# BIOLOGICAL & ENVIRONMENTAL SCIENCES

*Twenty Seventh Indian Antarctic Expedition 2007-2009*
*Ministry of Earth Sciences. Technical Publication No. 25, pp 205-219*

# Exploration of Faunal Diversity of Moss-inhabiting Terrestrial Invertebrates of Schirmacher Oasis and Larsemann Hills Along with some observations on Birds

**Anil Kumar**
Zoological Survey of India

**ABSTRACT**

Present investigation was mainly aimed to explore the faunal diversity of moss-inhabiting invertebrates in and around Schirmacher Oasis and Larsemann Hills area. Nine species were identified from Schirmacher Oasis area, while in Larsemann hills area four species were identified. The protozoans were the most dominant group with five species. Two species of tardigrades, two species of nematodes and one species of collembolan and one species of rotifer were identified. Apart from this, 26 species of birds were identified during voyage. Procellaridian was the most dominant group with 7 species. In the vocal repertoire of South Polar Skua Catharacta maccormicki, total four types of calls (namely territorial calls, alarm calls, begging calls and distress calls) were identified, based on behavioral correlates. Different calls of communication were observed for Adelie Penguins Pygoscelis adeliae. These were mainly composed of contact calls, alarm calls, threat calls and distress calls.

**Keywords:** East Antarctica, Faunal Diversity, Terrestrial Invertebrates, Acoustic Signals, Catharacta Maccormicki, Pygoscelis Adeliae.

## 1.0 INTRODUCTION

The terrestrial invertebrate fauna of the Antarctica has been documented in terms of species diversity, limited to a few invertebrates, such as springtails and mites (Pugh 1997, Greenslade 1995, Stevens and Hogg 2003, 2006), nematodes (Courtright et al. 2000) and tardigrades (McInnes and Pugh 1998). Review of the literature revealed that studies are scanty on the moss-inhabiting invertebrates of Schirmacher Oasis of Antarctica, as compared to lakes of maritime and sub-Antarctic islands, which were studied more intensively. Bardin and Leflat (1965) initiated the studies on chemical characteristics of Schirmacher Oasis. While Komarek and Ruzicka (1966) were pioneers in studying freshwater algae of the area. Studies are almost negligible on the moss-inhabiting invertebrates of Schirmacher Oasis (Mitra, 1999). Keeping the above in view, it was realized that the studies

on the moss-inhabiting fauna are still scanty and more extensive survey work is required to explore a detailed and comprehensive account of moss-inhabiting invertebrate fauna of Schirmacher Oasis.

The Antarctic region is the home of over 21 species of mammals, including 6 species of seals and 15 species of whales (Bonner 1985), and about 45 species of birds (Siegfried 1985). More than 25 nations have their permanent research stations in Antarctica. Over the years, they are working on different aspects of the biology of penguins. In contrast with the studies carried out by foreign scientists, our knowledge on the behavioural ecology and sociobiology of penguins is still scanty. Although some studies on population status and ecology were carried out by Indian scientists during earlier expeditions. The Wildlife Institute of India (WII) participated in 14th and 15th expeditions to Antarctica, for the birds and mammals census in Indian Ocean and India Bay (Bhatnagar and Satyakumar 1999a). During the voyage, 50 bird species and 14 mammal species were recorded. Apart from this, in Antarctica five aerial census sorties were conducted to record penguins and seals abundance, habitat occupancy and distribution in India Bay (Bhatnagar and Satyakumar 1999b). The scientists of Zoological Survey of India have conducted some studies on the behaviour of skuas in Schirmacher Oasis. Research work on nesting sites, breeding success and population studies of South Polar Skua Catharacta maccormicki were conducted and data was compared with other observations taken during earlier expeditions (Venkatraman and Hazra, 2005).

The present study was aimed to explore and estimate the faunal diversity of moss-inhabiting invertebrates in and around the Schirmacher Oasis and Larsemann Hills area. It was also planned to monitor the avian elements encountered during the voyage, and to conduct behavioural observations on South Polar Skua and Adelie Penguins.

