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Microclimate of the nest-sites of pygoscelid penguins (Admiralty Bay, South Shetland Islands)

ABSTRACT: The microclimate of the nest-sites of *Pygoscelis adeliae*, *P. antarctica* and *P. papua* was studied from December 1979 to January 1981. The temperature of the ground, air temperature at 0.05 m, 0.35 m ad 2 m and wind velocity at 0.35 m and 2 m above the ground were recorded. The wind velocity in the places chosen by penguins for nesting was lower than at the meteorological station by 22% to 60%. It was proved that in winter the mean monthly ground temperature at the nesting places was lower than that at the meterological station by 6 to 8°C due to the much thinner snow cover. Pygoscelid penguins chose for nesting places of specific microclimate and modified the wind velocity, temperature of the ground and, to a leser extent, the air temperature.

Key words: Antarctic, penguins, microclimate.

1. Introduction

The studies of the microclimate of penguin nesting places has been so far very limited. Sapin-Jaloustre (1960) observed that the microclimate in the colony of the Adélie penguins was milder than at a neighbouring meteorological station. Yeates (1968) has measured the microclimatic parameters at a distance of about 100 m from the colony of the Adélie penguins, hence his results may be not representative for the nest-sites (Geiger 1957).

There are no clear evidences of influence exerted by groups of nesting birds upon the microclimate. Stonehouse (1979) presumes that nesting birds decrease the wind velocity in a colony, while Yeates (1975) suggests that this influence is slight, especially at high winds.

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The aim of the present paper was to determine the yearly values of microclimatic factors in the nest-sites of three species of the genus *Pygoscelis*. An attempt was also made to distinguish the proper microclimate for the areas in which the penguin colonies occur from the microclimate which is generated by groups of nesting penguins.

2. Study area

The microclimate was investigated in the area of the colony of penguins situated on George Island, at the western shores of the Admiralty Bay, between Thomas Point and the Ecology Glacier (Fig. 1). This colony is described by Penney (1968) as the "West Point Thomas rookery". In the season of 1979/1980 9310 pairs of *Pygoscelis adeliae* (Hombron et Jacquinot), 526 pairs of *Pygoscelis antarctica* (Forster) and 620 breeding pairs of *Pygoscelis papua* (Forster) nested in the area (Jabłoński 1984b).

The area of the penguin colony at Thomas Point constitutes a minute part of the area free of ice, the whole of which constitutes 7% of the area of the drainage basin of the Admiralty Bay. The area of the drainage basin free of ice has increased during the recent 22 years due to a 3 km recession of glaciers (Rakusa-Suszczewski 1980). A description of the colony at Thomas Pt is included in the papers by C. Müller-Schwarze and D. Müller-Schwarze (1975), Volkman and Trivelpiece (1981) and Jabłoński (1984a).

The climate of South Shetland Islands is a humid marine one. In the period 1951—1960 at the station "Admiralty Bay" situated 10 km from the colony of Thomas Pt the mean yearly air temperature was -3.9°C, mean wind velocity — 6.6 m/s and mean yearly humidity — 84%. In comparison with the coasts of the Antarctic continent the relative air humidity of the region of the Admiralty Bay, similarly as the whole of the South Shetlands archipelago, is higher by about 15% and the precipitation in this area is more than twice larger (Moczydłowski 1978).

At the H. Arctowski Station, in 1980 the mean air temperature was -3.8°C, the mean ground temperature 0.2°C and the total precipitation 615 mm (own unpublished data).

In 1977—1978 winds were mostly of the SW directions (Nowosielski 1980, Zubek 1980). The total radiation value in the summer season 1978/79 at the H. Arctowski Station was 10% higher than that at the Bellingshausen Station (Krężel, Pęcherzewski 1981). A lesser cloud cover due to the frequent occurrence of foehn effect (Rakusa-Suszczewski 1980) as well as the favourable solar exposure of the H. Arctowski Station (Krężel, Pęcherzewski 1981) make the study area better insolated than the rest of King George Island.

3. Material and methods

Microclimatic parameters were measured in the area of the Thomas Pt colony between December 1979 and January 1981. Self-registering microclimatic stations were situated in places chosen for breeding by particular penguin species (Fig. 1).

The temperature of the ground was measured at a depth of 0.05 m. The air temperature was measured at 0.05, 0.35 and 2 m above the ground. The wind velocity was measured at 0.35 and 2 m above the earth surface. The total error in measuring the values of air and ground temperatures is ± 0.2°C, and that of wind velocity ± 0.3 m s^{-1}. The mean monthly and mean periodical values of parameters were calculated as an arithmetical mean from measurements carried out at main synoptic times, i.e. at 00, 06, 12, 18 GMT each day in summer months (November, December, January and February) and as arithmetical means from measurements at 12 GMT each day for other months. In the description of results, the following symbols were used: the mean monthly ground and air temperatures — MMGT and MMAT, mean periodical ground and air temperatures — MPGT and MPAT, mean monthly and mean periodical wind velocity — MMWV and MPWV, respectively.

In order to evaluate the error made in the calculations a comparative analysis of mean values of parameters calculated from 24 measurements over a day and mean values of parameters calculated from 4 and 1 measurements was made. The mean monthly value of wind velocity at 0.35 m in the breeding group of *P. papua* calculated from 24 measurements over a day in January 1980 amounted to 1 m s^{-1}; that calculated from 4 measurements over a day to — 1.3 m s^{-1}; and that obtained on the basis of 1 measurement during each day to — 1.4 m s^{-1}. The values for February were 1.1, 1.3 and 1.3 m s^{-1}, respectively.

The mean monthly temperature values found for summer months as arithmetical means from 4 measurements over a day differed in most cases by 0.1 to 0.2°C from the mean monthly values of the temperature calculated from 24 measurements over a day. The above differences were lower than the measurement error. Therefore the calculated mean values of parameters may be accepted for actual means. This is in agreement with similar comparative analysis of mean parameter values carried out by other authors (Conrad and Pollak 1950, Dolgin et al. 1977).

