

Wetland Ecosystem Series 6

Fauna of Sambhar Lake



Zoological Survey of India

Wetland Ecosystem Series 6

Fauna of Sambhar Lake (Rajasthan)

Desert Regional Station, Zoological Survey of India, Jodhpur, Rajasthan, India

Edited by the Director, Zoological Survey of India, Kolkata



**Zoological Survey of India
Kolkata**

CITATION

Editor : Director. 2005. Fauna of Sambhar Lake (Rajasthan), *Wetland Ecosystem Series*, 6 : 1-200. (Published Director, *Zool. Surv. India, Kolkata*)

Published : January, 2005

ISBN 81-8171-057-6

Project Coordinator

Dr. Sanjeev Kumar

Scientist-B

Zoological Survey of India, Desert Regional Station, Jodhpur-342005

© Government of India, 2005

ALL RIGHTS RESERVED

- No part of this publication may be reproduced stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without the prior permission of the publisher.
- This book is sold subject to the condition that it shall not, by way of trade, be lent, resold hired out or otherwise disposed of without the publisher's consent, in an form of binding or cover other than that in which, it is published.
- The correct price of this publication is the price printed on this page. Any revised price indicated by a rubber stamp or by a sticker or by any other means is incorrect and should be unacceptable.

PRICE

Indian Rs. 1,200.00

Foreign : \$ 80; £ 60

Published at the Publication Division, by the Director Zoological Survey of India, 234/4, AJC Bose Road, 2nd MSO Building, 13th floor, Nizam Palace, Kolkata 700020 and printed at Power Printers, New Delhi 110002.

FAUNA OF SAMBHAR LAKE

Wetland Ecosystem Series

No. 6

2004

1-200

CONTENTS

Chapter(s)	Author(s)	Page(s)
1. SAMBHARLAKE . AN OVERVIEW	Sanjeev Kumar	1-42
2. LIMNOLOGY	Sanjeev Kumar	43-63
3. ZOOPLANKTON	Sanjeev Kumar	65-81
4. CRUSTACEA	Sanjeev Kumar	83-96
5. INSECTA		97-137
Orthoptera	M.S. Shishodia	99-106
Dermaptera	G.K. Srivastava	107-109
Dictyoptera	M.S. Shishodia	111-112
Diptera : Chironomidae	Sanjeev Kumar	113-118
Coleoptera	P. Mukhopadhyay, S.K. Chakraborty, D.N. Biswas, S.K. Halder, S.K. Ghosh, P. Chakraborty and S. Sengupta	119-132
Coleoptera : Scarabacidae	S.K. Chatterjee and P. Mukhopadhyay	133-139
6. AVES	Sanjeev Kumar	141-150
7. FLAMINGOS AND BREEDING	Sanjeev Kumar	151-179
8. MAMMALS	Sanjeev Kumar	181-185
9. THREATS AND CONSERVATION	Sanjeev Kumar	187-200

LIST OF CONTRIBUTORS

1. Dr. D.N. Biswas, Zoological Survey of India, M-Block, New Alipore, Kolkata-700053.
2. Dr. P. Chakraborty, Zoological Survey of India, M-Block, New Alipore, Kolkata-700053.
3. Dr. S.K. Chakraborty, Zoological Survey of India, M-Block, New Alipore, Kolkata-700053.
4. Dr. S.K. Chatterjee, Zoological Survey of India, M-Block, New Alipore, Kolkata-700053.
5. Dr. S.K. Ghosh, Zoological Survey of India, M-Block, New Alipore, Kolkata-700053.
6. Dr. S.K. Halder, Zoological Survey of India, M-Block, New Alipore, Kolkata-700053.
7. Dr. Sanjeev Kumar, Desert Regional Station (DRS), Zoological Survey of India, P.O. Jhalamand, Pali Road, Jodhpur-342005.
8. Dr. P. Mukhopadhyay, Zoological Survey of India, M-Block, New Alipore, Kolkata-700053.
9. Mrs. S. Sengupta, 30, Ramkrishna Samadhi Road, F.B/18, Kolkata-700054.
10. Dr. M.S. Shishodia, Zoological Survey of India, M-Block, New Alipore, Kolkata-700053.
11. Dr. G.K. Srivastava, Zoological Survey of India, M-Block, New Alipore, Kolkata-700053.



Chapter 1

Sambhar Lake : AN OVERVIEW

Sanjeev Kumar

A view of vast expanse of Sambhar Lake with algal blooms



Photo: S. Kumar

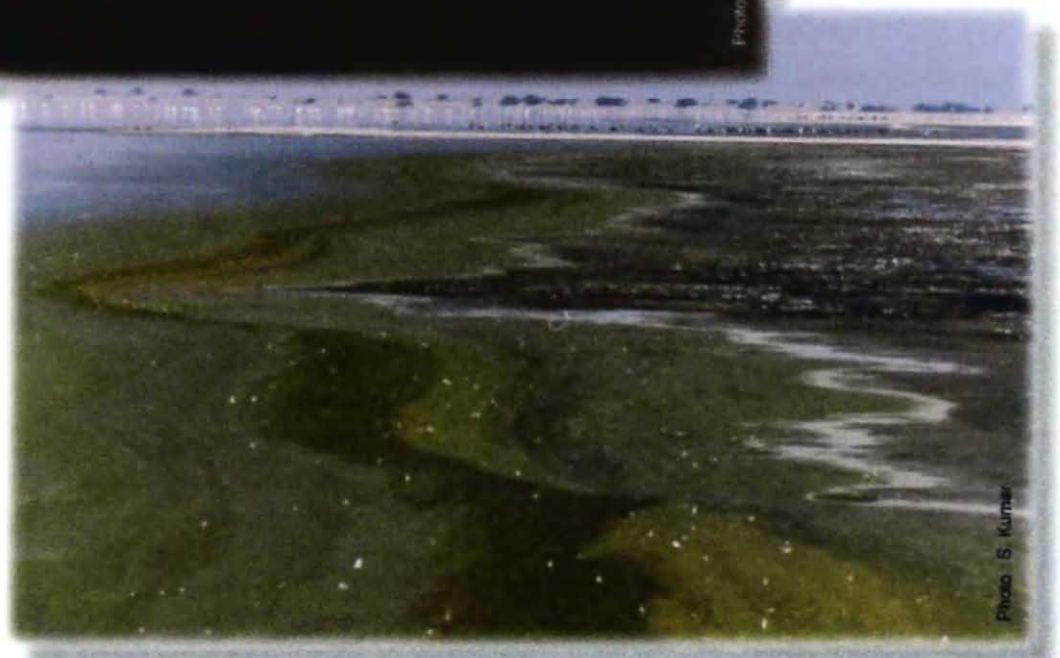


Photo: S. Kumar

INTRODUCTION

Wetlands are lifeline of present day civilization. They are the grand holes digesting waste of industrialization and human progress. Although the journey of early civilizations grew on the banks of wetlands but today their very existence is in the hands of civilization only.

Though freshwater wetlands have been held in reverence, as abodes of prosperity, however, the saline wetlands are considered less valuable and less important to mankind. In general, freshwater wetlands are found in every geographical regions of India but inland saline wetlands are very few in the country. The coastal saline wetlands have occupied large area all along the long coastline of approximately 7500 km whereas inland saline wetlands are few and sporadically located and scattered.

The total area under wetland in the world is estimated as 85.58,000 sq. kms, which is about 6.4% of the total land area (Maltby and Turner, 1983). Wetlands in India are distributed in various ecological regions ranging from the cold and arid zone of Ladakh in Jammu & Kashmir through the wet Imphal in Manipur; and the hot and arid zone of Rajasthan and Gujarat to the tropical monsoon zone of Central India; and the wet humid zone of the southern peninsula (Garg, *et al.*, 1998). The results of the nation wide wetland inventory (Garg, *et al.*, 1998) reveals that there are 27,403 wetland units in the country occupying 7.66 million ha, of which costal wetlands are of 3959 units with 4.0 million ha whereas inland wetlands are of 23,444 units with 3.6 million ha. The Ministry of Environment and Forests (Anon, 1992) estimated 4.7 million ha area, occupy different types of wetlands, of which 1.5 million ha are natural, 2.6 million of man-made and 0.6 million ha of mangrove vegetation.

Wetlands can be broadly classified into inland fresh water and saline as well as coastal freshwater and saline areas. Under the category of inland wetlands most of them are freshwater and very few are saline.

In Rajasthan, salt lakes and depressions are common in particular area of the Thar Desert namely Pachpadra, Sambhar, Didwana, Kanod, Lawan and Thob (Tewari, 1994a). The only important river system is Luni, which ultimately carries its water to the Rann of Kutch. Most of the other rivers are ephemeral and rainfed with internal drainage.

It is important to evaluate the value of salt concentration, which demarcates fresh from saline water. Here salinity needs clear definition to avoid confusion with the oceanic salinity. For limnologists, salinity is the sum total of ions! A conventional value, now widely accepted and with atleast some physico-chemical and biological basis, is 3 g/L or 3 ‰. This salinity is near :

- i) the calcite branch point,
- ii) the low points between modes when the frequency distribution of salinity of all lakes over 100 sq. kms area is plotted logarithmically,

- iii) the salinity at which most human first begin to taste salt and
- iv) the salinity below which biota typical of higher salinities are found and above which the freshwater biota begins quickly to disappear or do not extend.

Salt lakes are a good deal more varied in many physico-chemical features than freshwater lakes (Williams, 1996). Salinities are between 3 and >300 g/L (not <1-3 g/L as in freshwater lakes); salinity may vary widely on a seasonal (50->300 g/L) or secular basis or, as in freshwater lakes, scarcely at all and major ions may show a variety of patterns of dominance (most freshwater lakes are dominated by the divalent cations and bicarbonate).

Most saline lakes are also defined by endorheic drainage basins and most of the salt lakes represent the termini of inland drainage basins in which there is a balance between inputs and outputs. Since all inflows contain significant concentrations of salt without evaporation of water, salts accumulate in the lake itself. Coastal marine embayment, although saline and often lake-like are not the termini of inland drainage basins and have many physico-chemical and biological features closer to marine (thalassic) than inland (athalassic) environments. On the other hand, solar salt ponds drawing water from the sea and in which this water is progressively concentrated, do have many similarities to salt lakes. A few inland salt lakes, mostly in temperate areas, are not within endorheic basins; their high salinities derived from underground or local salt sources, often associated with mining. Salt lakes may contain water permanently, intermittently or episodically; water levels may be constant or fluctuate widely on a seasonal basis, often in accord with salinity fluctuations and they range from deep to shallow, small to extremely large, round to dendritic in shape. The salt lakes thus hold tremendous global importance (Williams, 1996).

Wetlands being one of the richest ecosystems, their productivity potential, conservation and management aspects have assumed greater significance only in recent years. Since these dynamic ecotones of nature are open to influence from natural and human factors, the global attention has been drawn to conserve their healthy status. In order to maintain their biodiversity, productivity and to allow wise use of their resources, proper management action plans have been suggested at various National and International forums. The Ramsar Convention is one such milestone in this regard, which has expressed the global concern over the alarming rate at which wetlands are degrading or disappearing.

RAMSAR CONVENTION

The Ramsar Convention on Wetlands of International Importance especially as waterfowl habitat is an intergovernmental treaty, which provides the basic framework for international co-operation for the conservation of wetland habitat throughout the world. Countries that join Ramsar are obligated to develop national wetland policies as well as include wetland conservation within national land use planning. The convention was adopted in 1971 at the Iranian city of Ramsar but did not come into force until late 1975. The Ramsar Standing Committee has also designated **2 February as World Wetlands Day**.

Wetlands of International Importance : Ramsar sites in India		
Wetland	State	Date of Declaration
Chilika Lake	Orissa	October 1981
Keoladeo National Park	Rajasthan	October 1981
Harike Lake	Punjab	March 1990
Loktak Lake	Manipur	March 1990
Sambhar Lake	Rajasthan	March 1990
Wular Lake	Jammu & Kashmir	March 1990

More than **118** countries have joined the convention bringing **1014** sites into the “list of wetlands of International Importance” covering an area of more than **72.7** million ha of land. India became a contracting party to the Ramsar Convention in October 1981 and only six wetlands in the country have been designated as Ramsar sites.

In addition to the broad objectives of the convention, it is obligatory on the part of the contracting parties to undertake four main obligations namely :

- to designate at least one wetland for inclusion in the list of Wetlands of International Importance;
- to promote the wise use of wetlands in their territory;
- to consult with each other about implementing obligations arising from the convention especially, but not exclusively, in the case of a shared wetland or water system and
- to create wetland reserves.

The Government of India has made concerted efforts for wetland conservation by setting up an expert group for compiling information on the ecological status of the wetlands in the country. Apart from bringing out the Directory of Indian wetlands (Anon, 1993a) the efforts were also made to evolve specific management strategies for selected wetlands. In this direction a national wetland committee was set up in 1987 consisting of experts on different disciplines for advising the Government on the selection of sites and drawing up conservation strategies. The terms of reference of the committee were :

- to frame broad policy guidelines for implementing the programmes on conservation, management and research on wetlands;
- to set up priority of wetlands for intensive conservation measures;
- to monitor the implementation of programme of conservation management and research and

- to advise on the preparation of inventory on Indian wetlands.

Among the 16 wetlands designated as *Wetlands of National Importance* and selected for evolving management strategies five wetlands are of International Importance and Sambhar Lake, Rajasthan is one of them.

Wetlands of National Importance			
1 Ashtamudi Lake	Kerala	9. Nalsarovar	Gujarat
2. Bhoj Wetland	Madhya Pradesh	10. Pichhola Lake	Rajasthan
3. Chilika Lake	Orissa	11. Renuka Lake	Himachal Pradesh
4. Harike Wetland	Punjab	12. Sambhar Lake	Rajasthan
5. Kabar Lake	Bihar	13. Sasthamkotta	Kerala
6. Kanjli Lake	Punjab	14. Sukhna Lake	Chandigarh
7 Kolleru Lake	Andhra Pradesh	15. Ujni Wetland	Maharashtra
8. Loktak Lake	Manipur	16. Wular Lake	Jammu & Kashmir

Further in this regard a number of Directories of Asian and Indian Wetlands were published (Scott, 1989 and Anon, 1993a).

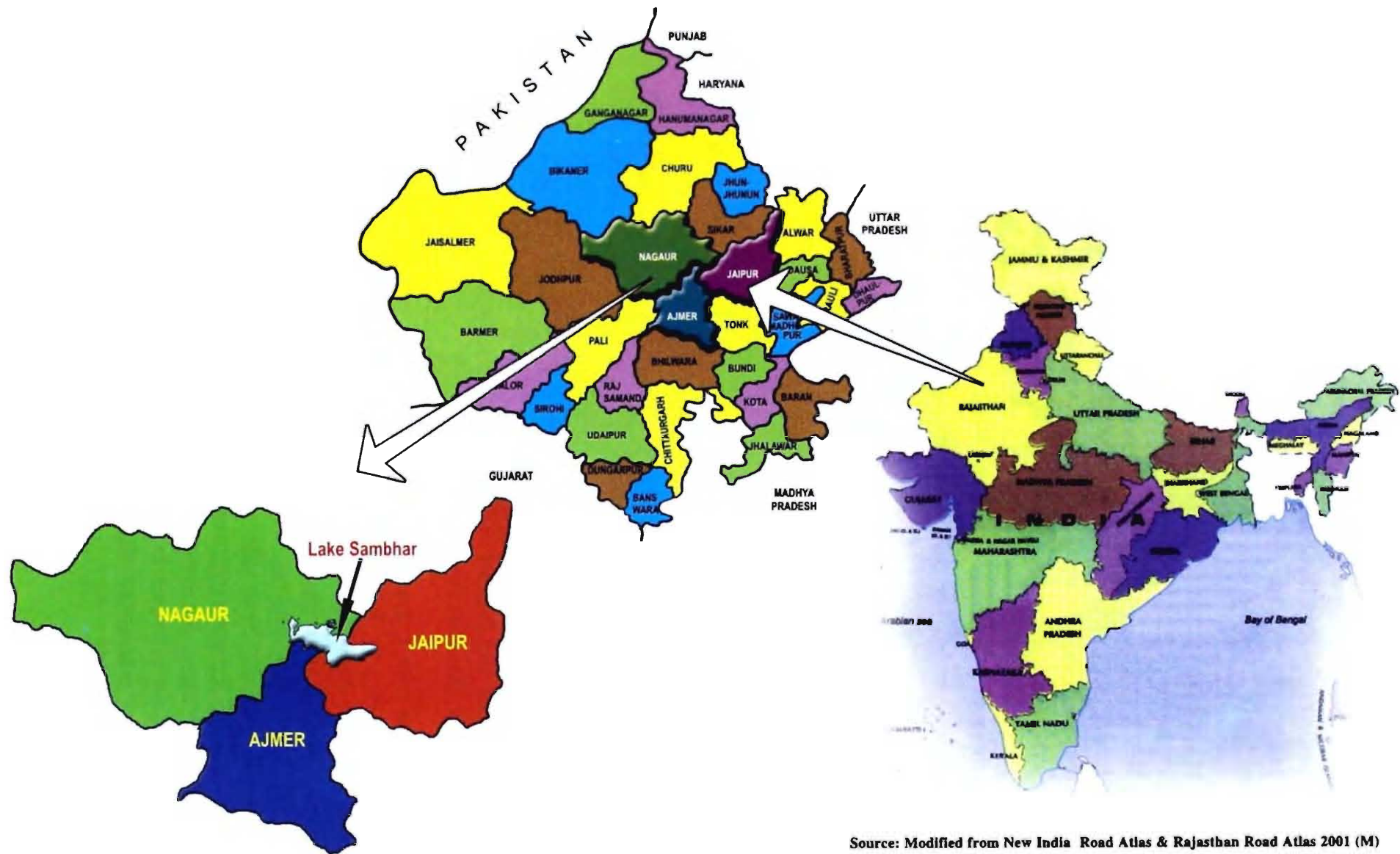
The Ministry of Environment and Forests has taken several important steps in order to explore, conserve and manage wetlands, mangroves and coral reef habitats in the country (Anon, 1992 and 1993b). The Botanical Survey of India and the Zoological Survey of India have been entrusted the work to carry out studies on flora and fauna respectively of all selected wetlands (Tewari, 1994b). Since Zoological Survey of India was assigned to assess the faunal resource of Sambhar Lake, the Desert Regional Station of the Zoological Survey of India, Jodhpur under the leadership of Dr. R.N. Bhargava and Dr. Sanjeev Kumar, took up a project entitled "Faunal Survey of Sambhar Lake, Jaipur District" Later, on supernation of Dr. Bhargava in May 1995, the project was carried out in the leadership of Dr. Sanjeev Kumar.

Many faunistic surveys were undertaken during 1994-1997 to collect and identify the faunal diversity of the Sambhar Lake. The survey parties also collected data on various other parameters of importance to the wetland so as to evolve strategies for the conservation of various valuable taxa and the wetland ecosystem.

SAMBHAR LAKE

Sambhar Lake is the largest inland saline wetland of India and a wetland of International Importance eminently called Ramsar site. It is a place where horizons stretches to infinity, water and sky merge in a shimmer of gauzy blue and civilization goes back a long, long time and legends abounds it.

Fig. 1 : Map Showing location of Sambhar Lake in three districts of Rajasthan, India



Source: Modified from New India Road Atlas & Rajasthan Road Atlas 2001 (M)

It is referred in the epic Mahabharata that Raja Yayati, emperor of Bharatvarsh and a descendent of Lord Brahma the Creator, married Devyani, daughter of Shukracharya, (the guru of demons) who lived by this lake. Another legend says that the goddess Shakambari bestowed the lake upon the people of the area some 2500 years ago. A small glimmering white temple in her honor stands under a rocky outcrop obtrude into the lake.

Sambhar Lake is situated at an altitude of 360 m AMSL in a relatively obscure habitat some 60 Km west of Jaipur at 26° 52' N – 27° 02' N and 74° 54' E – 75° 14' E just outside prosaically named Salt Lake City – Sambhar. This vast body of glacial saline is somewhat elliptical in shape having its long axis towards east-northeast to west-southwest. The lake basin is spread at the confluence of three districts of Rajasthan namely Jaipur, Nagaur and Ajmer close to the desert fringe line (Fig. 1. & 2.). To the northwest and west of the basin, the Aravali Ranges rise abruptly to a height exceeding 700 m in the form of hillocks, scattered along northern and southern periphery of the lake.

General morphometric features of Sambhar Lake	
Parameters	Values
Surface Area (Sq. Kms.)	190
Max. Length (Kms.)	22.5
Max. Width (Range Kms.)	11.2 – 3.2
Max. Depth (Mts.)	3 (at its full)
Average Depth (Cms.)	> 0.61

This largest playa is located in the gaps of the Aravalli mountain range and occupies a depression in the Aravalli schist's, which is a gateway to the Thar Desert. Though most of the lake basin lies in Jaipur and Nagaur districts and only a small portion in Ajmer district, the lake shares the Thar characteristic of the desert.

The bed is almost flat with a slope of less than 10 cm per km. The lake basin is divided into two sections by a 5.16 kms. long stone-earthen dam between the settlements of Jhapok to the south and Gudha in the north. The western part is a natural undisturbed water spread. The eastern part of the lake covering an area of 76.8 sq. kms. contains two large reservoirs for salt extraction, canals and saltpans. The water from the vast shimmering western part of the lake is pumped into the other side via sluice salt gates when it reaches an optimum degree of salinity required for salt extraction. The saltpans can be approached by the narrow mud bunds that separate them. An indigenously developed rail trolley system, laid by the Britishers, transport the salt extracted from the saltpans to the processing unit of Sambhar Salt limited. It also takes one across the dam and to various far-flung points in the salt works.

Fig. 2 : Map of Sambhar Lake



Review of literature revealed that earlier notable works on various aspects of Sambhar Lake either published or in the form of unpublished manuscripts are by Adam (1873 and 1874), Emerson (1939), McCann (1939), Dixit and Vachna (1942), Ratnam (1943), Aggarwal (1951 and 1956), Godbole (1951), Sapre and Mehta (1955), Mata and Mehta (1956), Baid (1958, 1959a, b & c, 1962, 1963, 1964, 1968, 1969 and 1975), Seshadri and Buch (1958 and 1959), Tiwari (1958 and 1966b), Baid and Mathur (1969), Sapre and Baxi (1959), Seshadri and Vyas (1960a & b), Seshadri and Langalia (1961), Biswas (1964, 1965a & b and 1971), Mahajan (1969 and 1971), Subbaramaiah and Doshi (1964a & b), Subbaramaiah (1965 and 1972), Subbaramaiah and Sitakararao (1965), Chandorikar (1968), Chaudhuri and Dave (1968), Mukherjee (1968), Bhatt and Sapre (1969), Chaudhary (1970), Gupta (1972), Seshadri and Datar (1969), Sharma (1970, 1971, 1974, 1978a & b, 1984 and 1988a & b), Singh, *et al.* (1972 and 1974), Deb (1973), Pareekh (1974), Yatiji (1974), Tank (1975), Chhotani and Roy (1976), Mahajan and Chandra (1976), Roy (1977 and 1980), Alam and Bhargava (1979a & b and 1981), Alam (1980, 1982), Chattopadhyay (1980 and 1982), Mittre and Saxena (1980), Sharma (1980), Sharma (1980), Dhabariya (1984), Nahar (1984), Rao and Chauhan (1984), Bhargava, *et al.* (1987a), Mohan, *et al.* (1987), Dayama (1988), Gohil, *et al.* (1988), Lal and Chhipa (1988), Shah, *et al.* (1988), Singh (1988), Vaidya (1988), Vyas, *et al.* (1988), Dua and Srivastava (1989), Saini *et al.* (1989), Jakher, *et al.* (1990), Susarla, *et al.* (1991), Bhatt and Hamidani (1992), Gohil and Joshi (1992), Sharma (1993), Bhargava and Jakhar (1994), Gopal and Sharma (1994), Mukherjee (1995), Kumar (1996a & b and 1998), Kumar and Bhargava (1996), Subba Rao (1996), Sinha and Panda (1997) and Sangha (1998).

In the present publication, the result of the survey, together with information available from earlier works have been collected, compiled and presented in the forms of separate papers on different faunal groups. Since the "Discovery of Breeding Ground of Flamingos" at Sambhar Lake (Fig. 2) was a historical event of natural history, it has been dealt separately in the chapter entitled flamingos and breeding. Brief information on relevant aspects as origin, history, geology, climate, catchment, soil and vegetation have been given to act as a general prologue to all the scientific contribution included in the publication.

ORIGIN

Various theories exist describing origin and formation of this unique saline habitat called Sambhar Lake. From pollen studies made by Birbal Sahani Institute of Palaeobotany, Lucknow, it has been estimated that Sambhar Lake was a sweet water lake just 2000 years back (Singh, *et al.*, 1972 and Singh, *et al.*, 1974). If we investigate the theory regarding origin of Rajasthan desert it is said that it was a bed of Tethys Sea and when Himalaya emerged, the Tethys sea receded to Arabian sea leaving behind its bed exposed as the Thar Desert. If this theory is considered as correct than it is counter to the above fact that the Sambhar Lake was a fresh water lake about 2000 years back. However, the conversion of Sambhar Lake from freshwater into the salt lake has a parallel with that of the formation of Iranian deserts Dast-e-Kavir and Dast-e-Lut, both having their extensive saline stretches.

HISTORY

Sambhar was the first capital of imperial Chauhan Kings of northern India. An interesting account of this dynasty is preserved in Sanskrit historical poem entitled "Prithviraja – Vijaya" composed by a Kashmiri poet named Jayanaka in the reign of Prithviraja, a resume of which was published by Dewan Bahadur Harbilas Sarada in an interesting article in the Journal of Royal Asiatic Society, 1913. The founding of the city Sambhar is attributed to Vasudeva. This king on a hunting expedition arrived at a spot, now represented by Sambhar and they built a lofty palace and started living in it. The old city, now known as Saratha is situated at a distance of 18 kms from the present site of the town. This town was founded near the temple of Goddess Shakambari (The consort of Shiva) and the place became well known after the name of the Goddess.

The old town of Sambhar must have been founded about 3rd century B.C. and continued to flourish until the 10th century A.D. when presumably due to the drying up of the adjacent freshwater lake, the site was deserted and the new town founded on the banks of the salt lake. The town was densely populated and well planned. The town was an important industrial center and its artisans specialized in the manufacture of ornamental pottery, cutting and polishing of hard stone etc.

In the past, the villages were in isolation and very poorly connected by cart tracks and footpaths or "*pagdandis*" The nomadic people settling near this saline wetland were mainly the banjaras or the Revari Tribes who enact their entire life in the open deserts surroundings. They were good traders (Elphinstone, 1916 and Hague, 1928) distributing mainly salt, (Aggarwal, 1956). With the onset of the rains, the Banjaras move towards saline basins where salt is manufactured being guided by a natural local instinct. The technological, socio-economical cum political development of the recent past have affected their nomadic life's, facing a social decay and also depriving them of their initial trade occupation.

An important place of pilgrimage in the neighbourhood of the modern town is large and well-constructed tank surrounded by a building dating from the 16th century downwards. The tank was originally constructed at a much earlier date and had a temple of about the 10th century A.D. attached to it, as is evident from a number of black stone images, which were recovered from the tank. This tank is known as Devayani Tank. Devayani (the daughter of Sukra and the queen of Raja Yayati), was thrown in this tank by princess Sharmishtha. The tank is surrounded by 19 old and new temples including four Shiva temples located in all the four directions.

Archaeological excavations at Naliasar, 4 km south of salt lake city, have yielded terracotta figurines and evidence of well-planned settlement going back to the Kushan and Gupta periods (Sharma, 1988a & b). It is also mentioned in the literature that the Rajasthan's first church was built near the shore of Sambhar Lake in 1648 (Pareekh, 1974).

The salt lake of this place remained a great source of income to the Chauhan rulers. A

fort was also built by the early Chauhan kings and existed during the Mughal period. But no trace of fort is found at present. In the year 1198 Sambhar passed to the sultanate of Delhi.

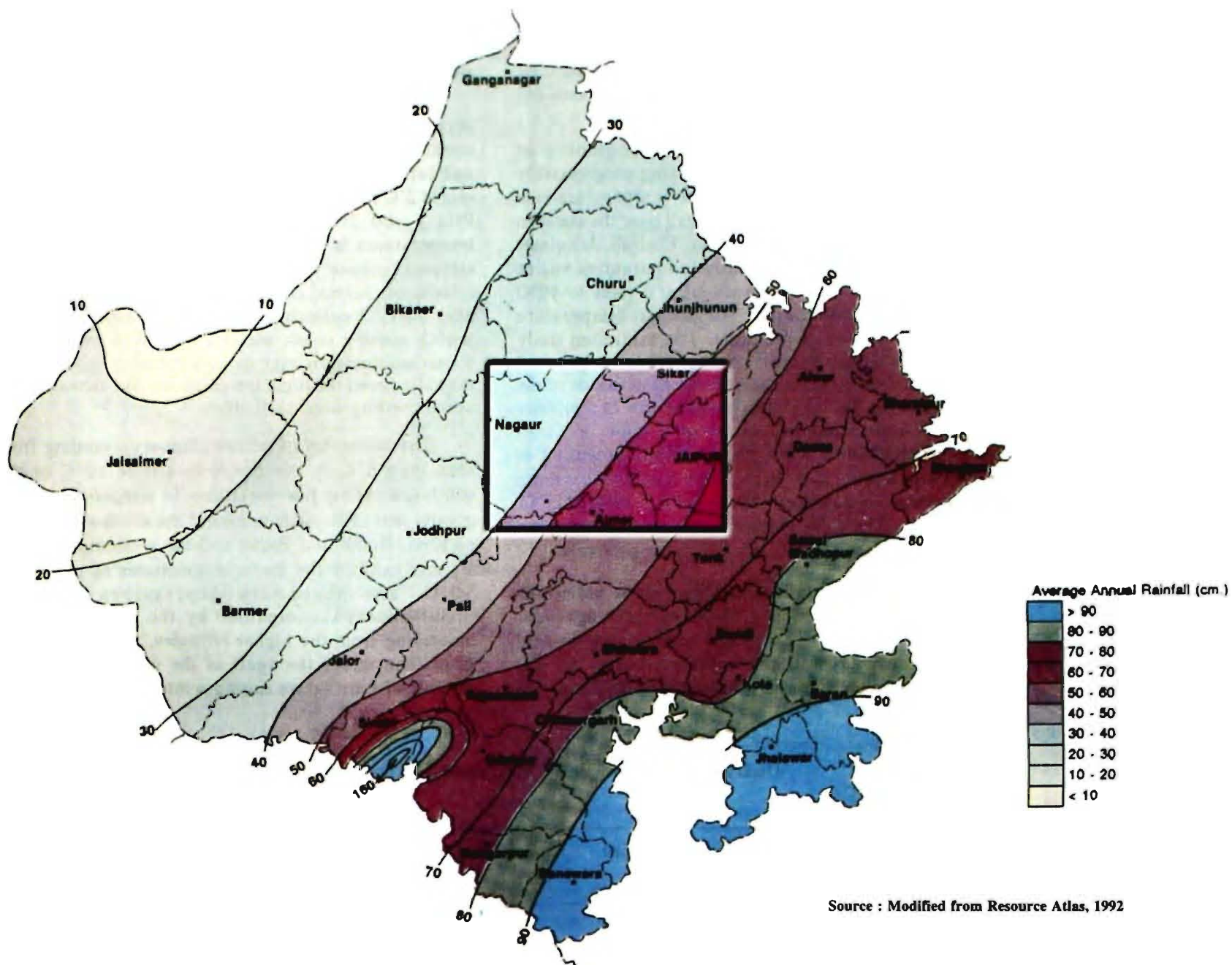
On account of its great repository of salt, it has always been a valued possession. Various rulers of the area have extracted salt from this lake for over a thousand years. Over the period of time, these have included the Sindhias, Rajputs, Marathas, Mughals and the rulers of Jaipur and Jodhpur who jointly owned the lake and even leased it to the British in 1870. After independence, the lake was taken over by the government and is now managed by Government undertaking – Sambhar Salt Limited, a joint venture of Hindustan Salts and the Government of Rajasthan.

CLIMATE

Since the lake lies in the eastern semi-arid climatic zone, the region is typically subtropical monsoonic. The year is distinctly marked with summer, rainy and winter seasons. The mean monthly summer temperature rises to above 40°C whereas mean winter temperature remains below 10°C. The maximum day temperature during May-June often rises above 49°C whereas during winter the minimum temperature often drops below 2°C. The average annual rainfall is 54 cm, which precipitates almost entirely during the period from July to September (Fig. 3).

Gopal and Sharma (1994) have reported characteristic feature of the climate of this region with extreme temporal variability in precipitation. The rainfall record of more than century shows that both the total annual rainfall and its period of occurrence and intensity during the season exhibit wide variations, resulting in frequent spells of drought and floods (Emerson, 1939 and Tank, 1975). The rainfall, which has often been low and as low as 16 cm in the year 1939, exceeded 100 cm in 1892, 1893 and 1917. According to the data compiled by Aggarwal (1951), as much as 15 cm rain had fallen during July and 31 cm rain within five days in September 1884, causing severe floods. Another example of excessive rain was recorded in July 1949 when more than 13 cm rain precipitated within three hours and again > 17 cm within 24 hours. In contrast, during dry years, rainfall was often well distributed over the whole season, recording only 3-5 cm in a month. Paleoclimatic evolution of lake was studied by Roy (1980). In the flood years, the Mendha and Turamati streams pour their water from north, north-east of the lake and mostly deposit the sand sheet of 30 to 60 cms thickness in the adjoining agricultural fields and acquire the dimensions of 3 to 4 kms width, otherwise bed remain dry through-out the year (Sharma, 1984). Flash floods have been registered fairly regular in recent years i.e. 1968, 1971, 1974, 1975, 1977, 1981 and 1983 (Gopal and Sharma, 1994). These floods were not due to excess rain but due to intense rainfall on certain days during the monsoon season. After the heavy monsoon rains of 1974, 1975, 1977 and 1980 the lake retained water throughout the year but in 1987 following four years of drought it was completely dry by December. Rainfall was heavy during the monsoon of 1992-1993 (Anon, 1993a). During 1994 to 1997 rainfall remained above normal mostly with intermittent rains even before and after the monsoon season.

Fig. 3 : Rainfall Pattern of Rajasthan Districts



Source : Modified from Resource Atlas, 1992

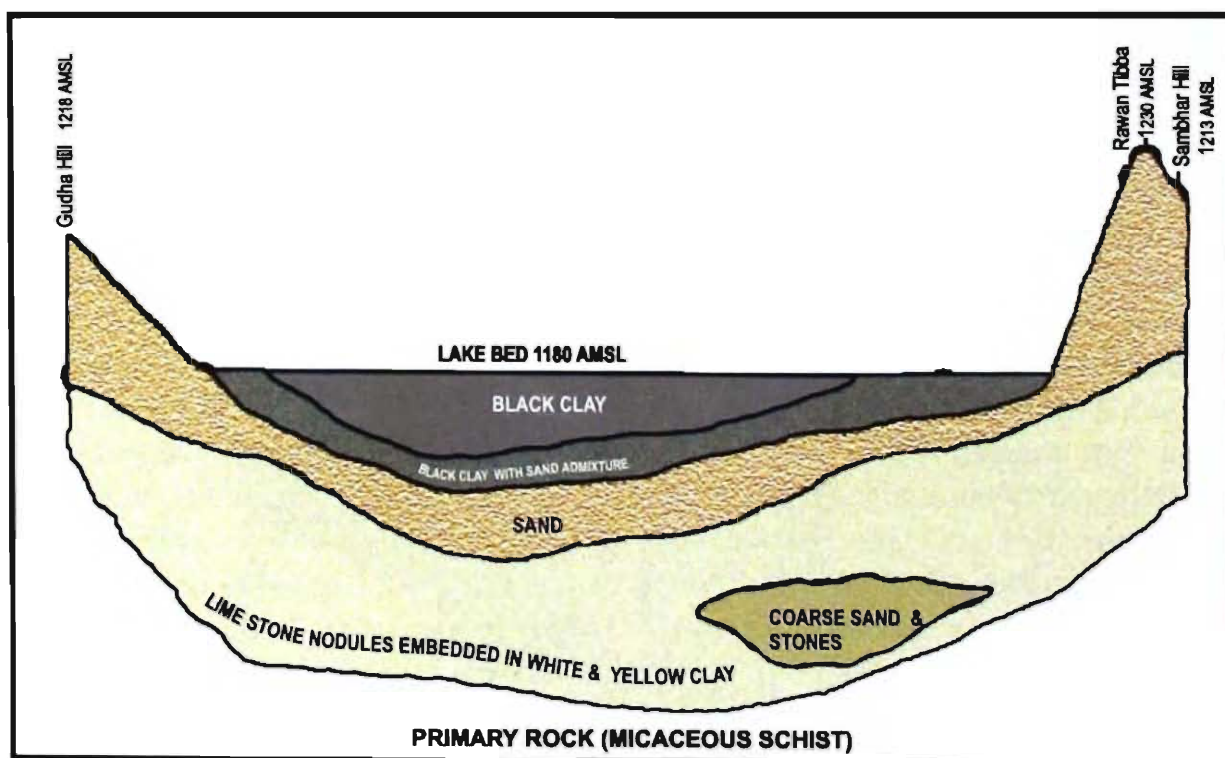
GEOLOGY

The discontinuous Aravalli range composed of residual hills with several wide gaps surrounds the region of Sambhar Lake with the Aravalli series underlie the basin. Micaceous schist's overlain with limestone nodules buried in clay form the basin bottom. Above these spreads a thick layer of sand, which, in turn is covered by a 20 m thick layer of calciferous silt (Fig. 4.). High terrace sand and clay deposits are also found on the Aravalli outcrops around the lake basin (Singh *et al.*, 1972 and Hackett, 1980). Chemical weathering of the Aravalli's, resulting in the production of soluble sodium salts and their drainage into the Sambhar basin, is the most accepted explanation for the presence of salts in the lake. But the origin of salt in the lake is still a debatable issue amongst the geologists and the chemists.

HYDROLOGY

Most of the limnological studies conducted on water quality was to find solutions for combating problems created by algae for better salt production and to develop culture of *Artemia salina* a brine shrimp used as food for fish in brackish water aquaculture (Vos, 1979). However, these studies were very elementary and scattered to arrive at any conclusion for the benefit of both salt production and brine shrimp aquaculture (Bhargava, 1984 and

Fig. 4 : Semi Diagrammatic Stratigraphical Section of Salt Lake deposit



Source: Modified from Phil. Trans. Royal Soc., London 1974

Bhargava, *et al.*, 1987a). The review on limnological aspect of the lake waters has been dealt separately in the chapter on limnology.

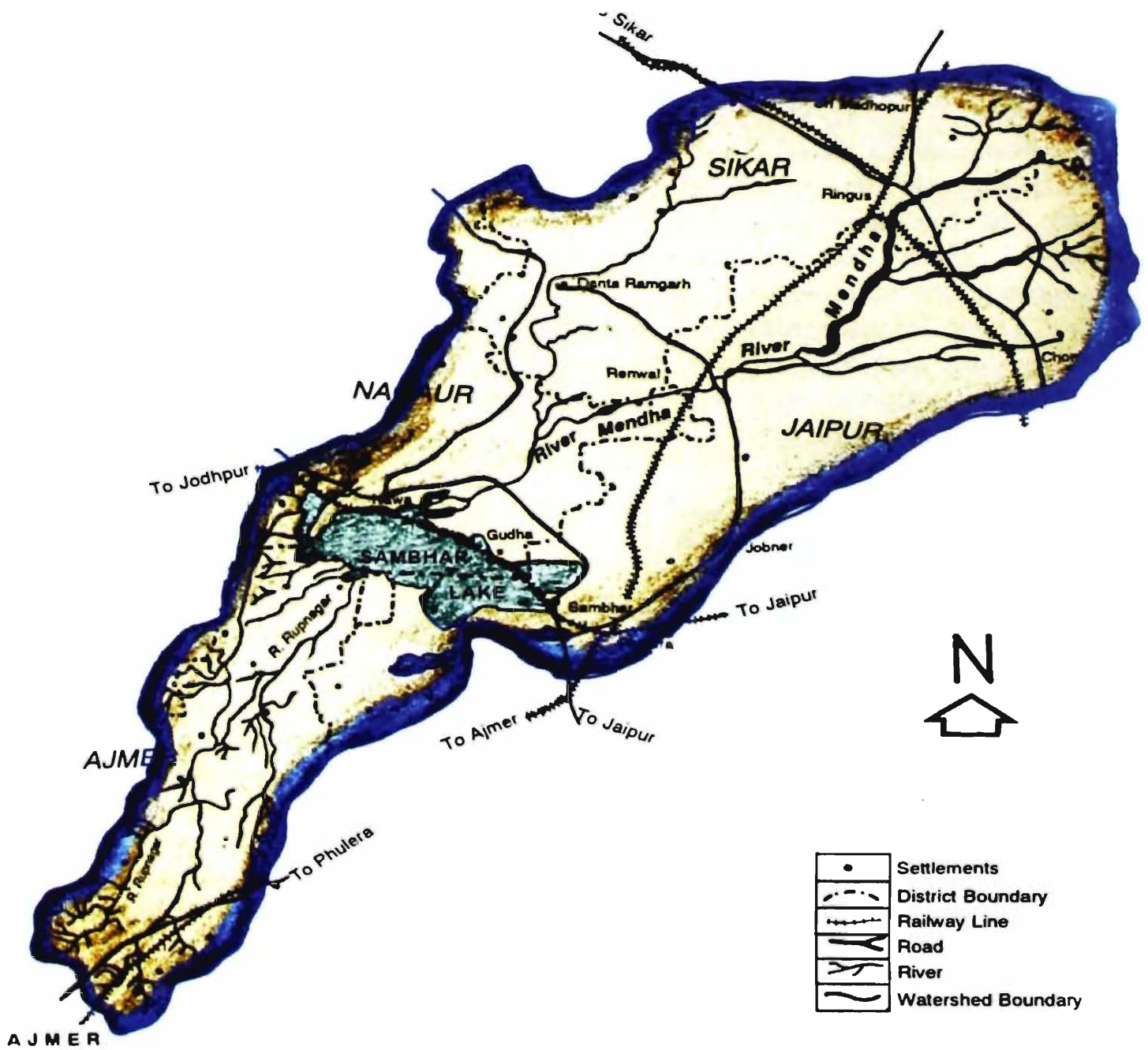
CATCHMENT

The Sambhar Lake has a vast catchment area encompassing over 7560 sq. kms most of which lies to the north and north-east of the wetland extending up to Sikar District of Rajasthan.

Four ephemeral streams Mendha, Rupangarh, Kharian and Khandel, numerous rivulets and surrounding surface run-off drains into the lake basin (Fig. 5). The largest feeder river Mendha originates in Sikar district and runs south-west and west and enters the lake from the north. The river drains in an area of about 3600 sq. kms, which is about half of the catchment of Sambhar Lake. The drainage area of river Mendha is sandy, undulating plain with a border to the north, west and east by residual projecting hillocks of Aravalli range. Saini *et al.* (1989) has made remote sensing studies, using Landsat False Colour Composites which shows that river Mendha has changed its course in antediluvian years and in the recent past. The vast catchment is subjected to sand encroachment and land transformation due to agricultural activities. Several paleochannels lie buried beneath the sand e.g., some segments of two major tributaries of Mendha Anokhi and Ranoli, which have disappeared under sand during the last two decades. Aeolian processes especially the movement of sand plays a major role in influencing the run-off and river flow entering the lake from catchment area. It is a popular view that the gaps in the Aravalli also called Sambhar gaps allow the movement of wind blown sands from the west of the range to get deposited in the area causing increase in desertification (Dhabariya, 1984). River Rupangarh rises in the Aravallis in the south near Ajmer city and runs north-east to enter the Sambhar Lake from the south. Its catchment is mostly rocky spread over about 625 sq. kms. The Kharian is a smaller stream entering the lake in the north-west whereas another small ephemeral stream Khandel drains into a limited area to the east of the lake before entry into the lake basin.

Several satellite wetlands ranging in size from less than hectare to a few hectares are generally scattered around the Sambhar Lake. They are brackish and freshwater wetlands mostly man-made like Devyani tank to the east, small to large size ponds near Jhapok village, Lake Phulera to the south of Sambhar city, numerous water bodies along the course of river Mendha and large to very large size wetlands on the western side of Aravalli at a distance of five to eight kms from Sambhar Lake (Seshadri and Datar, 1969). All these scatteredly located shallow often less than a meter deep wetlands, host and attract variety of faunal elements including waterfowls and allows avian wetland fauna to locally migrate when disturbed due to biotic interference in a large lake like Sambhar.

Fig. 5 : Watershed zone of Sambhar Lake



Source: Modified from Ramsar Atlas of India-Sambhar Lake, 1994.

SEDIMENTS

The lake basin sediments consists mainly of silt and clay to an extend of 6.1 m above the general surface in a raised beaches formed on the slope of the promontory jutting into the basin in the extreme northwest. The lake surface when wet develops a dark bluish colour but turn grayish when dry. During summer when the lakebed dries, the high clay content results in the appearance of deep polygonal mud cracks and encrusted with salt drawn upon through capillary action. Some parts of the basin are hard and calcareous but most of it is argillaceous with considerable amount of Mica derived from the surrounding areas. The brine table sinks to about 3m below the surface in the summer months (Sinha and Panda, 1997).

BIODIVERSITY RICHNESS

Due to high salinity regime the biodiversity richness is restricted mostly to salt-tolerant species. It is still more rare to find organisms that can survive wide range of salinity conditions, from nearly fresh to salt saturated, which the lake experiences every year from the time of its receiving first precipitation of the monsoon to a stage when it is drying completely in the summer. The major biotic components are phytoplankton, zooplankton, benthic invertebrates and waterfowls. The moist and wet or semidried margins of the lake are occupied by some halophytes, large number of wind blown derelict forms and some faunal elements casually visiting the lakes.

FLORA

The quaternary history of flora of Rajasthan was under taken by Singh, *et al.* (1974). More than 40 species of planktonic algae are so far recorded from Sambhar Lake: Ratnam (1943), Seshadri and Buch (1958), Subbaramaiah and Doshi (1964a & b), Subbaramaiah (1965, 1968 and 1972), Subbaramaiah and Sitakararao (1965), Rao and Chauhan (1984),

AQUATIC FLORAL DIVERSITY OF SAMBHAR LAKE

Chlorophyceae (Green algae)

<i>Dunaliella salina</i> Toed.	+	A
<i>Chlamydomonas</i> sp.	+	A
<i>Oedogonium</i> sp.	+	
<i>Mycanthococcus</i> sp.	-	
<i>Oocystis</i> sp.	-	
<i>Rhizoclonium</i> sp.	+	

Table contd.

Cyanophyceae (Blue-green algae)

<i>Aphanothece halophytica</i> Fremy	+	A
<i>Anabaena fertilissima</i> Rao	+	
<i>Arthrospira platensis</i> (Nordst)	-	
<i>Anabaenopsis arnoldii</i> Aptekarj	+	A
<i>Anabaenopsis circularis</i>	+	A
<i>Nostoc sphaericum</i>	-	
<i>Anabaena laxa</i>	+	A
<i>Chroococcus minor</i> (Kutz.)	+	
<i>Synechococcus elongatus</i> Naeg.	-	
<i>Oscillatoria</i> sp.	+	
<i>Oscillatoria simplicissima</i> Gomont	+	A
<i>Oscillatoria subbrevis</i> Schmid.	+	A
<i>Oscillatoria jasorvensis</i> Vouk	-	
<i>Oscillatoria salina</i>	+	A
<i>Microcoleus</i> sp.	-	
<i>Scytonema</i> sp.	+	
<i>Synechocystis</i> sp.	+	
<i>Myxosarcina concinna</i>	+	
<i>Lyngbya</i> sp.	-	
<i>Gloeotheca</i> sp.	+	
<i>Rameria</i> sp.	-	
<i>Phormidium</i> sp.	+	A
<i>Spirulina subsalsa</i> Corst.	+	
<i>Aphanocapsa</i> sp.	+	A
<i>Merismopedia</i> sp.	-	

Bacillariophyceae (Diatoms)

<i>Nitzschia</i> sp.	+	A
<i>Navicula</i> sp.	+	
<i>Synedra</i> sp.	-	
<i>Closterium</i> sp.	+	
<i>Cymbella</i> sp.	-	
<i>Melosira</i> sp.	-	
<i>Cosmarium</i> sp.	+	A

Euglenophyceae

<i>Euglena</i> sp.	+	A
--------------------	---	---

- = Reported earlier; + = Reported earlier and also recorded during 1994-97; A = Abundant

Sparse green vegetal cover surrounding Sambhar Lake

Trees	Shrubs	Grasses	Herbs
<i>Acacia nilotica</i>	<i>Acacia jacquemontii</i>	<i>Cenchrus pennisetiformis</i>	<i>Aerva persica</i>
<i>Acacia senegal</i>	<i>Calotropis procera</i>	<i>Cenchrus ciliaris</i>	<i>Ageratum conyzoides</i>
<i>Anogeissus pendula</i>	<i>Capparis decidua</i>	<i>Cenchrus setigerus</i>	<i>Argemone mexicana</i>
<i>Azadirachta indica</i>	<i>Euphorbia caducifolia</i>	<i>Chloris dolichostachya</i>	<i>Amaranthus spinosus</i>
<i>Boswellia serrata</i>	<i>Euphorbia royleana</i>	<i>Dactyloctenium aegyptium</i>	<i>Arnebia hispidissima</i>
<i>Maytenus emarginatus</i>	<i>Leptadenia pyrotechnica</i>	<i>Apluda mutica</i>	<i>Celosia argentea</i>
<i>Phoenix sylvestris</i>	<i>Salvadora oleoides</i>	<i>Aristida adscensionis</i>	<i>Convolvulus arvensis</i>
<i>Prosopis cineraria</i>	<i>Salvadora persica</i>	<i>Melanocentris jacquemontii</i>	<i>Evolvulus alsinoides</i>
<i>Prosopis juliflora</i>	<i>Sericostoma pauciflorum</i>	<i>Saccharum spontaneum</i>	<i>Digera muricata</i>
<i>Tamarix dioica</i>	<i>Crotalaria burhia</i>	<i>Saccharum bengalense</i>	<i>Phyllanthus sp.</i>
<i>Tecomella undulata</i>	<i>Tephrosia purpurea</i>	<i>Sporobolus helvolus</i>	<i>Leucas aspera</i>
		<i>Sporobolus sp.</i>	<i>Launaea sp.</i>
		<i>Perotis indica</i>	<i>Polygala irregularis</i>
		<i>Tetrapogon tenellus</i>	<i>Tribulus terrestris</i>
		<i>Eragrostis ciliaris</i>	<i>Vernonia cinerea</i>
			<i>Commelina</i>
			<i>benghalensis</i>
			<i>Farsetia hamiltonii</i>
			<i>Indigofera cordifolia</i>
			<i>Corchorus</i>
			<i>trilocularis</i>
			<i>Portulaca oleracea</i>
			<i>Mollugo cerviana</i>
			<i>Trianthema</i>
			<i>ortulacastrum</i>
			<i>Euphorbia hirta</i>
			<i>Heliotropium</i>
			<i>paniculatum</i>
			<i>Heliotropium</i>
			<i>marpifolium</i>
			<i>Gisekia sp.</i>
			<i>Suaeda fruticosa</i>
			<i>Cressa cretica</i>
			<i>Salsola foetida</i>
			<i>Haloxylon rtecurvum</i>
			<i>Zygophyllum simplex</i>
			<i>Trianthema triquetra</i>
			<i>Launaea nudicaulis</i>
			<i>Cleome brachycarpa</i>



Dayama (1988), Dua and Srivastava (1989) and Gopal and Sharma (1994). These microscopic organisms exhibit seasonal succession with gradual increase in salinity from early monsoon through winter to the summer. Species of the blue green algae like *Nostoc*, *Anabaenopsis*, *Anabaena*, *Arthrospira* and Diatoms like *Closterium* and *Cosmarium* develop large population giving bluish green colour to the water. With the increase in salinity, blooms of *Microcystis* and *Dunaliella salina* form thick scum over the water surface. The *Dunaliella salina* develops very dense population with a red-orange carotenoid pigment and imparts a pink colour to water. The occurrence of species of genera like *Spirulina*, *Oscillatoria*, *Aphanocapsa* and *Nitzschia* are found to develop in salinities upto more than 100 ppt. (Jakher *et al.*, 1990). Absolutely no macrophytic vegetation develops in the lake. Algal components and vegetation of Sambhar Lake are discussed in detail by Ratnam (1943) and Dayama (1988) respectively. However, succulent halophytes such as *Salsola* sp. and *Suaeda* sp. are found flourishing on the moist margins of the lake (Gopal and Sharma, 1994).

The vegetation surrounding the Sambhar Lake including watershed zone is basically thorn scrub, which is typical of arid and semi-arid areas. This vegetal cover exists having sparse growth of trees on sandy plains dominated by *Acacia nilotica*, *Acacia senegal*, *Prosopis cineraria*, *Capparis decidua*, *Salvadora persica*, *Salvadora oleoides*, etc. Whereas Aravalli side of the lake is covered with low growth of *Anogeissus pendula*, *Boswellia serrata* and *Euphorbia* sp. along with under growth of various shrubs species. A list of trees, shrubs, grasses and herbs are reported.

FAUNA

Faunal diversity of Rajasthan wetlands though scatteredly published but amply worked out by various workers. Most of the fauna worked out belongs to freshwater wetlands of Rajasthan. Some of the noteworthy publications in this field are by Hume (1878), Tiwari (1951, 1958, 1962a & b, 1963, 1965, 1966a & b, 1968 and 1996), Mathur (1952), Aggarwal (1957), Mathur and Sidhu (1957), Baid (1958, 1959a, b & c, 1962, 1963, 1964, 1965, 1966, 1968, 1969 and 1975), Krishna and Menon (1958), Baid and Mathur (1959), Dubey and Mehra (1962), Mahajan (1969, 1971 and 1977), Moona, (1963), Biswas (1964, 1965a & b and 1971), Nayar (1965, 1968 and 1971), Khera (1966), Dhawan (1967), Ray and Mukherjee (1969), Roonwal (1969 and 1982), Abdulali and Savage (1970), Datta and Majumdar (1970), Mansukhani and Murthy (1970), Vazirani (1970 and 1977), Deb (1973), Khosla (1973), Mathur and Yazdani (1973), Durve and Rajbanshi (1976), Kushwaha, *et al.* (1975), Bose and Mitra (1976), Chhotani and Ray (1976), Durve (1976), Mahajan and Chandra (1976), Rao (1976), Durve and Kakkar (1977 and 1979), Mathur (1977), Bohra (1978), Chaudhary (1978), Alam and Bhargava (1979a & b and 1981), Ali (1979 and 1982), Alam (1980 and 1982), Bhargava and Alam (1980a, b & c), Saxena and Bhargava (1980 and 1981), Sharma (1980), Sharma (1980), De Block (1981), Jakher, *et al.* (1981 and 1990), Johal and Dhillon (1981), Misra, *et al.* (1981), Prasad and Thakur (1981), Saxena and Baskaran (1981), Soota, *et al.* (1981), Soota, *et al.* (1981 and 1982), Basu and Choudhary

(1982), Bhargava (1982 and 1985), Johal (1982), Mahajan, *et al.* (1982), Mahajan, *et al.* (1982a & b), Sharma and Johal (1982), Bohra, *et al.* (1983), Jackson (1983), Soota and Saxena (1983 and 1984a & b), Saxena (1984, 1988 and 1996a & b), Bhargava (1984), Gole (1984), Jakher (1984 and 1986), Sharma, *et al.*, (1984), Gupta and Kulshreshta (1985), Karpowicz (1985), Thakur (1985), Sharma and Durve (1985a & b), Agoramoorthy and Mohnot (1986), Ali and Vijayan (1986), George (1986), Johal and Sharma (1986), Khatri (1986), Rao (1986a & b, 1991 and 1995), Bhargava, *et al.*, (1987a, b & c), Mohan, *et al.* (1987), Nama (1987), Tak and Sewak (1987), Gopalarao and Durve (1988 and 1989), Gopalarao, *et al.*, (1988), Haque and Vijayan (1988), Rao, *et al.*, (1988), Srivastava (1988), Venkataraman (1988, 1990 and 1992a & b), Bhupathy (1989 and 1990), Rao and Durve (1989 and 1992), Rao, *et al.* (1989), Saxena (1989), Tehsin (1989), Ajithkumar (1990, 1991 and 1993), Bhupathy and Vijayan (1990), Sharma and Kulshreshta (1991), Tyagi and Miller (1991), Ajithkumar and Asthana (1993), Ajithkumar and Mittal (1993), Ajithkumar and Sankar (1993), Bahura, *et al.* (1993a & b), Johal, *et al.*, (1993), Kumar and Asthana (1993), Ramachandran and Vijayan (1994), Soni (1994), Ajithkumar, *et al.* (1995), Katfu and Mohonot (1995), Mukherjee (1995), Kumar (1996a & b and 1998), Kumar and Bhargava (1996), Rahamani (1996 and 1997a & b), Roy (1996), Subba Rao (1996), Tak (1996), Vyas (1996), Yazdani (1996), Rahamani and Soni (1997), Sharma (1997), Vyas (1997), Bhupathy, *et al.* (1998), and Kumar and Rathore (1999).

Sambhar Lake holds its existence from the ancient times and it has been exploited for salt extraction from time immemorial but no significant records of its fauna except birds (Adam, 1873 and 1874) have ever been documented by rulers or by the British Raj. It is only in the recent past that attempts have been made to work out its physico-chemical nature and avian diversity by McCann (1939), Mukherjee (1968), Gopal and Sharma (1994), Mukherjee (1995), Kumar (1996a & b and 1998), Kumar and Bhargava (1996), Rahmani (1996 and 1997a & b) and Rahmani and Soni (1997). Some of the earlier notable contribution on fauna are by Baid (1958, 1959a, b & c, 1962, 1963, 1964, 1965, 1966, 1968, 1969 and 1975), Tiwari (1958, 1965 and 1966b), Mahajan (1969 and 1971), Chhotani and Ray (1976), Mahajan and Chandra (1976), Vazirani (1977), Bhargava and Alam (1980a & b), Alam (1982) and Bhargava, *et al.*, (1987a). Two families of Diptera are reported by Baid (1959c) and one by Sharma (1980). Most of the works relates to the fauna brought with the freshwater in the beginning of monsoon. But absolutely no work has been carried out of the period during which salinity increases and most of the allochthonous fauna brought by rivers from the catchment area perishes and only the saline tolerant species thrive in the lake waters. Infact most of the fauna recorded such as molluscs (Ray and Mukherjee, 1969; Roonwal, 1982 and Subba Rao, 1996) belongs to the Sambhar Lake region and not the saline wetland habitat of Sambhar Lake.

SUMMARY

Sambhar Lake being a unique saline wetland has a very little faunal background that too worked out meagerly. The lake has been exploited for salt extraction for centuries but no

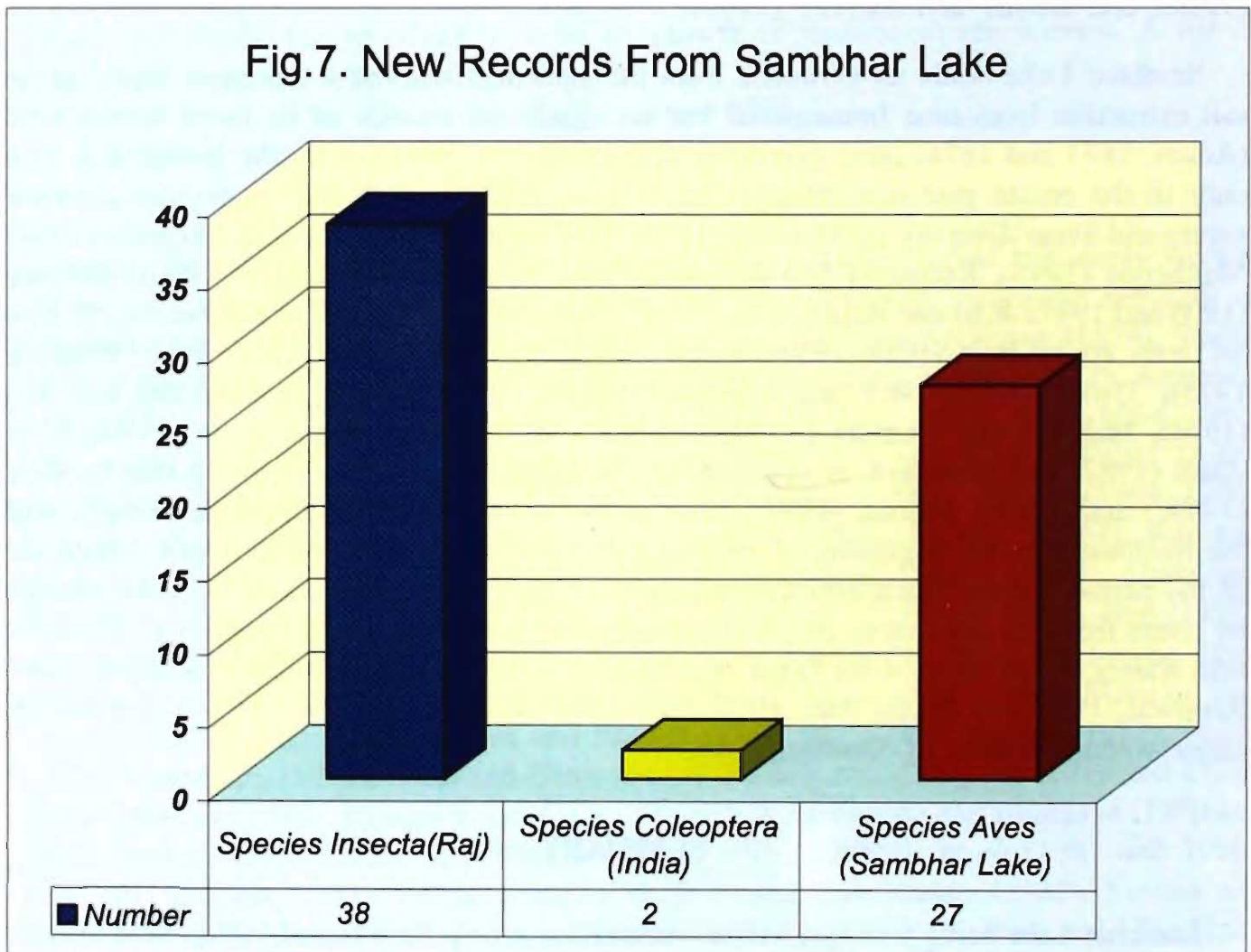
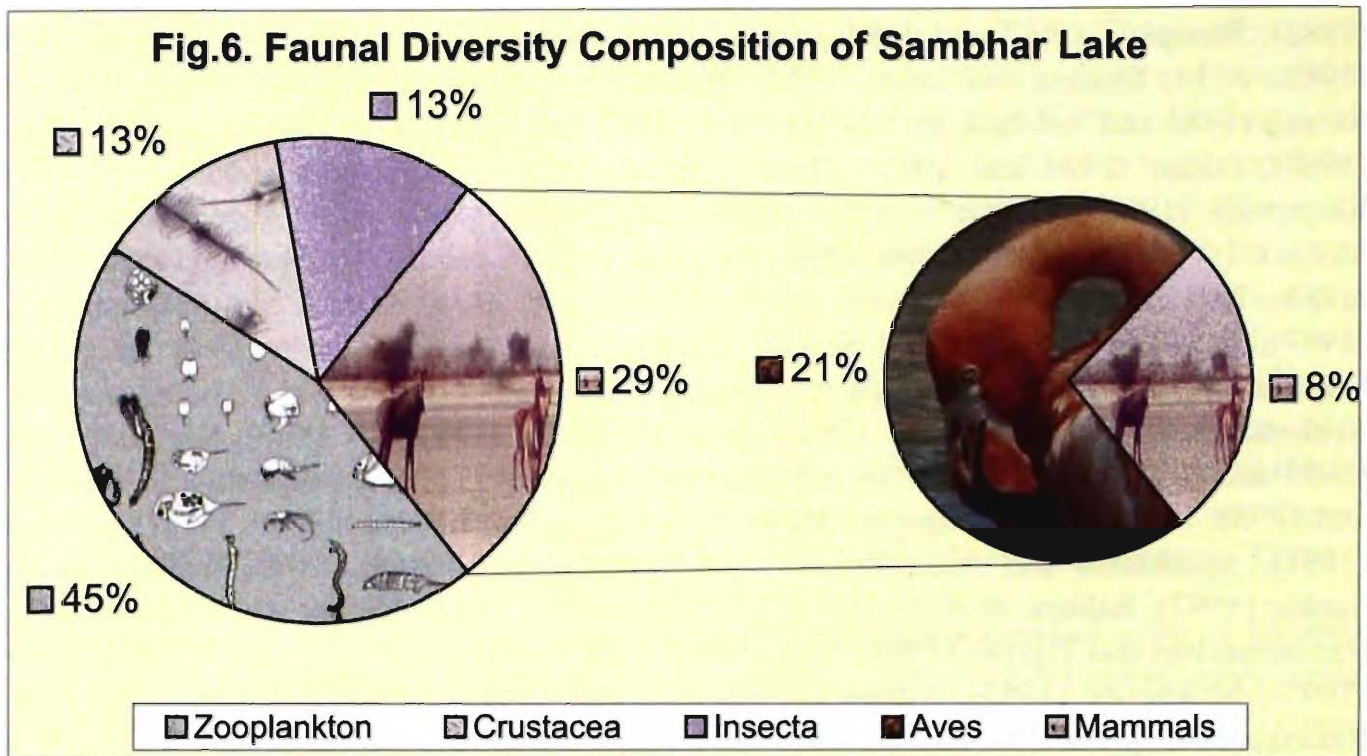


Table 1. Faunal Diversity in different groups recorded from the Lake				
Groups	Orders	Families	Genera	Species
Zooplankton	17	33	48	64
Crustacea	5	14	25	37
Insecta	5	17	53	71
Aves	8	17	44	71
Mammals	3	6	6	6

attention was paid by the rulers or the British Raj and present Government to document its biotic potential and ever-fluctuating hydrological regime. As has been mentioned earlier some attempts were made which just touched upon the biodiversity of this lake.

In the present publication attempt has been made to work out the faunal diversity of Sambhar wetland habitat along with its review on past physico-chemical characters and threats and conservation. All the available faunal groups were collected along with derelict forms and identified as far as possible (Table 1 & Fig. 6) except where group experts were not available. A total of 212 species of animals have been recorded from Sambhar Lake. Among them 38 species are recorded for the first time from Rajasthan, two species recorded for the first time from India and 28 species of wetland birds were added to the existing known avian fauna of the lake. The total faunal diversity composition is represented in Fig. 7.

The most significant achievement of the present study is the discovery of the breeding ground of flamingos at Sambhar Lake, which is the second largest wintering and breeding ground for flamingos in India.

ACKNOWLEDGEMENTS

I am thankful to Dr. J.R.B. Alfred, Director, Zoological Survey of India for giving me the opportunity to work on Ramsar site, the Sambhar Lake – a wetland of International Importance. I am deeply indebted to Dr. Q.H. Baqri, Additional Director and Officer-in-Charge, Desert Regional Station, Zoological Survey of India, Jodhpur for providing facilities, valuable suggestions and guidance all through the period of survey work. I acknowledge my sincere thanks to the Scientists of Zoological Survey of India, Kolkata who have identified the material and contributed papers in this publication. I express my sense of gratitude to Dr. R.N. Bhargava Retd. Scientist with whom I initiated this project and shared one year of working. I am gratefully indebted to Late Dr. I. Prakash, Professor of Eminence, for his encouragement and lucid suggestions during the course of study. I also offer my sincere thanks to Dr. N.S. Rathore, Dr. Padma Bohra, Dr. Ram Sewak and Mrs. Neena Tak

of Desert Regional Station, Zoological Survey of India, Jodhpur, for their fervent and frequently given encouragement. I also acknowledge the assistance of Smt. Venulata Nigam for library, Shri V. Muraleedharan for handling manuscript and Shri Moti Lal and Shri Sataynaran Dhadhich for sorting the vast material of the project. I am also thankful to Managing Director, Sambhar Salt Limited for providing accommodation and allowing me to work in the salt production area of the lake. I extend my thanks to various other organizations and individuals who helped me in various ways. I shall be failing in my duty if I do not thank my staff especially Shri Girdhari Ram, Driver and Shri Basti Ram, for their assistance in the field, working with me even in the late hours of night in a harsh environment of salinity with pungent odour of sulphide. I am deeply indebted to my family members especially to my father who gave me scientific temper and to my son Sh. Mudit Kumar and little daughter Ms. Jayavidhi Kumar who bore all the absence of my attention during this period. I finally express my thanks to Almighty God especially Maa Shakambari for giving me strength and devotion to successfully accomplish the project.

REFERENCES

- Abdulali, H. and Savage, C.D.W. 1970. Status of the Main Wildfowl Resorts in India. In: *Proc. International Regional Meeting on Conservation of Wildfowl Resources*, (ed.) Y.A. Isakov, Leningrad, USSR, 25-30 September 1968, 335-337.
- Adam, R.M. 1873. Notes on the birds of the Sambhar Lake and its vicinity. *Stray Feathers*, **1** (5) : 361-404.
- Adam, R.M. 1874. Additional note on the birds of the Sambhar Lake and its vicinity. *Stray Feathers*, **2** (4) : 337-341 & 465-466.
- Aggarwal, J.P. 1957. Contribution towards the Odonata fauna of Pilani. *Proc. 44th Indian Sci. Congr.*, Calcutta, Part III, Abstract : 309.
- Aggarwal, S.C. 1951. *Sambhar Lake Salt Source*. Government of India Publication, New Delhi. 365 pp.
- Aggarwal, S.C. 1956. *Panchpadra and Didwana Salt Source*, New Delhi, Government Press.
- Agoramoorthy, G. and Mohnot, S.M. 1986. Migratory water birds around Jodhpur, India. *Tiger paper*, **13** (1) : 4-7.
- Ajithkumar, C.R. 1990. The fish community of Keoladeo National Park, Baratpur, Rajasthan. India. In: *Proc. of the IInd Asian Fisheries Forum*, Tokyo, Japan, April 1989. (eds.) R. Hirana and I. Hanyu. The Asian Fisheries Society, Manila. Philippines. pp. 385-388.

- Ajithkumar, C.R. 1991. Community and habitat segregation of the fish in Keoladeo National Park. Kanpur University, Ph.D. Thesis.
- Ajithkumar, C.R. 1993. *Aplocheilus panchax* (Ham.) an addition to the fish fauna of Rajasthan. *J. Bombay nat. Hist. Soc.*, **90** (1) : 115.
- Ajithkumar, C.R. and Asthana, A. 1993. The fish fauna of Rajasthan, India. *Rev. Life Sci.*, **13** : 133-148.
- Ajithkumar, C.R. and Mittal, D.D. 1993. Habitat preference of fishes in wetlands in relation to aquatic vegetation and water chemistry. *J. Bombay nat. Hist. Soc.*, **90** (2) : 181-192.
- Ajithkumar, C.R., Ramachandran, N.K. and Asthana, A. 1995. Composition, abundance and distribution of fish in Banganga gambhir river system source of fish to the Keoladeo National Park, Bharatpur. *J. Bombay nat. Hist. Soc.*, **92** (1) : 30-39.
- Ajithkumar, C.R. and Sankar, K. 1993. Ichthyo-fauna of Sariska wild life sanctuary. *J. Bombay nat. Hist. Soc.*, **90** (2) : 299-300.
- Alam, M. 1980. Limnological studies of Sambhar Lake and its reservoir Ph.D. Thesis, Univ. Jodhpur, Jodhpur India. 158 pp.
- Alam, M. 1982. The flamingos of Sambhar Lake. *J. Bombay. nat. Hist. Soc.*, **79** (1) : 194-195.
- Alam, M. and Bhargava, S.C. 1979a. Diurnal variation in chlorophyll pigments in relation to some hydrological factors at Sambhar Lake, Rajasthan. *Trans. Isdt. and Ucds.*, **4** (1) : 7-10.
- Alam, M. and Bhargava, S.C. 1979b. Diurnal rhythm of zooplankton in relation to certain physico-chemical factors at Sambhar salt lake and its reservoir. *Geobios*, **6** : 207-211.
- Alam, M. and Bhargava, S.C. 1981. Effect of salinity. Fluctuations of the planktonic composition of salt water bodies of Semi-Arid region of Rajasthan. *Abstracts natnl. Sympos. Evaluation of our Environment* (Jodhpur, Apr. 1981), Jodhpur pp. 36-37.
- Ali, S. 1979. Keoladeo Ghana water bird sanctuary. *Hornbill*, **13** : 27-29.
- Ali, S. 1982. Bharatpur: Wetland refuge for birds. *Sanctuary*, **2** (2) : 114-129.
- Ali, S. and Vijayan, V.S. 1986. Keoladeo National Park Ecological Study. Summary Report 1980-85. Bombay Natural History Society, Bombay, March, 1986.
- Anonymous, 1992. *India's Wetlands. Mangroves and Coral Reefs*. Ministry of Environment & Forests. Govt. of India. New Delhi.

- Anonymous, 1993a. *Directory of Indian Wetlands*. WWF INDIA, New Delhi and AWB, Kuala Lumpur, xvi + 264 pp., 32 maps.
- Anonymous, 1993b. *Environment Action Programme, India*. Ministry of Environment and Forests, Govt. of India. New Delhi.
- Bahura, C.K., Bahura, P. and Saxena, M.M. 1993a. Environmental monitoring of waters of the Indian desert: Zooplanktonic community of Shivbari temple tank, Bikaner. *J. Ecobiol.*, **5** (1) : 5-7.
- Bahura, R., Bahura, C.K. and Saxena, M.M. 1993b. A survey of zooplankton community of some waters of the Indian desert. In: *Curr. Trends linnol. Res.*, Vol. II. (ed.) N.K. Shastree, Narendra Pub. House, Delhi.
- Baid, I.C. 1958. On the occurrence of *Artemia salina* in Sambhar Lake, Rajasthan. *Curr. Sci.*, **27** (2) : 58-59.
- Baid, I.C. 1959a. Some observations on the population of *Artemia salina* in Sambhar Lake, Rajasthan. *Proc. nat. Acd. Sci., India*. **28** : 416-423.
- Baid, I.C. 1959b. Occurrence of neoteny in the genus *Artemia*. *Nature*, **184** : 73-75.
- Baid, I.C. 1959c. Some preliminary notes on the insect life in Sambhar Lake. *J. Bombay nat. Hist. Soc.*, **56** (2) : 361-363.
- Baid, I.C. 1962. Ecological studies on crustacean and insect fauna of Sambhar Lake, Rajasthan, with special reference to *Artemia salina* L. Ph.D. Thesis, University of Rajasthan, Jaipur.
- Baid, I.C. 1963. The effect of salinity on growth and form of *Artemia salina*. *J. Exp. Zool.*, **153** : 279-283.
- Baid, I.C. 1964. Some preliminary notes on the crustacean fauna of Sambhar Lake. *Sci and Cult.*, **30** (3) : 153-154.
- Baid, I.C. 1965. The experimental studies in the population of *Artemia salina*, *Naturwissenschaften.*, **52** : 594.
- Baid, I.C. 1966. Survival of *Artemia* in different media. *Mesopotamia*. **1** : 13-17.
- Baid, I.C. 1968. On the development of *Artemia salina* L. *J. Bombay nat. Hist. Soc.*, **64** (2) : 432-439.
- Baid, I.C. 1969. The Arthropod fauna of Sambhar Salt Lake Rajasthan, India. *Oikoassay*, **19** (2) : 292-303.
- Baid, I.C. 1975. Description of a new species of *Branchinella* Sayce from Sambhar Lake, India (Crustacea: Branchiopoda: Anostraca). *J. Bombay nat. Hist. Soc.*, **72** (3) : 786-793.

- Baid, I.C. and Mathur, D.K. 1959. Some observations on the population of *Artemia salina* in Sambhar Lake, Rajasthan. *Proc. National Academy of Sciences, India*, **28** : 416-423.
- Basu, D. and Choudhary, S. 1982. Status of the Gharial in Chambal river (Madhya Pradesh/Rajasthan). In: *Indian Crocodiles: Conservation and Research. Proc. I.* (eds.) L.A.K. Singh and B.C. Choudhury, Indian Crocodile Research Scholars Symposium, Forum of crocodile Researchers, India, pp 7.
- Bhargava, R.N. 1982. Records of the flamingo, *Phoenicopterus roseus* from Rajasthan Desert. *Camel's mouth Newsl. Indian Soc. Desert Tech.*, No. **82** (2) : 5.
- Bhargava, R.N. 1985. Studies on aquatic Hemiptera of lentic habitats around Jodhpur. *Proc. Nat. Sympos. Evalu. Environ.* (Spl. Vol. *Geobios*). (eds.) S.D. Misra, D.N. Sen and I. Ahmad, pp. 318-320.
- Bhargava, S.C. 1984. Ecology and productivity of salt lakes of Rajasthan desert and culturing of brine shrimp *Artemia* for aquaculture. Proc. 2nd An. Workshop on MAB Projects, New Delhi, India. pp. 181-183.
- Bhargava, S.C. and Alam, M. 1980a. Occurrence of *Artemia salina* (Crustacean: Phyllopora) in Didwana Lake, Rajasthan. *J. Bombay nat. Hist. Soc.*, **77** (1) : 158-159.
- Bhargava, S.C. and Alam, M. 1980b. Some limnological features of two saline lakes of Rajasthan. (Abstracted). *5th All India Cong. Zoology Bhopal*, Nov. 80. p. 151.
- Bhargava, S.C. and Alam, M. 1980c. Macrobenthic fauna of Umaid Palace Pond. *Trans. Isdt. and Ucds.*, **5** (2) : 48-50.
- Bhargava, S.C. and Jakher, G.R. 1994. Planktonic composition of two saline lakes. Meeting of Experts on Gaps in Researches on the Faunal Diversity in the Thar Desert. (Abstract) DRS, ZSI. Jodhpur, 3-4 pp.
- Bhargava, S.C., Jakher, G.R., Saxena, M.M. and Sinha, R.K. 1987a. Rearing *Artemia* in a salt pan near Sambhar Lake (India). In: *Artemia Research and its Applications.* : 271-274. Vol. 3. Ecology, Culturing, Use in aquaculture. P. Sorgeloos, D.A. Bengtson, W. Decler and E. Jaspers (eds.). Universa Press, Wetteren, Belgium, 556 pp.
- Bhargava, S.C., Jakher, G.R. Saxena, M.M. and Sinha, R.K. 1987b. Ecology of *Artemia* in Didwana salt lake (India). 127-133. In: *Artemia Research and its Applications.* Vol. 3. Ecology, Culturing, Use in aquaculture. P. Sorgeloos, D.A. Bengtson, W. Decler and E. Jaspers (eds.). Universa Press, Wetteren, Belgium, 556 pp.
- Bhargava, S.C., Jakher, G.R. Saxena, M.M. and Sinha, R.K. 1987c. Laboratory culture and nutritional assessment of *Artemia* from Didwana salt lake (India). 193-198. In: *Artemia Research and its Applications.* Vol. 3. Ecology, Culturing, Use in aquaculture, P. Sorgeloos, D.A. Bengtson, W. Decler and E. Jaspers (eds.). Universa Press, Wetteren, Belgium, 380 pp.

- Bhatt, M.P. and Sapre, R.K. 1969. Crystallization of salt during solar evaporation of Sambhar pan brine. *Salt Research and Industry*, **6** (2) : 32-34.
- Bhatt, M.R. and Hamidani, A.U. 1992. Sambhar bittern evaporite-a source for recovery of sodium sulphate. *Salt Research and Industry*, **37** : 34-35.
- Bhupathy, S. 1989. Status of the freshwater turtles in Keoladeo National Park Bharatpur. Sympos. On *National Resources and their Conservation* organized by the Division of Wildlife Biology, A.V.C. College. Mannampandal, Tamil Nadu, February 1989.
- Bhupathy, S. 1990. Observations on the food of the Ganges soft-shell turtle, *Trionyx gangeticus* in Keoladeo National Park, Bharatpur. *J. Bombay nat. Hist. Soc.*, **87** (3) : 460-461.
- Bhupathy, S. and Vijayan, V.S. 1990. The fresh turtle fauna of eastern Rajasthan. *J. Bombay nat. Hist. Soc.*, **88** (1) : 118-121.
- Bhupathy, S., Vijayan, V.S. and Mathur, R. 1998. Population ecology of migratory waterfowl in Keoladeo National Park, Bharatpur. *J. Bombay nat. Hist. Soc.*, **95** (2) : 287-294.
- Biswas, S. 1964. A new species of the Cladoceran genus *Latona* Straus, 1820 (Crustacea: Cladocera: Sididae) from Rajasthan, India. *Proc. zool. Soc.*, **17** : 149-152.
- Biswas, S. 1965a. Fauna of Rajasthan, India, Part I. Crustacea: Cladocera, *Rec. zool. Surv. India*, **63** (1-4) : 96-139.
- Biswas, S. 1965b. A new species of the genus *Chydorus* Leach, 1843 (Crustacea: Cladocera: Chydoridae) from Rajasthan, India. *Crustaceana*, Leiden, **11** (2) : 113-114.
- Biswas, S. 1971. Fauna of Rajasthan India Part II Crustacea: Cladocera. *Rec. zool. Surv. India*, **63** (1-2) : 95-141.
- Bohra, O.P. 1978. Observations on diurnal rhythm of physico-chemical factors and Zooplankton at Chand Baori, Jodhpur. *Comp. Physiol. Ecol.*, **3** (2) : 91-94.
- Bohra, P., Tak, N., Bhargava, R.N. and Rathore, N.S. 1983. Frogs of the Indian desert with illustrated key to their field identification. *Trans. Isdt. and Ucds.*, **8** (2) : 113-118.
- Bose, B. and Mitra, T.R. 1976. The Odonata Fauna of Rajasthan. *Rec. zool. Surv. India*, **71** : 1-11.
- Chandorikar, M.V. 1968. Recovery of anhydrous sodium sulphate from Sambhar bittern by the floatation process. *Salt Research and Industry*, **5** (1) : 14-16.
- Chattopadhyay, G.S. 1980. Geomorphological review of a part of Mendha river catchment with special emphasis on desertification problem. In: *Arid Zone Research and Development*, (ed.) H.S. Mann, Scientific Publishers, Jodhpur. pp. 31-34.

- Chattopadhyay, G.S. 1982. Sediments of River Mendha. An adventure of humid and arid epoch. Geological Survey of India, Calcutta. 13 pp.
- Chaudhary, B.S. 1970. Golden rules for salt manufacturing. Unpublished mss. Sambhar Salts Ltd, Jaipur.
- Chaudhuri, J.C. and Dave, U.K. 1968. On the odour at Sambhar and Didwana lakes. *Annals Arid Zone*, **7** : 49-54.
- Chaudhary, R.S. 1978. Fish and fisheries of Rana Pratap Sagar. *J. Inland Fish. Soc. India*, **10** : 76-84.
- Chhotani, O.B. and Ray, K.K. 1976. Fauna of Rajasthan, India, Hymenoptera. *Rec. zool. Surv. India*, **71** (1-4) : 13-49.
- Datta, A.K. and Majumdar, N. 1970. Fauna of Rajasthan, India, Part 7 Fishes. *Rec. zool. Surv. India*, **62** (1 & 2) [1964] : 36-100.
- Dayama, O.P. 1988. Ecology of Sambhar lake (Rajasthan). Unpublished mss.
- Deb, M. 1973. Fauna of Rajasthan (India). Crustacea: Ostracoda. *Rec. zool. Surv. India*, **67** [1969] : 233-259.
- De Block, W. 1981. Some waterfowl counts in Gujarat and Rajasthan, India [1980]. Unpublished report.
- Dhabariya, S.S. 1984. Intensification of desertification hazard through Sambhar gap. A problem of environmental degradation in the Indian arid zone. *Proceedings 18th International Symposium on Remote Sensing of Environment, Paris*. 3 pp.
- Dhawan, S. 1967. Fish Fauna of Udaipur lakes. *J. Bombay nat. Hist. Soc.*, **66** (1) : 190-194.
- Dixit, S.C. and Vachna, S.V. 1942. *Serratia sambharianus*. *Current Science*, **11** : 107.
- Dua, P. and Srivastava, P. 1989. *Rhizoclonium*- a new record from Sambhar Lake. *Journal of Phytological Research*, **2** : 103-104.
- Dubey, G.P. and Mehra, R.K. 1962. Fish and Fisheries of Chambal river. *Proc. First All India Cong. Zool. Jabalpur*, pt. **II** : 647-665.
- Durve, V.S. 1976. The fisheries of the lake Jaisamand, Rajasthan. *J. Inland Fish. Soc. India*, **8** : 19-23.
- Durve, V.S. and Kakkar, V.K. 1977. Fishery of selected impoundment around Udaipur. *Proc. All India Seminar on Ichthyology*, **44** : 23-24.

- Durve, V.S. and Kakkar, V.K. 1979. Fishery of Guda reservoir in Bundi district (Rajasthan). *Seafd. Export J.*, **11** (6) : 9-14.
- Durve, V.S. and Rajbanshi, V.K. 1976. Fish mortality and fishing during an unprecedented drought in lake Pichhola, Udaipur. *Indian J. Fish.*, **22** (122) : 297-299.
- Elphinstone, M. 1961. History of India. London, John Murray.
- Emerson, D.B. 1939. Report on the floods of Sambhar Lake. Unpublished report.
- Garg, J.K., Singh, T.S. and Murthy, T.V.R. 1998. Wetlands of India, SAC (ISRO), Ahmedabad. Project Report : RSAM/SAC/RESA/PR/01/98. pp. 1- 239.
- George, J. 1986. Cannibalistic behaviour of freshwater turtles in Keoladeo National Park, Bharatpur, Rajasthan. *J. Bombay nat. Hist. Soc.*, **83** (3) : 670-671.
- Godbole, N.N. 1951. Does Sambhar Lake owe its salts to Rann of Kutch ? *Proceedings of the Rajasthan Academy of Sciences*, Special issue.
- Gohil, S.J. and Joshi, J.M. 1992. Sodium sulphate from Sambhar evaporates by cyclic process. *Salt Research and Industry*, **27** : 206-208.
- Gohil, S.J., Mohandas, V.P., Joshi, J.M., and Sanghavi, J.R. 1988. Sodium sulphate from inland evaporates by conversion reaction process. In : *Geographical Portrait : Proceedings of XIX All Rajasthan Geographical Conference* (ed.) M.L. Sharma, Government Shakambhar College, Sambhar Lake, Rajasthan. pp. 19-25.
- Gole, P. 1984. Some wetlands of ornithological importance in western India. Unpublished report submitted to the XXXth Annual Meeting of the International Waterfowl Research Bureau, Groningen, Netherlands, May 1984.
- Gopal, Brij and Sharma, K.P. 1994. *Ramsar sites of India: Sambhar Lake*. World Wide Fund for Nature, India, New Delhi. pp.1-37.
- Gopala Rao, N. and Durve, V.S. 1988. The probable antagonism in *Brachionus* (Rotatoria) species and Cyanobacteria in a Eutrophic lake of Udaipur, Rajasthan. *J. Environ. Biol.*, **9** (1) : 1-3.
- Gopalarao, N. and Durve, V.S. 1989. Cultural Eutrophication of the lake Rangasagar, Udaipur, Rajasthan, India. *J. Environ. Biol.*, **10** (2) : 127-134.
- Gopalarao, N., Durve, V.S and Sharma, L.L. 1988. Morphometric and bathymetric features of four Udaipur lakes. (Rajasthan, India). *J. Hydrobiol.*, **IV** (1) : 29-31.
- Gupta, R.S. 1972. Blue green algal flora of Rajasthan. *Nova Hedwigia*, **63** : 481-492.
- Gupta, S.N. and Kulshreshta, S.D. 1985. Fish and fishery of the District Jhalawar, Rajasthan. *Intl. J. Acad. Ichthyol.*, **6** : 91-96.

- Hackett, C.A. 1980. Salt Lake in Rajasthan. *Records of the Geological Survey of India.*, **13** : 197.
- Haque, M.N. and Vijayan, V.S. 1988. Food habits of the smooth Indian otter (*Lutra perspicillata*) in Keoladeo National Park, Bharatpur, Rajasthan. First International Asian Otter Symposium, Bangalore. October 1988. Abstract. *Asian Otter Specialist Group Newsletter*, **1** : 17.
- Hauge, W. 1928. Cambridge History of India, Vol. III, Turks and Afghans, Cambridge University Press.
- Hume, A.O. 1878. The birds of a drought. – *Stray Feather*, **7** : 52-68.
- Jackson, P. 1983. Crisis for birds and buffaloes at Bharatpur. Unpublished report.
- Jakher, G.R. 1984. Diurnal rhythm of zooplankton and certain abiotic factors in lake Balsamand (Jodhpur). *Oikoassay*, **1** (1 & 2) : 32-36.
- Jakher, G.R. 1986. Species diversity of macrobenthic fauna in a tropical lake. *Comp. Physiol. Ecol.*, **11** (4) : 217-225.
- Jakher, G.R., Bhargava, S.C. and Sinha, R.K. 1990. Comparative limnology of Sambhar and Didwana lakes (Rajasthan, N.W. India). *Hydrobiologia*, 197: 245-256.
- Jakher, G.R., Dey, T., Misra, S.D. and Bhargava, S.C. 1981. Diurnal variations in Physico-Chemical factors and zooplankton population in Balsamand Lake, Jodhpur. *Geobios*, **8** (3) : 119-122.
- Johal, M.S. 1982. Field key to the fishes of Ganganagar district, Rajasthan. *Res. Bull. Punjab Univ.*, **33** : 43-49.
- Johal, M.S., Chahal, I.S. and Tandon, K.K. 1993. Ichthyofauna of Rajasthan State. *J. Bombay nat. Hist. Soc.*, **90** : 404-411.
- Johal, M.S. and Dhillon, K.S. 1981. Ichthyofauna of Ganganagar district (Rajasthan), India. *Res. Bull. Punjab Univ.*, **32** : 105-107.
- Johal, M.S. and Sharma, K.P. 1986. Fish fauna of Swaimadhopur district, Rajasthan State, India. *Vest. cs. Spolec. Zool.*, **50** : 112-119.
- Karpowicz, Z. 1985. Wetlands in East Asia : A preliminary review and inventory. ICBP Study Report No. 6. Cambridge : International Council for Bird Preservation.
- Katfu, D. and Mohonot, S.M. 1995. A checklist of the winter birds of the Kailana-Bijolai area. Jodhpur. *Newsl. for Birdwatchers*, **35** : 13-15.
- Khatri, T.C. 1986. Diurnal movement of zooplankton in Lakhotia lake. *Rec. zool. Surv. India*, **83** (1-2) : 135-143.

- Khera, S. 1966. Nematodes from the banks of still running water. III *Rogerus rajasthanensis* n.sp. sub family Cyllindrolaiminae and *Monhystrella gracilis* n.sp. Monhysterinae from India. – *Nematologica*, **12** : 403-408.
- Khosla, S.C. 1973. Stratigraphy and microfauna of the Eocene beds of Rajasthan. *J. Geol. Soc. India*, **14** (2) : 142-152.
- Krishna, D and Menon, C.B. 1958. A note on the fishes of Jodhpur (Rajasthan) (In Hindi) *Vijnana Parishad Anusandhan Patrika*, **1** (4) : 207-209.
- Kumar, C.R.A. and Asthana, A. 1993. Fish fauna of Rajasthan. *Indian Review of Life Sciences*, **13** : 133-148.
- Kumar, Sanjeev. 1996a. New Flamingo Breeding ground at Sambhar Lake. *Hornbill*, No. (1) : 26-27.
- Kumar, Sanjeev. 1996b. Conservation of New Breeding grounds of Flamingoes at Sambhar Lake, India. In : *Salim Ali Centenary Seminar on Conservation of Avifauna of Wetlands and Grasslands*, BNHS, Bombay, February 12-15, 1996. Abstract : 45-46.
- Kumar, Sanjeev. 1998. Biodiversity of Sambhar Lake, A Ramsar site and its sustainable development. In : *International Conference on Asian Wetlands*, New Delhi/Bharatpur. January 29-31, 1998. Abstract : 7.
- Kumar, Sanjeev and Bhargava, R.N. 1996. Sambhar Lake–A new Breeding ground of flamingoes in India. *Sanctuary Asia*, **XVI** (2) : 59.
- Kumar, Sanjeev and Rathore, N.S. 1999. Faunal diversity and State of Health of Pichola Lake, Udaipur–A case study. In : *International Conference on Tropical Aquatic Ecosystems : Health, Management and Conservation*, Nainital, India October, 25-30, 1999. Abstract : 86.
- Kushwaha, K.S., Noor, A. and Joshi, F.L. 1975. Investigation on the control of tropical freshwater crab, *Paratelphusa jacquemontii* Rathbun in the Chambal Command area, Kota (Rajasthan, India). Memoir No. 1, *Pesticides Res. Worker's Assoc.*, Rajasthan, pp. 13.
- Lal, P. and Chhipa, M.P. 1988. Problems and prospects of utilization of poor quality waters for irrigation in Jobner tract (tehsil Sambhar). In : *Geographical Portrait: Proceedings of XIX All Rajasthan Geographical Conference* (ed.) M.L. Sharma, 35-42, Government Shakambhar College, Sambhar Lake, Rajasthan.
- Mahajan, C.L., Arora, N.K., Sharma, S.D. and Sharma, S.P. 1982. Protozoan fauna of a wetland ecosystem (Bharatpur Bird Sanctuary) during drought conditions. *Int. J. Ecol. Environ. Sci.*, **7** : 131-138.

- Mahajan, C.L., Sharma, S.P., Sharma, S.D. and Arora, N.K. 1982a. Changes in zooplankton population in a wetland ecosystem due to drought. *Int. J. Ecol. Environ. Sci.*, **7** : 139-143.
- Mahajan, C.L., Sharma, S.D., Sharma, S.P. and Arora, N.K. 1982b. Benthic fauna in a wetland ecosystem (Ghana Bird Sanctuary, Bharatpur) during drought conditions. *Int. J. Ecol. Environ. Sci.*, **7** : 145-148.
- Mahajan, K.K. 1969. Fauna of Rajasthan, India. Part 2.- Protozoa (No. 1). *Rec. zool. Surv. India*, **61** (3 & 4)[1963] : 377- 401.
- Mahajan, K.K. 1971. Fauna of Rajasthan, India. Part 10 Protozoa (No. 2). *Rec. zool. Surv. India*, **63** (1-4) [1965] : 45-76.
- Mahajan, K.K. 1977. Fauna of Rajasthan Protozoa (No. 3). *Rec. zool. Surv. India*. **72** (1-4) : 213-225.
- Mahajan, K.K. and Chandra, M. 1976. Report on a collection of leeches from Rajasthan, India. *Rec. zool. Surv. India*. **71** (1-4) : 143-148.
- Maltby, E. and Turner, R.E. 1983. Wetlands of the world. *Geog. Mag.*, **55** : 12-17.
- Mansukhani, M.R. and Murthy, T.S.N. 1970. Fauna of Rajasthan, India, Part. 6. Amphibia. *Rec. zool. Surv. India*, [1964] **62** (1 & 2) : 51-60.
- Mata Prasad and Mehta, D.J. 1956. Some observations on the Sambhar Lake brine and bitterns. *Chemical Age, India*, **7** (1) : 59-60.
- Mathur, B.B.L. 1952. Notes on fishes from Rajasthan, India. *Rec. Indian Mus.*, **50** (1) : 105-110.
- Mathur, D.S. 1977. On a collection of fishes from Jodhpur District (Rajasthan). *Newslett. zool. Surv. India*, **3** (4) : 158-159.
- Mathur, D.S. and Yazdani, G.M. 1973. Additional record of fish from Jodhpur with a list of species occurring in the district. *Sci and Cult.*, **39** (1) : 87-89.
- Mathur, S.N. and Sidhu, N.S. 1957. Occurrence of Apus (Crustacea: Notostraca) in Pilani, Rajasthan. *J. Bombay nat. Hist. Soc.*, **54** : 961-962.
- McCann, Charles. 1939. The flamingoes (*Phoenicopterus ruber antiquorum* Temmi.) *J. Bomb. nat. Hist. Soc.*, **44** (1) : 12-38.
- Misra, S.D., Bhargava, S.C., Dey, T. and Jakher, G.R. 1981. Seasonal study of zooplankton in Balsamand Lake. *Proc. Symp. Ecol. Anim. Popul. Zool. Surv. India*, Pt. **2**. 19-34.
- Mitre, V. and Saxena, A.K. 1980. Environmental analysis of the Holocene pollen from shallow saline and fresh water depressions in the Rajasthan desert. In : *Arid Zone Research and Development*, (ed.) H.S. Mann, Scientific Publishers, Jodhpur. pp. 35-39.

- Mohan, D., Bhargava, S.C. and Jakher, G.R. 1987. Salinity tolerance of fresh water fish in Sambhar Salt Lake. *Environment and Ecotoxicology*, 295-301.
- Moona, J.C. 1963. Notes on fishes from Bharatpur District Rajasthan. *Rec. Indian Mus.*, **58** (2) : 59-66.
- Mukherjee, R.N. 1968. Visit to Sambhar Lake area for Flamingos in November. *Newsletter for Birdwatchers*, **8** (4) : 9.
- Mukherjee, A.K. 1995. Birds of arid and semi-arid tracts, *Rec. zool. Surv. India, Occ. Paper* No. **142** : 1-303.
- Nahar, N.S. 1984. Algae problem in salt works at Sambhar. Seminar on Salt and Industry in India, 73-77. Hindustan Salts Ltd. Jaipur.
- Nama H.S. 1987. Helminth parasites from freshwater fishes in Rajasthan. *2nd Int. Symp. Ichthyoparasitology*, Sept. 27 Oct. 3, 1987, Tihany. Hungary P. 69 Abt.
- Nayar, C.K.G. 1965. Three new species of Conchostraca (Crustacea: Branchiopoda) from Rajasthan. *Bull. Syst. Zool. Cal.*, **1** : 19-24.
- Nayar, C.K.G. 1968. Rotifer fauna of Rajasthan. *Hydrobiologia*, **31** : 168-185.
- Nayar, C.K.G. 1971. Cladocera of Rajasthan. *Hydrobiologia*, **37** (3-4) : 509-518.
- Pareekh, N.K. 1974. *Esaaeuo Kaa Pahalaa Girjaaghar*. Bhoodarshan. (In Hindi).
- Prasad, M. and Thakur, R.K. 1981. Further additions to the Odonata (Insecta) Fauna of Rajasthan, *Jantu*, **1** : 26-28.
- Rahmani, A.R. 1996. Changing avifauna of the Thar Desert. In: *Faunal Diversity in Thar Desert: Gaps in Research*, (eds.) A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur, India. **32** : 307-323.
- Rahmani, A.R. 1997a. *Wildlife in the Thar*. New Delhi, Worldwide Fund for Nature, India WWF, New Delhi. pp. 1-100.
- Rahmani, A.R. 1997b. The effect of Indira Gandhi Nahar Project on the avifauna of the Thar Desert. *J. Bombay nat. Hist. Soc.*, **92** (2) : 233-266.
- Rahmani, A.R. and Soni, R.G. 1997. Avifaunal changes in the Indian Thar Desert. *J. Arid. Env.*, **36** : 687-703.
- Ramachandran, N.K. and Vijayan, V.S. 1994. Distribution and general ecology of Sarus Crane *Grus antigone* in Keoladeo National Park, Bharatpur, Rajasthan. *J. Bombay nat. Hist. Soc.*, **91** (2) : 211-223.
- Rao, K.S. 1976. Studies on freshwater Bryozoa. IV. The Bryozoa of Rajasthan, India. *Rec. zool. Surv. India*, **69** : 329-345.

- Rao, N.G. and Durve, V.S. 1989. Cultural eutrophication of the lake Rangasagar, Udaipur Rajasthan, India. *J. Environ. Boil.*, **10** (2) : 127-134.
- Rao, N.G. and Durve, V.S. 1992. Structure and dynamics of zooplankton community in lake Rangasagar, Udaipur Rajasthan, India. *J. Environ. Biol.*, **13** (3) : 343-355.
- Rao, N.G., Durve, V.S. and Shrikhande, V.J. 1988. Concept of planktonic species diversity in small water bodies – a case study of lake Rangasagar (Udaipur, Rajasthan). *Acta Hydrochem. Hydrobiol.*, **16** (5) : 517-524.
- Rao, P.S.N. and Chauhan, V.D. 1984. Some aspects of algal growth in Sambhar salt works. *Seminar on Salt Industry in India*, 85-87. Hindustan Salts Ltd, Jaipur.
- Rao, R.J. 1986a. Research on wildlife in the National Chambal Sanctuary Wildlife Institute of India. Unpublished report.
- Rao, R.J. 1986b. Freshwater turtle conservation in National Chambal sanctuary. *Tiger Paper*, **13** (3) : 28-29.
- Rao, R.J. 1991. Conservation management of freshwater turtles in the National Chambal Sanctuary. *J. Ecol. Soc.*, **4** : 43-53.
- Rao, R.J. 1995. Nesting ecology of the Gharial in National Chambal Sanctuary. *Zoo Zen.*, **10** (6) : 1-59.
- Rao, R.J., Hussain, S.A. and Sharma, R.K. 1989. The status and conservation of gangetic dolphin (*Platanista gangetica*) in the National Chambal Sanctuary. *Tigerpaper*, **15** (2) : 6-10.
- Ratnam, B.V. 1943. Algal flora of Sambhar Lake, Ph.D. Thesis. Agra University, Agra.
- Ray, H.C. and Mukherjee, A. 1969. Fauna of Rajasthan, India. Part 3. Mollusca. *Rec. zool. Sur. India*, **61** (3 & 4) [1963] : 403-436.
- Roonwal, M.L. 1969. Fauna of Rajasthan, India, Part. 1. General Introduction, with a list of collecting localities and a bibliography of Rajasthan Zoology. *Rec. zool. Surv. India*, **61** (3-4)[1963] : 291-376.
- Roonwal, M.L. 1982. Fauna of The Great Indian Desert (Past and Present Composition, Zoogeography, Ecology, Biology, Physiology and Conservation). In : *Desert Resources and Technology*, (ed.) Alam Singh, Scientific Publishers and Geotech-Academia, Jodhpur. Vol.1 : 1-86.
- Roy, P.K. 1977. Fresh water fossils from Sambhar. G.I.S. News No. 5. Sept. Oct., 1977.
- Roy, P.K. 1980. Palaeoclimatic aspects in the evolution of the Sambhar salt Lake—a geomorphological review, In: *Arid Zone Research and Development* (ed.) H.S. Mann, Scientific Publishers, Jodhpur. pp. 27-30.

- Roy, T. 1996. The crustacean fauna of the Thar Desert. In: *Faunal Diversity in the Thar Desert: Gaps in Research*. (eds.) A.K. Ghosh, Q.H. Baqri, and I. Prakash, Scientific Publishers, Jodhpur, India. **12** : 107-112.
- Saini, R.R., Nathawat, M.S., Raj, Sanjay and Punia, M. 1989. Mapping sand encroachment and changes in the Mendha River course with Landsat. *ITC Journal*, **2** : 112-114.
- Sangha, H.S. 1998. Flamingo surveys at Sambhar Lake (Rajasthan), India. *Flamingo Specialist Group Newsletter*, **8** : 24-25.
- Sapre, R.K. and Baxi, D.R. 1959. A process for the recovery of sodium chloride, sodium sulphate and sodium carbonate from Sambhar bittern. *Journal of Scientific and Industrial Research*, **18 A** : 430-434.
- Sapre, R.K. and Mehta, D.J. 1955. Colour changes in the algae of Sambhar Lake brine. *Journal of Scientific and Industrial Research*, **14 A** : 494.
- Saxena, M.M. 1984. Commercial fishes, their sale and some economic aspects of the trade in the fish market of Jodhpur (Rajasthan, India). *Intr. J. Acad. Ichthyol.*, **5** : 181-182.
- Saxena, M.M. 1988. A survey of Cyclops (Crustacea: Copepoda) population in some water bodies in Rajasthan in relation to the disease dracontiasis. *Abst. Nat. Sem. Adv. Econ. Zool.*, pp. 93.
- Saxena, M.M. 1996a. Freshwater sponges in the Thar Desert. In: *Faunal Diversity in the Thar Desert: Gaps in Research* (eds.) A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur, India. **4** : 37-41.
- Saxena, M.M. 1996b. Leech fauna of the Thar Desert. In: *Faunal Diversity in the Thar Desert: Gaps in Research* (eds.) A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur, India. **8** : 77-80.
- Saxena, M.M. and Bhargava, S.C. 1980. Macro-benthic fauna of Umaid Place pond, Jodhpur. *Trans. Isdt. and Ucds.*, **5** (2) : 48-50.
- Saxena, M.M. and Bhargava, S.C. 1981. Population ecology of two ponds of Jodhpur (Rajasthan) with special reference to planktonic fauna. *Jantu*, **1** : 6-11.
- Saxena, M.M. and Baskaran, S. 1981. Diurnal rhythm in physical, chemical and zooplanktonic components in a polluted water tank, Gulab Sagar (Jodhpur). *Proc. Nat. Sympos. Eval. Environ. Spl. Vol. Geobios*, 86-90.
- Saxena, V.S. 1989. Wetlands and their management as wildfowl habitats. In: *Wetland Conservation*. (eds.) L.N. Vyas and R.K. Garg, Env. Community Centre, Udaipur. 49-68 pp.

- Scott, D.A. 1989. *A Directory of Asian Wetlands*. IUCN, Gland, Switzerland and Cambridge.
- Seshadri, K. and Buch, S.D. 1958. Elimination of algae in Sambhar Lake brine by chlorination. *Journal of Scientific and Industrial Research*, **17 A** : 455-457.
- Seshadri, K. and Buch, S.D. 1959. Exploitation of Sambhar pan crust. *Journal of Scientific and Industrial Research*, **18 A** : 224-228.
- Seshadri, K. and Datar, D.S. 1969. Byproduct recovery from the saline lakes and alkaline soils, pp. 331-332. In : *Proc. Symposium on Problems of Indian Arid Zone*, Jodhpur, 23rd Nov.–2nd Dec., (1964), Ministry of Education, Govt. of India, New Delhi.
- Seshadri, K. and Langalia, J.K. 1961. Constituents of Sambhar lake brine. *Journal of Scientific and Industrial Research*, **20 D** : 243-244.
- Seshadri, K. and Vyas, R.P. 1960a. Commercial production of sodium sulphate from Sambhar Lake bitterns – Project costs. *Salt Research and Industry*, **5 (9)** : 282-287.
- Seshadri, K. and Vyas, R.P. 1960b. Improved recovery of sodium sulphate from Sambhar bittern by gypsum treatment. *Journal of Scientific and Industrial Research*, **19A**: 321-323.
- Shah, V.H., Parekh, J.M. Susarla, V.R.K.S., Chitnis, U.V. and Bhatt, M.P. 1988. Phase Chemistry of Sambhar Brine. In : *Geographical Portrait : Proceedings of XIX All Rajasthan Geographical Conference* (ed.) M.L. Sharma, 26-34. Govt. Shakambhar College, Sambhar Lake, Rajasthan.
- Sharma, H.S. 1993. Geomorphological aspects of the processes of desertification in the northeastern Rajasthan (India). *Z. Geomorph. N.F., Suppl. Bd.* **87** : 61-69.
- Sharma, K.P. and Johal, M.S. 1982. On the fish and fisheries of Jaisamand Lake, Rajasthan, India. *Vest cs. Spolec. Zool.*, **46** : 56-69.
- Sharma, K.P. and Kulshreshta, S.D. 1991. Fishes and fisheries of Kota district, Rajasthan. *J. Zool. Soc. India*, **33** : 63-70.
- Sharma, K.P., Tyagi, A.P. and Saxena, Ranjana. 1984. Fisheries potential of the Thar Desert, India. *Proc. Sem. Eff. Pest. Aq. Fau.*, : 91-97.
- Sharma, L.L. 1980. Some limnological aspects of Udaipur waters in comparison to selected waters of Rajasthan. Ph.D Thesis from University of Udaipur, Udaipur. pp. 1-251.
- Sharma, M.L. 1970. *Salt industry in Sambhar*. IV academic Conference in Geography, Shramajeevi College, Udaipur. Unpublished mss.
- Sharma, M.L. 1971. *Salt industry of Sambhar*. Bhoodarshan, Udaipur.
- Sharma, M.L. 1974. *Evolution of Sambhar lake salt town*. Bhoodarshan, Udaipur.

- Sharma, M.L. 1978a. Climate and salt production: A geographical appraisal of Sambhar Lake. Unpublished mss.
- Sharma, M.L. 1978b. Impact of fluctuating rainfall on the economy of Sambhar salt source. Unpublished mss.
- Sharma, M.L. 1984. *Sambhar Lake: A study in environmental hazards*. Unpublished mss.
- Sharma, M.L. 1988a. *Geographical Portrait. Proc. of XIX All Rajasthan Geographical Conference*. Sambhar Lake (Rajasthan). 26 to 28th September, 1987. Govt. Shakambhar College, Rajasthan. Rajendra Printers, Jaipur.
- Sharma, M.L. 1988b. *A perspective of Sambhar Lake's geohistory and culture*. Unpublished mss.
- Sharma, M.S. 1980. Studies on Plankton and productivity of Udaipur waters in comparison to the selected waters of Rajasthan. Ph.D Thesis from University of Udaipur, Udaipur. pp. 1-277.
- Sharma, M.S. and Durve, V.S. 1985a. Trophic status and fishery potential of Rajasthan waters *Proc. Nat. Sympos. Evalu. Environ. (Spl. Vol. Geobios)* (eds.) S.D. Misra, D.N. Sen and I. Ahmed [1981], pp. 180-186.
- Sharma, M.S. and Durve, V.S. 1985b. Morphological distribution and behavioural pattern of Zooplankton in Rajasthan waters. *J. Anim. Morphol. Physiol.*, **32** (1 & 2) : 161-170.
- Sharma, S.K. 1997. Freshwater snails of Southern Rajasthan. *J. Bombay nat. Hist. Soc.*, **94** (2) : 433-434.
- Singh, G., Joshi, R.D and Singh, A.B. 1972. Stratigraphic and radiocarbon evidence for the age and development of three salt-lakes deposits in Rajasthan, India. *Quat. Res.*, **2** (4) : 496-505.
- Singh, G., Joshi, R.D, Chopra, S.K. and Singh, A.B. 1974. Late Quaternary history of vegetation and climate of the Rajasthan Desert, India. *Philosophical Trans. Royal Soc. London*, **889** (267) : 467-501.
- Sinha, R. and Panda, S.K. 1997. Sediment-water interaction in a hypersaline lacustrine environment, Sambhar Lake, Rajasthan. In : *National seminar and XIV Convention of Indian Association of Sedimentologists*, 17-19 Dec.'97, University of Madras, Chennai.
- Singh, S. 1988. Geomorphology and desertification in Sambhar Lake region of Rajasthan. In: *Geographical Portrait : Proceedings of XIX All Rajasthan Geographical Conference* (ed.) M.L. Sharma, Government Shakambhar College, Sambhar Lake, Rajasthan. pp. 89-95.

- Soni, R.G. 1994. Checklist of birds of Indira Gandhi Nahar project stage II (Rajasthan). *Indian Forester*, **120** (10) : 929-935.
- Soota, T.D. and Saxena, M.M. 1983. Sponge fauna of some waters of Rajasthan and its ecology. *Trans. Indt. Ucds.*, **8** (2) : 131-133.
- Soota, T.D. and Saxena, M.M. 1984a. Leeches of some waters of Rajasthan and their ecology. *Geobios New Reports*, **3** : 125-127.
- Soota, T.D. and Saxena, M.M. 1984b. Leeches of some waters of the Indian desert and their ecology. *Oikoassay*, **1** (1 & 2) : 29-31.
- Soota, T.D., Baskaran, S. and Saxena, M.M. 1981. Sponges of lake Kailana (Jodhpur) their ecology with a note on role of sponges as indicators of water quality. (Abstract) *Nat. Sympos. Evo. Environ.*, Jodhpur.
- Soota, T.D., Saxena, M.M. and Baskaran, S. 1981. Leeches of arid region of Rajasthan around Jodhpur, and their ecology, (Abstract) *Nat. Sympos. Evo. Environ.* Jodhpur.
- Soota, T.D., Saxena, M.M. and Baskaran, S. 1982. Leeches of arid region around Jodhpur and their ecology. *Geobios New Reports*, **1** : 136 -138.
- Srivastava, G.K. 1988. Fauna of India and Adjacent countries. Dermoptera, **1** : xii + 268. Zoological Survey of India, Calcutta.
- Subba Rao, N.V. 1996. Molluscs in the Thar Desert. In: *Faunal Diversity in Thar Desert: Gaps in Research*, (eds.) A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur, India. **29** : 277-283.
- Subbaramaiah, K. 1965. Tolerance of the common algae of Sambhar Lake to sodium chloride. *Proceedings of the Seminar on Sea, Salt and Plants*, 146-149.
- Subbaramaiah, K. 1968. Life cycle of *Anabaenopsis arnoldii* Aptekari *in vitro*. *Indian Journal Microbiology*, **8** : 59-62.
- Subbaramaiah, K. 1972. The biology of the blue-green algae of the Sambhar Lake salt works. In: *Proceedings of the Symposium on Taxonomy and Biology of Blue-Green Algae*, (ed) T.V. Desikachary. pp. 439-441.
- Subbaramaiah, K. and Doshi, Y.A. 1964a. Salinity levels and the growth of algae in Sambhar Lake. *Salt Research and Industry*, **1 A** : 21 (Abstract).
- Subbaramaiah, K. and Doshi, Y.A. 1964b. Sambhar lake algae. Their culture for manure and organic chemicals. *Salt Research and Industry*, **1** (3) : 41-42.
- Subbaramaiah, K. and Sitakararao, V. 1965. Carotenoid pigments in Sambhar Lake brine and algae. *Indian Journal of Chemistry*, **3** (4) : 185.

- Susarla, V.R.K.S., Parekh, J.M. and Chitnis, U.V. 1991. Recovery of sodium chloride, sodium sulphate and sodium carbonate from Sambhar Lake brine-a theoretical study. *Proceedings of the Indian Academy of Sciences (Chemical Sciences)*, **103** : 9-16.
- Tak, N. 1996. Aquatic beetles of Thar Desert. In: *Faunal Diversity in the Thar Desert: Gaps in Research*, (eds.) A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur, India. **24** : 221-226.
- Tak, N. and Sewak, R. 1987. On the Collection of aquatic beetles (Coleoptera) from Lake Kailana (Jodhpur, India). *Oikoassay*, **4** (2) : 33-38.
- Tank, H.C. 1975. Floods and droughts in Sambhar Lake. Unpublished mss, Sambhar Salts Ltd, Jaipur.
- Tehsin, Raza, 1989. Faunal history of Fatehsagar Lake, Udaipur. In : *Wetland Conservation*. (eds.) L.N. Vyas and R.K. Garg. Environmental Community Centre, Udaipur pp. 109-117.
- Thakur, R.K. 1985. Field notes on the Odonata around lake Kailana Jodhpur (Rajasthan). *Bull. zool. Surv. India*, **7** : 143-147.
- Tewari, D.N. 1994a. Desert Ecosystem. Publ: International Book Distributors, DehraDun, 351 pp.
- Tewari, D.N. 1994b. Mangroves and Wetlands for Conserving Environment. In: *Forest and Environment*. International Book Distributors, Dehradun. pp. 88-99.
- Tiwari, K.K. 1951. Indian species of the genus *Apus* (Crustacea : Branchiopoda) with description of two new species. *Rec. Indian Mus.*, **49** (2) : 197-205.
- Tiwari, K.K. 1958. Diagnosis of a new species of the genus *Branchinella* Sayce (Crustacea: Branchiopoda: Anostraca) from Sambhar Lake, Rajasthan, *J. Bombay nat. Hist. Soc.*, **55** (3) : 585-588.
- Tiwari, K.K. 1962a. New species of conchostraca (Crustacea: Phyllopora) from Rajasthan. *Proc. of 1st All India Congr. Zool.*, (Jodhpur, 1959). Part-2, 180-190 pp.
- Tiwari, K.K. 1962b. Occurrence of fossil penaeid prawn in the Fuller's Earth Deposits of Kapurdi (Barmer district, Rajasthan). *Sci. and Cult.*, **28** : 244-245.
- Tiwari, K.K. 1963. Lower tertiary penaeid shrimps from Kapurdi (Barmer district, Rajasthan; India). *Crustaceana*, **5** : 205-212.
- Tiwari, K.K. 1965. *Branchinella kugenumaensis* (Ishikawa, 1894) (Phyllopora : Anostraca) in Rajasthan, Western India. *Crustaceana*, **9** : 220-222.

- Tiwari, K.K. 1966a. A new species of *Nuculana* Link (Mollusca : Bivalvia) from lower eocene Fuller's Earth Deposit of Kapurdi, Rajasthan (Western India). *Annals and Magazine of Natural History* (Ser.13)., **9** : 161-163.
- Tiwari, K.K. 1966b. A new genus and species of clamp shrimp (Crustacea: Branchipoda: Conchostraca) from the Sambhar Lake, Rajasthan. *Proc. Zool. Soc.*, **19** (1) : 67-76.
- Tiwari, K.K. 1968. A new fossil period fish from lower tertiary Fuller's Earth Deposits of Kapurdi, Barmer district, Rajasthan. *J. Zool. Soc. India*, **20** : 95-103.
- Tiwari, K.K. 1996. Branchiopod crustacea of Rajasthan Desert. In : *Faunal Diversity in the Thar Desert : Gaps in Research*. (eds.) A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur, India. **13** : 113-129.
- Tyagi, B.K. and Miller, P.L. 1991. A note on the Odonata collected in South-Western Rajasthan, India. *Notul. Odonatol.*, **3** (8) : 134-135.
- Vaidya, M.C. 1988. The status of research and development activities on Sambhar Lake. Unpublished mss.
- Vazirani, T.G. 1970. Fauna of Rajasthan India. Part. 5. Aquatic beetles (Insecta: Coleoptera: Dytiscidae). *Rec. zool. Surv. India*, **62** (1 & 2) [1964] : 29-49.
- Vazirani, T.G. 1977. Catalogue of Oriental Dytiscidae. *Rec. zool. Surv. India, Occ. Paper No. 6* : 1-111.
- Venkataraman, K. 1988. Cladocera of Keoladeo National Park, Bharatpur, Rajasthan II. New Records 1. *Moinodaphnia machleayii* (King 1853) and *Bosminopsis deitersi* (Richard, 1895). *J. Bombay nat. Hist. Soc.*, **85** (1) : 229-233.
- Venkataraman, K. 1990. New records of Cladocera of Keoladeo National Park, Bharatpur, III. *J. Bombay nat. Hist. Soc.*, **87** (1) : 166-168.
- Venkataraman, K. 1992a. I. Cladocera of Keoladeo National Park, Bharatpur, and its environs. *J. Bombay nat. Hist. Soc.*, **89** (1) : 17-26.
- Venkataraman, K. 1992b. Cladocera of Keoladeo National Park, Bharatpur-IV. New Records 1. *Camptocercus* CF. *australis* Sars, 1896 and *Indialona globulosa* (Daday, 1898). *J. Bombay nat. Hist. Soc.*, **89** (2) : 140-142.
- Vos, J. 1979. Brine shrimp (*Artemia salina*) inoculation in salt ponds : a preliminary guide for use in Thailand FAO/UNDP : THA/75/008. 15 p.
- Vyas, H.K. 1996. Insect pests in Indira Gandhi Canal region of the Thar Desert. In : *Faunal Diversity in the Thar Desert : Gaps in Research* (eds.) A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur, India. **22** : 203-213.

- Vyas, M.H. Shah, H.N., Vaidya, R.S. Bhatt, J.C. and Sanghavi, J.R. 1988. Recovery of soda ash from Sambhar bittern. In: *Geographical Portrait: Proceedings of XIX All Rajasthan Geographical Conference* (ed.) M.L. Sharma. Government Shakambhar College, Sambhar Lake, Rajasthan. pp. 13-18.
- Vyas, R. 1997. Gharial of Chambal. *Rajasthan Sujas*. **6** (3) : 38. (In Hindi).
- Williams, W.D. 1996. The largest, highest and lowest lakes of the world : Saline lakes. Peter Kilham Memorial Lecture, Sao Paulo, 1995. *Verh. Internat. Verein. Limnol.*, **26** : 61-79.
- Yatiji, Ramchandra. 1974. Sambhar Shetra : *Prakriti Evum Ayurved Kaa Saahcharya. Bhoodarshan*. Unpublished mss. (In Hindi).
- Yazdani, G.M. 1996. Fish diversity in the Thar Desert. In : *Faunal Diversity in the Thar Desert : Gaps in Research* (eds.) A.K. Ghosh, Q.H. Baqri and I. Prakash), Scientific Publishers, Jodhpur, India. **30** : 285-295.



Chapter 2

Limnology

Sanjeev Kumar

Recording Salinity

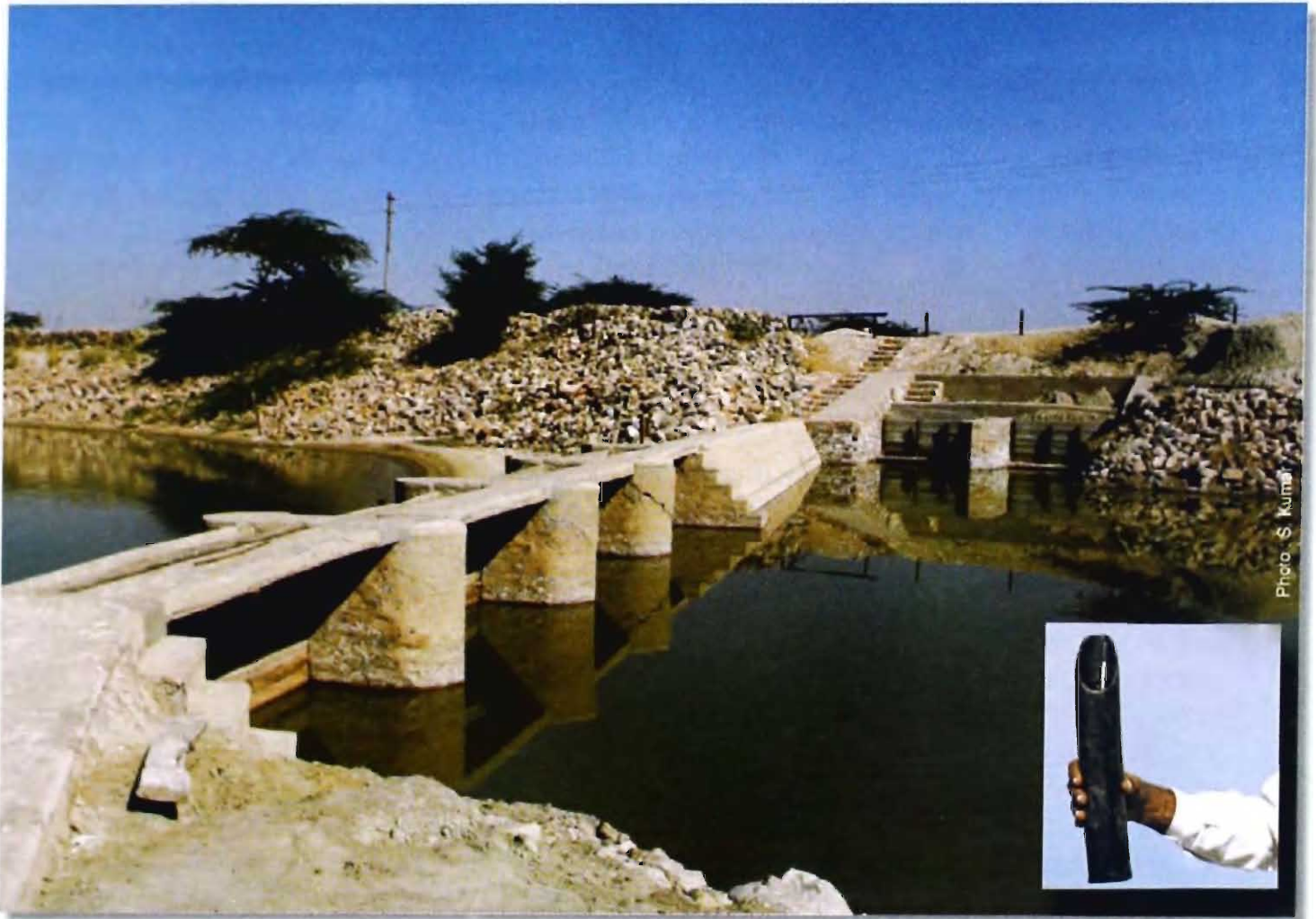


Photo: S. Kumar

INTRODUCTION

Limnology is a century-old science of studying wetlands of any type. It encompasses besides water, physico-chemical nature, biotic interaction and almost all environmental and abiotic entities of earth around it. Being the universal solvent, water plays a vital role due to its polar nature of molecules and therefore absorbs greater amount of ionic material. Due to its high specific heat, it also stabilizes atmospheric temperatures. The movement of water on land after precipitation drains through different ecological land forms gathering lot of organic material and absorbing nutrients to get accumulated in earth's depression both natural and man made.

The science of limnology thus originated deals with the study of different aspects of inland waters, their complex inter-relationships and influence of extra aquatic factors "water quality and biology" The biological opportunities in the lake investigation were first recognized by Forel (1874 -1879). With this beginning, the studies on lakes attracted scientists all over the world. Notable works on limnology were made by Hutchinson (1933 and 1957), Moyle (1946), Driver (1965), Edmondson (1959), Needham and Needham (1962), Welch (1952), Ruttner (1963) and Wetzel (1975). The work on Indian limnology was initiated by Ganapati (1940) on summer pools and temple tanks. Within no time a formidable work on inland freshwater wetlands, comprehensively known as limnology came into existence and worked out well for its contents and its quantum occupancy. But not much attention was paid towards inland saline wetlands and thus these saline ecological habitats remained almost untouched due to their small numbers and unknown nature.

The state of Rajasthan is known for its deserts and therefore considered more dry and waterless zone. But it has fairly large number of wetlands in Central Rajasthan other than long stretches of riverine systems and watersheds especially of perennial nature represented by rivers like the Chambal and the Mahi in south-east and south along with their numerous drier tributaries providing drainage to most of the eastern Rajasthan and the drier Luni and Banas in the east and monsoonal Ghaggar bed in the north. Most of the estimated freshwater potential lies in the south-eastern region of the state and about 0.62 million ha area is occupied in the Thar Desert.

The limnological work on Rajasthan reservoirs have been mainly carried out in last fifteen years or so. Some of the important works are of Das (1960), Das and Srivastava (1956), Srivastava (1956), Seshadri and Vyas (1960a & b), Seshadri and Langalia (1961), Nayar (1965, 1968 and 1971), Chaudhary and Dave (1968), Vyas (1968), Vyas and Kumar (1968), Seshadri and Dartar (1969), Deb (1973), Durve and Rajbanshi (1976), Misra, *et al.* (1975a & b), Bohra (1975a & b, 1976 and 1977a & b), Bohra and Bhargava (1976a & b and 1977), Dashora (1977), Bohra, *et al.* (1978 and 1979), Anon (1980), Khatri (1980 and 1984a, & b), Sharma (1980), Sharma (1980), Jakher, *et al.* (1981), Bhattacharya (1982), Saxena (1982), Sharma and Durve (1982 and 1991), Sharma and Johal (1982), Bhargava and Jakher (1983 and 1987), Dhabariy (1984), Saxena and Bhargava (1984), Sudan, *et al.* (1984),

Sharma, *et al.* (1984), Sharma and Durve (1985a & b), Bhargava and Saxena (1987), Kumar (1987), Rao (1987), Dayama (1988), Davis and Vander (1988), Gopalarao and Durve (1988), Gopalarao, *et al.* (1988), Gupta (1988), Karki (1988), Rao, *et al.* (1988), Shah, *et al.* (1988), Bahura, *et al.* (1989a & b), Dua and Srivastava (1989), Rao and Durve (1989 and 1992), Bahura (1990), Jakher, *et al.* (1990), Sharma and Gupta (1994) and Sharma and Selvaraj (1994).

In the present study, the morphometric data has been taken from the department of irrigation and computed after Wetzel (1975) and the limnological data is based on observations of earlier research carried out on Sambhar Lake by Baid (1962), Alam (1980), Sharma (1980), Sharma (1980) and Jakher, *et al.* (1990). Gopal and Sharma (1994) has remarked that these observation of earlier workers were confined mainly to one sampling point due to inaccessibility and vast expense of the lake making it impracticable to sample water from the entire lake within a short time. Hence, they do not give the account of whole gamut of physico-chemical parameters of the lake but represents only the indicative values of the lake water.

Earlier workers studied the physico-chemical parameters of Sambhar Lake without paying much importance to its existing biological diversity especially the faunal composition. Infact, the biological diversity of the lake should be the most preferred topic of research because it totally depends on the previously described parameters of water *i.e.* physics and chemistry and are key indicators of health of an ecosystem. It is due to this reason emphasis was made in the present study to explore the faunal wealth of Saline Sambhar Wetland.

DESCRIPTION OF STUDY AREA

Sambhar Lake is situated at the periphery of prosaically named Salt Lake City–Sambhar at an altitude of 360 m AMSL in a relatively obscure habitat some 60 Km west of Jaipur at 26° 52' N – 27° 02' N and 74° 54' E – 75° 14' E.

This vast body of glacial saline is somewhat elliptical in shape having its long axis towards east-northeast to west-southwest. The lake basin is spread at the confluence of three districts of Rajasthan namely Jaipur, Nagaur and Ajmer close to the desert fringe line. To the northwest and west of the basin, the Aravali Range rises abruptly to a height exceeding 700 m in the form of hillocks, scattered along northern and southern periphery of the lake. The lake covers a surface area of 190 sq. km with max. length 22.5 km and max. width range 11.2 – 3.2 Km. When full the depth becomes almost 3 m. and average being > 0.61 cms.

This largest playa is located in the gaps of the Aravalli mountain range occupying a depression in the ravines, which is a gateway to the Thar Desert. Though most of the lake basin lies in Jaipur and Nagaur districts and only a small portion in Ajmer district, the lake shares the predominant characteristics of the Thar Desert.

The bed is almost flat with a slope of less than 10 cm per km. The lake basin is divided into two sections by a 5.16 km long stone-earthen dam between the settlements of Jhapok



Photo : 1. Salt Pan area of Sambhar Salt Limited

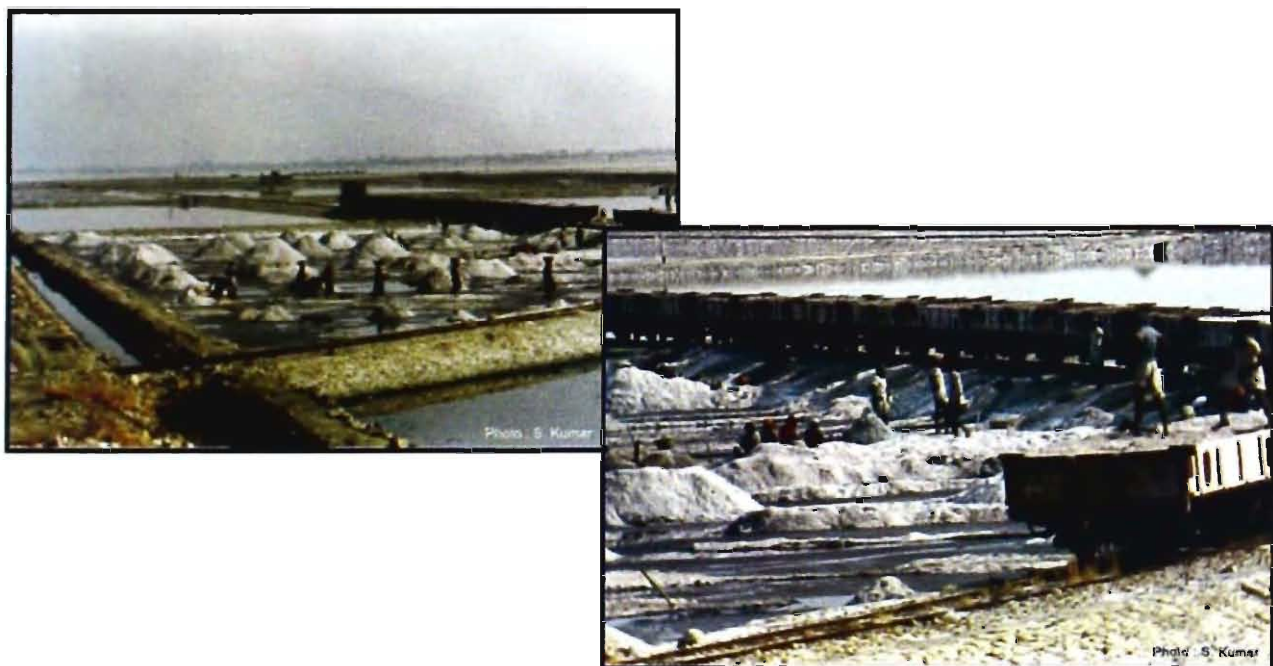


Photo : 2. Salt Production and Transportation by trolley

to the south and Gudha in the north. The western part is a natural undisturbed water spread. The eastern part of the lake contains two large reservoirs for salt extraction, canals and saltpans covering an area of 76.8 sq. km (Photo 1.). When an optimum degree of salinity required for salt extraction is obtained, the water from the vast lustrous western part of the lake is pumped into the other side via sluice salt gates. The saltpans can be approached by the narrow mud bunds that separate them and by indigenously developed rail trolley system, laid by the British for transporting the salt extracted from the saltpans to the processing unit of Sambhar Salt Limited (Photo 2.).

AREA REQUIRED FOR SALT PRODUCTION

The normal lake brine density is 3° to 3.5° Be. The total area (acre) required for the brine to attain density up to 25° Be. and the crystalizers to attain 29° Be is as under :

A	Reservoir	36.0
B	First Stage Condenser	23.0
C	Second Stage Condenser	12.0
D	Third Stage Condenser	12.0
E	Common Salt Crystallizer	11.0
F	Crude Salt or Mother Bitterness Area	0.5
G	Channels, Pathways, Ridges & Embankments	2.0
H	Storage yards	3.5
Total :		100.0

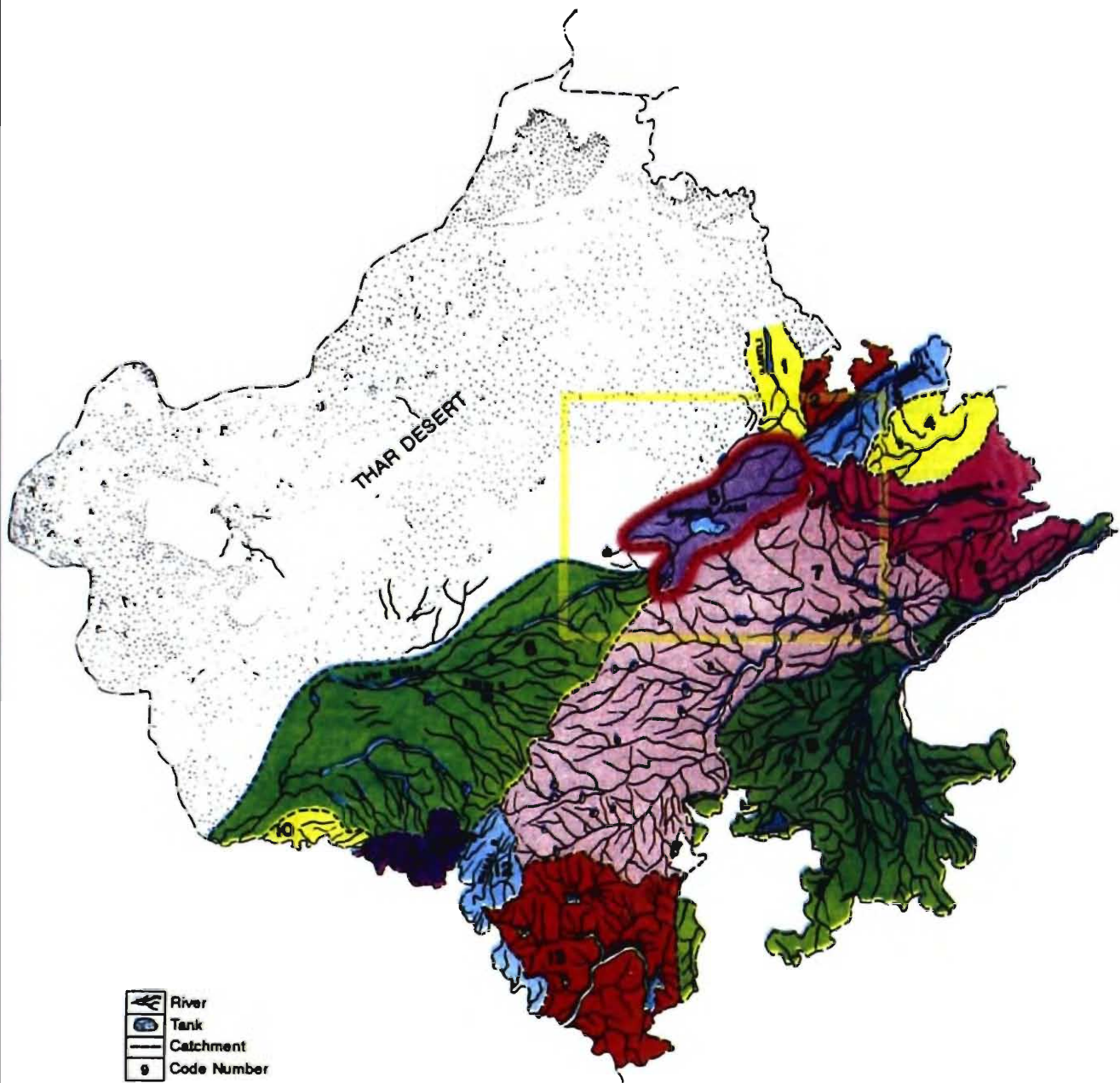
This is clear that only 11% area of the lake could actually be utilized for salt production. Rest other area is used for the condensation and other construction etc. It is all because Sambhar Salts Limited uses lake brine of 3° to 3.5° Be whereas the private salt manufacturers operating in the surrounding area of Sambhar Lake are using subsoil brine of 18° to 20° Be which requires less area for condensation (Aggarwal, 1951).

RIVERS AND THE CATCHMENT

The Sambhar Lake has a vast catchment area encompassing over 7560 sq. km most of which lies to the north and north-east of the wetland extending up to Sikar District of Rajasthan.

Four ephemeral streams **Mendha**, **Rupangarh (=Rupnagar)**, **Kharian** and **Khandel**, numerous rivulets and surrounding surface run-off drains into the lake basin (Fig.1.). The largest feeder river Mendha originates in Sikar district and runs southwest and west and

Fig. 1 : Rivers and Catchment (Inset) of Sambhar Lake



Source : Resource Atlas of Rajasthan, 1994

Total catchment area : 7560 Sq. km	
Source of water	Area
Mendha	3600 sq. km
Rupangarh	625 sq. km
Kharian	724 sq. km
Khandel	-
Numerous Rivulets	-
Surface Runoff	-

enters the lake from the north. The river drains in an area of about 3600 sq. km, which is about half of the catchment of Sambhar Lake. The drainage area of river Mendha is sandy, undulating plain border to the north, west and east by residual projecting hillocks of Aravalli range. Saini, *et al.* (1989) has made remote sensing studies, using Landsat False Colour Composites which shows that river Mendha has changed its course in antediluvian years and in the recent past. The vast catchment is subjected to sand encroachment and land transformation due to agricultural activities. Several paleochannels lie buried beneath the sand *e.g.*, some segments of two major tributaries of Mendha - Anokhi and Ranoli have disappeared under sand during the last two decades. Aeolian processes especially the movement of sand plays a major role in influencing the run-off and river flow entering the lake from catchment area.

It is a popular view that the gaps in the Aravalli also called Sambhar gaps allow the movement of wind blown sands from the west of the range to get deposited in the area causing increase in desertification (Dhabariya, 1984). River Rupangarh rises in the Aravallis in the south near Ajmer city and runs northeast to enter the Sambhar Lake from the south. Its catchment is mostly rocky spread over about 625 sq. kms. The Kharian is a smaller stream entering the lake in the north-west whereas another small ephemeral stream Khandel drains into a limited area to the east of the lake before entry into the lake basin. Several brackish and freshwater man made water bodies are found around the lake namely Devadani (=Devyani) tank to east, large ponds near Jhapok village, Lake Phulera to the south of Sambhar and numerous water bodies along the course of River Mendha. These are generally shallow water bodies attracting a variety of water birds.

SALT ACCUMULATION IN SAMBHAR LAKE

The accumulation of salt is attributed to various streams, which drains into the lake. The rainwater from catchment area of over 2000 sq. miles carries with its solution, the salts from the surrounding area. As compared with other fresh water streams, which normally

do not contain more than 5 parts per million of sodium chloride, these streams carry considerable amount of salts as seen from the salt content in the water of three of the principal feeder streams. The presence of sulphide in these salts is resulting into a pungent odour (Chaudhary and Dave, 1968). The monsoon rainfall in these areas averages about 16 inches. The runoff from these catchment areas in Sambhar Lake may be taken as 10% of the monsoon rainfall. On this basis the salt that can be expected to reach the lake in a year of average monsoon would be via Mendha = 1,22,950 ppt, via Kharia = 30,960 ppt, and via Rupnagar = 3,957 ppt. (Bhatnagar, 1995). These quantities of salt received annually with the surface runoff, thus accounting for almost inexhaustible nature of the Sambhar source.

Salt Accumulation in Sambhar Lake	
Main feeder Streams	Sodium Salt (ppm)
Mendha	1395
Kharian	665
Rupangarh	12
Khandel	77

Baid (1962) observed a maximum salinity of 164 ppt in April (the salinity of sea water averages 35 ppt), whereas Jakher, *et al.* (1990) recorded salinity as high as 267 ppt in May. The lake water is almost fresh just after monsoon registering salinity less than 2 ppt, which gradually increases through the winter season with the inflow of salts and evaporation of water simultaneously. With the drying up of the lake in early summer, salinity rises sharply and salt crystallization starts.

PHYSICO-CHEMICAL PARAMETERS

The water temperature varies from about 13°C in winter to more than 33°C in summer. Due to monsoon flooding and subsequent drying, the other lake water parameters follow a similar trend with low values during the monsoon and a gradual increase through the winter with peak values reached during early summer just before the lakes dries.

The alkalinity or the pH of the lake ranges from 7.5 to 9.5. Carbonate content varies from 35 ppm to 135 ppm, sodium sulphate from 23.2 ppt to 66 ppt, sodium carbonate from 6.6 ppt to 39.4 ppt and sodium chloride content from 8.6 ppt to 146 ppt. The Oxygen concentration in water however declines during summer season (Gopal and Sharma, 1994) or nearly absent during summer (Jakher, *et al.* 1990) and with no deficiency of oxygen concentration near Jhapok-Gudha dam even in summer (Baid, 1962). Repeated floods between 1974 and 1983 resulted in the dilution of the lake brine and the salinity along with the potential for salt production declined (Jakher, *et al.* 1990).

There are contradictory records on the presence of calcium and magnesium in the lake waters. Complete absence of calcium and magnesium was observed due to precipitation of these elements as a result of high alkalinity (Aggarwal, 1951 and Baid, 1962). According to Gopal and Sharma (1994) such observation is not possible as in such conditions growth of algae and other organisms will not take place. However, later calcium (16-80 mg/L) and magnesium (10-117 mg/L) concentrations were recorded by Jakher, *et al.* (1990). It is the case with potassium present in the brine being considered as unique by Shah, *et al.* (1988) and absent by Bhatt and Spare (1969). The presence of potassium (as KCL 51 mg/100ml brine (10.5° Be) was reported by Seshadri and Langalia (1961). The nitrate and phosphorus concentrations were found to increase from 30 µg/L in late winter to 240 µg/L during October 1984 and phosphate values extremely low below 4 µg/L during most of the monsoon and winters respectively.

Sulphur is present in the lake in the form of sodium sulphate producing hydrogen sulphide during anaerobic conditions, giving a characteristic smell. Sulphate concentration in lake was ranging between 250 mg/l and 320 mg/l. Jakher *et al.* (1990).

Natural waters exhibit wide variations in relative acidity and alkalinity, not only in actual pH values but also in the total amount of dissolved materials producing acidity or alkalinity. Three kinds of alkalinities are usually designated in terms of Carbonates (CaCO_3), hydroxide (OH^-), normal Carbonate (CO_3^{--}), bicarbonate (HCO_3^-) and the entire group is summed as total alkalinity. In natural unpolluted waters supporting good fish fauna, the later compounds range from 0 to 350 ppm, with values lying between 45 and 200 ppm. Free Carbon dioxide and bicarbonate are necessary to plant life upon which the fauna depends. Hydroxide alkalinity generally occurs in polluted waters. A mixture of bicarbonate and carbonate alkalinity generally encountered in water of pH ranging from 8.5 to 10.5. Total alkalinity was originally used by Schaperclaus (1933) as a measure of productivity stating that in high productive water, the alkalinity ought to be over 100 ppm. The range of pH of majority of lakes is between 6 and 9. pH range of 7-8 has been considered good for fish culture (Hora and Pillay, 1962).

The saline waters are expected to have more carbonate alkalinity. Driver (1965) reported the values 15.4 to 184 ppm of carbonates for a few saline lakes of Manitoba in Canada. In the famous saline lakes of Rajasthan Sambhar, the value recorded was only 2.5 ppm.

The seasonal variations in limno-chemical parameters are linked with the species composition and life processes of animals and plant communities inhabiting the water body. Davis (1955) considered pH as the most important factor influencing aquatic life. Sharma (1980) states that in Lake Fatehsagar pH is towards alkaline side ranging from 7.4 to 9.2 resembling that of lakes of East Indies (Ruttner, 1963). Such waters have been described as alkaline or calcareous waters on the basis of pH (Wehrle's, 1927). Wide variations in pH from 5.8 to 8.5 (Ranisagar) and 6.4 to 9.5 (Padamasagar) were noticed by Bohra (1977a & b). Low pH in June and high in February was recorded by Srivastava (1956) in Rajasthan waters being just the reverse reported by David, *et al.* (1969), observed high pH during June and low during February. Low pH during monsoon was also noticed for Rajasthan waters (Anon, 1977).

Hutchinson (1957) and Lakshminaryana (1965) established high pH to peak rise in pH indicating high phytoplankton. More phytoplankton means more photosynthesis and utilization of free CO₂. Spence (1964) categorized lakes with more than 60 ppm total alkalinity as nutrient rich. Rich nutrients combined with alkalinity above 80 ppm makes it best fish producers. Atkins (1923) stated that any amount in excess of 0.5 ppm phosphate indicates pollution. Thresh, *et al.* (1944) stated that presence of high chlorides in water indicates pollution of animal origin.

Pollution of salt lakes is yet another anthropogenic activity of wide spread importance, as is the ad hoc spread of exotic biota especially *Artemia* in Global Salt Lakes. But the only exotic saline tolerant *Artemia* sp., which might have been introduced into the Sambhar Lake at the time of Mughals or the British, has vanished completely from Sambhar Lake, where till sixties it was the most dominant faunal component of the lake. The disappearance of this species is indicative of the unpolluted ecological conditions in the past gradually becoming polluted on its own aging phenomenon or anthropogenic impact by the mushrooming up of private salt industries and the anthropogenic activities related to it.

The rich food source and sufficient numbers of waterfowls and waders were the criteria on which Sambhar Lake the India's largest inland Salt Lake was declared a Ramsar site. But, since then its condition is all the more deteriorating due to lack of proper implementation and management of such high declarations and decisions made by administrators. Such declarations are becoming all the more harmful to nature and its existing biota because when it comes into the notice of many ignorant people, they start over exploitation of such opportunities leading to a global threat to important natural heritage site of the country.

Rajasthan water is considered as mainly saline or "Khara" but almost all the water bodies with a normal pH above 7.0, is an indicator of the productiveness of these waters. Sharma and Durve (1985a) have elaborately worked out the high potential of fish production of Rajasthan waters. Being best suited for aquaculture and not surprisingly India's maximum fresh water fish production can be achieved from Rajasthan.

PHYTOPLANKTON

The planktonic microscopic algae are conspicuous but very few in numbers. With the rise in salinity there scale also rises in the early monsoon. Soon after the fresh inundation some blue-green algae of *Nostoc*, *Anabaenopsis*, *Anabaena*, *Arthrospira* and *Diatoms* develops in large population (Pearsall, 1923 and Kant, 1979). With the rise in salinity blooms of *Dunaliella salina* and *Aphanothece halophytica* form thick blue-green scum over the water surface. *Spirulina*, *Oscillatoria*, *Aphanocapsa* and a *Nitzschia* species survive at high salinities (Ratnam, 1943).

ZOOPLANKTON

Zooplankton component of Sambhar Lake is represented mainly by Protozoa, Rotifers and Crustaceas, Insecta being represented by Dipteran larvae and some species of aquatic coleoptera. Hemiptera were also recorded from the lake waters. The chironomid density was

as high as 1845/m². The number increased after the monsoon when the lake is freshly inundated and chloride values drops down. Some of the important studies made in the recent past on Zooplankton of Sambhar Salt Lake are by Tiwari (1951, 1958, 1962, 1965 and 1996), Baid (1958, 1959a, b & c, 1962, 1963, 1964, 1969 and 1975), Mahajan, (1969 and 1971), Biswas (1964, 1965a & b and 1971), Nayar (1965, 1968 and 1971), Deb (1973), Vos (1979), Bhargava and Alam (1980a & b), Sharma (1980), Bhargava (1984 and 1988), Bhargava and Jakher (1987 and 1994), Jakher, *et al.* (1990), Gopal and Sharma (1994) and Roy (1996).

The chironomids were the most predominant among the dipteran larvae. In the evening and late hours of night adults chironomids were observed to form swarms in large numbers gyrating above head. Such type of dominance of benthic chironomid and formation of swarms is well-marked phenomenon of Chironomidae and was also reported in high altitude lakes of the northwest Himalaya (Kumar, 1987).

Due to typical physico-chemical characteristics of the lake, species number is less but their population density is abundant. The species found are mainly high to low salinity tolerant. It is also stated by Allee and Schmidt (1963) that the number of animal species decreases with the increase in salt content. Extra abundance of highly salt tolerant species of crustacea like *B. biswasii* Tewari are found in good numbers may be due to elimination of enemies and less competition for their own survival. Earlier Sharma (1980) has stated that Sambhar Lake is highly productive due to low transparency of water.

SUMMARY

The physico-chemical quotient of Sambhar Lake can be summarized as salinity ranging from 2 to 264 ppt and pH from 7.4 to 9.7. The total annual yield of salt is 2.2 lac tons (1982-83: Sambhar Salt Ltd.) and 1.35 lac tons (1991-92: Sambhar Salt Ltd.).

The death and decay of different algae gives a brown tinge to salt water. The algal blooms which otherwise considered nuisance in salt production is profitably utilized as organic farm manure in agricultural fields fixing nitrogen in the soil as also acting as natural termite control agent. At Sambhar Lake farmers and others collect these algal blooms when dried.

The brine shrimp *Artemia* which once dominated the lake waters was also not reported during the course of studies. The nymphs of Hemiptera were also collected.

ACKNOWLEDGEMENTS

Author is thankful to Dr. J.R.B. Alfred, Director, Z.S.I., Calcutta and Dr. Q.H. Baqri, Additional Director and Officer-in-Charge, Desert Regional Station, Z.S.I., Jodhpur for providing facilities to work on this project of wetland. Thanks are also due to Managing Director, Sambhar Salt Limited for providing data on various parameters of lake, suggestions for biotic assessment and help during the course of our investigation.

REFERENCES

- Aggarwal, S.C. 1951. *Sambhar Lake Salt Source*. Government of India Publication, New Delhi. 365 pp.
- Alam M. 1980. Limnological studies of Sambhar Lake and its reservoir Ph.D. Thesis, Univ. Jodhpur, Jodhpur India. 158 pp.
- Allee, W.C. and Schmidt, K.P. 1963. *Ecological Animal Geography*. 2nd Ed. New York. John Wiley & Sons. Inc. London, 715 pp.
- Anon, 1977. Sixth Annual report of Central Inland Fisheries Research Institute, Barrackpore.
- Anon, 1980. Final report of the ICAR Scheme Hydrobiological and Ichthyological studies on lake Fatehsagar, Rajasthan. 74 pp.
- Atkins, C. 1923. The silicates content of some natural waters and of culture media. *J. Mar. Biol. Asso.*, U.K. **13** : 157.
- Baid, I.C. 1958. On the occurrence of *Artemia salina* in Sambhar Lake, Rajasthan. *Curr. Sci.*, **27** : 58-59.
- Baid, I.C. 1959a. Some observations on the population of *Artemia salina* in Sambhar Lake, Rajasthan. *Proc. National Academy of Sciences, India*. **28** : 416.
- Baid, I.C. 1959b. Occurrence of neoteny in the genus *Artemia*. *Nature* (London), **184** : 75.
- Baid, I.C. 1959c. Some preliminary notes on the insect life in Sambhar Lake. *J. Bombay nat. Hist. Soc.*, **56** (2) : 361-363.
- Baid, I.C. 1962. Ecological studies on crustacean and insect fauna of Sambhar Lake, Rajasthan, with special reference to *Artemia salina* L. Ph.D. Thesis, University of Rajasthan, Jaipur.
- Baid, I.C. 1963. The effect of salinity on growth and form of *Artemia salina*. *J. Exp. Zool.*, **153** : 279-283.
- Baid, I.C. 1964. Some preliminary notes on the crustacean fauna of Sambhar Lake. *Sci and Cult.*, **30** (3) : 153-154.
- Baid, I.C. 1969. The arthropod fauna of Sambhar salt lake Rajasthan, India. *Oikos*, **19** (2) : 292-303.
- Baid, I.C. 1975. Description of a new species of *Branchinella* Sayce from Sambhar Lake, India (Crustacea: Branchiopoda: Anostraca). *J. Bombay nat. Hist. Soc.*, **72** (3) : 786-793.

- Bahura, C.K. Bahura, P. and Saxena, M.M. 1989a. Environmental monitoring of waters of the Indian Desert: Phytoplanktonic productivity in Shivbari temple Tank, Bikaner, with a note on impact of various light wavelengths on it. *Oikoassay*, **6** (2) : 87-91.
- Bahura, C.K. Bahura, P. and Saxena, M.M. 1989b. Environmental monitoring of waters of the Indian Desert: Biotope and Phytoplanktonic community of Shivbari Temple Tank, Bikaner. In: *Perspective in Ecotoxicology* (ed.) N.K. Shastree, Narendra Pub. House, Delhi.
- Bahura, R. 1990. A planktological survey of some water bodies in and around Bikaner (Rajasthan). M.Phil. Dissertation, Dungar College, Bikaner (India). 64 pp.
- Bhargava, S.C. 1984. Ecology and productivity of salt lakes of Rajasthan desert and culturing of brine shrimp *Artemia* for aquaculture. Annual Report, MAB Projects: Department of Environment, Government of India, New Delhi. pp. 86-91.
- Bhargava, S.C. 1988. Ecology of Indian inland saline lakes. II. Primary production in Didwana Lake. *Verhandlungen der internationale Vereinigung fur Limnologie*, **23** : 2217-2220.
- Bhargava, S.C. and Alam M., 1980a. Occurrence of *Artemia salina* (Crustacean: Phyllopora) in Didwana Lake, Rajasthan. *J. Bombay nat. Hist. Soc.*, **77** : 158-159.
- Bhargava, S.C. and Alam, M. 1980b. Some limnological features of two saline lakes of Rajasthan. (Abstracted). *5th All India Cong. Zoology Bhopal*, 151 pp.
- Bhargava, S.C. and Jakher, G.R. 1983. Limnological characteristics of some fresh water lakes of arid region of Western Rajasthan, India. *Proc. XXII Cong. Inter nat. Assoc. of Limnology, Lyon, France*. 383 pp.
- Bhargava, S.C. and Jakher, G.R. 1987. Rearing *Artemia* in a saltpan near Sambhar Lake (India). *Artemia Research Application*. Vol. 3. Ecology, culturing in aquaculture P. Sorgeloos, D.A. Bengtson, W. Declair and E. Jaspers (eds.) Universa Press, Wetteren, Belgium. 556 pp.
- Bhargava, S.C. and Jakhar, G.R., 1994. Planktonic composition of two saline lakes. Meeting of Experts on Gaps in Researches on the Faunal Diversity in the Thar Desert. (Abstract) DRS, ZSI. Jodhpur, 3-4 pp.
- Bhargava, S.C. and Saxena, M.M. 1987. Studies on primary productivity and certain correlative factors in an Indian Desert Reservoir. *Arch. Hydrobiol. Beih (Ergebn. Limnol.)*, **28** : 455-461.
- Bhatnagar, U.S. 1995. Protection of Sambhar Lake as Wetland of International Importance under the Ramsar Convention - Demand of Rajasthan Government for taking over the Sambhar Salt Source. *Sambhar Salt Workers Union*, Letter No: 2-SSWU/95-96/281 to 296: 1-3, Sambhar Lake (Personal Communication).

- Bhatt, M.P. and Spare, R.K. 1969. Crystallization of salt during solar evaporation of Sambhar pan brine. *Salt Research and Industry*, **6** (2) : 32-34.
- Bhattacharya, P. 1982. Mutagenesis and nitrogen fixation studies on salt-tolerant bluegreen algae. Ph.D. Thesis, M. L. Sukhadia University, Udaipur.
- Biswas, S. 1964. A new species of the Cladoceran genus *Latona* Straus, 1820 (Crustacea: Cladocera: Sididae) from Rajasthan, India. *Proc. zool. Soc.*, **17** : 149-152.
- Biswas, S. 1965a. Fauna of Rajasthan, India, Part I. Crustacea: Cladocera, *Rec. zool. Surv. India*, **63** (1-4) : 96-139.
- Biswas, S. 1965b. A new species of the genus *Chydorus* Leach, 1843 (Crustacea: Cladocera: Chydoridae) from Rajasthan, India, *Crustaceana*, Leiden, **11** (2) : 113-114.
- Biswas, S. 1971. Fauna of Rajasthan India Part II Crustacea: Cladocera. *Rec. zool. Surv. India*, **63** (1-2) : 95-141.
- Bohra, O.P. 1975a. Observation on certain hydrological factors of freshwater reservoirs Padamsagar and Rani Sagar, Jodhpur (Raj.). *Geobios*, **2** (2 & 3) : 92.
- Bohra, O.P. 1975b. Freshwater planktons of kailana and two reservoirs of Jodhpur, *Geobios*, **2** (5) : 153.
- Bohra, O.P. 1976. Some aspects of Limnology of Padamsagar and Ranisagar, Jodhpur. Ph.D. Thesis, University of Jodhpur, India.
- Bohra, O.P. 1977a. Abiotic factors, Chlorophyll pigment and primary production in two lakes of Jodhpur. *Geobios*, (3) : 215-216.
- Bohra, O.P. 1977b. Comparative Limnology and Primary Productivity of two adjacent lakes, Padamsagar and Ranisagar, in semiarid region of Rajasthan, India. *C.I.F.E. News Letter*, **11** & **12** : 1-15.
- Bohra, O.P. and Bhargava, S.C. 1976a. Observations on some abiotic components of the Takhat Sagar during winter seasons. *Comp. Physiol. Ecol.*, **1** (1): 35-36.
- Bohra, O.P. and Bhargava, S.C. 1976b. Observations on the diel cycle of abiotic parameters at Jatabera, Jodhpur. *Comp. Physiol. Ecol.*, **2** (3) : 115-118.
- Bohra, O.P. and Bhargava, S.C. 1977. Abiotic factors, Chlorophyll pigment and primary production in two lakes of Jodhpur. *Geobios*, **4** (6) : 215-216.
- Bohra, O.P., Mishra, S.D. and Bhargava, S.C. 1978. Occurrence of thermocline in two lakes of semi-arid region in western Rajasthan, India. *Hydrobiologia*, **59** : 203-211.
- Bohra, O.P., Mishra, S.D. and Bhargava, S.C. 1979. Diurnal variation studies on Nakki lake, Mount Abu, India. *Bio-Research*, **3** : 33-43.

- Chaudhary, J.C. and U.K. Dave. 1968. On the odour at Sambhar and Didwana lakes. *Annals of arid Zone*, **7** : 49-54.
- Das, S.M. 1960. Hydrogen ion concentration, plankton and fish in freshwater eutrophic lakes of India. *Nature*, **191** : 4794.
- Das, S.M. and Srivastava, V.K. 1956. Quantitative studies of freshwater plankton II. Correlation between plankton and hydrobiological factors. *Proc. Nat. Acad. Sci., India*. **26** (4) : 243-254.
- Dashora, M.S. 1977. Algae in water supply of Rajasthan, Ph.D. Thesis, University of Udaipur, Udaipur.
- David, A., Ray, P., Govind, B.V., Rajagopal, K.V. and Banerjee, R.K. 1969. Limnology and fisheries of Tungabhadra Reservoir. *Bull. Cent. Int. Fish. Res. Inst. Barrackpore*, **13** : 188.
- Davis, C.C. 1955. The marine and freshwater plankton. Michigan State Univ. Press, East Lansing, 562 pp.
- Davis, C.B. and Vander, V.A. 1988. Ecology of a semitropical monsoonal wetland in India-The Keoladeo Ghana National Park, Bharatpur, Rajasthan. Final Report. Iowa State Univ. Ames., Iowa.
- Dayama, O.P. 1988. Ecology of Sambhar Lake (Rajasthan) Unpublished.
- Deb, M. 1973. Fauna of Rajasthan (India). Crustacea: Ostracoda. *Rec. zool. Surv. India*, **67** [1969]: 233-259.
- Dhabariya, S.S. 1984. Intensification of desertification hazard through Sambhar gap. A problem of environmental degradation in the Indian arid zone. *Proceedings 18th International Symposium on Remote Sensing of Environment*, Paris. p. 3.
- Driver, E.A., 1965. Limnological aspects of some Saline lakes in West Central Manitoba. *J. Fish. Res. Bd., Canada*, **22** (5) : 1165-1173.
- Dua, P., and Srivastava, P. 1989. *Rhizoclonium sambharianus*. *Current Sci.*, **11** : 107.
- Durve, V.S. and Rajbanshi, V.K. 1976. Fish mortality and fishing during an unprecedented draught in the lake Pichola, Udaipur. *Indian J. Fish.*, **22** : 297-299.
- Edmondson, W.T. 1959. *Freshwater biology*. (2nd Ed.) New York. John Willey and Sons, Inc. pp. xvi + 1-1248.
- Forel, F.A. 1874-1879. Le leman. *Bull. Soc. Vaud. Sci. Nat.*, **13-16** : 1-394.
- Ganapati, S.V. 1940. The ecology of temple tank containing a permanent bloom of *Microcystis aeruginosa* (Kutz.). *J. Bombay nat. Hist. Soc.*, **62** : 65-77.

- Gopal, Brij, and Sharma, K.P. 1994. *Ramsar sites of India: Sambhar Lake*. World Wide Fund for Nature, India, New Delhi. 1-37.
- Gopalrao, N. and Durve, V.S. 1988. The probable antagonism in *Brachionus* (Rotatoria) species and Cyanobacteria in a Eutrophic lake of Udaipur, Rajasthan. *J. Environ. Biol.*, **9** (1) : 1-3.
- Gopalrao, N., Durve, V.S and Sharma, L.L. 1988. Morphometric and bathymetric features of four Udaipur lakes. (Rajasthan, India). *J. Hydrobiol.*, **IV** (1) : 29-31.
- Gupta, M.C. 1988. Some aspects of limnology, primary productivity and Zooplankton of a shallow pond in Udaipur, Rajasthan. M.Sc. (Ag.) thesis, Rajasthan Agricultural University, Bikaner.
- Hora, S.L. and Pillay, T.V.R., 1962. Handbook on fish culture in the Indo-Pacific fisheries region, FAO. *Fish. Biol. Tech. Pap.*, **14** : 203.
- Hutchinson, G.E. 1933. Limnological studies at high altitudes in Ladakh. *Nature*, **132** (3325) : 136.
- Hutchinson, G.E. 1957. A treatise on Limnology, Vol. I. Geography, Physics and Chemistry, New York : *John Wiley & Sons, Inc.* pp. 1015.
- Jakher, G.R., Bhargava, S.C. and Sinha, R.K. 1990. Comparative limnology of Sambhar and Didwana lakes (Rajasthan, India). *Hydrobiologia*, **197** : 245-256.
- Jakher, G.R., Dey. T., Misra, S.D. and Bhargava, S.C. 1981. Diurnal Variations in Physico-Chemical factors and zooplankton population in Balsamand Lake, Jodhpur. *Geobios*, **8** (3) : 119-122.
- Kant, Shashi, 1979. Diatoms as indicators of water quality. *Proc. Symp. Environ. Biol.*, pp. 303-308.
- Karki, S.B. 1988. Studies on limnological aspects of selected water eco-system of Udaipur, India. Ph.D. Thesis. Sukhadia University, Udaipur.
- Khatri, T.C. 1980. Limnological studies of Lakhotia Lake, Pali (Rajasthan). Ph.D. Thesis, University of Jodhpur, Jodhpur (India). 134 pp.
- Khatri, T.C. 1984a. Diurnal fluctuations in physio-chemical parameters during summer season in Lakhotia Lake of Pali (Rajasthan). *Environ. & Ecol.*, **2** : 95-97.
- Khatri, T.C. 1984b. Seasonal variation of Dissolved Oxygen in Lakhotia Lake. *Environ. & Ecology*, **2** (4) : 338-340.
- Kumar, S. 1987. Certain aspects of water quality of lakes—Pichola and Fateh Sagar, Udaipur. M.Sc. Thesis, Rajasthan Agricultural University, Bikaner.

- Kumar, Sanjeev. 1987. Limnological Investigation of Dashauhar Lake (4,200 M. above M.S.L.) with Reference to Insect Fauna (Northwest Himalaya). Ph.D. Thesis, Agra University, AGRA. pp. 1-116, plate I-XXXIV & photos 1-27.
- Lakshminarayana, J.S.S. 1965. Studies on the phytoplankton of river Ganga, Varanasi, India, *Hydrobiologia*, **25** : 119-165.
- Mahajan, K.K. 1969. Fauna of Rajasthan, India. Part 2. Protozoa (No. 1). *Rec. zool. Surv. India*, **61** (3 & 4) [1963]: 377- 401.
- Mahajan, K.K. 1971. Fauna of Rajasthan, India. Part 10. Protozoa (No. 2). *Rec. zool. Surv. India*, **63** (1-4) [1965] : 45-76.
- Mahajan, K.K. 1977. Fauna of Rajasthan Protozoa (No. 3). *Rec. zool. Surv. India*, **72** (1-4) : 213-225.
- Misra, S.D., Bharagava, S.C. and Bohra, O.P. 1975a. Diurnal variation in physico-chemical factors at Padamsagar reservoir during premonsoon period of the year 1974. *Geobios*, **12** : 32-35.
- Misra, S.D., Bharagava, S.C. and Bohra, O.P. 1975b. Diurnal variation in certain hydrological factors and phytoplankton pigments at Padamsagar reservoir, Jodhpur (Raj.). *Trans. Isdt. and Ucds.*, **1** : 18-19.
- Moyle, J. B. 1946. Some indices on lake productivity. *Trans. Amer. Fish. Soc.*, **76** : 322-34.
- Nayar, C.K.G. 1965. Taxonomic notes on the Indian species of *Keratella* (Rotifera). *Hydrobiologia*, **26** : 457-462.
- Nayar, C.K.G. 1968. Rotifer fauna of Rajasthan. *Hydrobiologia*, **31** : 168-185.
- Nayar, C.K.G. 1971. Cladocera of Rajasthan. *Hydrobiologia*, **37** : 509-518.
- Needham, J.C. and Needham, P.R., 1962. A guide to the study of freshwater biology. Holden Day Inc. San Francisco, 106 pp.
- Pearsall, W.H. 1923. A theory of diatom periodicity. *J. Mar. Res.*, **11** : 165-185.
- Rao, N.G. 1987. Synecology of the lake Rangasagar in relation to limnology and eutrophication. Ph.D. Thesis, Sukhadia University, Udaipur, Rajasthan.
- Rao, N.G. and Durve, V.S. 1989. Cultural eutrophication of the lake Rangasagar, Udaipur Rajasthan, India. *J. Environ. Boil.*, **10** (2) : 127-134.
- Rao, N.G. and Durve, V.S. 1992. Structure and dynamics of zooplankton community in lake Rangasagar, Udaipur Rajasthan, India. *J. Environ. Boil.*, **13** (3) : 343-355.

- Rao, N.G., Durve, V.S. and Shrikhande, V.J. 1988. Concept of planktonic species diversity in small water bodies—a case study of lake Rangasagar (Udaipur, Rajasthan). *Acta hydrochemn. Hydrobiol.*, **16** (5) : 517-524.
- Ratnam, B.V. 1943. Algal flora of Sambhar Lake, Ph.D. Thesis. Agra University, Agra.
- Roy, T. 1996. The crustacean fauna of the Thar Desert. In: *Faunal Diversity in the Thar Desert: Gaps in Research*. (eds.) A.K. Ghosh, Q.H.Baqri, and I. Prakash, Scientific Publishers, Jodhpur, India. **12** : 107-112.
- Ruttner, F. 1963. Fundamentals of limnology (Tr. From German, D.G. Frey and F.E.J. Fry) Toronto, University, Press. pp. 295.
- Saini, R.R., Nathawat, M.S., Raj, Sanjay and Punia, M. 1989. Mapping sand encroachment and changes in the Mendha River course with Landsat. *ITC Journal*, **2** : 112-114.
- Saxena, M.M. 1982. Limnological studies of freshwater reservoirs: Sardarsamand. Ph.D. Thesis, Univ. Jodhpur, Jodhpur (India). 122 pp.
- Saxena, M.M. and Bhargava, S.C. 1984. Limnological studies on Sardarsamand reservoir: the phytoplankton. *Oikoassay*, **1** (1 & 2) : 43-46.
- Schaperclaus, W. 1933. Textbook of pond culture: rearing and keeping of carp trout and allied fishes (Tr. F. Hund). *Fish. Leaflet. Wash.*, **311** : 260.
- Seshadri, K. and D.S. Datar, 1969. Byproduct recovery from the saline lakes and alkaline soils, pp. 331-332. In: *Proc. Symposium on Problems of Indian Arid Zone*, Jodhpur, 23rd Nov.–2nd Dec., (1964), Ministry of Education, Govt. of India, New Delhi.
- Seshadri, K. and Langalia, J.K. 1961. Constituents of Sambhar Lake brine. *Journal of Scientific and Industrial Research*, **20 D** : 243-44.
- Seshadri, K. and Vyas, R.P. 1960a. Commercial production of sodium sulphate from Sambhar Lake bitterns—Project costs. *Salt Research and Industry*, **5** (9) : 282-87.
- Seshadri, K. and Vyas, R.P. 1960b. Improved recovery of sodium sulphate from Sambhar bittern by gypsum treatment. *Journal of scientific and Industrial Research*, **19A** : 321-23.
- Shah, V.H., Parekh; Susarla, J.M.; Chitnis, U.V. and Bhatt, M. 1988. Phase chemistry of Sambhar brine. In: *Geographical Portrait: Proceedings of XIX All Rajasthan Geographical Conference* (ed.) M.L. Sharma, Govt. Shakambhar College, Sambhar Lake, Rajasthan. 26-34 pp.
- Sharma, K.P. and Johal, M.S. 1982. On the fish and fisheries of Jaisamand Lake, Rajasthan, India. *Vest. Is. Spoiec. Zool.*, **46** : 56-69.

- Sharma, K.P., Tyagi, A.P. and Saxena, Ranjan. 1984. Fisheries Potential of the Thar Desert, India. *Proc. Sem. Eff. Pest. Aq. Fau.*, 91-97 pp.
- Sharma, L.L. 1980. Some limnological aspects of Udaipur waters in comparison to selected waters of Rajasthan. A Ph.D Thesis from University of Udaipur, Udaipur. pp. 1-251.
- Sharma, L.L. and Durve, V.S. 1982. Limnology vis-a-vis conservation need of lake Fatehsagar, Udaipur. *Poll. Res.*, 1 (1-2) : 25-29.
- Sharma, L.L., and Durve, V.S. 1991. Water clarity of 26 waters of Rajasthan in relation to phytoplankton. *Proc. 2nd Asian fisheries forum, Asian Fisheries Society* (eds.) R. Hirano and I. Hanyu. 915-918 pp.
- Sharma, L.L. and Gupta, M.C. 1994. Some aspects of water quality in a shallow pond of Udaipur, Rajasthan. *Rec. zool. Surv., India*. 94 (2-4) : 395-402.
- Sharma, M.S. 1980. Studies on plankton and productivity of Udaipur waters in comparison to selected waters of Rajasthan. Ph.D. Thesis. University of Udaipur, Udaipur. pp. 1-277.
- Sharma, M.S. and Durve, V.S. 1985a. Trophic status and fishery potential of Rajasthan waters. *Proc. Nat. Sympos. Evalu. Environ.* (Spl. Vol. *Geobios*) (eds.) S.D. Misra, D.N. Sen and I. Ahmed, 1985 (1981), 180 -186 pp.
- Sharma, M.S. and Durve, V.S. 1985b. Morphological distribution and behavioural pattern of Zooplankton in Rajasthan waters. *J. Anim. Morphol. Physiol.*, 32 (1 & 2) : 161-170.
- Sharma, M.S. and Selvaraj, C.S. 1994. Zinc, Lead and Cadmium toxicity to selected freshwater zooplankton. *Poll. Res.*, 13 (2) : 191-201.
- Spence, D.H.N., 1964. The macrophytic vegetation on freshwater lochs, swamps and associated fern. In: *The vegetation of Scotland*. (ed.) J.H. Burnell. Oliver and Boyd, Edinburgh and London. pp. 306-425.
- Srivastava, V.K. 1956. Benthic organisms of a freshwater fish tank. *Curr. Sci.*, 250 : 158-159.
- Sudan, Madhu, Sharma L.L. and Durve, V.S. 1984. Eutrophication of the lake Pichola in Udaipur. Rajasthan. *Poll. Res.*, 3 (2) : 39-44.
- Thresh, J.C. Suckling, E.V. and Beale, J.F. 1944. The examination of water supplies. (ed.) E.W. Taylor, 1949. pp. 6.
- Tiwari, K.K. 1951. Indian species of the genus *Apus* (Crustacea: Branchiopoda) with description of two new species. *Rec. Indian Mus.*, 49 (2) : 197 -205.

- Tiwari, K.K. 1958. Diagnosis of a new species of the genus *Branchinella* Sayce (Crustacea: Branchiopoda: Anostraca) from Sambhar Lake, Rajasthan, *J. Bombay nat. Hist. Soc.*, **55** (3) : 585-588.
- Tiwari, K.K. 1962. New species of Conchostraca (Crustacea: Phyllopoda) from Rajasthan. *Proc. of 1st All India Congr. Zool.* (Jodhpur, 1959). Part-2, pp. 180-190.
- Tiwari, K.K. 1965. *Branchinella kugenumaensis* (Ishikawa, 1894) (Phyllopoda: Anostraca) in Rajasthan, western India. *Crustaceana*, **9** : 220-222.
- Tiwari, K.K. 1996. Branchiopod Crustacea of Rajasthan Desert. In: *Faunal Diversity in the Thar Desert: Gaps in Research.* (eds), A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur. **13** : 113-129.
- Vos, J. 1979. Brine shrimp (*Artemia salina*) inoculation in salt ponds: a preliminary guide for use in Thailand FAO/UNDP: THA/75/008. 15 pp.
- Vyas, L.N. 1968. Studies on phytoplankton ecology of Pichola Lake, Udaipur. *Proc. Symp. Recent adv. Trop. Ecol.*, pp. 334-347.
- Vyas, L.N. and Kumar, H.D. 1968. Studies on the phytoplankton and other algae of Indrasagar tank, Udaipur, India. *Hydrobiologia*, **31** : 421-434.
- Wehrle, E. 1927. *Studien uber Wasserstoffionen koenzentrationsverhattnisse und Besiedung an Algenstandorten in der Umgebung Von Freiburg im Breisgau*, *Z. Bot.*, **19** : 207-287.
- Welch, P.S. 1952. *Limnology*. McGraw Hill book Co., 538 pp.
- Wetzel, R.G. 1975. *Limnology*, W. B. Saunders Company, 743 pp.

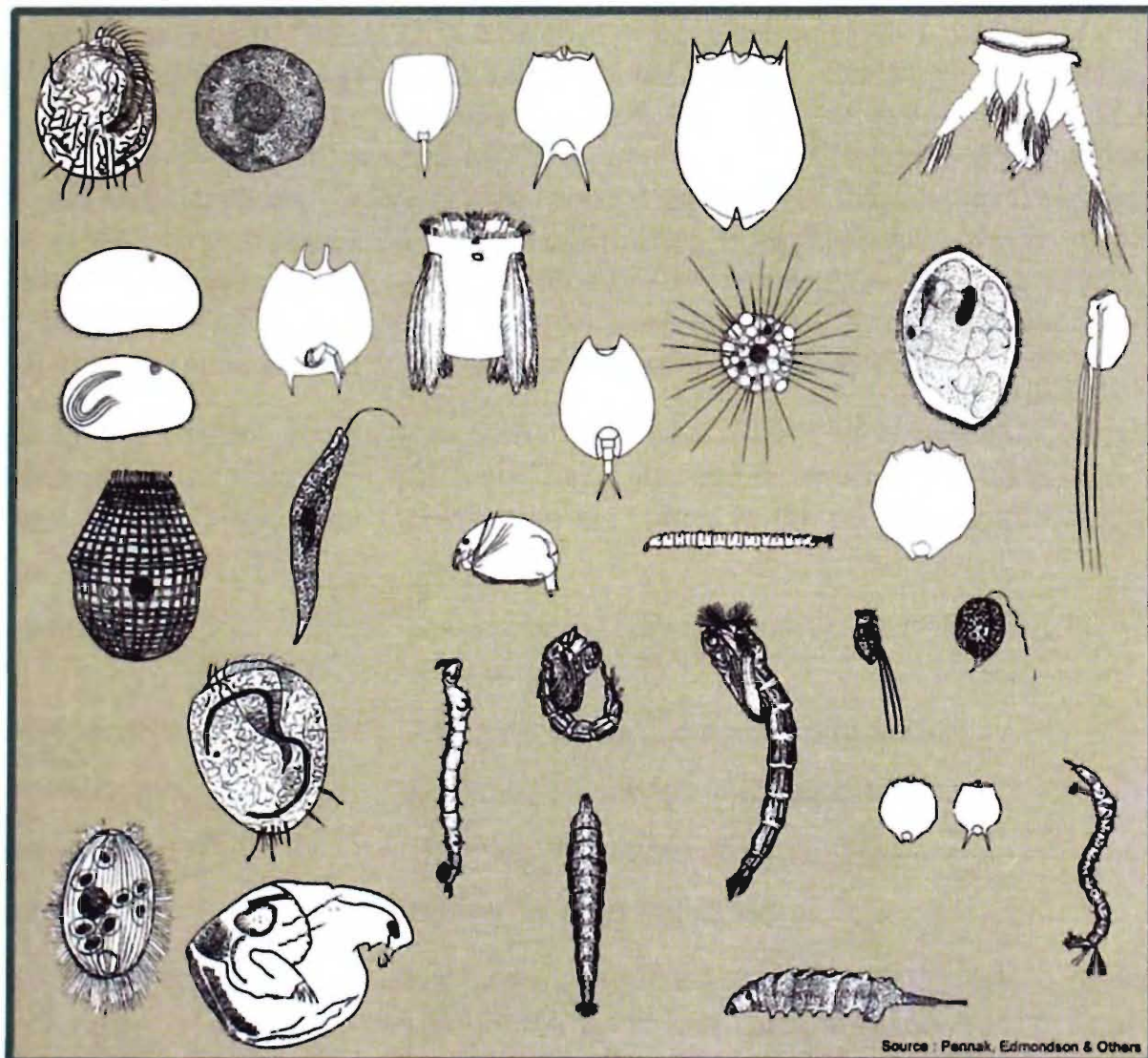


Chapter 3

Zooplankton

Sanjeev Kumar

Zooplankton composition of Sambhar Lake



Source - Pennak, Edmondson & Others

INTRODUCTION

The zooplankton forms the major faunal component of any aquatic ecosystem. They are the secondary producers. The higher hierarchy of animal diversity and their abundance remains entirely dependent on them. The freshwater zooplankton consists mainly of three main groups: The protozoa, the rotifera and the crustacea but in most of the waters, rotifers, limnetic crustaceans, protozoans along with larval insect forms constitutes the dominant component of zooplankton community (Srivastava, 1956). Zooplanktons are considered as good indicators of environmental status, water quality and aquatic productivity (Pejlier, 1983 and Sharma, 1991 & 1999).

Protozoans of Rajasthan were dealt by Mahajan (1969, 1971 and 1977). Whereas, Das (1996) reported the protozoans of the Thar Desert. Planktonic Crustaceans were reported from Sambhar Salt Lake by Tiwari (1951, 1958, 1962, 1965 and 1996), Baid (1958, 1959a, b & c, 1962 and 1969), Deb (1973), Sharma (1980), Sharma (1980), Jakher, *et al.* (1981), Jakher, *et al.* (1990), Bhargava and Jakher (1994), Gopal and Sharma (1994) and Roy (1996). Similarly Biswas (1964, 1965a & b and 1971), Nayar (1971) and Venkataraman (1988, 1990 and 1992a & b) worked on Cladocera; Deb (1973) worked on Ostracods; Nayar (1970) and Gopalarao and Durve (1988) worked on Rotifers from wetlands of Rajasthan. Sharma (1996) have reported 36 species of Rotifers from Rajasthan. Nayar (1965, 1968, 1970 and 1971) have studied seasonal variations of zooplankton, Sharma (1980), Gupta (1988) and Khatri (1992) have studied zooplanktons in general from Rajasthan. Sharma and Selvaraj (1994) studied toxicity in zooplankton from Rajasthan waters.

Among the benthic zooplankton, Sambhar Lake is rich in chironomid larval forms. Benthoses are those organisms, which are found attached or resting or thriving in the bottom sediments Odum (1959). The classification according to the niches occupied by different benthic communities is:

Rhizobenthos	:	Rooted in the substratum but well extended in to aquatic phase
Haplobenthos	:	Attached to an immersed solid surface
Herpobenthos	:	Growing or moving through mud
Psemmon	:	Growing or moving through sand
Endobenthos	:	Boring in solid substrate

Jhingram (1975) divided benthos into zoobenthos and phytobenthos. While phytobenthos along with phytoplankton are the producers in the lake ecosystem, the bottom fauna play a significant role as consumers. These together constitute a food chain (Elton, 1946). The limnological studies of Webb (1965) on Cedar lakes, Manitoba revealed co-relations between

physico-chemical factors and bottom fauna. Sharma (1980) has stated that if an average number of benthic animals exceed $1000/m^2$ than that particular water body harbours high-density bottom fauna. Such high density was recorded by Sharma (1980) in twenty six lake waters during November-December with a maximum chironomids density of $5020/m^2$ in Sambhar Lake. This may be due to dilution of highly saline water owing to monsoon rains. Contrary to this, Srivastava (1956) and Mandal and Moitra (1975) showed minimum benthos during January. Benthic organisms – chironomids were dominating in Sambhar lake in comparison to other (Sharma, 1980). High abundance of chironomids in high altitude lakes has also been reported by Kumar (1987). This high abundance of chironomid is also the indicator of health and productivity of the lake. Whereas less abundance of chironomids in other waters of Rajasthan is indicative that they are being polluted.

Chironomids, annelids and molluscs in Rajasthan waters mainly share the littoral fauna. Similar observations are by David, *et al.* (1969), Gupta (1976) and Mandal and Moitra (1975). But annelids and molluscs were lacking in Sambhar Lake (Sharma, 1980). The species diversity of lake Sambhar is typical of saline nature due to its physico-chemical characteristics. Allee and Schmidt (1963) stated that the number of animal species decreases with increase in the salt content. Least species diversity has been noted by Timms (1967, 1969, 1970, 1972 and 1974) for Australian lakes. The findings of Sambhar Lake correspond to those of Timms (*op. cit.*) and as per the studies of Sharma (1980). More-over the extraordinary abundance of few salt tolerant species in Sambhar Lake may be reasoned for the elimination of enemies and predators as suggested by Allee and Schmidt (1963). The large numbers of chironomids ($1845/m^2$) during present studies were recorded in November, December and January from lake Sambhar may be attributed to the dilution of water following monsoon rains and varied tolerance of fluctuations in salinity.

The present study was undertaken to record the species diversity and population density of zooplankton present in Sambhar Lake. The zooplankton collections were made during six surveys conducted from 1994–1997. The samples were collected with 50 cm diameter ring net made up of bolting silk of mesh size 0.33 mm. The collections were made by hauling the net horizontally for few minutes at different collection spots already planned for sample collection. The collected samples were preserved in 4-5 % neutralized formaldehyde and after processing enumerated by using Sedgewick's rafter counting cell under stereoscopic binocular microscope. Zooplankton numbers were estimated as individuals per litre. All samples were preserved in 4 % formaldehyde solution. Preserved zooplankton samples were examined under a binocular microscope with different magnifications. Taxonomic identification of zooplankton was made after Edmondson (1959), Needham and Needham (1962), Alfred, *et al.* (1973), Mahajan (1969 and 1971), Nayar (1965), Pennak, (1978), Michael and Sharma (1988) and Sharma (1999).

Protozoan, Rotifera, Anostraca, Conchostraca, Cladocera, Ostracoda, Copepoda and various larval forms of insects mainly constituted the zooplankton population of Sambhar Lake waters. Though considerable differences in diversity and density of zooplankton forms were found during different salinity, varying from just alkaline or fresh to highly salt tolerant

species but their species diversity has been recorded as representative faunal elements and density as average population in the lake waters. The saline tolerant fauna was however more predominant. Earlier, eighty-two species of Protozoa were known from Rajasthan out of which only nine species were reported from Sambhar Lake and its vicinity, Mahajan (1969 and 1971) and Tewari (1994). However, Das (1996) reported only 42 species present from the Thar Desert with mention of species collected from Sambhar Lake. A total of sixty-nine crustacean species were reported from Rajasthan waters by Tiwari (1996). Many saline species of Crustacea earlier reported from Sambhar salt lake by Biswas (1964, 1965a and 1971) and Tewari (1994) were later synonymized by Tiwari (1996).

Species marked with + sign were earlier reported from in and around Sambhar Lake and its vicinity such as Kyar near Phulera, Devdani tank, near Sambhar, Jaipur New Kyar Sambhar Lake, Reolai Dani village near Phulera and main Sambhar Salt. Saline brine shrimp earlier reported from Sambhar Lake by Bhargava (1984), Bhargava and Alam (1980), Bhargava and Jakher (1987) and Jakher, *et al.* (1990) was however, absent during the course of present studies.

The present paper reports a total of 13 species of Protozoa, 11 species of Rotifera, 37 species of Crustacea and 3 species of insect larvae from Sambhar Lake (Species marked with *).

Systematic list of free-living zooplankton hitherto recorded from the Sambhar Lake are :

PROTOZOA

Class MASTIGOPHORA

Order DINOFLAGELLIDA

Family PERIDINIIDAE

Genus *Peridinium* Ehrenberg

1. *Peridinium* sp. +*

Order CHRYSOMONADIDA

Family ACTINOPHRYIDAE

Genus *Actinosphaerium* Stein

2. *Actinosphaerium* sp. +*

Genus *Actinophrys* Ehrenberg

3. *Actinophrys* sp. +*

Order EUGLENOIDINA

Family EUGLENIDAE

Genus *Euglena* Ehrenberg

4. *Euglena acus* Ehrenberg *

Class SARCODINA
 Order TESTACEA
 Family ARCELLIDAE
 Genus *Arcella* Ehrenberg

5. *Arcella* sp. +*

Class CILIATA
 Order GYMNOSTOMATIDA
 Family COLEPIDAE
 Genus *Coleps* Nitzsch

6. *Coleps devdaniensis* Mahajan +*

Family TRACHELIIDAE
 Genus *Litonopus* Ehrenberg

7. *Litonopus fasciola* (Ehrenberg) +

Order SUCTORIDA
 Family PODOPHRYIDAE
 Genus *Sphaerophrya* Clapar'ede

8. *Sphaerophrya pusilla* Clapar'ede and Lachmann +*

Order HYMENOSTOMATIDA
 Family CINETOCHILIDAE
 Genus *Cinetochilum* Perty

9. *Cinetochilum margaritaceum* Perty +*

Family COHNILEMBIDAE
 Genus *Cohnilembus* Kahl

10. *Cohnilembus subulatus* (Kent) +*

Family FRONTONIIDAE
 Genus *Frontonia* Ehrenberg

11. *Frontonia atra* (Ehrenberg) *

12. *Frontonia complanata* (Wetzel) *

Order HYPOTRICHIDA
 Family EUPLOTIDAE
 Genus *Euplotes* Ehrenberg

13. *Euplotes pulmipes* Stokes *

14. *Euplotes inkystans* Chatton *

ROTIFERA

Subclass EUROTATORIA

Superorder MONOGONONTA

Order PLOIMIDA

Family BRACHIONIDAE

Genus *Brachionus* Pallas

1. *Brachionus angularis* Gosse +
2. *Brachionus calyciflorus* Pallas +
3. *Brachionus caudatus* Borrois and Daday +*
4. *Brachionus diversicornis* (Daday) *
5. *Brachionus plicatilis* Müller +
6. *Brachionus rubens* Ehrenberg +*

Genus *Keratella* Bory de St.Vincent

7. *Keratella tropica* (Apstein) *
8. *Keratella valga* Ehrenberg +

Genus *Platyias* Haring

9. *Platyias* sp. *

Family COLURELLIDAE

Genus *Lepadella* Bory de St. Vincent

10. *Lepadella patella* (Müller) *

Family LECANIDAE

Genus *Lecane* Nitzsch

11. *Lecane (Luna) luna* (Müller) +*

Family ASPLANCHNIDAE

Genus *Asplanchna* Gosse

12. *Asplanchna* sp. *

Family SYNCHAETIDAE

Genus *Polyarthra* Ehrenberg

13. *Polyarthra* sp. *

Order GNESIOTROCHA

Suborder FLOSCULARIACEA

Family HEXARTHRIIDAE

Genus *Hexarthra* Schmarda

14. *Hexarthra mira* (Hudson) *

Family FILINIDAE

Genus *Filinia* Bory de St. Vincent

- 15.
- Filinia longiseta*
- (Ehrenberg) *

CRUSTACEA

Order ANOSTRACA

Family ARTEMIIDAE

Genus *Artemia* Leach

- 1.
- Artemia salina*
- (Linnaeus) +

Family STREPTOCEPHALIDAE

Genus *Streptocephalus* Baird

- 2.
- Streptocephalus simplex*
- Gurney +*

Family THAMNOCEPHALIDAE

Genus *Branchinella* Sayche

- 3.
- Branchinella biswasi*
- Tiwari +*

Order CONCHOSTRACA

Family CYZICIDAE

Genus *Bairdestheria* Baird

- 4.
- Bairdestheria boysii*
- (Baird) + *

Family CAENESTHERIIDAE

Genus *Eocycticus* Daday (= *Estheria*)

- 5.
- Eocycticus politus*
- (Baird) *

Family LEPTESTHERIIDAE

Genus *Leptestheria* Sars

- 6.
- Leptestheria biswasii*
- Tiwari +

- 7.
- Leptestheria laevis*
- Gurney +

Genus *Leptestheriella* Sars

- 8.
- Leptestheriella sp. prox gigas*
- Karande and Inamdar +*

Genus *Sevellestheria* Sars

- 9.
- Sevellestheria sambharensis*
- Tiwari + *

Order CLADOCERA

Family SIDIDAE

Genus *Latonopsis* Sars

- 10.
- Latonopsis australis*
- Sars *

Genus *Diaphanosoma* Fisher

11. *Diaphanosoma sarsi* Richard *
12. *Diaphanosoma excisum* Sars *

Family DAPHNIIDAE

Genus *Daphnia* Müller

13. *Daphnia carinata* King *
14. *Daphnia lumholtzi* Sars *

Genus *Ceriodaphnia* Dana

15. *Ceriodaphnia cornuta* Sars *
16. *Ceriodaphnia rigaudi* Richard +*

Genus *Scapholeberis* Schoedler

17. *Scapholeberis kingi* Sars *

Genus *Simocephalus* Schoedler

18. *Simocephalus vetulus* (O.F. Müller) +*

Family MOINIDAE

Genus *Moina* Baird

19. *Moina micrura* Kurz +*
20. *Moina macrocopa* (Straus) +*
21. *Moina brachiata* (Jurine) +*

Family MACROTHRICIDAE

Genus *Macrothrix* Baird

22. *Macrothrix spinosa* King +*

Genus *Ilyocryptus* Sars

23. *Ilyocryptus spinifer* Herrick +*

Family CHYDORIDAE

Subfamily CHYDORINAE

Genus *Chydorus* Leach

24. *Chydorus ventricosus* Daday +*
25. *Chydorus reticulatus* Daday +
26. *Chydorus denticulatus* Henry +*

Genus *Dunhevedia* King

27. *Dunhevedia crassa* King +*

Subfamily ALONINAE

Genus *Alona* Baird

28. *Alona pulchella* King *
29. *Alona rectangula richardi* (Stingelin) *
30. *Alona* sp. *

Genus *Leydigia* Kurz

31. *Leydigia acanthocercoides* (Fischer) +*
32. *Leydigia laevis* Gurney +
33. *Leydigia* sp. *

Subclass OSTRACODA

Order PODOCOPA

Family ILYOCYPRIDIDAE

Genus *Ilyocypris* Brady and Norman

34. *Ilyocypris biplicate* (Koch) *

Family CYCLOCYPRIDIDAE

Genus *Physocypris* (Sars)

35. *Physocypris megalops* (Sars) +
36. *Physocypris crenulate* (Sars) +

Family CYPRIDAE

Genus *Cyprinotus* Brady

37. *Cyprinotus megalops* (Sars) +*
38. *Cyprinotus makua* Tressler +*
39. *Cyprinotus gunningi* +*
40. *Cyprinotus ovatus* (Sars) +*
41. *Cyprinotus sulinus* (Brady) +

Genus *Cypris* O.F. Müller

42. *Cypris* sp. +*

Genus *Heterocypris* Brady and Norman

43. *Heterocypris* sp. +*

Genus *Centrocypris* Sars

44. *Centrocypris* sp. +

Genus *Stenocypris* Sars

45. *Stenocypris fulleborni* Daday +

Family CYPRIDOPSIDAE

Genus *Cypridopsis* Brady

46. *Cypridopsis newtoni* Brady and Robertson +

Subclass COPEPODA

Order CALANOIDA

Family DIAPTOMIDAE

Genus *Diaptomus* Westwood

47. *Diaptomus* sp. *

Order CYCLOPOIDA

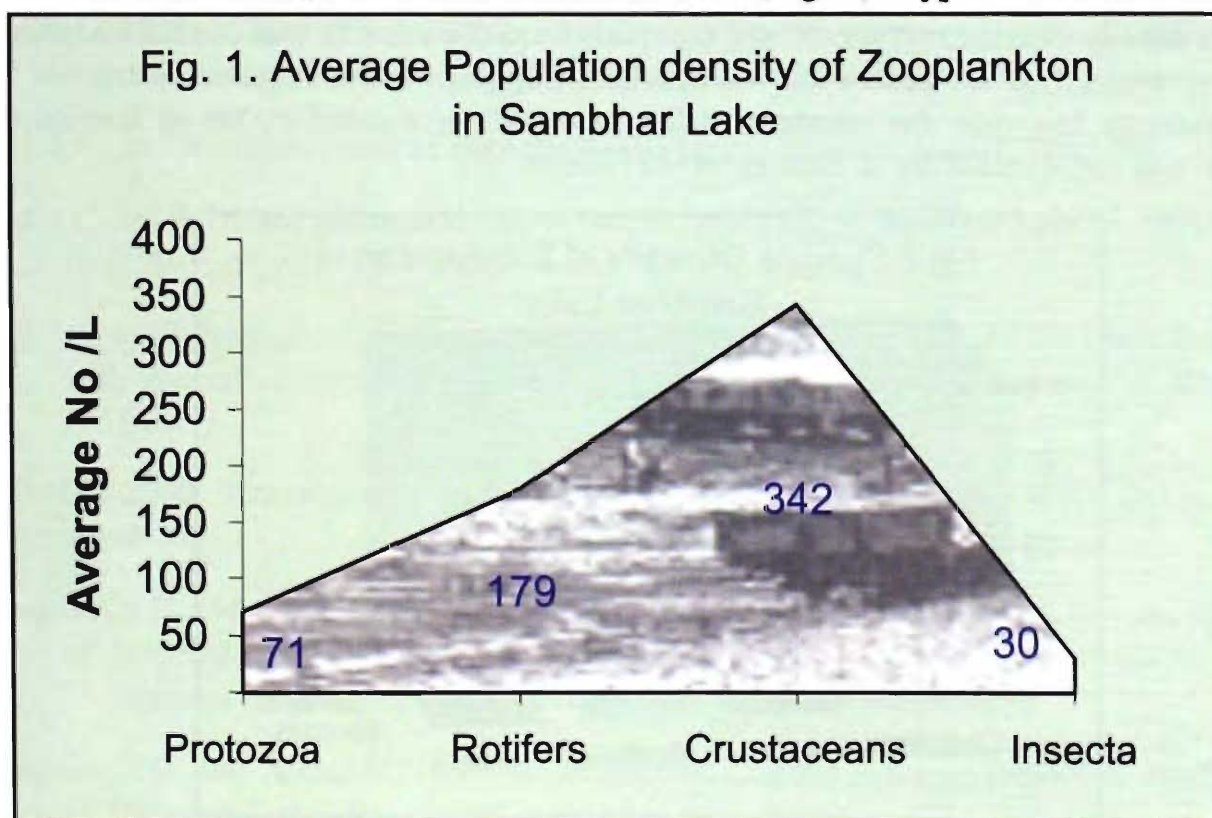
Family CYCLOPIDAE

Genus *Cyclops* O. F. Müller

48. *Cyclops* sp. *

RESULTS AND DISCUSSION

Protozoa were found to be < 71 no./l. Five are reported new to Sambhar Salt Lake. Salinity tolerant rotifers were found with average density 179 no./l. Eight species of rotifers are reported for first time from Sambhar Lake. Eleven species of cladocera are new records from Sambhar Lake. Cladocerans were the most dominant of the Crustaceans (230 no./l) followed in total density after benthic Chironomidae (Fig. 1). Cyprids were also found to



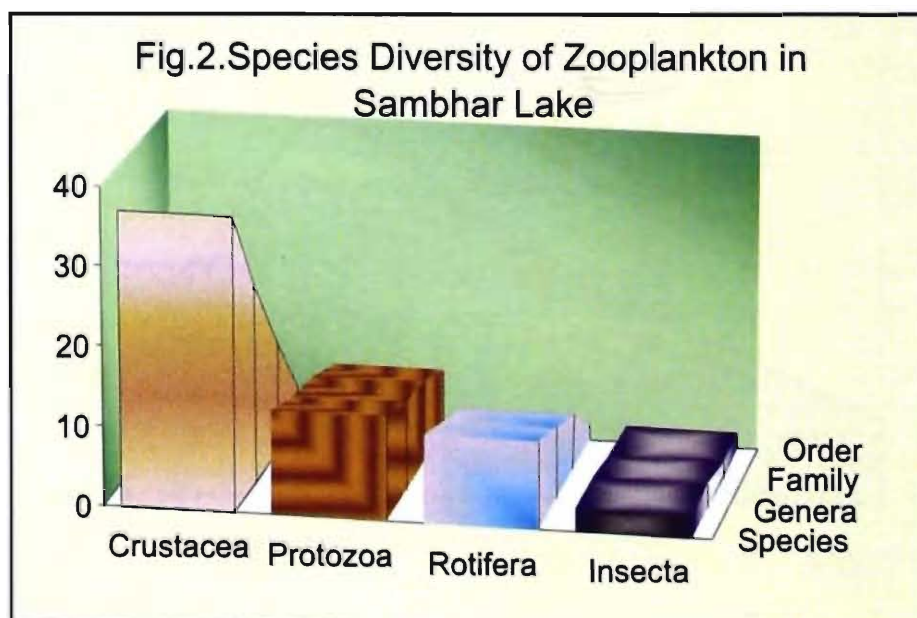
be in sufficient numbers represented by seven species of low to high tolerant salinity < 12 no./l. and hence holds poor and insignificant density in comparison to Cladocera. Copepods were important components of zooplankton mass represented by calanoids, its nauplii and cyclops.

They were regular in occurrence more or less uniformly distributed throughout the lake waters and even dominated certain sampling sites. The population of nauplii (40 no./l.) was found to be more than adult forms (4 no./l.), which were determined mainly as *Diaptomus* sp. The Cyclops were found to be most abundant forms of zooplankton mass regularly occurring in all sampling sites with a uniformly higher density, the average being 56 no./l. Both freshwater and saline species are found in the Sambhar Lake due to variation in the salinity from very low to very high.

The insecta constituted sizeable component of the total zooplankton mass with moderate diversity of 30 no./l. including larvae of Diptera (Chironomidae and Ephydriidae), Hemiptera and nymphs of aquatic beetles.

SUMMARY

Protozoans were well represented by thirteen species. Rotifers were represented by eleven species. (Fig. 2). Cladocerans were the most dominant group of zooplankton reported from Sambhar Lake represented by twenty-two species and thirteen genera belonging to five families. Copepods though an important component of zooplankton mass was represented by two genera under two family regularly occurring throughout the study period. Nauplii were the most regular zooplankton component. Anostraca and Conchostraca though less in average density than the rotifers and the copepods formed a sizeable part of total zooplankton mass represented by six genera and six species belonging to five families. Ostracods were comparatively less than the numbers earlier recorded represented by seven species only. Insecta was represented by a density of 1875/sq.m.



Zooplankton being good indicators of water quality needs detailed systematic studies on various aspects to ascertain their use as indicators and their role in the food web and productivity of an aquatic ecosystem.

ACKNOWLEDGEMENTS

The author is thankful to Dr. J.R.B. Alfred, Director, Zoological Survey of India and Dr. Q.H. Baqri, Additional Director, Desert Regional Station, ZSI, Jodhpur for help to carry out this work. Thanks are also due to Dr. P. Mathur, M.D.S. University, Ajmer for confirming the species identification.

REFERENCES

- Alfred, J.R.B., Bernia, S., Lambert, I.M., Michael, R.G., Rajendran, M., Royan, J.P., Sumitra, V., and Wycliffe, J. 1973. A guide to the study of fresh-water organisms. *J. Madurai Univ. Suppl.*, pp. 185.
- Allee, W.C., and Schmidt. K.P. 1963. *Ecological Animal Geography*, 2nd Ed. New York. John Wiley and Sons. Inc. London, pp. 715.
- Baid, I.C. 1958. On the occurrence of *Artemia salina* in Sambhar Lake, Rajasthan. *Curr. Sci.*, **27** : 58-59.
- Baid, I.C. 1959a. Some observations on the population of *Artemia salina* in Sambhar Lake, Rajasthan. *Proc. National Academy of Sciences, India*. **28** : 416.
- Baid, I.C. 1959b. Occurrence of neoteny in the genus *Artemia*. *Nature*, (London), **184** : 75.
- Baid, I.C. 1959c. Some preliminary notes on the insect life in Sambhar Lake. *J. Bombay nat. Hist. Soc.*, **56** (2) : 361-363.
- Baid, I.C. 1962. Ecological studies on crustacean and insect fauna of Sambhar Lake, Rajasthan, with special reference to *Artemia salina* L. Ph.D. Thesis, University of Rajasthan, JAIPUR.
- Baid, I.C. 1969. The arthropod fauna of Sambhar salt lake Rajasthan, India. *Oikos*, **19** (2) : 292-303.
- Bhargava, S.C. 1984. Ecology and productivity of salt lakes of Rajasthan desert and culturing of brine shrimp *Artemia* for aquaculture. Annual Report, MAB Projects: 86-91. Department of Environment, Govt. of India, New Delhi.
- Bhargava, S.C. and Alam, M. 1980. Occurrence of *Artemia salina* (Crustacean: Phyllopoda) in Didwana Lake, Rajasthan. *J. Bombay nat. Hist. Soc.*, **77** : 158-159.

- Bhargava, S.C. and Jakher, G.R. 1987. Rearing *Artemia* in a saltpan near Sambhar Lake (India). *Artemia Research Application*. Vol. 3. Ecology, culturing in aquaculture P. Sorgeloos, D.A. Bengtson, W. Decler and E. Jaspers (Eds.) Universa Press, Wetteren, Belgium, pp. 556.
- Bhargava, S.C. and Jakhar, G.R. 1994. Planktonic composition of two saline lakes. In: *Meeting of Experts on Gaps in Researches on the Faunal Diversity in the Thar Desert*. (Abstract) DRS, ZSI. Jodhpur, pp. 3-4.
- Biswas, S. 1964. A new species of the Cladoceran genus *Latona* Straus, 1820 (Crustacea: Cladocera: Sididae) from Rajasthan, India. *Proc. zool. Soc.*, **17** : 149-152.
- Biswas, S. 1965a. Fauna of Rajasthan, India, Part I. Crustacea: Cladocera, *Rec. zool. Surv. India*, **63** (1-4) : 96-139.
- Biswas, S. 1965b. A new species of the genus *Chydorus* Leach, 1843 (Crustacea: Cladocera: Chydoridae) from Rajasthan, India. *Crustaceana*, Leiden **11** (2) : 113-114.
- Biswas, S. 1971. Fauna of Rajasthan India, Part II. Crustacea: Cladocera. *Rec. zool. Surv., India*, **63** (1-4) [1965]: 95-141.
- Das, A.K. 1996. Protozoa in the Thar Desert. In: *Faunal Diversity in the Thar Desert: Gaps in Research*. (eds.), A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur, India. **2** : 19-24.
- David, A., Ray, P., Gobind, B.V., Rajagopal, K.V. and Banerjee, R.K. 1969. Limnology and fisheries of Tungabhadra reservoir. *Bull. Cent. Inl. Fish. Res. Inst.*, Barrackpore, **13** : 188.
- Deb, M. 1973. Fauna of Rajasthan (India). Crustacea: Ostracoda. *Rec. zool. Surv. India*, **67** [1969] : 233-259.
- Edmondson, W.T. 1959. Rotifera: In *Fresh-water biology*. (2nd. Ed.) New York. John Wiley and Sons. Inc. pp. xvi + 1-1248.
- Elton, C. 1946. A Limnological study of four lakes near rotoram. *N.Z.J. Mar. Freshw. Res.*, **4** : 165-194.
- Gopal, B. and Sharma, K.P. 1994. *Ramsar sites of India: Sambhar Lake*. World Wide Fund for Nature, India, New Delhi. 1-37.
- Gopalarao, N. and Durve, V.S. 1988. The probable antagonism in *Brachionus* (Rotatoria) species and Cyanobacteria in a Eutrophic lake of Udaipur, Rajasthan. *J. Environ. Biol.*, **9** (1) : 1-3.
- Gupta, M.C. 1988. Some aspects of limnology, primary productivity and zooplankton of a shallow pond in Udaipur, Rajasthan. M.Sc. (Ag.) Thesis, Rajasthan Agricultural University, Bikaner.

- Gupta, S.D. 1976. Macrobenthic fauna of Luni reservoir. *J. Inland Fish. Soc. India*, **8** : 49-59.
- Jakher, G.R., Bhargava, S.C. and Sinha, R.K. 1990. Comparative limnology of Sambhar and Didwana lakes (Rajasthan, India). *Hydrobiologia*, **197** : 245-256.
- Jakher, G.R., Dey, T., Misra, S.D. and Bhargava, S.C. 1981. Diurnal Variations in Physico-Chemical factors and zooplankton population in Balsamand Lake, Jodhpur. *Geobios*, **8** (3) : 119-122.
- Jhingran, V.G. 1975. Fish and Fisheries of India. Hindustan Publ. Corp. (India) : 954 pp.
- Khatri, T.C. 1992. Seasonal distribution of Zooplankton in Lakhotia Lake. *Env. and Ecol.*, **10** : 317-322.
- Kumar, Sanjeev. 1987. Limnological Investigation of Dashauhar Lake (4,200 M. above M.S.L.) with Reference to Insect Fauna (Northwest Himalaya). Ph.D. Thesis, Agra University, AGRA. pp. 1-116, plate I-XXXIV & photos 1-27.
- Mahajan, K.K. 1969. Fauna of Rajasthan, India. Part 2.- Protozoa (No. 1). *Rec. zool. Surv. India*, **61** (3 & 4)[1963] : 377- 401.
- Mahajan, K.K. 1971. Fauna of Rajasthan, India. Part 10 Protozoa (No. 2). *Rec. zool. Surv. India*, **63** (1-4) [1965] : 45-76.
- Mahajan, K.K. 1977. Fauna of Rajasthan Protozoa (No. 3). *Rec. zool. Surv. India*. **72** (1-4) : 213-225.
- Mandal, B.K. and Moitra, S.K. 1975. Studies on the bottom fauna of a freshwater fishpond at Burdwan. *Joun. Inl. Fish. Soc., India*, **7** : 43-48.
- Michael, R.G. and Sharma, B.K. 1988. *Fauna of India, Indian Cladocera (Crustacea: Branchiopoda: Cladocera)*. (ed.) Director, ZSI. Technical and General Press, Director Zoological Survey of India, Calcutta. pp. 257.
- Nayar, C.K.G. 1965. Three new species of Conchostraca (Crustacea: Branchiopoda) from Rajasthan. *Bull. Syst. Zool. Cal.*, **1** : 19-24.
- Nayar, C.K.G. 1968. Rotifer fauna of Rajasthan. *Hydrobiologia*, **31** : 168-518.
- Nayar, C.K.G. 1970. Studies on the rotifer population of two ponds at Pilani, Rajasthan. *J. zool. Soc. India*, **22** : 168-185.
- Nayar, C.K.G. 1971. Cladocera of Rajasthan. *Hydrobiologia*, **37** : 509-518.
- Needham, J.G. and Needham, P.R. 1962. A guide to the study of freshwater biology. Holden Day Inc. San Francisco, 106 pp.

- Odum, E.P. 1959. Fundamentals of ecology, 2nd Ed. W.B. Saunders Co. Philadelphia and London, 546 pp.
- Pejlíer, B. 1983. Zooplankton indicators of trophy and their food. *Hydrobiologia*, **101** : 111-114.
- Pennak, R.W. 1978. Fresh-water Invertebrates of the United States. 2nd Edition. Wiley-Interscience pp. xv + 1-783.
- Roy, T. 1996. The crustacean fauna of the Thar Desert. In: *Faunal Diversity in the Thar Desert: Gaps in Research*. (eds.) A.K. Ghosh, Q.H. Baqri, and I. Prakash, Scientific Publishers, Jodhpur, India. **12** : 107-112.
- Sharma, B.K. 1991. Rotifera. In: Animal Resources of India: Protozoa to Mammals: State of Art. Zoological Survey of India, Calcutta. pp. 69-88.
- Sharma, B.K. 1996. Biodiversity of freshwater rotifers in India: A status report. *Proc. Zool. Soc.*, Calcutta. **49** (2) : 73-85.
- Sharma, B.K. 1999. Freshwater Rotifers (Rotifera: Eurotatoria). In : *State Fauna Series 3: Fauna of West Bengal, Part 1* [1998] : 341-461.(Edited by Published by the Director Zool. Surv. India, Kolkata)
- Sharma, L.L. 1980. Some Limnological aspects of Udaipur waters in comparison to selected waters of Rajasthan. Ph.D. Thesis. University of Udaipur, UDAIPUR. pp. 1-251.
- Sharma, M.S. 1980. Studies on plankton and productivity of Udaipur waters in comparison to selected waters of Rajasthan. Ph.D. Thesis. University of Udaipur, UDAIPUR. pp. 1-277.
- Sharma, M.S. and Selvaraj, C.S. 1994. Zinc, Lead and Cadmium toxicity to selected freshwater zooplankton, *Poll. Res.*, **13** (2) : 191-201.
- Srivastava, V.K. 1956. Benthic organism of a freshwater fish tank. *Curr. Sci.*, **250** : 158-59.
- Tewari, D.N. 1994. *Desert Ecosystem*. Publ: International Book Distributors, Dehra Dun. 1-351 pp.
- Timms, B.V. 1967. Ecological studies on the Entomostraca of a Queensland pond with special reference to *Boeckella minuta* Sars (Copepoda: Calanoida). *Proc. Roy. Soc. Qd.*, **79** : 41-70.
- Timms, B.V. 1969. A limnological survey of the Woolli Lakes, New South Wales. *Proc. Linn. Soc. N. S. W.*, **94** : 105-112.
- Timms, B.V. 1970. Aspects of the Limnology of five small reservoirs in New South Wales. *Proc. Linn. Soc. N.S.W.*, **95** (1) : 46-59.

- Timms, B.V. 1972. Meromictic lake in Australia. *Limnol. Oceanogr.*, **17** (6) : 918-922.
- Timms, B.V. 1974. Morphology and Benthos of three Volcanic Lakes in the Mt. Gambier district, South Australia. *Aust. J. Mar. Freshw. Res.*, **25** : 287-97.
- Tiwari, K.K. 1951. Indian species of the genus *Apus* (Crustacea: Branchiopoda) with description of two new species. *Rec. Indian Mus.*, **49** (2) : 197-205.
- Tiwari, K.K. 1958. Diagnosis of a new species of the genus *Branchinella* Sayce (Crustacea: Branchiopoda: Anostraca) from Sambhar Lake, Rajasthan. *J. Bombay nat. Hist. Soc.*, **55** (3) : 585-588.
- Tiwari, K.K. 1962. New species of Conchostraca (Crustacea: Phyllopoda) from Rajasthan. *Proc. 1st All India Congr. Zool.* (Jodhpur, 1959). Part-2, 180-190 pp.
- Tiwari, K.K. 1965. *Branchinella kugenumaensis* (Ishikawa, 1894) (Phyllopoda: Anostraca) in Rajasthan, western India. *Crustaceana*, **9** : 220-222.
- Tiwari, K.K. 1996. Branchiopod Crustacea of Rajasthan Desert. In: *Faunal Diversity in the Thar Desert: Gaps in Research.* (eds.), A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur. **13** : 113-129.
- Venkataraman, K. 1988. Cladocera of Keoladeo National Park, Bharatpur, Rajasthan II. New Records 1. *Moinodaphnia machleayii* (King 1853) and *Bosminopsis deitersi* (Richard, 1895). *J. Bombay nat. Hist. Soc.*, **85** (1) : 229-233.
- Venkataraman, K. 1990. New records of Cladocera of Keoladeo National Park, Bharatpur, III. *J. Bombay nat. Hist. Soc.*, **87** (1) : 166-168.
- Venkataraman, K. 1992a. I. Cladocera of Keoladeo National Park, