914)	1	47.0	32.5			1-2[3]			
Peterman I. (65°10'S)	GAIN (1914)	5	45.8 (43.0-48.0)	33.5 (31.0-35.0)	30.2 (27-35)	5	1-2[3]			

[1] 1 nest with 3 eggs – 5 Jan 1979.

[2] 31.6% of which are losses caused by predators.

[3] 3-egg brood also reported.

data from King George I may therefore be acknowledged as representative of this region, the more so because they have been based on a considerable number of measurements. Longer eggs of *S. vittata* than in this region were found in some parts of the breeding range where this bird lays only one egg, which may be connected with a small pressure of predators and, in consequence, a small number of second broods. On Campbell I despite a 10° difference in latitude the losses in eggs caused by predators and the long egg-laying period connected with the losses (second brood) are similar to those on King George I; and so are the lengths of their eggs (OLIVER 1955).

The egg incubation period found at present and averaging 24.1 days (22-26 days) agrees with the data obtained for the populations nesting at considerable distances and in different climatic zones: Anvers I – 22-24 days (PARMELEE, MAXSON 1975), the Snares Is – 24 days (SAGAR 1978).

C. Chicks

1. Dates of the hatching of chicks in successive breeding seasons

The dates of the hatching of the first chicks and the period of their mass hatching did not always agree with those expected on the basis of the observation of the earliest clutches and the duration of incubation, which was accounted for by the losses caused by unfavourable weather conditions, frequent at that time.

In the 1978/79 season I found the first chick in the region of Jardin Pk on 30 December, whereas there were no chicks observed on "ornithologists' moraine" till 11 Jan 1979, and they should have been hatching there since mid-December from the eggs laid in November. It may therefore be supposed that those early clutches had been destroyed and the eggs laid between 6 and 10 December constituted repeated clutches following the loss of the first ones (they lay in old nests): Mass hatching started after 10 Jan 1979. The numbers of chicks falling to one nest at different times were alike (Table IX).

In the season 1979/80 the earliest chick hatched on 21 December, which points to the destruction of the first-laid eggs by snowfalls (Table X). Mass hatching continued long (24 Dec – 18 Jan), reflecting the prolonged period of mass egg-laying when favourable weather set in.

In the season 1980/81 the situation resembled that in the preceding year and the first chicks did not hatch before 21 December but the mass hatches lasted shorter: 30 December – 10 January (Table XI).

2. Development

Freshly hatched chicks were covered with grey down, verging on light brown; their legs were pink-red and the beak brown-red at the base and black at the end. In the moulting season the whole beak was already black.

The mean body weight from 24 newly hatched chicks was 15 g (13.0-18.0 g) in the 1978/79 season; in the next two seasons the means from 48 chicks were nearly equal: 16.1 g (13.0-19.5 g). The most chicks weighed 15 or 16 g (Table XVI). Above 37% of the young weighed more than the mean. The body weight of the newly hatched chick was correlated with the weight of the fresh egg (Fig. 15).

Table XVI

Body weight of Antarctic Tern chicks immediately after hatching in the Admiralty Bay region (seasons: 1979/1980, 1980/1981)

Body weight in g	No of chicks	%
13	2	4.2
14	2	4.2
15	15	31.2
16	11	22.9
17	4	8.3
18	5	10.4
19	9	18.7
Total	48	99.9

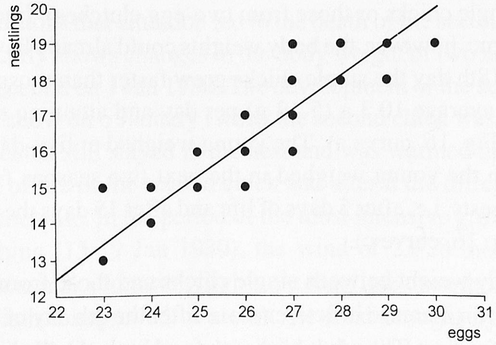

Fig. 15. Relationship between the weight of fresh eggs and that of freshly hatched chicks of Antarctic Terns on King George I.

The first feeding took place 1-4 hours after the removal of the shell after hatching. For the first 2-4 days of life of the young the parents stayed on the nest by turns. From the 3rd to the 5th day the nestlings began to go beyond the edge of the nest in cases of an alarm in the colony (the appearance of a man or skua) or at the sight of an adult bird with food in the beak. After 5 days they left the nest up to the border of the breeding territory, marked by the parents with faeces during incubation, or somewhat further, for a distance of 3-5 m. From the 7th or 8th day the chicks became mere lively, moving away from the nest for a distance of 15-25 m. It is interesting that if that occurred at the time of an alarm, the other parents did not drive them out of their territories, which they generally did squawking, if the chick assumed a "begging" posture in expectation of food. Between the 16th and the 18th day the young more often than not stayed at a distance of 30-40 m from the nest, hiding among stones. That moving away little by little outside the breeding territory was connected with the fact that the parents offered food to their chicks at increasing distances from the nest.

The mean time the young stayed in the colony (from hatching to flying out) was 29.2 days from 74 individuals (Table XVII).

Table XVII

Times Antarctic Tern chicks stay at the breeding site (until capable of flight) in the Admiralty Bay region

No of days	No of chicks in particular breeding seasons			Total
	1978/79	1979/80	1980/81	
27	7	3	2	12 – 16.2%
28	5	4	2	11 – 14.9%
29	6	10	5	21 – 28.4%
30	1	7	4	12 – 16.2%
31	1	5	2	7 – 9.4%
Total of chicks observed	20	36	18	74 – 100%

The cumulative growth curves are presented in Fig. 16. At the time when the chicks stayed in the nest (and were brooded), that is, up to the 4th/5th day of life the values of their body weight were alike (whether of single chicks or those from two-egg clutches). Intensive growth continued till the 18th day. At that time, however, the body weights could already have differed considerably. Between the 5th and the 18th day the single chicks grew faster than those from two-egg clutches, putting on weight on the average 10.3 g (5-13 g) per day and attaining the weight of adult birds about the 17th/18th day (Fig. 16, curve a). The young weighed at five-day intervals in the season 1978/79 were lighter than the young weighed in the next two seasons from the time when they started to walk out of the nests, i.e. after 5 days of life and after 15 days the increase in their weights was distinctly slower (Fig. 16, curve c).

The differences in body weight between single chicks and those from broods of two began to become more distinct with an increase in activeness or after the 8th day of life. This was connected with the method of chick feeding. The adult bird with food in the beak alighted on a stone at some distance from the nest and as a rule the more active chick received the food. At next feedings the stronger chick again received the food, while the other, weaker, got nothing until the first one was

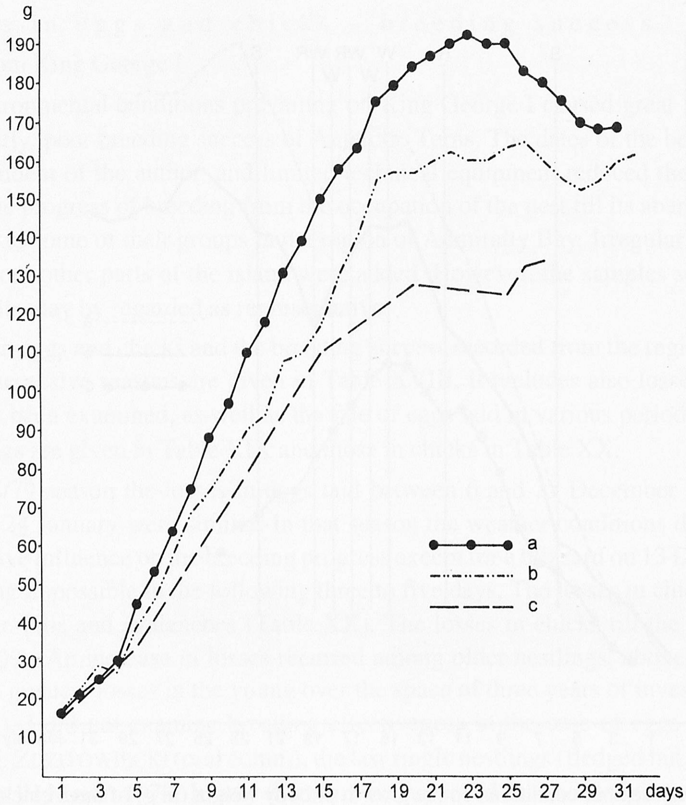

Fig. 16. Mean rise in body weight (in g) of Antarctic Tern chicks on King George I on successive days of their life. a – single young in the seasons 1979/80 and 1980/81 (number of individuals: 48 on the first day to 4 on the 31st day), b – second young in 1979/80 and 1980/81 (number of individuals: 16 on the first day to 1 on the 32nd day), c – all young together in 1978/79 (number of individuals: 24 on the first day – 8 on the 25th day).

satiated and its "begging activeness" slackened. As a result, when the weather conditions were unfavourable, for instance, strong winds were blowing and it was difficult for the parents to acquire food, the stronger chick received it in a reduced amount and the weaker one was permanently hungry. In extremal conditions that situation led to the death of the second chick. This is illustrated in Fig. 17, which graphically shows changes in the body weight of two nestlings. The first hatched on 30 Dec 1979 and the second on 1 Jan 1980. The development of the second proceeded normally till the 8th day. A fall of snow on 6 January (when the second chick was 5 days old) did not check it, because the younger chick still stayed in the nest and was warmed up by the parents. One-day rain fell on the 11th day of life of the second chick and after it the differences in the body weight of the siblings began to increase. In the period of the most intensive growth, between the 14th and the 18th day after hatching (15-19 Jan 1980), the wind of 23-28 m/sec made it hard or quite impossible for the adults to make foraging flights. At that time even the first chick was undernourished and when the weather improved, it ate all the food brought by the parents. Under such circumstances the second chick, starving and wet through, died two days later.

The mean increment in weight in single chicks diminished between the 19th and the 23rd day (it was then 2-5 g per day), but the weight they attained was higher than the mean weight of adult

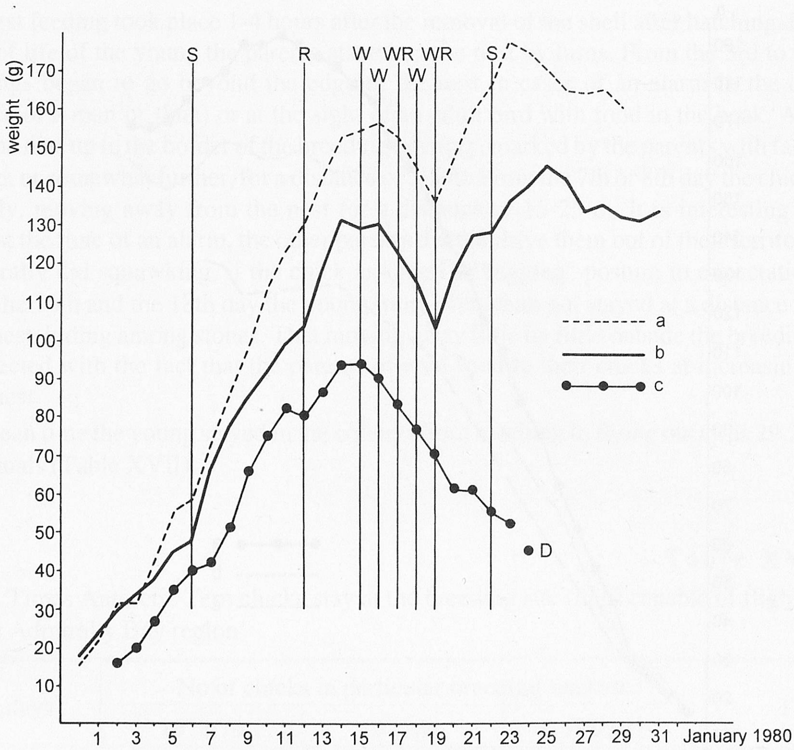

Fig. 17. Influence of weather conditions on the growth of body weight (in g) of three chicks in two nests of Antarctic Terns, 4 m apart, in the colony on "ornithologists' moraine". a – single young, b – first young from a nest with two chicks, c – second young; S – snawfall, W – wind, R – rainfall, D – day of death of second chick.

birds; in the final stage the weight of chicks decreased distinctly till the day when they became capable of flying. In the nests with two chicks the drop in weight increments after the 19th day was far more distinct and more extended in time (between the 19th and the 26th day), whereas the final drop in the weight was slight. Eventually, the weight of single nestlings was therefore only little higher at the time they became volant (Fig. 16).

