Third Indian Expedition to Antarctica Scientific Report 1986
Department of Ocean Development Technical Publication No 3 pp 133 147

Microbiological Studies in Schirmacher Oasis, Antarctica Effect of Temperature on Bacterial Populations

S G. Prabhu Matondkar[1]

ABSTRACT

Seasonal and site wise variation in size and diversity of bacterial population was observed in Schirmacher Oasis Antarctica. Prevailing soil temperature limited the distribution and abundance of groups of bacteria like psychrophiles psychrotrophs and mesophiles. Pulses in the bacterial cycle were also found in the Basis as a function of daily and seasonal variations in air and soil temperature. Requirement of growth temperature of individual bacterium is the best physiological marker to work out the survival strategies of micro organisms. Effect of seasonal variations in temperature was directly manifested in diversity index and generation time of micro organisms. In temperature response study organisms like *Serratia* were found tolerating very low temperatures (-40°C) indicating the physiological adaptation of bacteria to sub freezing temperatures persisting in Schirmacher Oasis during Antarctic winter.

INTRODUCTION

The existence of an extensive microflora in Antarctic soils is well established (Boyd *et al* 1966 Benoit *et al* 1970 Evans, 1982 and Matondkar *et al* 1983) Cameron (1972) attempted a micro biological study of Antarctic ice sheet with reference to survival of viable microbes in dry valleys and mountains of the interior. Some information about distribution pattern of endolithic microbes and its environment are also available (Mckay *et al* 1985). In all these studies mainly distribution and ecology during austral summers were attempted with few exceptions of round the year studies. Wynn-Williams (1980) studied the decomposer activity over a period of one year at Signy Island.

A review of literature clearly indicates that the effects of abiotic factors on microbial population are inadequately studied in Antarctica. As a part of Indian Scientific Expedition to Antarctica the ecophysiological aspects of survival mechanisms in individual species of microflora, are being studied and the present communication deals with the effect of temperature on bacterial population isolated from Schirmacher Oasis, Antarctica.

Schirmacher Oasis (Fig 1) is situated in between shelf ice and land ice, 35 km^2 ice free area, with lakes lagoons, ponds, water streams, dome shaped hills, gentle slopes and polar climate is a typical snow free part of Queen Maud land Antarctica. Most part of Oasis is moraine covered bare ground. The weathering products and glacial deposits from these exposed rocks form the soil. Soil sampled from Oasis is mostly sandy and favoured by moss *Bryum* sp Small ponds and lakes (around 200 nos) are formed because of glacial melt water. These water bodies are found supporting the growth of blue green algae. The organic input is by moss and algae in oasis ecosystem. During 1982 austral summer, Matondkar *et al* (1983) reported the primary productivity of lakes ranging from 0 14-0 68 mg cm^{-3} hr^{-1}, which is quantitatively considerable and bacterial counts of some of the sites as high as temperate soils.