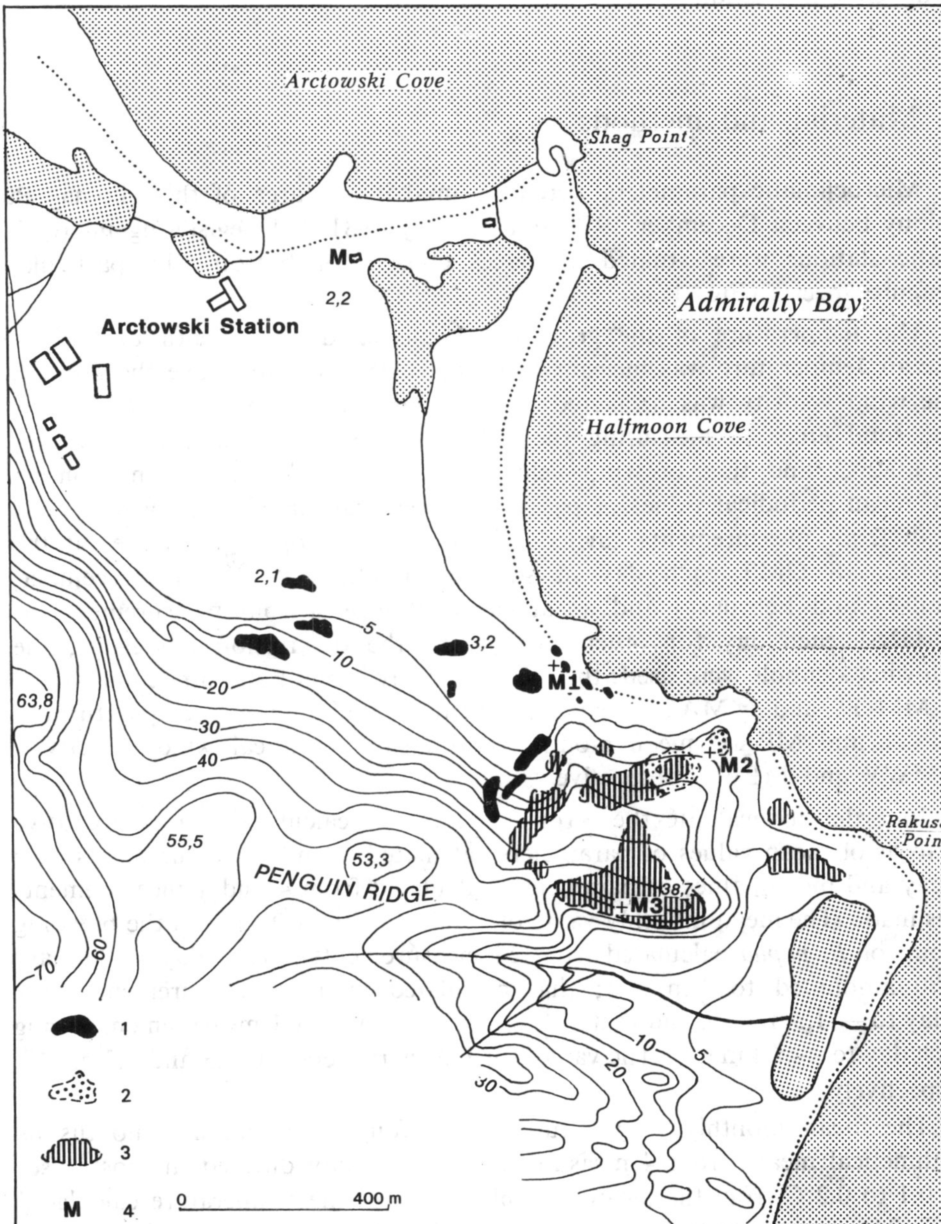

Fig. 1. Breeding colony of penguins of the genus Pygoscelis at Thomas Point according to Dutkiewicz and Furmańczyk (unpubl.). The distribution of measuring stations. 1 — Breeding groups of *P. papua*+station M1; 2 — Breeding groups of *P. antarctica*+station M2; 3 — Breeding groups of *P. adeliae*+station M3; 4 — H. Arctowski meteorological station.