## 2.0 METHODOLOGY

### 2.1 Studies on moss-inhabiting invertebrates

In order to explore the moss-inhabiting invertebrates, samples of moss were collected from various localities/ fresh water lakes in Schirmacher Oasis (**Fig. 1**) between 6th to 22nd January 2008 and in Larsemann Hills (Bharati, McLeod and Fisher islands) between 27th February to 9th March 2008. All the samples were kept in polythene bags and properly stored under low temperature, to avoid decomposition. Standard methodology of

extraction and preservation was used; as provided in the handbook of ZSI on collection, preservation and identification of animals (Alfred and Ramakrishna, 2004).

*Fig. 1: Collection of the moss samples in Schirmacher Oasis, Antarctica*

### 2.2 Monitoring of Birds and Behavioural Observations

For monitoring of avian elements, systematic daily observations (ca. 4 to 6 hrs. per day: 2-3 hrs. in forenoon and 2-3 hrs in afternoon) were made from the ship, during onward and return journey. On the sighting of species: location, date, time, weather conditions, number of individuals and behavioural activity were recorded. Where identification was not possible through direct sighting, photographs of the individual were taken for further identification. Behavioural observations on the acoustic communication, displays and postures were made on the South polar skuas and Adelie penguins. Total 7 pairs of South Polar Skua were targeted for behavioural observations in Schirmacher Oasis area. Total 2 families of skuas (each on Bharati and McLeod islands) were studied in Larsemann Hills for this purpose. Two flocks of Adelie penguins were studied on shelf ice in Russian Bay; while 2 flocks on Fisher Island and 1 on McLeod Island were also studied. Vocalizations were recorded with the help of Marantz PMD 670 Digital Sound Recorder and Audio-Technica unidirectional microphone. Recordings were transferred to a computer and analyzed with the help of sound analysis software, Avisoft SAS Lab Pro.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Studies on Moss-inhabiting Invertebrates

A total 40 samples of mosses and soil were collected in Schirmacher Oasis area and 67 samples of mosses and moss-mixed soil were collected from 3 main islands i.e. Bharati, McLeod and Fisher islands in Larsemann Hills. All samples were deposited to the HQ of ZSI, Kolkata for further detailed studies. Some additional samples (10 samples from Schirmacher Oasis area and 10 samples from Larsemann Hills area) were analyzed at ZSI-Haridwar, as such analysis facilities were not available at ZSI-Itanagar. Standard extraction methods were used for the isolation of microscopic faunal elements. Temporary slides were prepared and these were examined under compound microscope. Total 11 species (excluding some unidentified taxa) were identified, based on their morphological features. The protozoans were the most dominant group with 5 species. Two species of tardigrades, 2 species of nematodes, 1 species of collembolan and 1 species of rotifer were identified (Table 1).

**Table 1— Different species of Invertebrate fauna identified in the moss/ sediments collected from Schirmachar Oasis & Larsemann hill areas in Antarctica**

| S. No. | Name of the species | Schirmachar Oasis area | Larsemann hills area | Remark |
|---|---|---|---|---|
| **I. Protozoa** | | | | |
| 1 | *Arcella arenaria* | * | * | Common species |
| 2 | *Arcella catinus* | * | - | |
| 3 | *Centropyxis aerophila* | * | - | |
| 4 | *Assulina muscorum* | * | - | |
| 5 | *Oxytricha fallax* | * | - | |
| **II. Rotifera** | | | | |
| 6 | *Philodina gregarina* | - | * | |
| **III. Tardigrada** | | | | |
| 7 | *Hypsibius chilensis* | * | - | |
| 8 | *Macrobiotus polaris* | - | * | |
| **IV. Collembola** | | | | |
| 9 | *Cryptopygus* sp. | * | * | Common species |
| **V. Nematoda** | | | | |
| 10 | *Drylaimellus* sp. | * | - | |
| 11 | *Tylenchorhynchus* | * | - | |