[1]National Institute of Oceanography Goa

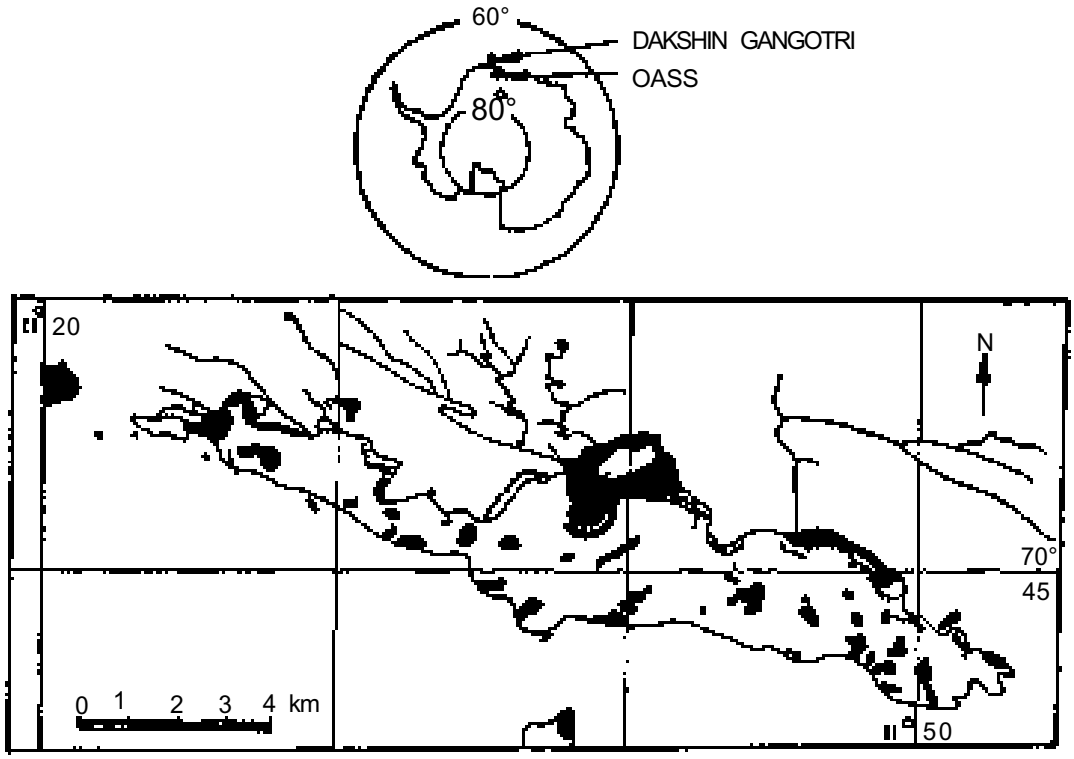

Fig 1 Schimache Oasis Antarctica

As a part of detailed site characterisation study occurrence of invertebrate fauna was noted. Moss beds were found supporting the growth of invertebrates like rotifer nematode and tardigrades. In one site (moss *Bryum* sp) mites were also seen. But majority of soil sites were devoid of invertebrate population and hence energy must be passing through decomposer sub system in the environment. As a part of this study a comparative account of biotic assemblages like bacteria fungi yeast and algae was also maintained and are reported separately. In this the bacterial population was found to dominate over the other microbial components Cameron (1972) also reported the same fact from Victoria Valley Antarctica. In a similar study of subantarctic island fungi and yeasts also were found to be equally important components as bacteria (Smith *et al* 1982).

MATERIAL AND METHODS

Selection of sampling area All possible soil samples from Schirmacher Oasis (Fig 1) were collected for bacteriological investigation. It included soil from moss lichen and algal patches dry and wet soil and sand soil under rocks and boulders receding glaciers and under snow and water cover.

Collection and processing of samples surface and subsurface layer of soil was collected with sterile spatula in sterile plastic bags using a spirit lamp flame. Streak plating was done immediately in the field on pre dried media plates of soil agar medium poured earlier (Matondkar *et al* 1983). All plated samples were transported to station laboratory and incubated at 10° ± 2°C. Winter soil samples were in hard frozen state and hence processed in laboratory at temperature 10°C to avoid the risk of contamination possibly arising out of winter clothing and windy regime. Counts were taken once a week over a period of one month. A cold tray was used to maintain agar plate temperature below 10°C while working at a higher room temperature up to 20°C.

For pure culture studies, isolates were chosen from characteristically seven different sites. Isolates were randomly selected and purified by three sequential streaking in agar slants in permanent base laboratory. The pure culture results reported here concern temperature growth response and indicates the effect of season (temperature component) on bacterial population in the dry valleys or oasis eco-systems.

RESULTS

The total counts of bacteria for different seasons and sites are shown in table 1. During January, 1982, counts varied from 80.0 - 4.5 x 10^5 g^{-1} of soil. Thus dry soil having very low level of moisture had low counts and algal soils with higher level of moisture and organic matter supported higher bacterial counts. The bacterial density in soil samples assayed during January clearly corroborated with changes in the air temperatures, which for a short period went upto +6°C but most of the time it was around 0°C. (Fig. 2).

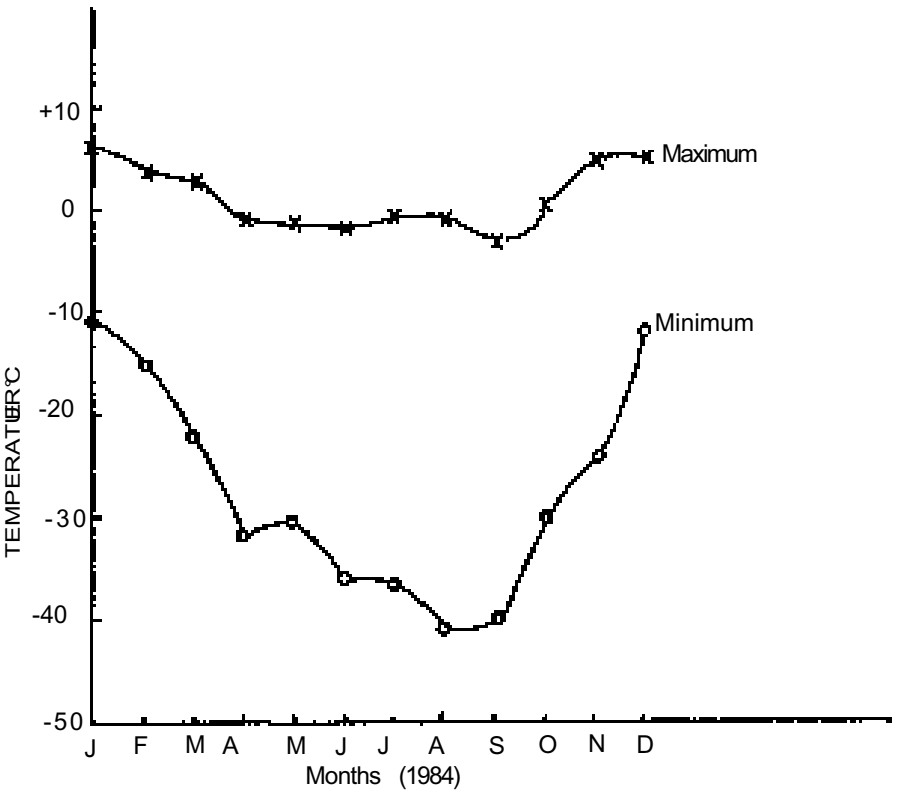

Fig 2. Temperature cycle in Oasis.