3. Comments

A decrease in the rate towards the end of the weight growth and next the loss of weight in the last days preceding the young becoming volant are a well-known phenomenon in some members of various orders of birds (e.g. Despin 1977; Jabłoński 1986; Sagar 1978; Tomek 1988; Wasilewski 1986; Williams et al. 1984; Yones 1963). Likewise, the unpropitious influence of bad weather conditions on the development of Common Tern nestlings is well known (Dunn 1975; Langham 1972; Lemmetyinen 1972). Dunn (1975) presented the dependence of weight increase in the young of Sandwich, Common and Roseate Terns on the wing velocity on Coquet I ($55^{o}20$'N, $1^{o}32$'W) in the form of a simple regression, emphasizing the particularly negative role of the wind blowing during rainfalls. In the breeding season the speed of wind often exceeds 20-25 m/sec in the Antarctic regions and so its effects may be much more harmful than in the temperate zone. The mechanism of the indirect action of winds and precipitation (food limitation and chilling) on the development and survival of the young of Antarctic Terns has been discussed above.

D. Losses in eggs and chicks – breeding success

Findings from King George I

Severe environmental conditions prevailing on King George I caused great losses in broods and, consequently, poor breeding success of Antarctic Terns. The dates of the beginning of field studies, independent of the author, and limited technical equipment reduced the possibilities of investigating the progress of breeding from the occupation of the nest till its abandonment by the fledglings only to some of their groups in the region of Admiralty Bay. Irregular complementary observations from other parts of the island were added. However, the samples seem big enough and so the results may by regarded as representative.

The losses in eggs and chicks and the breeding success recorded from the region of Admiralty Bay in three successive seasons are given in Table XVIII. It includes also losses, the causes of which have not been examined, as well as the fate of eggs laid in various periods. The causes in the losses in eggs are given in Table XIX and those in chicks in Table XX.

In the 1978/79 season the losses in eggs laid between 6 and 25 December and between 26 December and 24 January were similar. In that season the weather conditions did not exert any distinct restrictive influence on the breeding progress except for a blizzard on 13 December, which made egg-laying impossible in the following three to five days. The losses in chicks were chiefly caused by stone-falls and avalanches (Table XX). The losses in chicks till the 10th day of life amounted to 50%. An increase in losses recurred among older nestlings, above 24 days of age. These were the greatest losses in the young over the space of three years of investigation (Tables XVIII and XX). I did not examine breeding effectiveness in the case of eggs laid in January. According to K. ZDZITOWIECKI (oral comm), the last single nestlings (fledged but not volant) were encountered on 19 March 1979. It may therefore be supposed that no fledglings flew out of the nests in which eggs had been laid at the beginning of February.

Table XVIII

Losses in eggs and chicks and the overall breeding success of Antarctic Terns on the shores of the Admiralty Bay, King George I, in the breeding seasons 1978/79, 1979/80, 1980/81 (* – lack of data caused by absence from the study area)

Season and period of egg-laying	Eggs			Chicks				Total losses		Overall breeding success in %
	No of eggs laid	Losses No	Losses %	No of chicks hatched	Losses No	Losses %	No of young fledged	No	%	
1978/79:										
6-25 Dec	91	29	31.9	62	42	67.7	20	70	77.7	22.2
26 – 24 Jan	88	29	32.9	59	*		*	*		
1979/80:										
21 Nov – 10 Dec	155[1]	*		101	36	35.6	65	*		
11-25 Dec	212	143	67.4	69	33	47.8	36	176	83.0	7.0
26 Dec – 14 Jan	171	143	83.6	28	22	78.6	6	165	96.5	3.5
1980/81:										
26 Nov – 15 Dec	208	178	85.6	30	9	30.0	21	187	89.9	10.1
16 Dec – 14 Jan	117	101	86.3	16	5	31.2	11	106	90.6	9.4

[1] Approximate figure fixed on the basis of the number of eggs at the time preceding hatching.

Table XIX

The causes of losses in eggs in chosen colonies of Antarctic Terns in the Admiralty Bay region in particular seasons of study

Causes of losses	Breeding seasons						Total (1978-1981)	
	1978/79 initial data: 91 eggs = 100%		1979/80 initial data: 212 eggs = 100%		1980/81 initial data: 192 eggs = 100%		Initial data: 495 eggs = 100%	
	N	%	N	%	N	%	N	%
Washout (water, mud, fine rubble)	6	6.6	58	27.4	70	36.5	134	27.1
Rockfalls and stone avalanches	12	13.2	41	19.3	61	31.8	114	23.0
Snow avalanches	5	5.5	20	9.4	21	10.9	46	9.3
Snow drifts	–	–	11	5.2	–	–	11	2.2
Predation:								
– *Catharacta*	1	1.1	2	0.9	–	–	3	0.6
– *Larus*	–	–	1	0.5	–	–	1	0.2
Unknown	5	5.5	10	4.7	13	6.7	28	5.7
Total	29	31.9	143	67.4	165	85.9	337	68.1
Persisting till hatch period (No of chicks)	62		69		27		158	

Table XX

The causes of losses in chicks in chosen colonies of Antarctic Terns in the Admiralty Bay region in particular seasons of study (percentage losses relative to the number of chicks hatched – cf. Tab. XIX)

Causes of losses	No of chicks hatched in particular breeding seasons						Total (1978-1981) initial data: 158 chicks	
	1978/79: 62 chicks		1979/80: 69 chicks		1980/81: 27 chicks			
	Losses of chicks							
	N	%	N	%	N	%	N	%
Washout (water, mud, fine rubble)	7	11.3	15	21.7	2	7.4	24	15.2
Rockfalls and stone avalanches	26	41.9	10	14.5	5	18.5	41	25.9
Snow avalanches	–		3	4.3	–		3	1.9
Predation:								
– *Catharacta*	3	4.8	1	1.4	–		4	2.5
– *Larus*	1	1.6	1	1.4	–		2	1.3
Unknown	5	11.9	3	4.3	2	7.4	10	6.3
Total	42	67.6	33	47.8	9	33.3	84	53.2
Surviving till fledge (No of young)	20	32.3	36	52.2	18	66.6	74	46.8

In the 1979/80 season the losses in the eggs laid between 11 and 25 December formed 67.4% (Table XVIII); they were highest in the final phase of incubation because of outwash by water and mud, stone-falls and snow avalanches following the rainfalls on 6 and 12 January. The losses in the eggs laid after 25 December were higher (83.6% – Table XVIII) and were chiefly caused by heavy rainfalls and squalls of sleet between 18 and 22 January 1980. In this season the height of losses in chicks was determined by rainfalls in the first days of their life, on 6 and 12 January (hatches between 4 and 18 January – cf. Table X). The young from the eggs laid from the end of November till 10 Dec 1979 had the most favourable conditions for survival. Mortality among the chicks from this group of eggs most affected the youngest chicks (i.e. those hatched between 20 Dec 1979 and 3 Jan 1980). On the other hand, mud carried and deposited by runoff water after heavy sleet between 18 and 22 January did not cause great losses in the young already fledged at that time and staying out of the nests. The losses recorded were mostly caused by mechanical injury (birds hit by falling stones or buried under a stone avalanche). Unfavourable weather conditions from 3 to 8 February however destroyed the nestlings that had hatched between 14 Jan and 7 Feb 1980 (cf. Table X). The highest mortality rate (78.6%) was found for chicks from the eggs laid between 26 Dec 1979 and 14 Jan 1980 (notably between 10 and 14 January). Breeding success in that group of eggs was scarcely 3.5% (cf. Table XVIII). Lack of adult individuals in the areas of large colonies starting from mid-February confirms the vastness of losses in this part of population.

In the 1980/81 season the losses in eggs laid in various periods were very similar (Table XVIII) and they were the highest of the losses in the three seasons under discussion. Their size was influenced by (1) thick snow layers accumulated in the upper parts of rocks; they melted and the water was washing stones and silt away till the second half of December; (2) very heavy rainfalls on 23 and 26 December, which gave rise to rapid torrents silting the nests (in Table XIX these two causes are included in the category "washout"), and (3) rolling-down stones. The rainfalls destroyed both some eggs just before their hatching and those freshly laid after 16 December. The losses in the young that had hatched till 8 Jan 1981 (and so from the eggs from the period of intense egg-laying) were caused by heavy rainfalls in the first days of their life.

The main cause of losses in the region of Admiralty Bay were abiotic factors connected with weather conditions, whereas predation played a minor role. For even if we assume that all the losses due to "unknown" causes should be ascribed to predators, still the cumulative losses in eggs and chicks were small (Tables XIX and XX). This is to some extent confirmed by casual investigations of the food of the Antarctic Skua (JABŁOŃSKI unpubl.). In 29 food samples gathered in the neighbourhood of the large penguin colonies on the Barton Peninsula I found remnants of only one Antarctic Tern fledgling.

The observations made at Hennequen Pt in the summer of 1980/81 indicate however that under certain circumstances predation can grow to considerable proportions. In that place in addition to Antarctic Terns, 31 pairs of Antarctic Skuas and 32 pairs of Southern Black-backed Gulls nested in a small ice-free area, there being no colonies of penguins in close proximity, whose eggs and chicks constitute the main food of these predators. Restriction of the natural food resources caused, among other things, the appearance of cannibalism, foraging flights to the Arctowski Station in the hours when kitchen offals were thrown away, and an increase in aggression on *S. vittata*. The terns of that grouping, accustomed to the close neighbourhood of skuas did not defend their nests by assaulting the predator at a large distance from the nests (just as they did, for instance, at Demay Pt, where the alarm was raised in the colony as soon as the predator had approached to a distance of 120-150 m). This coincidence brought about considerable local losses in eggs and chicks of the Antarctic Terns. The snatching of eggs and chicks proceeded as follows: one bird of a skua pair provoked an attack of the terns and was being driven away by them, while the other, flying 15-25 m behind the first, seized the prey. At the same time, the gulls sitting anticipatingly on the rocks, came into operation. In one breeding group of *S. vittata* composed of 6 nests the skuas took 3 eggs and 6 chicks (i.e. all) in that way and in other groups (together, 20 nests with 31 eggs) the skuas took at least 2 eggs and 17 nestlings and the gulls 2 eggs and four nestlings. The total loss caused by the predators at Henequen Pt reached 85%.

Other accidental losses in broods were observed in the 1979/80 season at Uchatka Pt, where in a colony of Antarctic Terns located besides in a place not typical of this species, that is, on the highwater ridge, a group of elephant seals scattered, destroying 15 nests with eggs and hatching chicks.

2.Comparisons and comments

The losses in eggs and nestlings till these last become volant and the breeding success of the population of Antarctic Terns inhabiting Antarctic areas are characterized by great variability. The losses show a tendency to increase with increasing nearness to the pole: on Snares Is (48°02'S) the losses in eggs and nestlings formed 64.3% (SAGAR 1978), on King George I (62°09'S) averaged 84.7% (author's own material – Table XVIII and PETER et al. 1988) and on the Antarctic Peninsula (63°24'S) were as high as 94.5% (CORDIER et al. 1983). PARMELEE and MAXSON's (1975) data from Anvers I (64°46'S) – 40.4%, apparently deny that tendency but it should be remembered that their data are incomplete, for they stopped collecting them a long time before the young were capable of flying.