**** = mark of presence; - = mark of absence***

In the present study, 9 species were identified from Schirmacher Oasis area, while in Larsemann Hills area 4 species were identified. In previous studies, these species have already been reported (Hazra 1994). Matondkar and Gomes (1983) were the first Indians to conduct biological studies on lakes, while Ignole and Parulekar (1987, 1990 and 1993) studied +composition and spatial distribution of microfauna of 10 freshwater lakes. A review on the biological studies carried out from 1st to 6th Indian Antarctic Expeditions (Dhargalkar, 1988) showed that the data collected during summers do not show continuity. Richer et al. (1990) reported some unidentified mites and springtails from Schirmacher Oasis. Hazra (1994) recorded and studied the ecology of 5 genera of soil nematodes of this region. During the above mentioned investigations, Ignole and Parulekar (1987) reported 7 microfaunal groups such as Protozoa, Turbellaria, Nematoda, Oligocheta, Tardigrada, Rotifera and Acarina and identified only 8 species up to generic level. Arif (1995) reported some groups of invertebrate fauna such as Earthworm, Nematode, Mite, Collembola, Diptera (adults and larvae) and Lepidoptera without proper taxonomic identity. Somme (1985) pointed out that our knowledge on Antarctic invertebrates is still fragmentary and more work on their taxonomy, zoogeography, population and physiology is needed. Later on, during 15$^{th}$ expedition (1995-96), some lakes in Schirmacher Oasis area were surveyed by ZSI scientists. As a result of this study, 2 species of rotifera, 2 species of tardigrada, 17 species of protozoa, 5 genera of nematode, 2 species of mites and 2 families of collembolan have been reported from this area (Mitra, 1999).

### 3.2 Monitoring of Birds

Avian elements encountered during the voyages from Goa to India Bay, to Larsemann Hills, to Goa (return) were recorded with the help of field binocular (12x50) and field guide. In case of unidentified elements, photographs were taken for further identification and final inventrization of avian elements. Total 26 species (excluding some unidentified birds) have been identified based on their morphological characters. Procellaridian group was the most dominant group with 7 species. Albatross were observed during storms also. Two large mixed species flocks (comprise more than 1000 individuals) of boobies were observed about 2200 km from Cape Town towards Antarctica. A Red-footed booby came on the ship and stayed for days. These birds were observed commonly hunting the fish and crustaceans in sea. (details in Table-2).

*Fig. 2: A flock of Adelie Penguins in Larsmann Hills area, East Antarctica*

*Fig. 3: A pair of South Polar Skua in Schirmacher Oasis. Male is giving territorial calls*

*Fig. 4: A mixed species flock of boobies*

*Fig. 5: White-chinned Petrel was observed during voyage*

In a previous study carried out by Bhatnagar and Sathyakumar (1999a), total 50 species of birds were recorded. Later on during 16th Indian expedition, Hussain and Saxena (2000) recorded 64 species of birds. Most of them (62 species) were pelagic seabirds. Petrels and shearwaters were the most dominant taxa, followed by terns, albatrosses and strom-petrels.

**Table 2— Different species bird identified during the voyage**

| S. no. | Common Name | Species name |
|---|---|---|
| **I. Diomedeidae** | | |
| 1 | Wandering Albatros | *Diomedea exulanus* |
| 2 | Royal Albatross | *Diomedea epomophora* |
| 3 | Yellow-nosed Albatross | *chlororhynchos* |
| **II. Sulidae** | | |
| 4 | Masked Booby | *Sula dactylatra* |
| 5 | Brown Booby | *Sula leucogaster* |
| 6 | Red-footed Booby | *Sula sula* |
| **III. Procellariidae** | | |
| 7 | Southern Fulmar | *Fulmarus glacialoides* |
| 8 | Antarctic Petrel | *Halassoica antarctica* |
| 9 | Blue Petrel | *Halobaeona caerulea* |
| 10 | Cape Petrel | *Daption capensis* |
| 11 | Snow Petrel | *Pagodroma nivea* |
| 12 | White-chinned Petrel | *Porcellaria aequinoctialis* |
| 13 | Antarctic Prion | *Pachyptila desolata* |
| **IV. Spheniscidae** | | |
| 14 | Adelie Penguin | *Pygoscelis adeliae* |
| 15 | Emperor Penguin | *Aptenodytes forsteri* |

(Contd....)