August was the coldest month, when minimum air temperature went up to -40°C and soil temperature to -30.5°C (Table 2). This period was characterised by total darkness except for 2 hrs of light regime. During storms and blizzards air temperature, even during winter season, went up to +2°C and relatively high biological activity (for short period) was noticed. Hence it was not surprising that, even in August, bacterial counts were 10-1.8 x 10^3 g^{-1}soil. Thus inspite of extremely, low soil temperature of -30°C to -40°C, bacterial flora as seen from viable plate count technique, thrived well in August. The sudden increase in bacterial population in dry soil during winter (Table 1) can only be explained on the topography of a site. During December a gradual increase in bacterial population was observed. But some of the soil samples were found to be sterile. However, moistening of soil can support very high density of bacteria reaching up to 10° order counts g^{-1} of soil. In totality, December was the most productive month, in the annual cycle of bacterial productivity.

TABLE 1

Seasonal variation in bacterial counts in Schirmacher Oasis Antarctica

Sites/Seasons	*No of samples*	*Jan 84*	*Aug 84*	*Dec 84*	*Jan 85*	*Feb 85*
Algal soil	10	$3x10^5$-4 $5x10^5$	2 $5x10^2$-2 0x10	$40x10^2$-5 $2x10^4$	4 $2x10^4$-3 $8x10^3$	2 $0x10^2$-1 8x10
Loam	10	300-$8x10^2$	25-150	$20x10^2$-3 $1x10^2$	$12x10^2$-2 $5x10^3$	00-1 $35x10^2$
Dry soil	10	80-145	4 $2x10^2$-$38x10^2$	72-1 $8x10^2$	175-$13x10^2$	230-5 $1x10^3$
Moist soil	10	$16x10^3$-$18x10^4$	6 $2x10^2$-1 $8x10^3$	1 $6x10^5$-3 $8x10^6$	$21x10^4$-$14x10^5$	1 6x10-1 $2x10^2$
Moss soil	10	0 5 10^2-4 $8x10^3$	25-130	$15x0^3$-1 $8x10^4$	$10x10^2$-1 $2x10^3$	40-1 $5x10^5$
Sand	10	$100x10^2$-10 $4x10^3$	50-150	00-1 $2x10^2$	$12x10^3$-1 $8x10^4$	1 $6x10^2$-$14x10^4$
Lichen soil	10	1100-3 $2x10^4$	10 180	$10x10^4$-1 $4x10^5$	$10x10^2$-1 $8x10^3$	00-1 $2x10^2$
Oasis total	70	80-4 $5x10^5$	10-1 $8x10^3$	00-1 $6x10^5$	175-$21x10^4$	00-1 $5x10^5$

TABLE 2

Seasonal variation in soil temperature (°C) in Schirmacher Oasis Antarctica

Sites/Seasons	*No of samples*	*Jan 84*	*Aug 84*	*Dec 84*	*Jan 85*	*Feb 85*
Algal soil	10	(14 8)-(3 2)	(-20 5)-(-30 5)	(21) (13)	(20)-(4 2)	(00 00)-(-1 0)
Loam	10	(5 0)-(1 0)	(-29 5)-(-30 5)	(22 0)-(18 5)	(7 0)-(5 5)	(1 0)-(-3 0)
Dry soil	10	(8 5)-(3 6)	(-20 0)-(-30 0)	(23)-(16 5)	(4 8)-(2 0)	(-1 0)-(-4 0)
Moist soil	10	(11 2)-(6 8)	(-10)-(-15)	(13)-(8)	(11)-(7 5)	(-2)-(-5)
Moss soil	10	(21 5)-(15)	(-19)-(-27 5)	(27-(22)	(27)-(11 5)	(-2 5)-(-5 0)
Sand	10	(8)-(2 0)	(-29)-(-30)	(18)-(5)	(13)-(11)	(-1)-(-7)
Lichen soil	10	(31)-(11)	(-20 5)-(-25 5)	(24)-(25)	(20)-(10)	(-1)-(-3)
Oasis total	70	(1)-(31)	(-10)-(-30 5)	(27)-(8)	(27)-(4 2)	(1)-(-5)

The growth-temperature ranges of isolates consonant with temperature variation in Oasis were extreme (Fig 2). As bacteria respond rapidly to environmental changes use of temperature as physiological marker to indicate the survival mechanism of individual group of bacterial flora has been made here. In January 1984 isolates from most of the samples were stenothermal growing well at 15°C except dry soil samples where 50 per cent organisms were eurythermic and displayed growth under the temperature range from 0°C to 15°C.

TABLE 3

Diurnal variations in Air and Soil temp (°C) in Oasis environment

Time Gmt. Hrs.	*12 August '84*		*15 December '84*		*20 January '85*		*20 February '85*	
	Air	*Soil*	*Air*	*Soil*	*Air*	*Soil*	*Air*	*Soil*
00	-35	-30	- 4	0.0	-12	- 2	- 15	-4
03	-32	-30	- 4	0.0	-10	- 2	- 12	-4
06	-32	-30	- 2	2.0	- 3	- 2	- 8	-4
09	-30	-30	0.0	4.0	0.0	0.0	- 6	-6
12	-32	-30	+ 2	15.0	+ 5	+ 6	+ 3	0.0
15	-33	-30	+ 1	18.0	+ 4	+ 8	+ 2	0.0
18	-30	-30	0.0	8.0	- 3	+ 2	0.0	-2
21	-30	-30	0.0	4.0	- 5	0.0	- 6	-4
00	-34	-30	- 2	2.0	-10	0.0	- 12	-5
Maxi (Month)	-1	-20	+ 2	+ 28	+ 5	+ 17	+ 3	0.0
Min (")	-35	-35	- 9	0.0	-13	- 4	- 16	-7.0

Cultures isolated in August, yielded results the other way as most of the organisms were eurythermic, growing well from 0°C to 15°C and growth got inhibited at higher temperature. December isolates were also found growing well in higher temperature range (10°-25°C) and only 25 percent isolates thrived temperature lower than the range (Table 4). February samples also showed growth of majority of isolates under a wide range of temperature of 0°C to 30°C.