The fluctuations of losses in the same population in successive breeding seasons may be very considerable; for instance, on King George I the losses in chicks approached either those occurring in the sub-Antarctic region or the losses recorded from the Antarctic Peninsula. Breeding success depended besides upon the time of egg-laying, being the poorest in the case of eggs laid last (Tables IX, X, XI). In the colonies studied by me abiotic factors were the main cause of losses, while predation played a minor role (Table XIX). This may be connected with the specific location of the colonies examined on a slope and in the neighbourhood of large rookeries of penguins, the main source of food for predators. In Antarctic Terns' colonies situated a long way away from rookeries of penguins (e.g. at Hennequen Pt) predation was the chief cause of losses, just as on the Heard Is (DOWNES et al. 1959), South Georgia (MATTHEWS 1929) and Anvers I (HOLDGATE 1963; PARMELEE, MAXSON 1975).

Wind can influence the survival of the young unfavourably in various ways. Its destructive mechanical action was recorded from Tristan da Cunha (ELLIOTT 1957) and Gought I (SWALES 1965); the chilling of wet chicks by gales on the Snares and Kerguelen Is was reported by SAGAR (1978, 1991), whereas TAYLOR (1983) pointed out that a wind blowing at a speed of 12.5 m/sec makes it difficult for adult birds to forage and thus causes the undernutrition of their young.

E. Diurnal activity

1.Foraging flights in the period of egg incubation

Intensive foraging flights started at 5 pm and continued till midnight (Fig. 18). In these hours many birds returned to the colony, fed their partners sitting on eggs or relieved them on the nest. Birds that had lost their broods and nonbreeders also returned by midnight. After 3 am both the birds that did not participate in breeding and some of the incubating birds flew away to forage. There was another short peak of morning activity between 7 and 8 am. Then the birds which had been brooding from 3 to 4 am flew off to the foraging ground. Partners, as a rule, changed over only on the nests with fresh eggs, whereas the birds brooding the eggs advanced in the process of incubation were fed by their partners twice daily, between 3 and 8 am and between 5 pm and 11 pm. It was chiefly the birds which during the two preceding peaks brought food to their brooding partners or substituted for them on the nests that were foraging at the time of the peak from 9 am to 10 am. As a result of these changeovers and feedings of incubating birds, all the birds filled their stomachs twice a day.

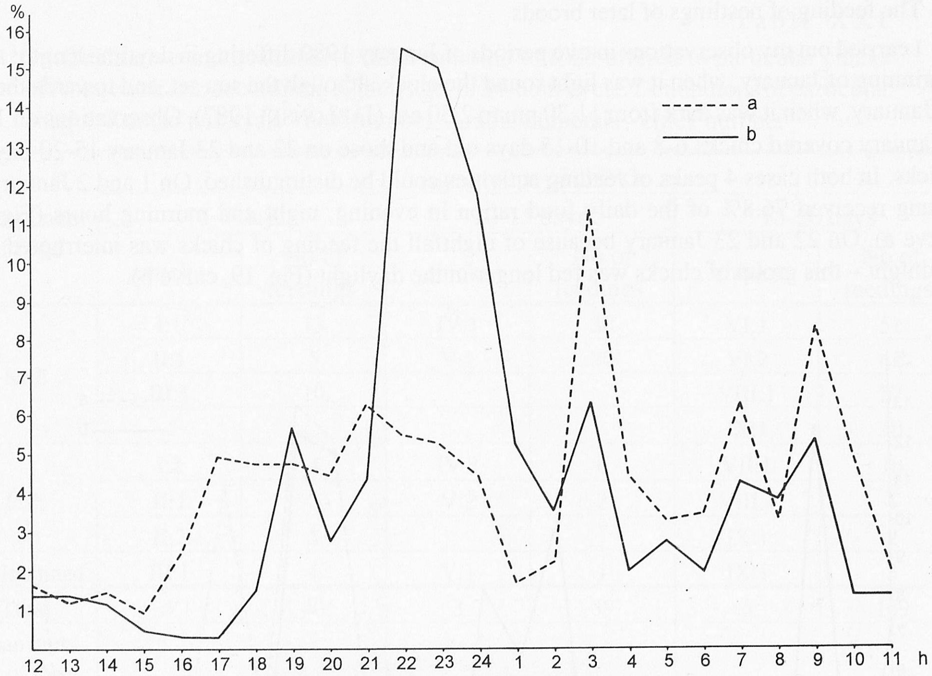

Fig. 18. Daily schedule of foraging flights of Antarctic Terns in the region of Admiralty Bay in the period of egg incubation (a) and feeding the young (b). Data referring to the incubation period come from 20-21 Dec and 23-24 Dec 1978 (flights of non-breeders staying in the colony area are also included; total number of flights: 399=100%), data referring to the period of feeding come from 10-11 Jan and 15-16 Jan 1979; total number of flights 646=100%).

Antarctic Terns from the colony on "ornithologists' moraine" usually foraged in the region of the mouth of the river flowing from under the nearby Ecology Glacier into the sea. Part of the birds of this colony penetrated about 4 km along the shore towards Thomas Pt and further up to Defayel I or flew about 3 km straight over Jardin Pk to the surroundings of this island. The Antarctic Terns from a colony lying 1 km away in the Italia Valley had also a feeding ground near Defayel I. Birds of these two colonies foraged together in the periods of mass occurrence of krill under the water surface. A signal for them was the concentration of feeding penguins (JABŁOŃSKI 1985).

2.Foraging flights in the initial period of feeding the young

The highest intensity of foraging in the initial period of feeding the young occurred in night hours (Fig. 18), between 10 and 12 pm. At that time the birds foraged on shoals of *Euphausia.* In the hours of the mass occurrence of krill under the water surface the terns less frequently penetrated the littoral zone but flew straight towards the foraging penguins. I also observed their direct flights to the krill shoals at the time of early-morning activity peaks, about 3 am. In the remaining periods of day the terns usually flew along the shore line, forming concentrations at the mouths of rivers flowing from under the glaciers. The terns from the colony on "ornithologists' moraine" grouped near the Ecology Glacier and those from the Italia Valley by the rockwall Cytadela. In the nests with chicks to the 5th day of life one of the incubating birds remained and was fed by its partner during the night peak of foraging activity. Partners generally changed over at the nest once a day, between 7 and 9 am. Besides, about 25% of the partners changed over again in evening hours.

The feeding of nestlings of later broods

I carried out my observations in two periods of January 1980 differing in daytime length: at the beginning of January, when it was light round the clock although the sun set, and towards the end of January, when it was dark from 11.30 pm to 2.30 am (JABŁOŃSKI 1987). Observations on 1 and 2 January covered chicks 6-8 and 10-15 days old and those on 22 and 23 January 15-20-day-old chicks. In both cases 4 peaks of feeding activities could be distinguished. On 1 and 2 January the young received 76.8% of the daily food ration in evening, night and morning hours (Fig. 19, curve a). On 22 and 23 January because of nightfall the feeding of chicks was interrupted after midnight – this group of chicks was fed longer in the daylight (Fig. 19, curve b).

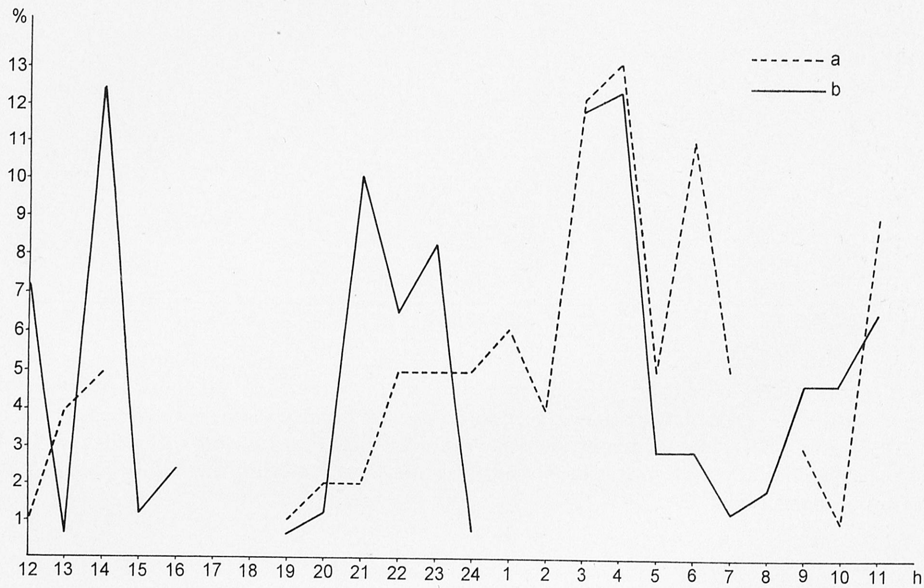

Fig. 19. Frequency of feeding of young Antarctic Terns in the Admiralty Bay region in dependence on the changing length of daytime. a – observations from 1-2 Jan 1980 (8 chicks 6-15 days old in 5 nests – daily number of feedings = 99), b – observations from 22-23 Jan 1980 (5 chicks in 4 nests – daily number of feedings = 69).

The number of prey items offered to the chicks increased with their age, being in addition dependent on the food composition, e.g. in the case of krill the number of feedings was higher than when food consisted of fish (Table XXI).

Detailed observations of diurnal activity of two pairs in the period of feeding of 15-20-day-old nestlings were conducted in the colony on "ornithologists' moraine" on 22 and 23 Jan 1980. The parents were marked with a different colour each to make them distinguishable from a distance (Table XXII). These birds took 26.9-32.7% of the 24-hour cycle for foraging flights. About 37% of the flights were made between 7 and 12 pm and about 29% from 3 to 5 am. They foraged on a small shoal of krill, occupying an area of about 80-100 x 20-30 m in Admiralty Bay.

The above-mentioned two marked pairs of terns fed their young generally from 3 to 6 am, 9 to 12 am, 2 to 4 pm and 7 to 12 pm. Breaks in feeding lasted 1-4 hours. Both chicks of pair "A" received only krill: the older one 51 times and the younger 42 times during the 24-hour observa-

Table XXI

Qualitative and quantitative differentiation of food offered to particular chicks of Antarctic Tern, accordinng to their age, in 24-hour cycle. Denotations of particular chicks: Roman numerals - nest number, Arabic numerals - chick number

Component of food	Age groups of chicks					
	6-8 days		10-15 days		15-20 days	
	chicks	No of feedings	chicks	No of feedings	chicks	No of feedings
Krill	I:1	13	IV:1	30	VI:1	51
	II:1	5	V:1	20	VI:2	42
	III:1	10			VIII:1	27
					IX:1	30
Fish	I:2	4	IV:2	6	VII:1	10
	II:1	2	V:2	2	VIII:1	4
	II:2	5			IX:1	2
Undermined	III:1	1	V:1	1	IX:1	3
Total	5	40	3	59	5	169
Mean number of feedings of a chick/day	8		19.7		33.8	

tions. The single chick of pair "B" was given food 35 times, of which krill 30 times, fish twice and probably amphipods 3 times. In the aggregate, pair "B" with a single chick spent less time flying to forage and feeding their young and more staying in the colony (Table XXII). When the parents were absent from the colony, the young manifested "begging" behaviour, consisting of walking, squeaking and looking out for the adults. The most intense "begging" was noted between 6 and 9

Table XXII

Time (in minutes) used by parental birds use for particular activities during a day (24 hours) in the period of chicks raising (A – pair with 2 chicks, B – pair with one chick; parental birds marked with different colours)

Kind of activity	Breeding pairs											
	"A" – 2 juv.						"B" – 1 juv.					
	Parental birds						Parental birds					
	"green"		"red"		Total		"yellow"		"brown"		Total	
	Minutes	%	Minutes	%	Minutes	%	Minutes	%	Minutes	%	Minutes	%
Foraging flights	441	30.6	502	34.9	943	32.7	425	29.5	351	24.4	776	26.9
Feeding of young	72	5.0	49	3.4	121	4.2	13	0.9	51	3.5	64	2.2
Rest, on guard	904	62.8	868	60.3	1772	61.5	985	68.4	1020	70.8	2005	69.6
Driving away of intruder	23	1.6	21	1.4	44	1.5	17	1.2	18	1.2	35	1.2
Total	1440	100	1440	100	2880	100	1440	100	1440	100	2880	99.9

pm. The single young of pair "B" "begged" for 29 min 48 sec daily, the older chick of pair "A" for 41 min 50 sec and the younger for 88 min 48 sec. The effect of "begging" was dependent on a quick start towards the returning parent.