**Table 2—(Contd....)**

| S. no. | Common Name | Species name |
|---|---|---|
| **V. Stercorariidae** | | |
| 16 | South Polar Skua | *Catharacta maccormicki* |
| **VI. Oceanitidae** | | |
| 17 | Grey-backed Storm Petrel | *Garrodia nereis* |
| 18 | Wilson's Storm Petrel | *Oceanites oceanicus* |
| **VII. Sternidae** | | |
| 19 | Caspian Tern | *Sterna caspia* |
| 20 | Royal Tern | *Sterna maxima* |
| 21 | Sooty Tern | *Sterna fuscata* |
| **VIII. Laridae** | | |
| 22 | Kelp Gull | *Larus dominicanus* |
| **IX. Phaethontidae** | | |
| 23 | White-tailed Tropic-bird | *Phaethon lepturus* |
| **X. Unidentified species** | | |
| 24 | Penguin sp. | Most probably *Sphenicus demersis* |
| 25 | Frigatebird | Most probably *Fregata magnificens* |
| 26 | Sooty Albatross | *Pheobetria fusca* ta |

### 3.3 Behavioural Studies on South Polar Skua and Adelie Penguins

In the vocal repertoire of South Polar Skua, total four types of calls were identified based on their behavioral correlates. Territorial calls were harsh, stereotyped, used by both male and female individuals, when another skua entered in their territory. Often they produced these calls just to mark or claim for boundaries of their territories. Duets were also observed. Often male produced more loud sounds as compared to female. Begging calls were used by juveniles to parents for demand of food. It seems that few categories of begging calls were used in this species. These were

simple, stereotyped, narrow-band calls composed of monosyllabic elements with inter-element variations. These calls were more frequent in older nestlings. Individuals were observed to use Distress calls when captured/ handled. The nestlings and fledglings also produced these calls. These signals phonetically rendered as cheearr.... chseerr.... (not exactly), and composed of a wide range of frequencies. When the nests or nestlings of skuas were approached, both male and female produced alarm calls to defend their nest or nestlings. Some visual displays were also associated with these calls. Often female produced calls prior to male, while rate of production was higher in males.

Previous studies indicate that the South Polar Skua is a monogamous nesting seabird; it breeds in isolated pairs/ loose colonies (Charrier et al. 2001). This species is known to produce 3 types of calls such as courtship calls, contact calls and alarm calls (Spellerberg 1971, Jouventin and Guillotin 1979, Pietz 1985). The courtship call was used for mate recognition and contact calls were used for fast meeting. The alarm call was used in a danger situation, such as when an intruder approaches the nesting site. In the present study also, the context of production was same. Parents produced these calls when their nest or nestlings were approached. The vocalizations of another species of skua i.e. Brown Skua Catharacta antarctica lonnbergi have also been documented (Janicke et al. 2007). Both sexes of this species have been reported to use at least 3 call types' i.e. long calls, alarm calls and contact calls (Pietz 1985, Furness 1996). Long calls were produced to proclaim the ownership of territory and to greet a mate. While, the context of production of alarm calls and contact calls was same as in South Polar Skua (Janicke et al. 2007).

Adelie penguins were observed using different calls in their communication. These were mainly composed of contact calls, alarm calls, threat calls and distress calls. Contact calls were loud calls often used by both male and female individuals, to maintain pair bonding and cohesiveness among flock members. Alarm calls were used irrespective of gender and social status of individuals, mostly after arrival of predators such as skuas and seals. Individuals produced these calls due to the presence of human observers also. Threat calls were uttered when individuals were approached closely. These were short, stereotyped loud barking. Distress calls were usually produced by isolated individuals, when closely approached and pointed with microphone most probably due to stress.