Results of experiment on short term variations in bacterial population are presented in Fig 3. Upto 23rd of January, air temperature, soil temperature and bacterial population showed increasing trend, whereas around the beginning of February, the bacterial population seemed to be affected due to lowering of air and soil temperatures (Fig 3). Thus even during active growing season pulses of bacterial population were observed.

Effect of low temperature on natural population was studied and the results are presented in table 5. In case of *Serratia* sp gradual increase in counts was observed from September onwards obtaining maxima in November - December. Similarly effect of temperature on *Pseudomonas* sp was also monitered in the field. This species was found to favour relatively higher temperature and hence more counts were encountered in December-January. During November soil temperature was - 11°C whereas in December it went up to 21°C.

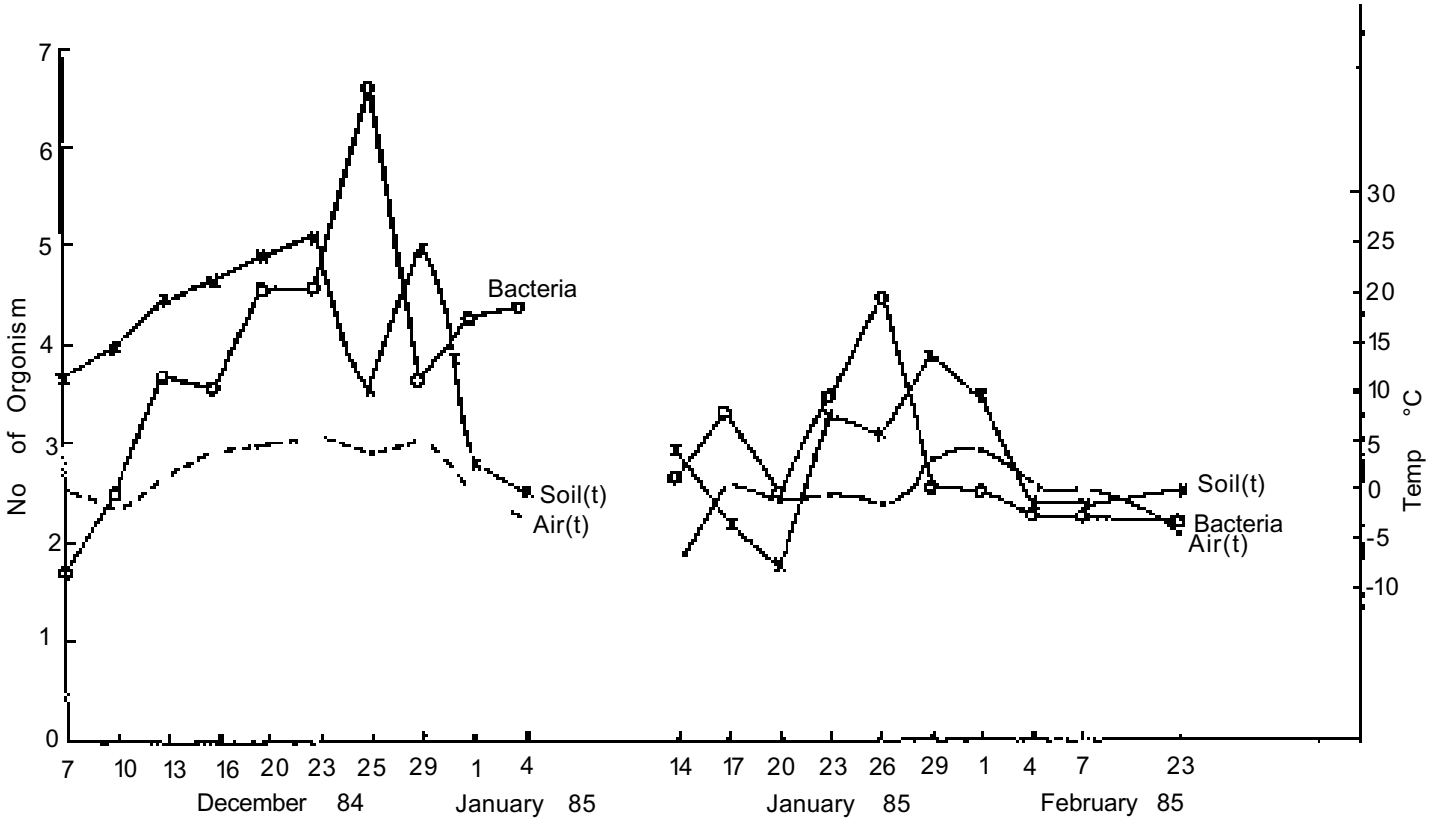

Fig 3 Effect of daily temperature variations on bacterial population

TABLE 4

Isolate Temperature Responses

Site	*Percentage organisms growing at t°C*							*No of organisms tested*
	0	*5*	*10*	*15*	*20*	*25*	*30*	
				Jan 84				
Algal soil	16 7	26 7	26 7	100	16 7	16 7		30
Loam	32	40	40	100	8			25
Dry soil	50	50	50	100	20			20
Moist soil	21 8	21 8	45 5	100	18	27 3	27 3	55
Moss soil	16 7	27 8	33 3	100	33 3	38 9	11 1	90
Sand	51 4	45 7	71 4	100	5 7			35
Lichen soil	35 2	35 2	56 5	100	47	47	53	85