Despite the small size of the above-mentioned shoal, several species of birds foraged on it at the same time, applying various methods of catching prey. Three to 6 Giant Petrels *Macronectes giganteus* "trawled", swimming with their heads submerged parallel to the water surface for several metres; beside them Antarctic Terns fished krill by the method described by TAYLOR (1983) as "contact dip" (catching prey close to the water surface in gliding flight but not diving); Wilson's Storm Petrels *Oceanites oceanicus*, hovering above the water surface, caught krill with beaks, and Southern Black-backed Gulls *Larus dominicanus* "pecked water" behind Giant Petrels or applied a method similar to that of terns.

F. Food

1. Food of young Antarctic Terns

The results of an analysis of food samples of chicks are presented in Table XXIII. Krill was the most frequently offered food. Of 154 identified individuals of *Euphausia* the species *E. superba* formed 57.8% and *E. crystallorophias* the rest. *E. superba* was more frequently caught by the birds foraging on the Bransfield Strait side and in the middle of Admiralty Bay, while *E. crystallorophias* by the bird foraging in the region of Dufayel I. These observations agree with the data about the occurrence of krill in this area (RAKUSA-SUSZCZEWSKI, STĘPNIK 1980; JACKOWSKA 1980; STĘPNIK 1982).

Table XXIII

Food composition of young Antarctic Terns in the Admiralty Bay region in successive age groups

Food component	Number of prey items in particular age groups of chicks: 1-5 days		6-8 days		9-14 days		15-20 days		Total	
	N	%	N	%	N	%	N	%	N	%
Euphausia	107	74.8	54	54.5	50	84.7	92	49.2	303	62.1
Amphipoda	14	9.8	19	19.2	–	–	28	15.0	61	12.5
Pisces	6	4.2	9	9.1	8	13.6	40	21.4	63	12.9
Indeterminate (Amphipoda, *Euphausia*)	16	11.2	17	17.2	1	1.7	27	14.4	61	12.5
Total	143	100	99	100	59	100	187	100	488	100

The numbers of individuals of *Euphausia* offered to young Antarctic Terns varied with the time of day (Table XXIV), which is particularly well seen regarding older nestlings. The length of members of the genus *Euphausia* caught ranged from 30 to 57 mm. It may be supposed that terns took such individuals as were most abundant in the groupings: mature krill comes up to the surface of water, hence large individuals of both species prevailed in the food (Fig. 20). In the food acknowledged as "undetermined", obtained after emetic had been administered, partly digested parts of *Euphausia* were dominant, while amphipods occurred less abundantly. It may be assumed that the proportion of krill in the diet of young terns was actually higher than that shown in Table XXIII.

Table XXIV

Mean number of prey items per hour eaten by young Antarctic Terns from the Admiralty Bay region in two age groups, in three periods of feeling activity during 24 hours (acc. to local time)

Food component	Young 6-9 days old			Young 15-20 days old		
	Hours of feeding			Hours of feeding		
	03.01-07.00	07.01-16.00	16.01-01.00	03.01-07.00	07.01-16.00	16.01-01.00
Euphausia sp.	2.0	8.0	6.3	6.7	2.7	6.8
Amphipoda	1.5	4.0	1.7	2.0	1.4	1.2
Pisces	0.7	4.0	0.3	1.7	1.2	1.5
Indeterminate (Amphipoda, *Euphausia*)	1.5	4.0	1.3	1.7	1.2	1.5
Total	5.7	20.0	9.6	12.1	9.0	9.5

Amphipods constituted complementary food (Table XXIII). They were taken from pools formed along the shore line after gales and at the outflows of rivers from under the glaciers. In 11 food samples they made the bulk of item. Among the amphipods K. JAŻDŻEWSKI (in prep.) identified five species from the family Lysianassidae: *Abyssochromene plebs*, *Cheirimedon femoratus*, *Hippomedon kergueleni*, *Waldeckia obesa* and *Ochromenella rotundifrons*. Most individuals (87%) belonged to the first two species. *Ch. femoratus* is a form of shallow waters, whereas *A. plebs* has been hitherto considered to prefer a deeper zone of sub-littoral (from a dozen or so to 100 m and more). All the species were necrophagous forms, although in pools taking rise after gales non-necrophages were fairly common. This atypical set of species was connected with a

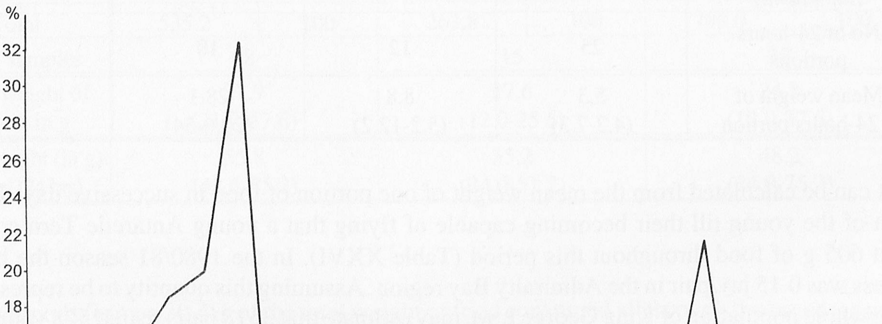

Fig. 20. Distribution of lengths of krill individuals in the food of young Antarctic Terns from the Admiralty Bay region (*E. superba* – N=89; *E. crystallorophias* – N=65).

carcass of an elephant seal lying in the sea not far from the shore and luring necrophagous amphipods, even those living deeper in the sea. The necrophages gathered at the carion were hurled by gale into the pools, where, occurring in great concentrations, they fell an easy prey to terns.

Up to the 8th day of life of chicks fish was a subsidiary food; it did not play a major role until the young were older (Table XXIII). Fishes were most frequently caught between 7 am and 4 pm. They ranged from 3.9 to 6.7 cm in length and weighed from 1.8 to 4.4 g. The species *Pleuragramma antarcticum* constituted 58.2% and the juvenile forms of the Nototheniidae (i.e. *Notothenia nybelini*, *N. rossi* and *N. neglecta*) 30.9%. The remaining juvenile forms of fishes have not been determined (perhaps, they belonged to the genus *Chionodraco*)

Krill was chicks' fundamental food in the first 8 days of life. In the period of their intense growth (i.e. between the 15th and 20th day) the proportion of fish by weight increased (Table XXV).

Table XXV

Weight of particular food components (in g) of young Antarctic Terns from the Admiralty Bay region in successive age groups.

Food components	Age groups						Total	
	1-5 days		6-8 days		15-20 days			
	g	%	g	%	g	%	g	%
Euphausia sp.	102.2	77.5	50.6	47.8	86.2	30.7	239.0	46.1
Amphipoda	4.2	3.2	5.7	5.4	8.4	3.0	18.3	3.5
Pisces	10.8	8.2	34.2	32.3	162.1	57.7	207.1	39.9
Indeterminate (Amphipoda, *Euphausia*)	14.6	11.1	15.3	14.5	24.3	8.6	54.2	10.4
No of 24-hours portions	25		12		10			
Mean weight of a 24-hours portion	5.3 (4.2-7.3)		8.8 (5.2-12.2)		28.1 (20.6-34)			

It can be calculated from the mean weight of one portion of food in successive days from the hatch of the young till their becoming capable of flying that a young Antarctic Tern consumes about 605 g of food throughout this period (Table XXVI). In the 1980/81 season the breeding success was 0.15 juv/pair in the Admiralty Bay region. Assuming this quantity to be representative of the whole population of King George I, we may estimate that 3518 pairs reared 528 young birds. Multiplying this figure by the mean weight of food eaten up by one nestling until it becomes volant, we receive a total of about 319 kg of food eaten by the young Antarctic Terns during that period in the 1980/81 season (108.3 kg of krill, 11.2 kg of amphipods, 170.6 kg of fish and 29.1 kg of *Euphausia* and amphipods in undetermined food mass).

2. Food of adult Antarctic Terns

The composition of the diet of adult Antarctic Terns is presented in Table XXVII. Both krill species together formed 50.0% of the weight of food collected in 33 samples throughout the breeding period (from November till the end of February) and 45.7% in the period of incubation and feeding of the young. *Euphausia superba* formed 84.4% of the weight of these crustaceans. The lengths of 10 individuals of *E. superba* ranged from 52 to 56 mm and those of 10 *E. crystallorophias* from 33 to 35 mm.

Table XXVI

Food eaten by a young Antarctic Terns during first 29 days of life (until it acquires capability of flight) in the Admiralty Bay region

Days of life		Food components and their weight in g				Total
		Euphausia	Amphipoda	Pisces	Indeterminate	
1-5		20.5	2.6	1.1	3.0	27.2
6-10		21.0	2.4	14.2	6.4	44.0
11-29		163.9	16.0	308.1	45.9	533.9
	g	205.4	21.0	323.4	55.3	605.1
	%	33.9	3.5	53.4	9.1	99.9

Table XXVII

Food of adult Antarctic Terns in the Admiralty Bay region in two periods of the breeding cycle.

Food component	Return to colony – nest building Nov 1980		Egg-laying – incubation – feeding of young Dec – Feb (data from 1978-1981)		Total	
	Weight in g	%	Weight in g	%	Weight in g	%
Euphasia	276.2	51.6	123.2	46.7	399.4	50.0
Amphipoda	171.3	32.0	71.5	27.1	242.8	30.4
Pisces	86.2	16.1	68.1	25.8	154.3	19.3
Others	1.5	0.3	1.0	0.4	2.5	0.3
Total	535.2	100	263.8	100	799.0	100
No of samples	18		15		33	
Mean weight of portion in g	27.9 (21.3-37.6)		17.6 (12.0-25.6)		24.2 (12.0-37.6)	
Mean weight (in g) per day (24 hrs)	55.8 (42.6-75.2)		35.2 (24.0-51.2)		48.2 (24.0-75.2)	

Amphipods formed 30.4% of the total weight of food consumed all through the breeding period and 27.1% of that in the period of incubation and feeding of the young. Their considerably higher proportion in the samples taken in November 1980 can be accounted for by (1) the concentration of amphipods in pools arising close to the shoreline e.g. after windstorms (out of the 18 food samples as many as 14 came from such puddles), (2) the occurrence of small quantities of krill in Admiralty Bay (this was also evidenced by a lower proportion of krill in penguins' diet than in other seasons – JABŁOŃSKI 1985). It turns out however that when the wind is light and there are no pools on the sea-shore, amphipods little contribute to the diet of Antarctic Terns (Table XXVIII).