The vocalizations of penguins have been studied both in wild and captivity, and different categories of vocalizations have been reported

(Robisson et al. 1993). Spheniscus penguins have been studied in captivity. Several species specific categories of vocalization were observed (Thumser and Ficken 1998). Boersma (1974) identified 6 different calls in the Galapagos penguin: Yell, Throb, Haw, Bray, Courtship Bray and Peep. Yelling is a high intensity threat, which corresponds to the Aggressive Bray or Bark in the African penguin (Boersma 1974, Eggleton and Siegfried 1979). Throbs are very soft calls given when a mate returns to the nest and may serve to reinforce pair bonding (Boersma 1974). The Haw call is usually given by lone birds and used to locate other birds mainly while foraging at sea (Boersma 1974). It has also been described as the Contact call for African, Humboldt, and Magellanic penguins (Jouventin 1982). The Bray occurs during the breeding period and is given only by the male in Galapagos penguins to advertise availability and to establish a territory (Boersma 1974). The Bray corresponds to the Ecstatic Display of African and Magellanic penguins, which is given by both sexes (Eggleton and Siegfried 1979, Jouventin 1982).

Emperor penguin, Aptenodytes forsteri and King Penguin, A. patagonicus have been reported to use display calls (Beer 1970, Charrier at al. 2001, Aubin and Jouventin 2002). For Emperor and King penguins, there is no nest and parents carry the single egg or young chick on their feet. These species breed in dense colonies of up to 1 million individuals. Mates must find each other, as they shift the egg or chick back and forth and they take turns feeding at sea (Stonehouse 1960). The adults, on return from the sea, call at regular intervals (Lengagne et al. 1999). On hearing the display calls of parent, the chick reciprocates, and approaches towards the parent. After acoustic recognition, the adult feeds its chick (Jouventin 1972, 1982). Penguins perform individual recognition by analyzing the spectral profile and pitch of calls. They use two-voice system to recognize each other. Individual vocal recognition is supported in the time domain by an amplitude/ time analysis for the Emperor penguin, and by a frequency/time analysis for King Penguin (Robisson 1992a, 1992b, Aubin and Jouventin 2002).

**Acknowledgements**

The author is grateful to Director, Zoological Survey of India, Kolkata, and Programme Coordinator, Antarctica Expeditions, ZSI, Kolkata. I am also grateful to the Director, NCAOR, to Programme Director, NCAOR and to the Expedition Leader of the 27th IAE. I am thankful to Officer-in-Charge, APRC, ZSI, Itanagar and ZSI Staff for active

cooperation at various levels. Special thanks are due to all of my friends, who helped me in a number of ways during the expedition.

## REFERENCES

1. Alfred J.R.B. and Ramakrishna (2004). Collection, preservation and identification of animals: 1-310. (Published: Director, Zoological Survey of India, Kolkata).

2. Arif M. (1995). Occurrence of invertebrate fauna in Schirmachar Oasis, Antartica. Department of Ocean Development. Tech. Pub. No. 9: 301-311.

3. Aubin T. and Jouventin P. (2002). Localization of an acoustic signal in a noisy environment: the display call of the King penguin Aptenodytes patagonicus. J. Exp. Biol. 205, 3793-3798.

4. Beer C.G. (1970). Individual recognition of voice in the social behaviour of birds. Adv. Study Behav. 3, 27-74.

5. Bardin V.I. and Leflet O.N. (1965). Khimizm vod Oazisa Schirmakhera (Chemical characteristics of water in Schirmacher Oasis); Informationnyy Byulleten Sovestskoy Antarkticheskoy Ekspeditsii, 52, 51-55 (English translation 5, 361-362, 1966).