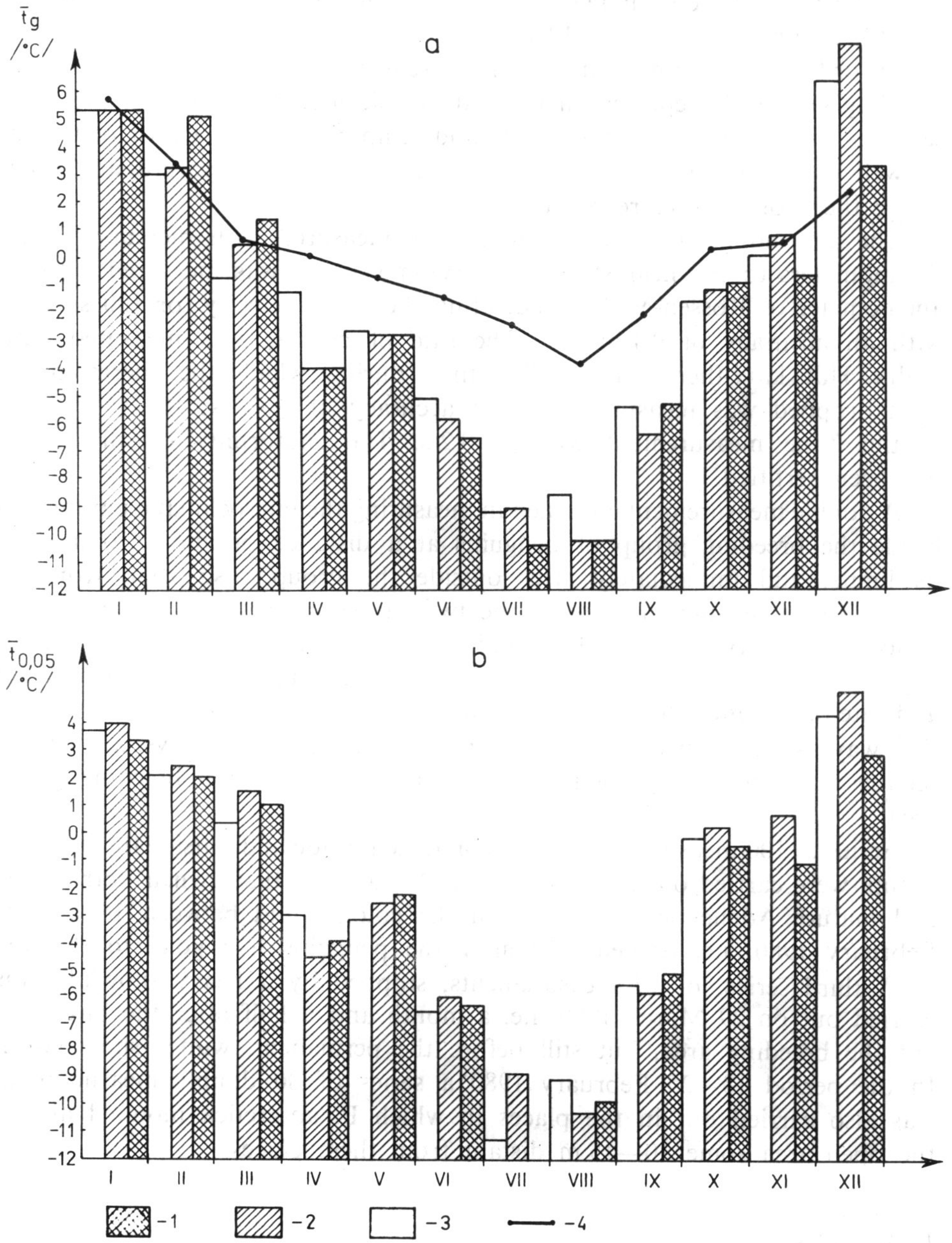

Fig. 2. Mean monthly ground temperature values at the depth of 0.05 m (a) and mean monthly air temperature values at 0.05 m above the ground surface (b) in the Thomas Pt. colony in 1980. 1 — station M1 — *P. papua*; 2 — station M2 — *P. antarctica*; 3 — station M3 — *P. adeliae*; 4 — H. Arctowski meteorological station.

Due to technical difficulties the data on ground air temperatures for the following periods are excluded from calculations: 1—9 January, 27 January, 14—18, 20 and 21 February 1980.

In order to determine if the measurements at a single point in the breeding group are representative for its whole area there were made three series of double measurements of ground temperature at a depth of 0.05 m as well as wind velocity, rate of cooling and air temperature at 0.35 m above the ground were recorded.

The air and ground temperatures were measured with mercury Hallay thermometers to the nearest $\pm 0.1°C$. Wind velocity was measured with an anemometer of Rossen-Müller, indicating the mean velocity for 100 seconds with an accuracy of $0.1\ m \cdot s^{-1}$. The rate of cooling was measured with a dry Hill kata-thermometer. The time during which the thermometric fluid dropped was measured with an accuracy of ± 0.1 s; the total error of this time measurement was $\pm$ 0.2 s. The conformity of all devices has been certified.

A double measurement consisted in measuring the microclimatic parameters inside the breeding group of penguins at a distance of about 10 m from its limits, and immediately after outside the group, also 10 m from its limits. The time interval between the two measurements was about 10 min. A low variability in air and ground temperatures, a long time period of approaching the mean value in the case of measuring the wind velocity and rate of cooling allowed to consider a pair of measurements conducted in that way as simultaneous ones. The measurements were always carried out on the windward (on particular day) limits of the penguin breeding group area.

Series of 100 measurements, each conducted inside and outside the breeding group, were carried out between 17 and 25 January 1980 (when both young and mature Adélie penguins were in the colony) and between 14 and 21 February 1980, i.e. immediately after the penguins had gone to the sea.

A third series, of 17 measurements, stopped by a heavy snowfall, was carried out on 29 March 1980, i.e. a month and a half after the birds had left the breeding area, but still before the permanent, winter snow cover. In the period 18—25 February 1980 a series of 80 double measurements was also carried out in the places in which P. antarctica moulted and in the open area some 10—15 m distant from these places.

4. Results

4.1. Ground and air temperature

In the period January — February 1980, and also in March the mean monthly ground temperatures (MMGT) in the breeding group of *P. papua*