The species composition of fish in the diet of adults was the same as with the young. The measurements of fishes ranged from 6.4 to 9.7 cm and the weight from 2.6 to 4.9 g. Fishes constituted only 19.3% of the total weight of food taken in the whole breeding period and 25.8% during the period of incubation and feeding of the young. Under favourable weather conditions

Table XXVIII

Composition of food of adult Antarctic Terns in the periods of incubation and feeding the young relative to weather conditions in the Admiralty Bay region

Food components	Summer 1978/79				Summer 1979/80	
	Propitious weather, wind up to 10 m/sec, no precipitation (samples from 11 Jan and 8 Feb 1979)		After gale and blizzard (samples from 14 Dec 1978)		Wind in gusts up to 23-24 m/sec, tides, *Euphasia* scarce in the Admiralty Bay (samples from 23 Dec – 20 Jan)	
	Weight in g	%	Weight in g	%	Weight in g	%
Euphasia	22	35.5	35	50.7	66.2	49.8
Amphipoda	2	3.2	19	27.5	50.5	38.0
Pisces	38	61.3	14	20.3	16.1	12.1
Others	–	–	1	1.4	–	–
Total	62	100	69	99.9	132.8	99.9
No of samples	4		4		7	
Mean weight of portion in g	15.5 (12.0–18.0)		17.2 (15.0–19.0)		19.0 (12.4–25.6)	
Mean weight (in g) per 24 hrs	31.0 (24.0–36)		34.4 (30.0–38.0)		38.0 (24.8–51.2)	

(propitious for catching other kinds of prey than amphipods from the shore pools) fishes can become basic food for adults. This is indicated by data from the season 1978/79 (Table XXVIII).

Examples of chance food: (1) On 8 November 1980 Cape Petrels (called also Cape Pigeons) were pecking a medusa drifting on the sea surface to pieces and terns snatched its bits; (2) on 9 Nov 1980 more than ten terns fished floating pieces of fat of an elephant seal carcass (the fat got into water during fights between skuas foraging on the carcass); a piece of fat was found in a sample from an adult bird; (3) a small piece of ham was present in a sample taken on 14 Dec 1978.

On the return to their breeding area terns foraged more intensively than in following stages of the breeding period (Table XXVII). At that time they ate on the average 55.8 g in 24 hours. In the period of incubation and feeding of the young the weight of food taken was smaller and when the wind was light and there was no precipitation it averaged 32.0 g. The size of a sample was then influenced by weather conditions (Table XXVIII).

In the 1980/81 season the breeding population of terns on King George I numbered 3518 pairs or 7036 individuals. If this figure has been increased by the number of non-breeders, which on the basis of data from Admiralty Bay reached 6.0-13.9% of the total of breeding birds (Table VI), the size of the whole population living on the island may be estimated at 7520-8015 birds. When the weather conditions were favourable, one adult bird ate about 31 g of food in 24 hours (of which 15.5 g fell to krill); and so the whole population consumed 233-250 kg. During the 60-day-long reproduction cycle adult Antarctic Terns ate up 13980 to 14905 kg.

In these calculations I have taken into account only 60 days of breeding cycle (from egg-laying to abandonment of the nest), since this period can be compared with other seasons. In the 1980/81 season the population consisted only of 240-256 individuals on 14 October and of 2175-2318 in November. Assuming that at that time the mean daily food ration was 55.8 g for one individual, it may be estimated in approximation that the Antarctic Terns ate up 187-200 kg of food in October and 3640-3880 kg in November.

3. Food consumed by the whole population of Antarctic Terns during the 60-day-long breeding period

During the 60-day-long breeding period adult and young Antarctic Terns ate up 14305-15223 kg of food (Table XXIX). On account of the small effectiveness of breeding (volant fledglings formed only 6.6-7.0% of the whole population) the young ate scarcely 2.1-2.2% of the total weight of food. It may be supposed that the quantity of food eaten by the young in other seasons was also small in view of high mortality in the first days of their life and low effectiveness of breeding, which in successive seasons of my investigation was: 0.31 juv/pair in 1978/79, 0.24 juv/pair in 1979/80, 0.15 juv/pair in 1980/81 and according to PETER et al. (1988) 0.19-0.52 juv/pair in 1983/84 and 0.23-0.47 juv/pair in 1984/85. On the assumption that the abundance of adults is similar and the maximum breeding effectiveness index is 0.52 juv/pair, the percentage of food of the young by weight cannot exceed 7%.

Table XXIX

Estimative amount of food eaten by adult and young Antarctic Terns on King George I in the 1980/81 season during 60 days of the breeding period (i.e. in the period of egg-incubation and feeding of unfledged young)

Food component	Weight of food (in kg)		Total (in kg)
	Adults	Young	
Euphausia	6531.5-6960.2	108.3	6639.8-7068.5
Amphipoda	3790.2-4039.0	11.2	3801.4-4050.4
Pisces	3608.0-3845.2	170.6	3779.6-4015.8
Others	55.9-55.6	29.1	85.0-88.7
Total	13985.6-14904.0	319.2	14304.8-15223.2

4. Comparisons and Comments

The composition of food of Antarctic Terns is markedly differentiated in different places of their distribution. The data shown in Table XXX provide evidence of the following variants of the composition: (1) solely krill (South Orkneys), (2) solely fish (Snares Is, Antipodes Is, Marion I), (3) krill and fish (South Georgia, Deception I), (4) food qualitatively and quantitatively differentiated (King George I and notably the Heard Is and Bouvet I). The great diversity of food items was found for Antarctic Terns foraging after gales in the shore zone washed by the splashes of waves carrying some bottom-living organisms up from deeper water layers (EALEY 1959; SOLYANIK 1964; present data from King George I). Differences found at present in the percentages of particular components making up the diet of terns in dependence on weather conditions are confirmed by SAGAR and SAGAR's (1989) observations, who ascertained that the velocity of wind modifies Antarctic Terns' technique of catching prey and, in consequence, the composition of their food.

It seems that differences in the food composition shown in Table XXX may, at least partly, be due to the fact that samples were taken at different times of day, for the present materials indicate that e.g. *Euphausia* was mostly caught in early morning hours and from evening till night (Table XXIV). I found a similar variability in the food composition during a day-and-night period (i.e. krill from evening till dawn and fish in the daytime) in *Pygoscelis antarctica* (JABŁOŃSKI 1985).

Table XXX

Composition of food of Antarctic Terns observed in different geographical regions

Region	Author	Sort of food	No of samples/ /observation
Tristan da Cunha I. (37°05'S)	LÖNNBERG (after MURPHY 1936)	Small fish (*Notothenia macrocephala*)	No data
Gough I. (40°20'S)	LÖNNBERG (after MURPHY 1936)	Small fish (*Notothenia macrocephala*)	No data
Marion I. (46°54'S)	RAND (1954)	Remnants of fish in stomachs	No data
	BERRUTI, HARRIS (1976)	Foraging 20-200 m off the shore	
Bounty I. (47°42'S)	OLIVER (1955)	Small fish	Single observations
	ROBERTSON, VAN TETS (1982)	Amphipoda in littoral zone	
Snares Is. (48°02'S)	SAGAR (1978)	Fish (*Cheilodactylus macropterus*, *Notothenia microlepdodta*), 76, 80, 90 mm in length	No data
	SAGAR P. M., SAGAR J. L. (1989)	21.2% of birds: fish; 78.8%: Crustacea	
Kerguelen Is. (48°27-50'S)	SAGAR (1991)	7 birds – fish (*Macrocystic* sp.) length 9.4 cm 6.2 cm and 6.7 cm 4.7 cm caught in littoral zone; 5- Crustacea	12 stomachs?
Antipodes I. (49°41'S)	WARRHAM, BELL (1979)	Small fish	No data
Campbell I. (52°35'S)	SADLEIR et al. (1986)	Small fish	Single observations
Heard Is. (53°06'S)	EALEY (1954)	Pisces, *Euphausia*, Polychaeta; in littoral zone: groundlings Polychaeta, Gastropoda and often Amphipoda (77 individuals in one stomach) more rarely *Euphausia*	12 ad. stomachs
	DOWNEY et al. (1959)	2 small fishes, 7 Amphipoda	1 juv.
South Georgia Isl. (54°15'S)	MATHEWS (1929)	Small fish, *Euphausia* from littoral zone	No data
Bouvet I. (54°26'S)	SOLYANIK (1964)	Polychaeta, Pisces, *Euphausia*, *Thysanoessa* and bottom-dwelling Crustacea from splash zone after gale	No data
South Orkney Is. (60°61'S)	CLARKE (1906)	*E. superba*	No data
King George I. (62°09'S)	JABŁOŃSKI this study (material from 1978-1981)	In total mass of food of both old and young birds: 46.4% *Euphausia,* 26.6% Amphipoda, 26.4% Pisces, 0.6% others	80 samples
	PETER et al. (1988)	*Euphausia* 8%, Pisces 25%, Amphipoda 50%, others 17%	1 sample
Deception I. (62°57'S)	JABŁOŃSKI (unpubl.)	Pisces, *Euphausia* boiled after eruption of geysers (young capable of flying)	19 samples

This regularity is governed by vertical migrations of krill, which, according to KALINOWSKI and WITEK (1980), remains close under the sea surface from evening till morning and sinks deeper in the day time. The differentiation of data may also be connected with the examination of a few or single samples from chicks varying in age (not specified by the authors), for it can be seen from Table XXV that the quantitative proportion of krill changes from 30.7 to 77.5% according to the age of chicks and that of fish from 8.2 to 57.7%. Sometimes the proportion of krill in the food of terns is also determined by the absence of the concentration of krill in the neighbourhood of the colony, just as in the Admiralty Bay region in the 1980/81 season.

G. Excrement

1. Excrement of the young

Evacuation of excrement by young terns began 1 hour before the morning peak of feeding activity (Fig. 21). It should be assumed that then they eliminated waste from food received during the night peak of feeding activity (7-12 pm) or 2-3 and even 5 hours after the feeding. The intensity of evacuation rose also 5 hours after the early-morning feeding, lasting till 9 am. After the feeding from 11 to 12 am I observed the most evacuations between 2 and 3 pm, whereas after the feeding at 2 pm between 5 and 10 pm after an interval of 3-9 hours.

I found fluctuations in the number of defecations in particular chicks: from 8-12 (= 10.6) in 6-8-days-olds to 12-19 (= 14.3) in 15-29-days-olds. Dry matter of one portion of faeces averaged 0.125 g (N=8) for chicks 5-8-days-old, 0.389 g (N=9) for the young 15-20-days-old and 0.356 g (N=10) for those aged 20-25 days. All samples were taken in the colonies on the Blue Dyke and

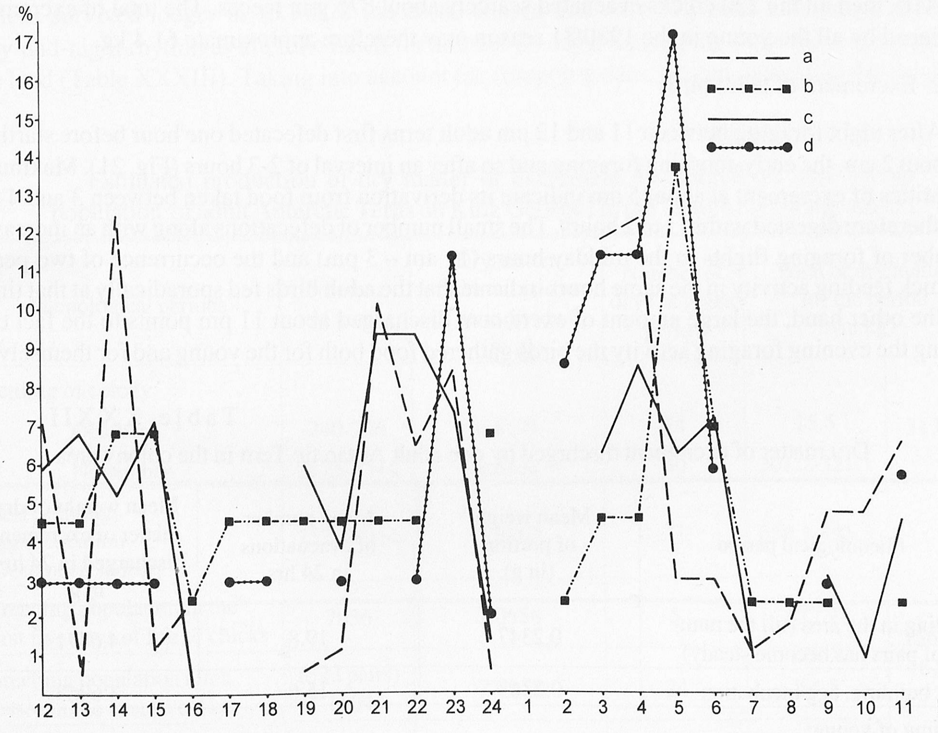

Fig. 21. Daily distribution of feedings and defecations in Antarctic Terns in the Admiralty Bay region. a – feeding of young (N=169), b – number of defecations of the young (N=44), c – time spent on foraging by 4 adults jointly (N=1719 min), d – number of defecations of 4 adults inside the colony (N=36).

on "ornithologists' moraine" from 22 to 26 Jan 1980. And so one chick discharged altogether an average of 114.7 g of dry matter of excrement during 29 days of its stay in the colony (Table XXXI).