6. Bhatnagar Y.V. and Satyakumar S. (1999a). Developing a long term monitoring programme for birds and mammals in the Indian Ocean and Antarctica. Fifteenth Indian Expedition to Antarctica, Scientific Report, 1999, Department of Ocean Development, Technical Publication No. 13, pp. 131-164.

7. Bhatnagar Y.V. and Satyakumar S. (1999b). Daily monitoring and aerial census of penguins and seals in Antarctica. Fifteenth Indian Expedition to Antarctica, Scientific Report, 1999, Department of Ocean Development, Technical Publication No. 13, pp. 165-182.

8. Boersma P.E. (1974). The Galapagos Penguin: a study of adaptations for life in an unpredictable environment. Ph.D. thesis, Ohio State University, Columbus.

9. Bonner W.N. (1985). Birds & mammals- Antarctic seals. In Key Environments, Antarctica.

10. Charrier I., Jouventin P., Mathevon N. and Aubin T. (2001). Individual identity coding depends on call type in the South Polar Skua Catharacta maccormicki. Polar Biol, 24, 378-382.

11. Charrier I., Mathevon N., Jouventin P. and Aubin T. (2001). Acoustic communication in a black-headed gull colony: how do chicks identify their parent? Ethology 107, 961-974.

12. Courtright E.M., Wall D.H., Virginia R.A., Frisse L.M. Vida J.T. and Thomas W.K. (2000). Nuclear and mitochondrial DNA sequence diversity in the Antarctic nematode Scottnema lindsayae. J. Nematol, 32, 143-153.

13. Dhargalkar V.K. (1988). Biological studies in the Antarctic water. A review, proceeding of workshop on Antarctic studies, D.O.D. CSIR, New Delhi, 407-418.

14. Eggleton P. and Siegfried W.R. (1979). Displays of the Jackass Penguin. Ostrich 50, 139-167.

15. Furness R.W. (1996). Family Stercorariidae (skuas). In: del Hoyo J., Elliott A., Sargatal J. (eds) Handbook of the birds of the world, vol 3, Lynx Edicions, Barcelona, pp 556-571.

16. Greenslade P. (1995). Collembola from the Scotia Arc and Antarctic Peninsula including descriptions of two new species and notes on biogeography. Pol. Pismo. Entomol, 64, 305-319.

17. Hazra A.K. (1994). A study on the population ecology of soil nematode fauna in relation to some edaphic factors in Schirmacher Oasis, Antarctica, D.O.D. Tech Pub. No. 6 pp. 65-90.

18. Hussain S.A. and Saxena A. (2000). Developing long term monitoring programme for birds and mammals in the Indian Ocean and Antarctica. Sixteenth Indian Expedition to Antarctica, Scientific Report, 2000, Department of Ocean Development, Technical Publication No. 14, pp. 1-36.

19. Ingolesis, Antarctica: 1. Water moss communities, Scientific report of Indian expedition to Antarctica, Tech pub no. 4, pp. 139-148.

20. Ingole B.S. and Parulekar A.H. (1990). Limnology of Priyadarshini Lake, Schirmachar Oasis, Antarctica; Polar Record 26: 13-17.

21. Ingole B.S. and Parulekar A.H. (1993). Limnology of freshwater lakes at Schirmachar Oasis, East Antarctica. Proc. Indian natn. Sci. Acad, B 59, No. 6, pp 589-600.

22. Janicki T., Ritz M.S., Hahn S. and Peter Hans-Ulrich (2007). Sex recognition in brown skuas: do acoustic signals matter? J. Ornithol, 148, 565-569.

23. Jouventin P. (1972). Un nouveau systeme de reconnaissance acoustique chez les oiseaux. Behaviour 43, 176-186.

24. Jouventin P. (1982). Visual and Vocal Signals in Penguins, their Evolution and Adaptive Characters. Berlin: Springer Verlag.

25. Jouventin P. and Guillotin M. (1979). Socio-ecologie du skua antarctique a Pointe Geologie. Terre Vie Rev Ecol, 33, 109-127.

26. Komerek J. and Ruzicka J. (1966). Freshwater algae from a lake in proximity of the Novolazarevskaya station, Antarctica. Preslia, 38, 233-247.

27. Lengagne T., Jouventin P. and Aubin T. (1999). Finding one's mate in a king penguin colony: efficiency of acoustic communication. Behaviour 136, 833-846.

28. Matondkar S.G.P. and Gomes H.R. (1983). Biological studies on the ice shelf and in

the freshwater lake at Princes Astrid Coast, Dronning Maud Land, Antarctica, In scientific report of first Indian expedition to Antarctica, pp. 186-190.

29. May John (1988). The Greenpeace Book of Antarctica (A new view to the 7th Continent). Dorling Kindersley, London, p.192.

30. McInnes S.J. and Pugh P.J.A. (1998). Biogeography of limno-terrestrial tardigrada, with particular reference to the Antarctic fauna. J. Biogeogr, 25, 31-36.

31. Mitra B. (1999). Studies on moss inhabiting invertebrate fauna of Schirmacher Oasis. Fifteenth Indian Expedition to Antarctica, Scientific Report, 1999, Department of Ocean Development, Technical Publication No. 13, pp 93-108.

32. Pietz P.J. (1985). Long call displays of sympatric south polar and brown skuas. Condor, 87, 316-326.

33. Pugh P.J.A. (1997). A synonymic catalogue of the Acari from Antarctica, the sub-Antarctic Islands and Southern Ocean. J. Nat. Hist., 27 323-421.

34. Richter W., Haendel D. and Jughans P. (1990). The animals of the Schirmacher Oasis (East Antarctica). Ant. Res. Proc. Symp. Held at Potsdam GDR, VII pp. 495-503.

35. Robisson P. (1992a). Vocalizations in Aptenodytes penguins: application of the two-voice theory. The Auk 109, 654-658.

36. Robisson P. (1992b). Roles of pitch and duration in the discrimination of the mate's call in the King penguin Aptenodytes patagonicus. Bioacoustics 4, 25-36.

37. Robisson P., Aubin T. and Bremond J. -C. (1993). Individuality in the voice of the Emperor penguin Aptenodyptes forsteri: adaptation to a noisy environment. Ethology 94, 279-290.

38. Seigfried W.A. (1985). Birds and mammals - Oceanic birds of the Antartic. In. Key Environments, Antartica. Bonner W.N. and Walton D.W.H. (Ed.). Oxford, IUCN and Pregamon Press, p. 381.

39. Somme L. (1985). Terrestrial habitats of invertebrates in key environment, Antarctica 106-117 (eds) Bonner, W.N. and D.W.H. Walton, Pergamon Press.

40. Spellerberg I.F. (1971). Breeding behaviour of the McCormick skua Catharacta maccormicki in Antarctica. Ardea, 59, 189-229.

41. Stevens M.I. and Hogg I.D. (2003). Long-term isolation and recent range expansion revealed for the endemic springtail Gompgiocephalus hodgsoni from southern Victoria Land, Antarctica. Mol. Ecol., 12, 2357-2369.

42. Stevens M.I. and Hogg I.D. (2006). Molecular ecology of Antarctic terrestrial Invertebrates. In Huiskes A. Convey P. and Bergstrom D. eds. Trends in Antarctic Terrestrial and Limnetic Ecosystems. Kluwers.

43. Stonehouse B. (1960). The King penguine Aptenodytes patagonicus of South Georgia. Breeding behaviour and development. Falk. Is. Dep. Surv. Sci. Rep. 23, 1-81.

44. Thumser N.N. and Ficken M.S. (1998). A comparison of the vocal repertoires of captive Spheniscus penguins. Marine Ornithology 26, 41-48.

45. Venkatraman K. and Hazra A.K. (2005). Studies on South Polar Skua (Catharacta maccormicki) in and around Maitri, Schimachear Oasis, Antarctica. Rec. zool. Surv. India, 105(Part 1-2): 139-145.