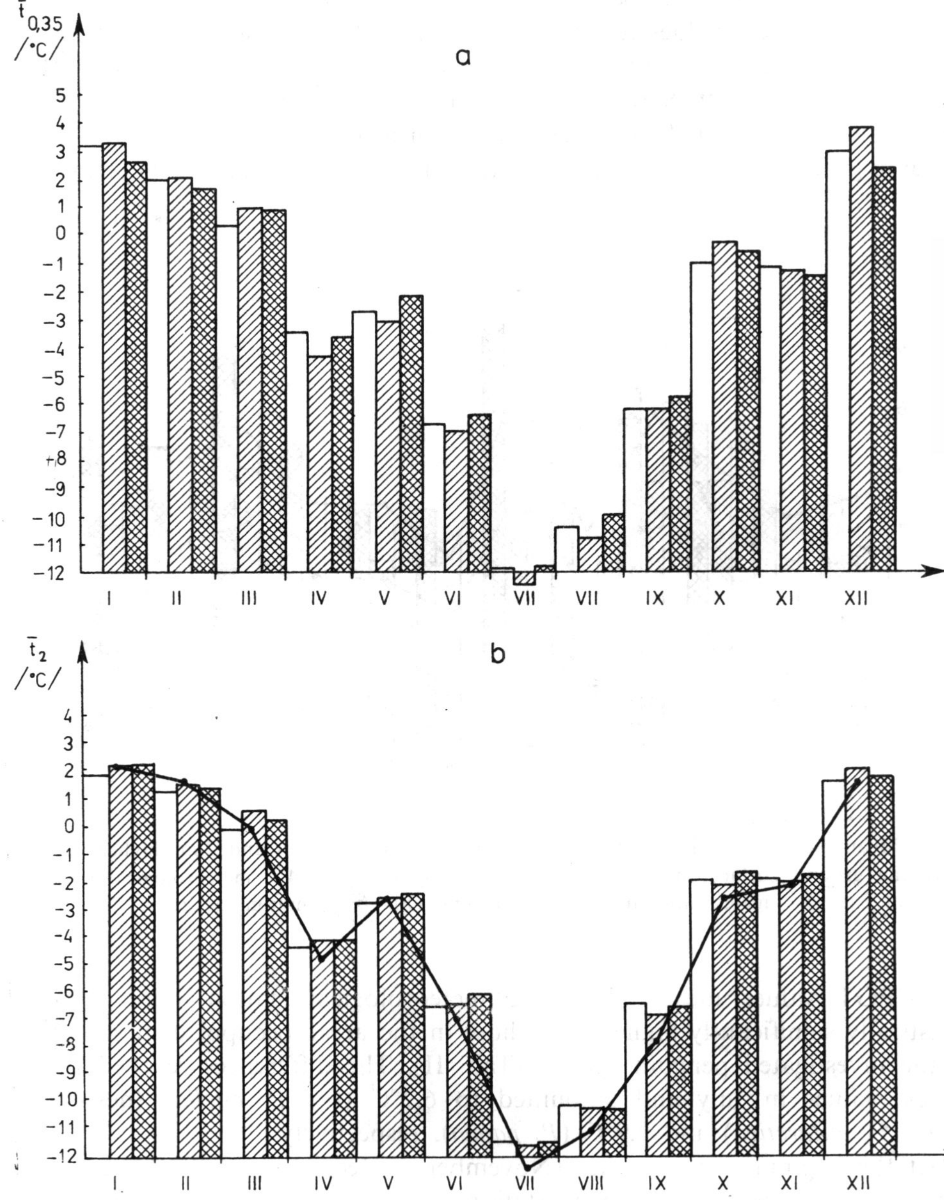

Fig. 3. Mean monthly air temperature values at 0.35 m (a) and 2 m (b) above the ground surface in the Thomas Pt. colony in 1980. Designations as in fig. 2.

were significantly higher than those in the breeding group of *P. antarctica* and *P. adeliae* (Tab. I and II. Fig. 2), whereas in next summer (November — December 1980) MMGT was higher in the breeding group of P. antarctica.

The mean ground temperature in the winter season (MPGT) was highest in the area of summer occurrence of *P. adeliae* and was statistically different from these values for the areas of the other two species. In October the MPGT values in the breeding areas of all species became equal (Tab. II).

At the end of summer the MPGT values measured at the meteorological station did not differ from such values measured in the areas of each breeding group. On the other hand, in the winter season (April — September)

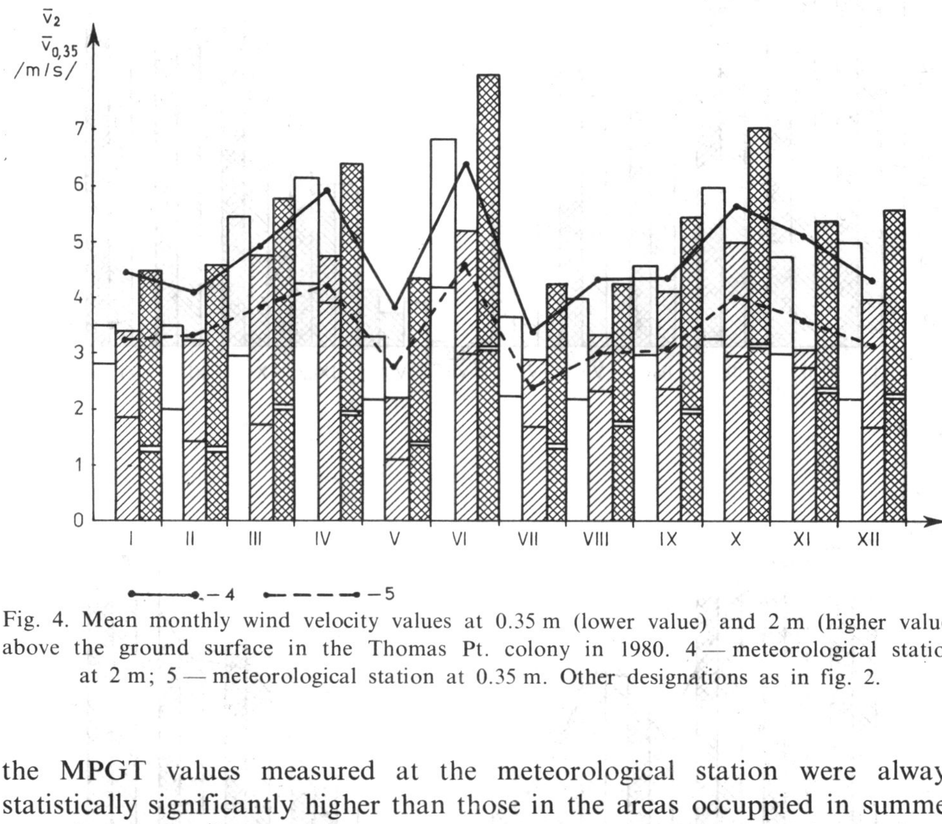

Fig. 4. Mean monthly wind velocity values at 0.35 m (lower value) and 2 m (higher value) above the ground surface in the Thomas Pt. colony in 1980. 4 — meteorological station at 2 m; 5 — meteorological station at 0.35 m. Other designations as in fig. 2.

the MPGT values measured at the meteorological station were always statistically significantly higher than those in the areas occuppied in summer by the investigated penguin species (Tab. II). The differences reached their highest values in July and amounted to 6.2°C (for *P. adeliae* (nest-site) 6.3°C (*P. antarctica*) and 7.9°C (*P. papua*), respectively.

At the beginning of summer (November — December 1980) the ground temperature at the meteorological station increased slower than in the area occuppied by penguins and the mean value calculated for this period was statistically lower than those of the *P. antarctica* and *P. adeliae* breeding areas (Tab. I, II, Fig. 2).

The mean monthly air temperature values (MMAT) at 0.05 m, 0.35 m and 2 m above the ground had a yearly pattern similar to that of ground temperature. The highest values occurred in summer months with a maximum in December or January, and the lowest ones in July or August. Differences

Table I

Mean ground temperature (in °C) at the depth of 0.05 m below the ground surface and mean air temperature at 0.05 m above the surface in the breeding groups of *P. papua* (P.p.), *P. antarctica* (P. an.), *P. adeliae* (P. ad.) and at the meteorological station (M.st.) in the Thomas Pt. colony in phenological periods in 1980. Standard deviation values are given in brackets.

Study period	Number of measurements	Mean temperature (°C)						
		of the ground at the depth of 0.05 m				of the air at 0.05 m		
		P.p.	P.an.	P.ad.	M.st.	P.p.	P.an.	P.ad.
Summer January-February	192	5,0 (3,3)	4,0 (3,7)	3,9 (3,9)	4,3 (3,4)	2,6 (2,9)	3,1 (3,2)	2,7 (3,2)
March	31	1,2 (2,1)	0,3 (1,6)	−0,8 (1,8)	0,6 (0,9)	1,0 (2,8)	1,5 (2,8)	0,3 (2,9)
Winter April-September	183	−6,7 (4,6)	−6,5 (3,5)	−5,5 (3,9)	−1,8 (1,5)	−6,8 (5,8)	−6,5 (1,7)	−6,6 (5,2)
October	31	−1,2 (1,9)	−1,3 (1,9)	−1,8 (1,6)	0,2 (0,2)	−0,9 (2,8)	0,1 (2,6)	−0,3 (2,7)
Summer November-December	224	0,8 (3,0)	3,6 (5,1)	2,6 (4,6)	1,1 (2,8)	0,4 (3,4)	2,5 (4,3)	1,3 (4,2)

Table II

Differences between the mean ground temperature values in the nest-sites of *P. papua*, *P. antarctica*, *P. adeliae* and the meteorological station at the Thomas Pt. colony in phenological periods of 1980.

Measuring station	Summer January-February		March		Winter April — September		October		Summer November — December	
	temp. (°C) diff.	p	temp. (°C) diff.	p	temp. (°C) diff.	p	temp. (°C) diff.	p	temp. (°C) diff.	p
P. papua — *P. antarctica*	0,9	0,02	0,8	0,1	−0,2	●	0,1	●	−2,8	0,001
P. papua — *P. adeliae*	1,0	0,02	2,0	0,001	−1,2	0,01	0,6	●	−1,8	0,001
P. antarctica — *P. adeliae*	0,1	●	1,2	0,01	−1,0	0,02	0,5	●	−1,0	0,05
St. meteo — *P. papua*	−0,6	0,1	−0,5	●	4,9	0,001	1,4	0,001	0,3	●
St. meteo — *P. antarctica*	0,3	●	0,3	●	4,7	0,001	1,5	0,001	2,4	0,001
St. meteo — *P. adeliae*	0.4	●	1,5	0,001	3,7	0,001	2,0	0,001	−1,4	0.001

"●" p-values > 0.1.

between the MMAT values within the breeding areas of three investigated species decreased together with increase in height at which air temperature was measured (Fig. 2 and 3).

The mean air temperature values (MPAT) at 0.05 m above the ground calculated for particular phenological periods statistically differed significantly only in the initial period of the summer season (November — December 1980). In this period the MPAT values at 0.05 m above the ground in the *P. antarctica* breeding area (M2) were higher by 2.1°C than in the breeding area of *P. papua* (M1), and by 1.2°C higher than in the *P. adeliae* breeding area (M3) (Tab. III).

Table III

Mean air temperature (in °C) at 0.35 m and 2 m in the nest-sites of *P. papua* (P.p.), *P. antarctica* (P. an.), *P. adelia* (P. ad.) and at the metcorlogical station (M.St.) at the Thomas Pt. colony in the phenological periods of 1980. Standard deviations are given in brackets.

Study period	Number of measurements	Mean air temperature (°C)						
		at 0.35 m			at 2 m			
		P.p.	P.an.	P.ad.	P.p.	P.an.	P.ad.	M.st.
Summer January — February	192	2,1 (2,5)	2,6 (2,9)	2,4 (2,7)	1,8 (2,2)	1,9 (2,2)	1,6 (2,2)	2,0 (2,3)
March	31	0,9 (2,9)	0,9 (2,6)	0,3 (2,5)	0,3 (3,0)	0,7 (2,6)	−0,1 (2,7)	0,05 (3,0)
Winter April — September	183	−6,6 (6,3)	−7,4 (6,3)	−7,1 (6,2)	−6,8 (6,2)	−7,0 (6,4)	−7,0 (6,1)	−7,6 (6,8)
October	31	−0,7 (2,7)	−0,4 (3,1)	−1,2 (3,2)	−1,7 (3,2)	−2,2 (3,7)	−2,0 (3,3)	−2,8 (4,4)
Summer November — December	224	0,2 (3,1)	1,0 (4,0)	0,6 (3,4)	−0,3 (2,7)	−0,3 (2,9)	−0,4 (2,7)	−0,5 (2,9)

The monthly mean air temperatures (except the December mean), as well as mean temperatures of distinguished phenological periods in 1980 at 0.35 m and 2 m above the ground for the breeding areas of all three species (Tab. III, Fig. 3) were not statistically significantly different. In December the MMAT values at 0.35 m above the ground at station M2 (*P. antarctica*) were significantly higher, by 0.8°C, than at station M3 (*P. adeliae*) and by 1.5°C higher than at station M1 (*P. papua*).

No statistically significant differences in the MPAT values measured at

2 m above the ground were observed between the meteorological station and measuring sites in the breeding groups of the three investigated penguin species.

4.2. Wind velocity

The histograms of mean monthly wind velocity values MMWV in the areas of the investigated breeding groups of penguins and at the meterological station have a similar pattern both at 2 m and at 0.35 m above the ground (Fig. 4).

The mean periodical value of wind velocity (MPWV) at 2 m above the ground was highest at station M1 (*P. papua*) in all phenological periods (Tab. IV). In summer (January — February 1980) it was higher by over 1 m s^{-1} in comparison with station M3 (*P. adeliae*) and by 1.4 m s^{-1} in comparison with station M2 (*P. antarctica*) (differences statistically singnificant at $p<0.001$). Statistically significant differences in the MPWV values at 2 m above the ground at $p < 0.001$ were also recorded in the

Table IV

Mean wind velocity ($m \cdot s^{-1}$) at 0.35 m and 2 m in the nest-sites *P. papua* (P.p.), *P. antarctica* (P.an.), *P. adeliae* (P.ad.) and at the meteorological station (Mst.) at the Thomas Pt. colony in the phenological periods of 1980. Standard deviations are given in brackets.

Study period	Number of measurements	Mean wind velocity ($m \cdot s^{-1}$) at 0.35 m				at 2 m			
		P.p.	P.an.	P.ad.	M.st.	P.p.	P.an.	P.ad.	M.st.
Summer January — February	240	1,3 (1,2)	1,6 (3,2)	2,5 (3,3)	3,3 (2,3)	4,6 (3,8)	3,3 (3,2)	3,5 (3,6)	4,6 (3,3)
March	31	2,1 (1,9)	1,7 (2,7)	3,0 (3,0)	3,8 (2,5)	5,8 (5,0)	4,8 (3,9)	5,4 (4,3)	5,4 (3,5)
Winter April — September	177	1,9 (1,9)	2,4 (3,2)	3,0 (3,0)	3,3 (2,7)	5,4 (4,5)	3,8 (3,2)	4,8 (3,9)	4,7 (3,8)
October	31	3,2 (2,8)	3,0 (3,5)	3,2 (3,7)	4,0 (3,1)	7,0 (6,3)	5,0 (4,6)	6,0 (5,3)	5,7 (4,4)
Summer November — December	224	2,5 (1,7)	2,4 (2,6)	2,8 (2,2)	3,6 (2,1)	6,0 (3,8)	3,8 (2,5)	5,3 (3,7)	5,1 (3,0)

periods April — September and November — December between stations M1 and M2 (differences between the means: 1.7 m s^{-1} and 2.1 m s^{-1}, respectively), and between stations M3 and M2 (1.0 m s^{-1} and 1.4 m s^{-1}, respectively).

In the months intermediate between the summer and winter seasons, i.e. in March and in October, differences between MPWV values at stations M1, M2 and M3 were statistically insignificant.

The mean periodical wind velocity value (MPWV) at 2 m above the ground recorded for the meteorological station statistically did not differ significantly from those at station M1 (*P. papua*) in all phenological periods. It did not differ also from that value at station M3 (*P. adeliae*), where MPWV was significantly lower than at the meteorological station only in the summer period (January — February 1980). On the other hand, the MPWV values at the meteorological station were by 0.9—1.3 m s^{-1} higher than those at stations M1, M2, M3 in all phenological periods except March and October, when differences of this parameter were statistically insignificant.

The MPWV value at 0.35 m above the ground in all phenological periods was highest at station M3 (*P. adeliae*) (Tab. IV). Differences in the values of this parameter between the areas of the breeding groups of particular species were statistically significant in the following cases. In summer season of 1980 (January — February) the MPWV value at 0.35 m was higher by 1.1 m s^{-1}, and by 0.8 m s^{-1} at station M3 (*P. adeliae*) than at stations M1 (*P. papua*) and M2 (*P. antarctica*), respectively. In winter season (April — September), the value of this parameter was higher by 1.1 m s^{-1} at station M3 (*P. adeliae*) than at station M1 (*P. papua*) (the difference was statistically significant at $p<0.001$). In other periods the differences were statistically insignificant.

In all phenological periods the MPWV values at 0.35 m in the breeding areas of particular species were lower by 0.8 m s^{-1} to 2 m s^{-1} from the values calculated for the meteorological station. Statistically insignificant differences between values recorded at station M3 (*P. adeliae*) and those recorded at the meteorological station occurred only in March, April-September and in October.

4.3. Microclimate of the area occuppied by penguins and adjoining areas

Arithmetical mean values of wind velocity, air temperature, ground temperature and the cooling rate for measuring series carried out in places occuppied by the Adélie penguins and their neighbourhood are given in Table V.

During the first series of measurements, between 17 and 25 January

Table V

Mean values of the microclimatic parameters for a series of measurements in the nest-sites of *P. adeliae*, in moulting places of *P. antarctica* an outside these areas at the Thomas Pt. colony. Standard deviation values are given in brackets; n = number of double measurements in a series.

Study period	Mean arithmetical values of parameters							
	in the *P. adeliae* nest-site				outside the *P. adeliae* nest-site			
	wind velocity ($m \cdot s^{-1}$)	air temp. (°C)	ground temp. (°C)	cooling W/m^2	wind velocity ($m \cdot s^{-1}$)	air temp. (°C)	ground temp. (°C)	cooling W/m^2
17—25.II.1980 n = 100	2,0	2,6	4,6	1216	3,2	2,3	4,0	1672
area occuppied by *P. adeliae*	(2,1)	(3,1)	(4,5)	(453)	(3,1)	(2,9)	(4,2)	(451)
14—21.II.1980 n = 100	1,8	3,5	5,5	1138	2,1	3,3	4,9	1222
area just after the leaving of *P. adeliae*	(1,6)	(3,2)	(4,7)	(353)	(1,8)	(3,1)	(4,4)	(397)
29.III.1980 n = 17	3,8	1,8	1,9	1773	3,1	1,9	0,8	1585
area in 1,5 months after the leaving of *P. adeliae*	(2,0)	(1,0)	(1,4)	(490)	(2,1)	(1,0)	(1,2)	(456)
	Moulting places of *P. antarctica*				Outside the moulting places of *P. antarctica*			
18—26.II.1980 n = 80	2,5	4,5	—	1296	4,0	4,3	—	1556
	(2,0)	(2,5)	—	(455)	(2,6)	(2,3)	—	(448)

1980, i.e. when the area was occuppied by birds, the mean wind velocity value within the breeding group was lower by 1.1 m s^{-1}, that is by 36%, than outside of the breeding area (a statistically significant difference). The cooling rate in the breeding area was lower by 27% from the area outside the group. Immediately after leaving of the breeding area by Adélie penguins and a month and a half later no statistically significant differences between all measured parameters were recorded in these two areas.

Differences between the mean wind velocity values and mean values of cooling in the moulting places of *P. antarctica* and outside these places were also statistically significant. The mean wind velocity value in the places of moulting was higher by 40% and the mean value of cooling by 20% lower than the mean values of these parameters measured outside the penguins' moulting area.

The mean air and ground temperatures in the *P. adeliae* breeding group and outside its area and in the moulting places of *P. antarctica* did not differ in a statistically significant way (Tab. V). However, between 17 and 25 January 1980 the air and ground temperatures were higher in the area of the *P. adeliae* breeding group than outside this area in $70 \pm 9.0\%$ of pairs of measurements. Between 14 and 21 February 1980, i.e. when the birds had left the area, the air temperature was higher in $44 \pm 9.7\%$ and the ground temperatre was higher in $64 \pm 9.4\%$ of pairs of measurements in the breeding area than outside the area. Between 18 and 26 February 1980 also in the *P. antarctica* moulting area the air temperature was higher than outside this area in $60 \pm 10.7\%$ of pairs of measurements.

5. Discussion

Among the investigated penguin species, the *P. adeliae* breeding groups are characterized by the highest nest density, *P. antarctica* by a lower one and the lowest nest density occurs in the P. papua breeding groups. The mean distances between nests measured in 24 breeding colonies were the following: 77.3 cm, 86.4 cm and 103.4 cm, respectively (C. Müller-Schwarze and D. Müller-Schwarze 1975). The breeding groups of the first two species in the investigated region are also much more abundant than the *P. papua* groups (Volkman and Trivelpiece 1981, Jabłoński 1984a). Thus, it seems that the highest efficiency in modification of microclimatic factors due to the penguins' presence should occur in the breeding groups of *P. adeliae*. However, a slight increase in air temperature in the *P. adeliae* breeding groups in summer is of no importance in the energy budget of these birds. And still more this slight increase is not important in the energetic budget of two other species. Mean air temperatures at 0.35 m in the breeding groups of all three species were similar. Hence, it may be assumed that higher density of nests and higher abundance of breeding groups do not cause significant increase in the air temperature around the nesting birds.

The above mentioned slight increase in air temperature in the area of the nesting Adélie penguins disappeared after the birds had left the area. This implies that the penguins' presence modifies the air temperature. It also indicates that in respect to air temperature areas chosen for breeding to not differ from the adjoining areas.

Ground temperatures at 0.05 m below the surface of the penguins nest--sites distinctly differed from those recorded outside these areas. The cause of these differences lies in dissimilarity of substrate, of snow cover thickness and in the degree to which the ground surface is modified by penguins.

A higher ground temperature at station M1 (*P. papua*) than at the other stations at the end of the summer period (January — March) is probably due to a higher value of the specific heat and coefficient of heat conductivity of the substrate. The storm-ridge, a characteristic nesting place of *P. papua*, is formed of cobbles, and space between stones is filled with air. Such a structure is characterized by a good water permeability, and thus its low retention. Soil of low water content is also characterized by a low value of thermal conductivity. The storm-ridge is thus a kind of thermostat — it becomes heated lowly and retains for a long time the accumulated thermal energy (Birkenmajer, pers. communication). The soil of the hardened moraine, and especially the rocky substrate — which are characteristic for the *P. adeliae* and P. *antarctica* nest-sites — loses quickly during the night the thermal energy it has absorbed during the day.

At the end of the summer season (January — March) temperature at station M1 (*P. papua*) reached its highest values. At that time the penguins were present at all stations, M1, M2 and M3. On the other hand, in the beginning of summer (November — December) there were no nesting penguins around station M1. The ground temperature at that time was lower there by 1.8°C to 2.8°C from those at stations M2 and M3. This evidences that the continuous presence of penguins causes an increase in ground temperature. It is brought about by the diminishing of the albedo value of the ground surface, that causes an increase in the amount of solar energy absorbed (author's unpubl. data).

In winter high differences in MMGT values between the meteorological station and stations in the penguin nest-sites, amounting to 8°C, are mainly due to the differences in the thickness of the snow cover. The breeding areas of pygoscelid penguins, almost devoid of a snow cover, cool much more than neighbouring areas that are covered in winter with thick snow.

Wind velocity values recorded in the Thomas Pt. colony prove the former opinion that penguins nest in milder conditions than those observed at the meteorological station (Sapin-Jaloustre 1960, Stonehouse 1967). In summer wind velocity value at the H. Arctowski meteorological station at 0.35 m above the ground was higher in 22%—60% than those measured in the breeding areas. The main cause of the higher wind velocity values at the meteorological station is its location in an open area in order to avoid the possible influence of orography upon measurement results.

Wind velocity values at stations M1, M2 and M3 were proportional to the degree of adaptation of particular penguin species to polar conditions. The best adapted high Antarctic species, *P. adeliae* (Stonehouse 1967), nests in an area of the highest wind velocity value. On other hand *P. papua*, which mostly inhabits subantarctic islands, in the Thomas Pt colony choses its nesting places mainly in the areas well protected against dominant winds and their breeding areas are characterized by the lowest wind velocity values.

The distinguishing feature of nest-sites of pygoscelid penguins is their wind exposure. This exposure may account for the apparently paradoxical distribution of snow cover in the investigated region; it was recorded namely that the places exposed to weaker winds (stations M1, M2, M3) were in winter almost free of the snow cover, whereas at the meteorological station, at which wind was stronger, the thickness of the snow cover amounted to 90 cm (author's unpubl. dta). Therefore the relief of the areas occuppied in summer by nesting penguins is most probably characterized by a perfect wind exposure.

The results obtained allow us to suggest that the surface of the hatching areas may constitute a factor limiting further increase in the abundance of pygoscelid penguins. The hatching areas should be covered in winter with a very thin snow cover, and at the same time they are characterized by low wind velocity values. The thin snow cover is a necessary, although not a sufficient condition for new areas to be colonized, because it enables the penguins to build nests and to reproduce during short Antarctic summer. On the other hand mild microclimate is of secondary importance for pygoscelid penguins that are well adapted to polar conditions (Stonehouse 1967, 1970, 1975; Kooyman 1975, Kooyman et al. 1976, Burger and Williams 1975, Taylor 1985).

6. Резюме

Исследования микроклимата в колонии мыса Томас проводились с декабря 1979 года до января 1981 года на территории мест гнездования пингвинов: *P. adeliae, P. antarctica, P. papua* (рис. 1). Измеряли температуру почвы на глубине 0,05 м, температуру воздуха на высоте 0,05 м, 0,35 м и 2 м над поверхностью, скорость ветра на высоте 0,35 м и 2 м, а также величину охлаждения. Эти данные сравнивались со значениями, измеренными на близлежащей метеорологической станции им. Г. Арцтовского. Были определены также некоторые факторы микроклимата в местах незаселенных пингвинами а также в местах, используемых *P. antarctica* во время линьки.

Территории гнездования пингвинов из рода *Pygoscelis* характеризуются специфичным микроклиматом. Отличительными факторами этого микроклимата являются температура почвы и скорость ветра. Температура почвы на местах гнездования в зимнем периоде является значительно меньшей по сравнению с соседними территориями ввиду небольшой толщины снежнего покрова, а более высокой в гнездовом периоде благодаря физическим свойствам почвы и ее модификации гнездящимися пингвинами (табл. I).

Температура воздуха на территории гнездования в гнездовом периоде является только несколько большей по сравнению с соседними районами и не играет роли при смягчении климата (табл. III, V).

Скорость ветра на территории, занятой пингвинами, является меньшей, чем по соседству (табл. IV). Разница эта является более существенной в гнездовом периоде

по сравнению с зимой из-за модифицирующего действия птиц. Места линьки *P. antarctica* глаеным образом из-за меньшей скорости ветра, характеризуются небольшим охлаждением по сравнению с соседними районами (табл. V).

7. Streszczenie

Badania mikroklimatu w kolonii Thomas Point prowadzono w okresie od grudnia 1979 do stycznia 1981 r. na terenach lęgowych pingwinów: *P. adeliae*, *P. antarctica*, *P. papua* (rys. 1). Mierzono temperaturę gruntu na głębokości 0,05 m, temperaturę powietrza na wysokości 0,05, 0,35 i 2 m nad powierzchnią gruntu, prędkość wiatru na wysokości 0,35 i 2 m oraz wielkość ochładzania. Dane te porównano z wartościami zmierzonymi na pobliskiej stacji meteorologicznej im. H. Arctowskiego. Określono także niektóre czynniki mikroklimatu miejsc niezasiedlonych przez pingwiny oraz miejsc wykorzystywanych przez *P. antarctica* w okresie pierzenia się ptaków.

Tereny lęgowe pingwinów z rodzaju *Pygoscelis* charakteryzują się specyficznym mikroklimatem. Wyróżniającymi czynnikami tego mikroklimatu są: temperatura gruntu i prędkość wiatru. Temperatura gruntu na terenach lęgowych jest znacznie niższa niż na terenach sąsiednich w okresie zimowym ze względu na małą grubość pokrywy śnieżnej i wyższa w okresie lęgowym dzięki fizycznym właściwościom podłoża i jego modyfikacji przez gniazdujące pingiwny (tab. I).

Temperatura powietrza na ternach gniazdowania jest w okresie lęgowym tylko nieznacznie wyższa w stosunku do obszarów sąsiadujących i nie ma praktycznie znaczenia w łagodzeniu klimatu (tabele III, V).

Prędkość wiatru na obszarach zajmowanych przez grupy lęgowe pingwinów jest mniejsza niż w sąsiedztwie (tab. IV). Różnica ta jest większa w okresie lęgowym niż zimą z powodu modyfikującego oddziaływania gniazdujących ptaków. Miejsca pierzenia się *P. antarctica*, głównie dzięki mniejszej prędkości wiatru, charakteryzują się małym ochładzaniem w porównaniu z obszarami sąsiednimi (tab. V).

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