Table XXXI

Dry matter of excrement discharged by one young Antarctic Tern in the Admiralty Bay region throughout its stay in colony (i.e. 29 days)

Age of young (days)	Dry matter of average portion in g	Mean number of evacuations per day	Dry matter per day in g	Number of days (N)	Dry matter in g
1-10	0.1250	10.6	1.3250	10	13.2500
11-20	0.3889	14.3	5.5613	10	55.6130
21-29	0.3562	14.3	5.0937	9	45.8433
Total				29	114.7063

In the season 1980/81 the breeding success came to 0.15 juv/pair or, in other words, 528 young birds developed a capability of flight all over King George I. In the 29 days of their stay in the colony all of them left together about 60.5 kg of dry matter of excreta. The amount of excrement discharged by the young which had not survived is much less exactly estimated because of different dates of their deaths (most of them died between the 3rd and 5th day of life). 230 chicks had gone up to the 5th day of life. If one chick of that age eliminated 1.32 g of dry matter in 24 hours (Table XXXII), then all the 230 chicks evacuated scarcely about 875 g in faeces. The total of excrement produced by all the young in the 1980/81 season may therefore approximate 61.4 kg.

2. Excrement of adult birds

After night foraging between 11 and 12 pm adult terns first defecated one hour before starting, at about 2 am, the early-morning foraging and so after an interval of 2-3 hours (Fig. 21). Maximum quantities of excrement at about 5 am indicate its derivation from food taken between 3 and 4 am and therefore digested within 1 to 2 hours. The small number of defecations along with an increased number of foraging flights in the midday hours (11 am – 3 pm) and the occurrence of two peaks of chick feeding activity in the same hours indicate that the adult birds fed sporadically at that time. On the other hand, the large amount of excrement discharged about 11 pm points to the fact that during the evening foraging activity the birds gathered food both for the young and for themselves.

Table XXXII

Dry matter of excrement dischrged by one adult Antarctic Tern in the colony area

Phenological period	Mean weight of portion (in g)	Mean number of evacuations in 24 hrs	Mean weight of dry matter of excrement discharged in 24 hrs, in g
Settling in the area (till the number of pairs has become steady)	0.2347	19.8	4.6471
Nest building, egg incubation	0.2363	15.6	3.6963
Feeding of young:			
– breeding population	0.2363	8.7	2.0558
– nonbreeding population	0.2363	15.6	3.6863

At the time of round-the-clock observations on 22-23 Jan 1981 four tagged adult terns defecated 35 times (x=8.7 for one bird over 24 hours). Both pairs stayed out of the colony area 24.4-34.9% of the time. If we assumed that the discharge of excrement at sea and on land occurred with the same frequency, the number of defecations in 24 hours would be 11-13. Observations of 8 non-breeders, which spent less time on the sea than did the breeders and more at the roost on the moraine, show that the number of defecations was similar to that calculated theoretically, i.e. 13-17 (x=15.6). I received a higher day-and-night mean for the initial stage of settling in the colony on 28 Oct 1980: x=19.8 (13-38). The Antarctic Terns stayed 79-85% of day on land at that time, but they ate less.

The dry matter of one portion of excrement at the time of settling in the colony averaged 0.235 g. This value changed according to the kind of food: from 0.273 (11 samples) after the birds had consumed *Euphausia* and amphipods to 0.197 g (17 samples) after their eating fish. In next phases of the breeding period the dry matter was on the average 0.236 g after the diet composed of *Euphausia* and fish (10 samples from 28 Dec 1980). The weight of excrement discharged by an individual in 24 hours consequently underwent changes in successive phases of the breeding cycle (Table XXXII).

At the beginning of the breeding season 1980/81, when birds were settling in the colony, the Antarctic Terns discharged 317-338 kg of dry matter of faeces on land (Table XXXIII). Nevertheless, it may be assumed that in seasons with more favourable weather conditions (making it possible for terns to start settling in the colony as early as September) the amount of excrement is considerably larger in this phenological period. Dry matter of the daily portion of excrement left on land in the period of nest building is similar for breeders and nonbreeders because the time they spend on land is similar then. High losses in chicks to the 5th day of their life (in the season 1980/81 chicks survived longer in 15.7% of the nests) caused that only 522 pairs maintained the same day-and-night rhythm as after the hatch for another 24 days, leaving the same mass of excrement on land (Table XXXIII). Taking into account the foregoing data, we can determine the weight of

Table XXXIII

Estimated production of dry matter of excrement discharged on land by the population of adult Antarctic Terns on King George I in the 1980/81 breeding season

Phenological periods	Number of terns	Dry matter of diurnal portion of an individual (in g)	Number of days in given period	Total of dry matter for the period (in kg)	
Settling of colony:					
October	240-256	4.6171	14	15.5	317.2-337.6
November	2175-2318	4.6171	30	301.7-321.1	
Nest building, egg incubation (December, January)	7521-8014	3.6863	31	859.5-915.8	1562.9-1672.0
Breeding population in the first five days of life of chicks	7036	2.0558	5	72.3	
Breeding population after losses in the first five days	(522 pairs) 1104	2.0558	24	54.5	
Breeding population after the loss of chicks	5932	3.6863	24	524.8	
Nonbreeding population	485-978	3.6863	29	51.8-104.6	

dry matter of excrement discharged by adult Antarctic Terns on King George I during the 60-day breeding period in the 1980/81 season in approximation at 1563-1672 kg and together with that of the young at 1624-1735 kg. Thus, the excrement of the young constituted only less than 4% of the total of dry matter.

V. THE SHARE OF ANTARCTIC TERNS IN THE MATTER BALANCE OF THE COASTAL SYSTEM

The krill biomass in the Admiralty Bay region is estimated at 630-780 tonnes (RAKUSA-SUSZCZEWSKI 1992c). Its fluctuations are chiefly induced by changes in the direction of winds. Westerlies drive sea currents with these crustaceans to the Bransfield Strait, while the northerlies restrain their influx. The size of the population of Antarctic Terns in the Bay region in the 1980/81 season was 3927-4242 birds (Table VI). In the 60-day period of incubation and feeding the young the mean daily food portion of an adult bird was 31 g, in which 15.5 g of krill. Therefore, the mass of krill consumed by adult terns inhabiting this region during 60 days (December and January) may be assessed at 3.65-3.94 tonnes and together with the young 3.7-4.0 tonnes. In the pre-breeding period the biomass of krill eaten by terns was small. The terns began to take up their nests in the colony after 8 October and initially their number was small – on the average 105.8 individuals occurred in the Admiralty Bay region till the end of October. In November the number of terns was rising and averaged 1055 birds. In the colony-forming period the mean daily portion of krill eaten by one bird was 29 g. As a result, during 23 days of October the Antarctic Terns consumed 0.07 tonne of krill and in November about 0.92 tonne. And so all through the breeding season 1980/81, i.e. until the young became volant, the consumption of krill by the Antarctic Terns in the Admiralty Bay region was 4.69-4.93 tonnes, that is 0.60-0.78% of its biomass.

Taking into consideration the above-quoted number of adult birds in the 60-day breeding period in the 1980/81 season and the weight of dry matter of faeces of one adult individual in particular phases of reproduction as well as the losses in broods and the dry matter of excrement discharged by the young during 29 days, I calculated that the whole breeding population of Antarctic Terns in the Admiralty Bay region evacuated from 0.76 to 0.82 tonne of dry matter of faeces on land during 60 days of breeding. It is very little in comparison with penguins, whose production of guano in that region was determined by RAKUSA-SUSZCZEWSKI (1992d) at about 277 tonnes.

The specific nature of Antarctic Terns' breeding grounds (rock rubble) causes that even in a period of intense precipitation their excrement is not directly washed off into the sea, but it permeates through rock-waste. Having infiltrated through rock-waste the water is much poorer in nutrients and contains no organic suspended matter (TATUR, MYRCHA 1983). In connection with the small quantity of excreta left on land and their infiltration as well as with the considerable dispersion of nests in comparison with penguins, the role of Antarctic Terns in the formation of ornithogenic soil is not great. TATUR (1992) emphasizes however that colonies of volant birds may be of great importance to the initiation and development of plant associations; this becomes manifest in periods of dry and sunny weather, when the intensified volatilisation of ammonia takes place. This may be evidenced by the occurrence of thin coats of nitrophilous lichen *Caloplaca cirrochrooides* on a rocky islet east of Bell I (Fig. 3, No 56), and rich assemblages of *Xantoria* sp. and *C. cirrochrooides* on Atherton I (Fig. 3, No 57) against the simultaneous lack of vegetation on neighbouring islets, on which Antarctic Terns did not occur.

REFERENCES

ARAYA B., ARAVENA W. 1965. Les aves de Punta Armonia, Isla Nelson, Antarctica Chilena. Censo y distribution. Publ. Inst. Antarct. Chileno, **7**: 1-18.

ARAYA B., ARRIETA A. 1971. Les aves de Caleta Potter, Isla Rey Jorge, Antarctica Chilena - censo y distribution. Rev. Biul. mar., Valparaiso, **14** (3): 121-128.

ARDLEY R.A.B. 1936. The birds of the South Orkney Islands. Disc. Rep., London, **12**: 349-376.

BAILEY A.M., SORENSEN J.H. 1972. Subantarctic Campbell Island. Proc. Denv. Mus. Nat. Hist., **10**: 1-305.

BANNASCH R., ODENING K. 1981. Zoologische Untersuchungen im Gebiet der sowjetischen Antarktisstation "Bellingshausen". Geod. geoph. Veröff., **1** (8): 3-20.

BERRUTI A., HARRIS A. 1976. Breeding schedules of Antarctic and Kerguelen Terns at Marion Island. Notornis, **23** (3): 243-245.

BIRKENMAJER K. 1980a. Tertiary volcanic-sedimentary succession at Admiralty Bay, King George Island (South Shetland Islands, Antarctica). Stud. geol. pol., **64**: 7-65.

BIRKENMAJER K. 1980b. New place names introduced to the area of Admiralty Bay, King George Island (South Shetland Islands, Antarctica). Stud. geol. pol., **64**: 7-65.

BIRKENMAJER K. 1980c. Geology at Admiralty Bay, King George Island,South Shetland Islands - an outline. Pol. polar Res., **1** (1): 29-54.

BIRKENMAJER K. 1981. Geological relations at Lyons Pump, King George Island (South Shetland Islands, Antarctica). Stud. geol. pol., **72**: 75-87.

BIRKENMAJER K. 1984. Further new place names for King George Island and Nelson Island, South Shetland Islands (West Antarctica), introduced in 1981. Stud. geol. pol., **64**: 7-65.

BIERMAN W.H., VOOUS K.H. 1950. Birds observed and collected during the whaling expeditions of the "Willen Berendsz" in the Antarctic, 1946-1947 and 1947-1948. Ardea, **37** (Suppl.): 1-123.

BROWN R.G.B., COOKE F., KINNEAR P.K., MILLS E.L. 1975. Summer seabird distribution in Drake Passage, the Chilean fjords and off Southern America. Ibis, **117** (3): 339-356.

CLARKE W.E. 1906. Ornithological results of the Scottish National Antarctic Expedition. II. On the birds of the South Orkney Island. Ibis, **6**(**21**): 145-187.

CLARKE W.E. 1913. Ornithology of the Scottish National Antarctic Expedition. Sect. 5 - the birds of the South Orkney Islands.Sci. Res. scot. nat. antarctic Exp., **4**: 219-247.

CORDIER J.R., MENDEZ A., MOUGIN J.L., VISBEEK G. 1983. Les oiseaux de la baie d'Espérance, Péninsule antarctique (63 24'S, 56 59'W). L'Oiseau et R.F.O., **53** (4): 371-390.

CRAWFORD A.B. 1952. The birds of Marion Island, South Indian Ocean. Emu, **52** (1): 73-85.

DESPIN B., MOUYGIN J.L., SEGONZAC M. 1972. Oiseaux et mammiferes de l'ile de l'Est, archipel Crozet (46 25'S, 52 12'E). Com. nat. fr. Res. Ant., **31**: 1-106.

DOWNES M.C., EALEY E.H.M., GWYN A.M., YOUNG P.S. 1959. The birds of Heard Island. ANARE Rep., Melbourne, Ser.B, Zoology, **1**: 1-135.

DUNN E.K. 1975. The role of environmental factors in the growth of tern chicks. J. animal Ecol., **44** (3): 743-755.

EALEY E.H.M. 1954. Analysis of stomach contents of some Heard Islands birds. Emu, **54** (3): 204-210.

EDGAR R., WHITE F.L.S. 1909. Subantarctic islands of New Zealand. XXV. Vertebrata of the subantarctic islands of New Zealand. Aves. Adelaide, **2**: 554-584.

ELLIOTT H.F. 1957. A contribution to the ornithology of the Tristan da Cunha group. Ibis, **99** (4): 545-586.

ERIKSON A.W., GIBEERT J.R., POTRIDES G.A., OCHLENSCHLAGER R.J., SINHA A.A., OTIS J. 1972. Populations of seals, whales and birds in the Bellinghausen and Amundsen seas. Antarct. J. USA., **7** (4): 70-72.

ERIKSON A.W., DENNEY R.N., BRUEGGEMAN J.J., SINHA A.A., BRYDON M.M., OTIS J. 1974. Seal and bird population off Adélie, Clairiđ and Banzare Coast. Antarct. J. USA., **1974** (Nov./Dec.): 292-296.

FALLA R.A. 1937. Birds. BANZARE 1929-1931 Report, Adelaide, (Ser.B) **2**: 1-304.

FALLA R.A. 1964. Distribution patterns of birds in the Antarctic and high-latitude subantarctic. [In:] HERMAN (Ed.) Biologie Antarctique, Paris, p.: 367-0376.

FELVELDEN S.E., SØMME L. 1977. Observations of birds and seals at Bouvetøya. Norsk Polarinst. Årbuk, **1976**: 367-371.

FURSE J.R. 1979. Elephant Island. An antarctic Expedition. A.Nelson, 256 pp.

FURSE J.R., BRUCE G. 1975. Birds of the Elephant Island group. Ibis, **117** (4): 529-531.

GAIN L. 1914. Oiseaux antarctiques. Doc. sc. deux. exp. antarct. fr. 1908-1910. Paris. 200 pp.

GRIFFITHS A.M.1982. Reactions of some seabirds to a ship in the Southern Ocean. Ostrich, **53** (4): 228-235.

HAGEN Y. 1952. Birds of Tristan da Cunha. [In:] Res. Norw. Sc. Exp. to Tristan da Cunha 1937-1938, Oslo, **20**: 1-248.

HOLDGATE M.W. 1963. Observations of birds and seals at Anvers Island, Palmer archipelago, in 1955-57. Brit. antarct. Surv. Bull., **2**: 45-51.

HOLGERSEN H. 1957. Ornithology of the "Brategg" expedition. Sc. Res. "Brategg" Exp. 1947-1948, Bergen, **4**: 1-80.

HOLGERSEN H. 1960. Fugls i Norske Biland - 2. Bouvet-oya. Sterna, **4** (1): 1-8.

HUNT G.L., HEIDEMANN D., VEIT R.R., HEYWOOD R.B., EVERSON J. 1990. The distribution, abundance and community structure of marine birds in southern Drake Passage and Bransfield Strait, Antarctica. Cont. Shelf Res., **10** (3): 243-257.

JABŁOŃSKI B. 1980. Distribution and numbers of birds and pinnipedes on Pewnguin Island (South Shetland Islands) in January 1979. Pol. polar Res., **1** (1): 109-116.

JABŁOŃSKI B. 1984. Distribution and numbers of penguins in the region of King George Island (South Shetland Islands) in the breeding season 1980/81. Pol. polar Res., **5** (1): 17-30.

JABŁOŃSKI B. 1985. The diet of penguins on King George Island, South Shetland Islands. Acta zool. cracov., **29** (8): 117-186.

JABŁOŃSKI B. 1986. Distribution, abundance and biomass of summer community of birds in the region of the Admiralty Bay (King George Island, South Shetland Islands, Antarctica) in 1978/1979.Pol. polar Res., **7** (3): 217-260.

JABŁOŃSKI B. 1987. Diurnal pattern of changes in the number of penguins on land and the estimation of their abundance (Admiralty Bay King George I., South Shetland Islands). Acta zool. cracov., **30** (8): 97-118.

JABŁOŃSKI B., KRZEMIŃSKI W., ZDZITOWIECKI K. 1987. Distribution and number of fur seals, *Arctocephalus gazella* (PETERS, 1875) of King George Island (South Shetlands). Acta zool. cracov., **30** (9): 119-136.

JACKOWSKA H. 1980. Krill monitoring in Admiralty Bay (King George Island, South Shetland Islands) in summer 1979/1980. Pol. polar Res., **1** (4): 117-125.

JEHL J.R., TODD J.F.S., RUMBELL M.A.R., SCHWARZ D. 1979. Pelagic birds in the South Atlantic Ocean and at South Georgia in the austral autumn. Le Gerfaut, **69** (1): 13-27.

JOHNSTONE G.W., KERRY K.R. 1976. Ornithological observations in the Australian sector of the Southern Ocean. Proc. 16-th Int. Ornith. Congress. Canberra, Australia, 12-17 August 1974. p.: 725-738.

KALINOWSKI J., WITEK Z. 1980. Diurnal vertical distribution of krill aggregations in the West Antarctic. Pol. polar Res., **1** (4): 127-146.

KOROTKEVICH E.S. 1959. Ptitsy vostochnoy Antarktidy. Probl. Arktiki i Antarktiki, Leningrad, **1**: 95-108.

KOROTKEVICH E.S. 1964. Observation on birds during the first wintering of the Soviet Antarctic Expedition. Sov. Antarct. Exp., Leningrad, **1**: 149-152.

KRYLOV V. 1968. Morskiye mlekopitayushchiye i ptitsy v rayoniye stancii Bellingshausen. Inf. Byull. sov. anterkt. Eksp., Leningrad, **83**: 87-93.

LANGHAM N.P.E. 1972 Chick survival in terns (*Sterna* sp.) with particular reference to the common tern. J.animal Ecol., **41** (2): 385-395.

LEMMENTYINEN R. 1972. Growth and mortality in the chicks of Arctic Terns in the Kongsfjord area, Spitsbergen in 1970. Ornis fenn., **49** (2): 45-53.

LINKOWSKI T., REMBISZEWSKI J.M. 1978. Distribution of sea birds of Argentina coast and the feeding habits of the bird fauna in the Drake Passage and Scotia Sea. Pol. Arch. hydrobiol., **25** (3): 717-727.

LOVE D.R., KINNEAR N.B. 1930. British Antarctic ("Terra Nova") expedition 1910. Birds. Zoology, **4** (5): 103-193.

LUNDE T. 1965. Fra besøk pa Bouvetøya. Norsk Polarinst. Årbuk, **1963**: 197-203.

MATTHEWS L.H. 1929. The birds of South Georgia. Disc. Rep., London, **1**: 561-592.

MENEGAUX A. 1907. Oiseaux. Expédition antarctique française 1903-1905, commandée par le Dr. Jean Charcot. Oiseaux, Paris, **4**: 1-75.

MURPHY R.C. 1936. Oceanic birds of South America. New York, **1**, 1245 pp.

MURPHY R.C. 1938. On Pan-Antarctic terns. Birds collected during the Whitney South Sea Expedition. Amer. Mus. Novitates, **977**: 1-17.

MÜLLER O.B., SCHOEMAN F.R., Van ZINDEREN BAKKER E.M. 1967. Some notes on a biological reconnaissance of Bouvetoya (Antarctic). South Afr. J. Sc., **63** (6): 260-263.

OLIVER W.R.B. 1955. New Zealand birds. Wellington. 611 pp.

OLROG C.C. 1963. Lista y distribucion de las aves Argentinas. Opera Lilloana, Tucumán, **9**: 1-337.

PARMELEE D.F. 1988. Unexpected weight gain in resident Antarctic Terns *Sterna vittata* during the austral winter. Ibis, **130** (): 438-443.

PARMELEE D.F., FRASER W.R., NEILSON D.R. 1977. Birds of the Palmer Station area. Antarct. J. USA., **1977** (March/June): 14-21.

PARMELEE D.F., MAXSON S. 1975. The Antarctic Terns of Anvers Island. Living Bird, **13** [1974]: 233-250.

PARMELEE D.F., RIMMER C.C. 1985. Ornithological observations at Brabant Island, Antarctica. Brit. antarct. Survey Bull., **67**: 7-12.

PAULIAN P. 1953. Pinnipdes, cétacés, oiseaux des dles Kerguelen et Amsterdam. Mem. Inst. Sci. Madagaskar, Paris, (A: Biol.anim.), **8**: 111-234.

PEFAUR J.E., MURUA R. 1972. Aves de la Peninsula de Isla Robert. [In:] Estudios ecologicos en Isla Robert (Shetland del Sur). Inst. Antarct. Chileno, Ser, cient., **2** (2): 11-23.

PETER H.H., KAISER M., GABAUER A. 1988. Untersuchungen an Vögel und Robben auf King George Island (South Shetland Islands, Antarktis). Geod. geoph. Veröff., **1** (14): 1-127.

PRESLER P. 1980. Phenological and physiographical observations carried aut during the first wintering at the Arctowski Station in 1977. Pol. Arch. hydrobiol., **27** (2): 245-252.

PREVOST J. 1976. Population, biomass and energy requirements of Antarctic birds. [In:] SCAR/SCOR Conf. Liv. Res. Southern Ocean 14-21 August 1976, New York, 12 pp.

PREVOST J., MOUGIN J.L. 1970. Guide des oiseaux et mammiféres des Terres Australes et Antarctiques francaises. Paris.

PRINCE P.N.,PAYNE M.A. 1979. Current status of birds at South Georgia. Brit. antarct. Survey Bull., **48**: 103-118.

RAKUSA-SUSZCZEWSKI S. 1980. Environmental conditions and the funcioning of Adiralty Bay (South Shetland Islands) as a part of the near shore Antarctic ecosystem. Pol. polar Res., **1** (1): 11-27.

RAKUSA-SUSZCZEWSKI S. 1992a. Wstep. [In:] Zatoka Admiralicji. Inst. Ekol. PAN, p.: 9-32.

RAKUSA-SUSZCZEWSKI S. 1992b. Funkcjonowanie Stacji. [In:] Zatoka Admiralicji. Inst. Ekol. PAN, p.: 33-40.

RAKUSA-SUSZCZEWSKI S. 1992c. Euphausiacea. [In:] Zatoka Admiralicji. Inst. Ekol. PAN, p.: 105-110.

RAKUSA-SUSZCZEWSKI S. 1992d. Bilans materii i drogi jej transportu w ekosystemie strefy przybrzeznej. [In:] Zatoka Admiralicji. Inst. Ekol. PAN, p.: 269-287.

RAKUSA-SUSZCZEWSKI S., MIĘTUS M., PIASECKI J. 1992. Pogoda i klimat. [In:] Zatoka Admiralicji. Inst. Ekol. PAN, p.: 41-50.

RAKUSA-SUSZCZEWSKI S., STĘPNIK R. 1980. Three species of krill from Admiralty Bay (King George, South Shetlands), in summer 1978/79. Pol. Arch. hydrobiol., **27** (2): 273-284.

RAND B.E. 1954. Notes on the birds of Marion Island. Ibis, **96** (2): 137-206.

ROBERTSON C.J.R., VAN TETS G.F. 1982. The status of birds at Bounty Island. Notornis, **29** (4): 311-336.

SADLEIR R.M.F., TAYLOR R.H., TAYLOR G.A. 1986. Breeding of Antarctic Terns (*Sterna vittata bethunei*). Notornis, **33** (4): 264-265.

SAGAR P.M. 1978. Breeding of Antarctic Terns at the Snares Islands, New Zealand. Notornis, **25** (1): 50-70.

SAGAR P.M. 1991. Aspects of the breeding and feeding of Kerguelen and Antarctic Terns at the Kerguelen Islands. Notornis, **38** (3): 191-196.

SAGAR P.M., SAGAR J.L. 1989. The effects of wind and sea on the feeding of Antarctic Terns at the Snares Islands, New Zealand. Notornis, **36** (3): 171-182.

SALOMONSEN F. 1972. Zoogeographical and ecological problems in arctic birds. Proc. XV-th Int. Ornith. Congress. Hague 30 August - 5 September 1970. p.: 25-77.

SEGONZAC M. 1972. Données récontes sur la faune des iles Saint-Paul et Nouvelle Amsterdam. L'Oiseau et R.F.O., **42** (No spec.): 3-68.

Simonov J.M. 1975. Fizyko-geograficheskaya kharakteristika Polostrova Failds (Yuzhnye Shetlandskiye Ostrova). Dokl. Kom. Izuch. Antarktiki, Leningrad, **17**: 128-145.

Siple D.A., Lindsey A.A. 1937. Ornithology of the second Byrd Antarctic expedition. Auk, **54** (2): 147-159.

Sierakowski K. 1991. Birds and mammals in SSSJ No 8 in the season 1988/89 (South Shetland Islands, King George Island, Admiralty Bay). Pol. polar Res., **12** (1): 25-54.

Solyanik G.A. 1964. Some birds observations on Bouvet Island. Soviet antarctic expedition. Inform. Bull. Amsterdam, London, New York, **2**: 97-100.

Stahl J.C., Jouventin P., Mougin J.L., Roux J.P., Weimerskirch H. 1985. The foraging zones of seabirds in the Crozet Islands sector of the Southern Ocean. [In:] Siegfried W.R., Condy P.R., Laws R.M. (Eds.): Antarctic nutrient cycles and food webs. Springer V., Berlin, p.: 478-486.

Starck W., Wyrzykowski R. 1982. Seabirds observations in the Southern Drake Passsage and Bransfield Strait (Biomass – Fibex programme) in February-March 1981. Pol. polar Res., **3** (3-4): 313-332.

Stead E. 1948. Bird life on the Snares. N.Z. Bird Notes, **3** (3): 70-80.

Stępnik R. 1982. All-year populational studies of Euphasiacea (Crustacea) in the Admiralty Bay (King George Island, South Shetland Islands, Antarctica). Pol. polar Res., **3** (1): 49-68.

Stonehouse B. 1964. Bird life. [In:] Priestley R., Adie R.J.A., Robin G.D.E. (Eds.): Antarctic research, London, p.: 219-239.

Swales M.K. 1965. The seabirds of Gough Island. Ibis, **107** (1): 15-42, (2): 215-229.

Syroyechkovskiy E.E. 1959. Veter, relyef i osobyennosti ekologii ptits Antarktiki. Ornitologiya, **2**: 282-286.

Tatur A. 1992. Gleby ornitogenne. [In:] Zatoka Admiralicji. Inst. Ekol. PAN, p.: 221-230.

Tatur A., Myrcha A. 1983. Changes in chemical composition of waters running off from penguin rookeries in the Admiralty Bay region (King George Island, South Shetland Islands, Antarctica). Pol. polar Res., **4** (1-4): 113-125.

Taylor L.R. 1983. Effect of the foraging behaviour of Common and Sandwich Terns. Ornis scand., **14**(2): 90-96.

Thomas T. 1983. Données récentes sur l'avifaune des iles Kerguelen (Terres australes et antarctiques françaises). L'Oiseau et R.F.O., **53** (4): 133-141.

Tickell W.L.N. 1962. The Dove Prion, *Pachyptila desolata* Gmelin. Falkland I. Dep. Surv. Scientific Rep., London, **33**: 1-55.

Tickell W.L., Woods R.W. 1972. Ornithological observations at sea in the South Atlantic Ocean, 1954-1964. Brit. antarct. Surv. Bull., **31**: 63-84.

Tomek T. 1988. The breeding biology of the Dunnock *Prunella modularis* (Linnaeus, 1758) in the Ojców National Park (South Poland). Acta zool. cracov., **31** (3): 115-166.

Uspenskiy S.M. 1964. Osnovnye cherty zhiznyennoy formy "arkticheskoye zhivotnye" na primyerye avifauny Arktiki i Subartiki. Tr. III Vses. Ornit. Konf. Lvov 1962, p.: 30-36.

Veit R.R., Hunt Jr. G.L. Broadscale density and aggregation of pelagic birds from a circumnavigational survey of the Antarctic Ocean. Auk, **108** (4): 790-800.

Voous K.H. 1965. Antarctic birds. [In:] Van Mickhan J., Van Oye R. (Eds.): Biogeography and ecology of Antarctica, Hague, **17**: 649-689.

Warrham A., Bell B.D. 1979. The birds of Antipodes Island, New Zealand. Notornis, **26** (2): 121-169.

Wasilewski A. 1986. Ecological aspects of the breeding cycle in the Wilson's sdtorm petrel (*Oceanites oceanicus* (Kuhl)) at King George Island (South Shetland Islands, Antarctica). Pol. polar Res., **7** (3): 173-216.

Watson G.E. 1975. Birds of the Antarctic and Sub-Antarctic. Am. Geoph. Union, Washington, 350 pp.

Watson G.E., Angle J.P., Harper P.C., Bridge M.A., Schlatter R.P., Tickell W.L.N., Boyd J.C., Boyd M.M. 1971. Birds of the Antarctic and Subantarctic. [In:] Antarctic map folio 14, Amer. Geogr. Soc., New York.

Weimerskirch H., Zotier R., Jouventin P. 1989. The avifauna of the Kerguelen Islands. Emu, **89** (1): 15-29.

Westerkov K. 1960. Birds of Campbell Island. Wellington, Wildlife Publ., **61**, 83 pp.

Williams A.J., Cooper J., Hockey P.A.R. 1984. Aspects of the breeding biology of the Kelp Gull at Marion Island and in South Africa. Ostrich, **55** (3): 147-157.

Winsnes T.S. 1966. Besøk på Bouvetøya: 1958 og 1966. Norsk Polarinst. Årbuk, **1965**: 143-149.

Yones N.N. 1963. The Cheatbill, *Chionis alba* (Gmelin), at Signy Island, South Orkney Islands. Brit. antarct. Surv. Bull., **2**: 53-71.

GUIDE TO AUTHORS

General remarks

Acta zoologica cracoviensia publishes original papers dealing with systematics, biology, faunistics, zoogeography, ecology and paleontology of land and fresh-water animals. All papers are accepted on the understand- ing that they have not been published or submitted for publication elsewhere. Manuscripts are submitted to referees for evaluation. Their editing may sometimes be extensive, but this will be done in communication with the Author.

Authors will receive the first proof only. Eventual changes of text or illustrations should be kept to a minimum.

50 reprints are supplied free of charge. Additional reprints may be ordered at cost, not later than together with the proof.

Manuscripts

Manuscripts in English should be submitted in two copies, typewritten, double-spaced, with at least 4 cm margin on the left side. All underlining and indention should be avoided. It is welcomed that Authors submit their material stored as WordPerfect or ASCII files on IBM compatible discs together with one printed copy.

The first page should contain: the title of the paper, full Author's name, abstract, key words, repeated author's name and full address (for every coauthor). In papers dealing with lower taxa, the higher ones should be noted in the title [e.g. Nestling food of *Phylloscopus bonelli* (*Passeriformes: Sylviidae*)]

Longer papers should be divided into several chapters numbered with Roman numerals. Acknow- ledgements should be gathered under a single heading (acapit) at the end of introduction.

Tables should be typed on separate sheets and numbered with Roman numerals.

Figures (drawings, maps, diagrams etc.) done in black ink, should be submitted as original and one copy (xero), numbered with Arabic numerals [Fig. 1., Fig. 2. ...]; figures, letters and symbols used on illustrations should be drawn so large that they will be at least 1.5 mm high after reduction in print. Photographs must be sharp and contrast; they will be treated also as figures. Every illustration should bear its own number and Author's name. All captions of illustrations should be gathered on a separate sheet (not incorporated in the figure or photograph itself).

Nomenclature. First used binominal Latin names, according to Intern. Codex of Nomenclature, should be used full i.e. together with not abbreviated names of their authors and dates after coma – be careful using brackets [e.g. *Passer domesticus* (LINNAEUS, 1758) but *Aquila pomarina* BREHM, 1831]. If repeated later on in text the names might be abbreviated [e.g. *P. domesticus, A. pomarina*].

Citation in text: VOOUS (1962) or (VOOUS 1962), (DEMENTEV & GLADKOV 1952; BROWN et al. 1988).

References. The list of references must be complete and prepared in the following method:

Journal: MACARTHUR R. H., MACARTHUR J. W. 1961. On the bird species diversity. Ecology, **42**: 594-598.

Book: VAURIE C. 1959. The birds of the Palearctic fauna. Passeriformes. Witherby, London.

Chapter: OSBORN J. W. 1978. Morphogenetic gradients: fields versus clones. In: P. M. BUTLER and K. A. JOYSEY (Eds.) – Development, function and evolution of teeth. Academic Press, London-New York-San Francisco. Pp: 171-201.

In the case of papers written in the other than Latin letters, if there is English (or German, or French) title in the summary it may be used:

TOMKOVICH P. S. 1985. Sketch of the Purple Sandpiper (*Calidris maritima*) biology on Franz Josef Land. [In Russian with English summary]. Ornitologiya, **20**: 3-17.

If there is not English summary or even title – author's name must be transcribed and title of the paper also transcribed (using anglo-american transcription) or translated into English:

DEMENTEV G. P., GLADKOV N. 1952. Ptitsy Sovetskogo Soyuza. **2**. or: [The birds of the Soviet Union (in Russian)], **2**

Manuscripts not conforming to the requirements will be returned for revision.

CONTENTS

ISBN 83-901631-7-9
ISSN 0065-1710