TABLE 4(a)

Isolate Temperature Responses

Site	*Percentage organisms growing at t°C*							*No of organisms tested*
	0	*5*	*10*	*15*	*20*	*25*	*30*	
				Aug 84				
Algal soil	80	100	100	50	10			10
Loam	100	100	100	40				5
Dry soil	40	100	80	40				5
Moist soil	60	100	80	12	4			25
Moss soil	34	100	50	13 4	3 4			30
Sand	100	100	100					2
Lichen soil	6 7	100	100	13 4				15

TABLE 4(b)

Isolate temperature Responses

Site	*Percentage organisms growing at t°C*							*No of organisms tested*
	0	*5*	*10*	*15*	*20*	*25*	*30*	
				Dec 83				
Algal soil	20	20	20	100	100	100	18 2	55
Loam	33 4	33 4	33 4	100	100	100	40	30
Dry soil	30	30	30	100	100	100	52 5	40
Moist soil	22 5	22 5	22 5	100	100	100	0 5	80
Moss soil	14 4	14 4	14 4	100	100	100	16 8	125
Sand	9 7	9 7	9 7	100	100	100	9 7	31
Lichen soil	22 2	22 2	22 2	100	100	100	23 2	108

TABLE 4(c)

Isolate Temperature Responses

Site	*Percentage organisms growing at t°C*							*No of organisms tested*
	0	*5*	*10*	*15*	*20*	*25*	*30*	
				Jan 85				
Algal soil	28 9	33 4	44 5	48 9	17 8	4 5		45
Loam	38 7	58 7	67 8	67 8	16 7			31
Dry soil	50	64 3	64 3	75 4	16 7	7 2		42
Moist soil	30 8	33 9	33 9	63	3 1	10 8	4 6	65
Moss soil	33 4	33 4	35	43 4	9 2			120
Sand	45 4	90 9	100	100	59 1	18 2		22
Lichen soil	27 5	55	55	80	35			40

TABLE 4(d)

Isolate Temperature Responses

Site	*Percentage organisms growing at t°C*							*No of organisms tested*
	0	*5*	*10*	*15*	*20*	*25*	*30*	
				Feb 85				
Algal soil	50	50	68 2	68 2	90 9	100	50	22
Loam	50	50	65	65	100	100	50	20
Dry soil	50	50	75	75	100	100		8
Moist soil	50	50	62 5	62 5	93 8	12 5	6 25	32
Moss soil	66 7	66 7	91 7	91 7	100	16 7		12
Sand					50	100		2
Lichen soil	38 7	38 7	80 6	80 6	93 5	19 4	3 2	31

TABLE 5

Effect of temperature on individual population of bacteria (In Oasis)

	Site Near moss bed						
Organisms/Months	*Aug*	*Sept*	*Oct 1984*	*Nov*	*Dec*	*Jan*	*Feb 1985*
Serratia sp	21 $2x10^2$	13 $1x10^3$	$18x10^4$	$16x10^6$	$87x10^6$	$62x10^5$	$72x10^2$
Pseudomonas sp	$31x10^1$	$47x10^1$	$54x10^1$	$21x10^3$	$41x10^5$	$18x10^3$	$38x10^3$
Soil Temp °C	-25 5	-23 0	-18 0	-11 0	21 0	10 5	0 0
Daily mean air temp °C	-18 0	-17 6	-13 7	- 6 4	-0 8	-1 2	-3 9

DISCUSSION

In a detailed microbiological study on subantarctic island Smith et al (1982) established direct correlation of bacterial population with available moisture. In the lake sediment having higher temperature and free moisture Ellis-Evans (1982) obtained higher bacterial counts. In the present study sites with vegetation like moss algae and moist soil were rich in bacterial population. Organic nutrients and moisture level in soil seemed to be conducive for bacterial population in vegetation rich soil environment. Initially organic nutrients and free water are released in the system during seasonal and daily freeze thaw cycle. This cycle is mediated by the temperature variations in the Oasis Wynn Williams (1980) demonstrated spring peak of bacterial flora follwed by freeze thaw cycles at 0°C. Hurst *et al* (1985) also reported the profound effect of freeze thaw cycles on leaching of soluble carbohydrate from subantarctic plant material.

During August-September minimum temperature upto -40°C was recorded in Oasis. At the same time because of the local conditions like blizzards the temperature increased as high as +2°C. In such conditions availability of mositure in soil (for short period) cannot be ruled out. Vestal *et al* (1984) reported the photosynthetic activity of cryptoendoethic microbiota at - 3°C and very low level of illumination of 10 Ei/m^2/sec. From these observations it is evident that autotrophic and heterotrophic processes are continued even during extreme Antarctic winter season. Hence the temperature relation of individual organism from thermally unstable region is worked out systematically in field and laboratory.

Considerable difference was observed in air and soil temperature during different seasons and the same is depicted in Fig 2 and table 2 respectively. Climatological parameters like wind cloud cover and snowfall contributed equally. The bacterial population existing in oasis ecosystem are subjected to very high degree of temperature variation. Diurnal temperature cycle during spring summer is clearly responsible for ambient temperature variations (Table 3). In diurnal studies during summer season (December-January) soil temperature was found to decrease upto -2°C and restored back to 0° to 4°C. In this season temperature recorded (Table 3) was adequate to keep moisture in free condition for bacterial growth and activity. In a laboratory experiment population size was found to be affected by a number of freeze and thaw cycles in soil samples.

Pure cultures isolated from Oasis were also found to be adapted to large ranges of temperature. In a similar study Mckay *et al* (1985) characterised temperature variations during austral summer as of low frequency (diurnal) and large amplitude because of the sun's heating effect. These oscillations are responsible for the onset and cessation of metabolic activity. Temperature response study data was interesting with respect to site and season of sampling (Table 4).

During January, majority of organisms grew at 15°C. 15 to 70 per cent of organisms were found growing below and above 15°C temperature. Variation in temperature response can be attributed to the taxonomical groups taking part in system (Table 11). December soil samples were found rich with respect to total population and variety of taxonomic groups. The organisms which grew well in the temperature range of 15°-25°C can be assigned to the mesophiles. A total of eight groups were found during summer season. Out of these, five genera were found to survive well during the winter season (Table 11). In these cases, it should be considered that, study of these five genera can be of great help to work out the strategies of survival during winter period. One of the approaches to solve this mystery is to study the metabolic rates at very low temperatures. Agar plates inoculated with pure cultures could support growth even at -10°C but it was rather slow when compared to 0° and -10°C, in station laboratory.

Growth curves of two typical bacteria (Fig 4) explain the metabolic response of these organisms at low temperature. After 2 days in liquid culture psychrophiles were found growing over a range of 0°-25°C whereas mesophiles could grow over a larger range of 5°-40°C in laboratory. From growth curves (Fig 4) it is evident that optimum growth temperature of psychrophile was 10° - 15°C whereas for mesophile it was 30°C. In case of psychrophile cell production at 0°C was around 35-40 per cent of the maximum and this is of great ecological interest. The temperature for entire year was low and hence it is open for assumption that psychrophilic organisms play a vital role for entire year in this ecosystem. Recently Ellis-Evans *et al* (1985) worked out the temperature/ growth characteristics of lake and terrestrial isolates from Signy Island. All lake isolates had optimum temperatures less than 20°C whereas terrestrial isolates had slightly higher optimum temperature. Hence adaptability of bacterial life to environment is an important criteria towards the characterisation of life from dry valleys in Antacrtica.

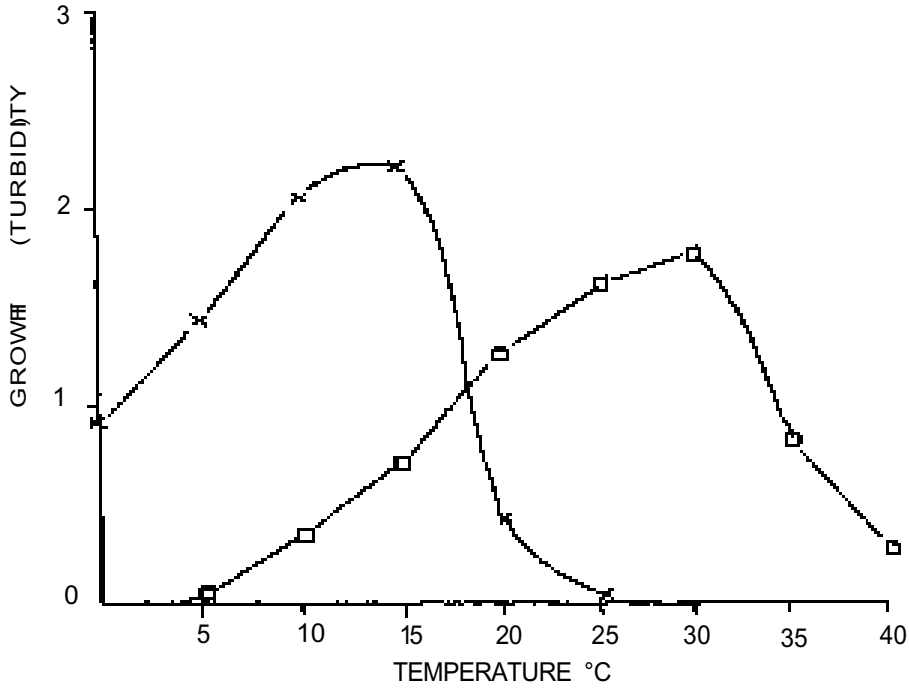

Fig 4 Effect of temperature on Psyohrophiles and mesophiles bacteria

Response of bacterial population to temperature has also been worked out by incubation temperature spectra (Table 7). During January-February season, psychrophilic population ranged from 70 to 80 per cent of total bacterial population, whereas in August, further low temperature adaptation of psychrophiles was observed. During December, groups of bacteria favouring wide range of temperature were conspicuous. In this respect, the adaption strategy varied from season to season in the same flora and was worked out by monitoring temperature effect on known organisms in environment (Table 5) and simultaneously in laboratory (Table 6). Highest counts of *Serratia* sp reached in November and persisted upto December. In case of *Pseudomonas* sp maximum counts were recorded in December with a decline in January.

TABLE 6

Effect of temperature (°C) on growth of individual population of bacteria (in laboratory) from Oasis

Organisms studied	*Temp °C*							*Lower limit for viability*
	0	*5*	*10*	*15*	*20*	*25*	*30*	
Serratia sp	+++	+++	+++	+	+			-40°C
Pseudomonas sp	++	++	+++	+++	+++	++	++	-20°C
Planococci sp	+++	+++	+++	+++	+++	+++	+++	-40°C

TABLE 7

Incubation temperature spectra for Schirmacher Oasis soil bacteria

	Site: moss soil					
Percentage of total counts (%)						
Jan. 84						
(20)	(20)	(80)	(100)	(70)	(70)	(5)
Feb. 85						
(20)	(50)	(100)	(75)	(62)	(50)	(-)
Aug. 84						
(60)	(80)	(55)	(22)	(5)	(-)	(-)
Dec. 84						
(15)	(15)	(65)	(100)	(10)	(60)	(35)*
0	5	10	15	20	25	30

incubation temperature °C

*isolates are also showing thermophilic properties in further laboratory study

TABLE 8

Diversity Index

No. of bacterial isolates	*Season*	*Diversity index*
200	Summer 1984	3.0
100	Winter 1984	1.1
250	Spring 1984	3.25

From above observations it may be stated that bacterial flora appear as a part of microbial succession. In laboratory study *Serratia* favoured 0° - 10°C and *Pseudomonas* 10°-20°C. These temperature requirements of individual bacteria are corroborating with the observation on environmental temperature data in November to January season. Another identified strain of *Planococci* thrived well over a wide range of temperature from 0°- 30°C. The environment was found thermally unstable specially during active season (summer) and organisms favouring different range of temperature may be having a major role to play depending upon the magnitude of daily seasonal and annual temperature cycle in soil ecosystem.

Effect of seasonal variation in temperature was also reflected in certain characteristics of the population. Diversity index was considerably low during winter whereas in summer and spring it was high and similar. Generation time of winter population ranged from 20-30 hrs which was remarkably high compared to summer and spring population. It indicated that winter population although belonged to the same taxonomic group as in summer and spring exhibited distinctly different adaptations to cold and effect of other environmental stresses and were directly reflected in the generation time of the winter bacterial population.

Summer and spring populations are mainly pigmented and motile. Continuous exposure to light during these seasons may be playing some role in these characteristics. Salt requirement was observed for 10-30 per cent of population(Table 10). Bacteria were found capable of growing in 5% of NaCl. In the same study (Table 10) domination of halotolerant population during winter was also recorded. Halotolerant nature of dry valley isolates has been reported by Miller *et al* (1983) and found as a function of temperature where one strain was capable of growing in the presence of 2M NaCl at 0°C. Soil samples collected from Schirmacher Oasis were mostly saline and subjected to long periods of sub freezing temperature. In this context physiology of life exist ng in Oasis is of maximum interest for understanding the basic life processes.

TABLE 9

Generation Time (hrs)

No of bacterial isolates	*Season*	*Generating time*
100	Summer 1984	3 5—7 0
50	Winter 1984	20 —30
100	Spring 1984	2 5—4 0

TABLE 10

Characteristics of bacterial populations (% of population)

MORPHOLOGICAL	*Summer*	*Winter*	*Spring*
Pigmented	90	30	95
Motile	60	35	85
Gram (+)	80	75	75
Gram (—)	20	25	25
PHYSIOLOGICAL			
Growth — 0% Nacl	10	10	10
Growth — 0 5% Nacl	10	30	25
Growth — 2% Nacl	30	60	10
Growth — 5% Nacl	30	75	30
Micro — aerophieic	100	100	100
ENZYMATIC			
Cellulase	30	10	80
Amylase	35	10	60
Cata lase	95	60	90
Oxidase	90	65	95
Nitrate reductase	80	70	90
NUTRITIONAL			
Glucose	60	80	90
Acetate	20	30	40
Lactate	5	10	35
Glycerol	30	20	50

Physiological characterisation of bacterial flora further helped to understand their nutritional requirements. Population capable of degrading complex substrates like cellulose and starch were observed. Nitrate reduction was significant. Nitrogen is known to limit life in dry valleys (Boyd *et al* 1966) and bacterial cultures studied may be referred as important in mobilising nitrogen inside the oasis ecosystem Hurst *et al* (1983) isolated fungi from South Georgia Island phanerogams capable of producing similar extracellular enzymes like cellulase protease and pectinase and some of the isolates were lignolytic in nature.

Thus the only source of organic nutrients for microbial life is either from degradation products of moss algae and lichens or release of low molecular weight compounds of growing vegetation during freeze and thaw cycles. It is now known that sucrose glucose and fructose are the main leachates (Hurst *et al* 1985) but little is known about fate of these compounds in the ecosystem. In the present study the minimum nutritional requirement of majority of organisms was observed to be fulfilled by up take of glucose which may be an import substrate in this ecosystem.

Ramsay *et al* (1983) using glucose reported that only 8% bacterial population from penguin rookery was metabolically active. In future use of glucose as substrate for characterising metabolic activity of bacterial population could be worked out to understand their quantitative role in ecosystem. Very few reports are available on Antarctic primitive life where physiology is being studied as a function of temperature. Micro organisms from dry valleys were halotolerant at 0°C (Miller *et al* 1983).

In the present study bacterial flora like *Micrococcus Corynebacterium Pseudomonas* and *Serratia* were found thriving during winter season in Schirmacher Oasis (Table 11). Results presented in table 5 and 6 regarding the *Pseudomonas* and *Serratia* indicated that these organisms were responding positively to subfreezing temperatures. Results of optimisation study of bacterial flora was also interesting in this line (Table 12). Optimum temperature of 10 isolates belonging to *Pseudomo nas* was 5°-20°C and maximum growth temperature was 25°C. Earlier reports from Signy Island (Ellis-Evans 1985) gave the optimum temperature of growth for *Pseudomonas* as 24 7°C and the maximum as 33 1 °C. Temperature wise both are distinctly different environments and micro organisms from Schirmacher Oasis clearly showed physiological adaptations to low temperature.

TABLE 11

Distribution of bacterial flora in Oasis

Organisms	*Summer 1984*	*Winter 1984*	*Spring 1984*
Bacillus	+	—	+++
Micrococcus	+++	+++	+++
Corynebacterium	+++	+++	+++
Pseudomonas	++	++	+++
Achromobacter	+	—	+++
S marcescens	+++	+++	+++
S Aurus	++	++	+++
Planococus	—	—	+++

TABLE 12

Optimum and Maximum growth of temperature

Organisms 10 isolates each	*Isolation (t)*	*Optimum growth (t)*	*Maximum growth (t)*	*Lower limit for viability*
Bacillus	10	15-25	30	(-10)
Micrococcus	10	5-15	20	(-40)
Pseudomonas	10	5-20	25	(-20)
S marcescens	10	0-15	20	(-40)
S aurus	10	0-15	20	(-30)
Total (50)	10	0-25	20-30	(-10)-(-40)

The data on ecophysiology of Antarctic oasis bacteria presented above is of considerable importance for basic ecological research. This data is also applicable for studies of more complex systems in other parts of the world.

ACKNOWLEDGEMENTS

I wish to express my gratefu! thanks to Dept of Ocean Development and C S I R New Delhi for giving me opportunity to participate in Indian Antarctic programme My sincere thanks are also to Drs V V R Varadachan H N Siddiquie, T S S Rao and A H Parulekarfor constant encouragement and guidance from time to time

REFERENCES

Benoit R E and Hall C L Jr (1970). The microbiology of some dry valley soils of Victoria land Antarctica. In *Antarctica Ecology* Ed Holdgate M V Vol 2 Academic Press London 697-701.

Boyd W L Staley JT and Boyd J W (1966). Ecology of soil microorganisms of Antarctica. In *Antarctic soils and soil forming processes.* Antarctic Research Series Vol 8 American Geophysical Union publication 725-760.

Cameron R E (1972). Microbial and ecologic investigations in Victoria valley southern Victoria land Antarctica. In *Antarctic Terrestrial Biology.* Ed Llano G A Antarctic Research Series Vol 20 American Geophysical Union publication 195-260.

Ellis-Evans J C (1982). Seasonal microbial activity in Antarctic fresh water lake sediments. *Polar Biology* 1 129-140.

Ellis - Evans J C and Wynn-Williams D D (1985). The interaction of soil and lake microflora at Signy island. In *Antarctic nutrient cycles and food webs.* Ed Siegfried W R Condy P R and Laws R M. Springer Verlag Berlin 662-668.

Hurst J L Pugh C J F and Walton D W H (1983). Fungal succession and substrate utilisation on the leaves of three South Georgia phanerogams. British *Antarctic Survey Bulletin* 58 89-100.

Hurst J L Pugh C J F and Walton D W H (1985). The effect of freeze-thaw cycles and leaching on the loss of soluble carbohydrate from leaf material of two subantarctic plants. *Polar Biology 4* 27-31.

Miller K J Leschine S B and Huguenin R L (1983). Halotolerance of microorganisms isolated from saline antarctic dry valley soils. Antarctic Journal of V S XVII (5) 222-223.

Matondkar S G P and Gomes H R (1983). Biological studies on the ice shelf and in a fresh water lake at Princess Astrid Coast Dronning Maud land Antarctica. *Scientific Report of the first Indian Expedition to Antarctica* 186-190.

Mckay C P and Friedmann El (1985). The cryptoendolithic microbial environment in Antarctic cold desert temperature variations in nature *Polar Biology* 4 19-25.

Ramsy A J (1983). Bacterial biomass in ornithogenic soils of Antarctica. *Polar Biology* 1 221-225.

Smith V R and Steyn M G (1982). Soil microbial counts in relation to site characteristics at a subantarctic island *Microbial Ecology 8* 253-266.

Vestal J R Federle T W Friedman El (1984). The effect of light and temperature on antarctic cryptoendolithic microbiota in v tro. *Antarctic Journal of United States XIX* (5) 173-174.

Wynn - Williams D D (1980). Seasonal fluctuations in microbial activity in Antarctic moss peat (1980). *Ecology in Antarctic* Ed Bonner W N and Berry R J Academic Press London 11-28.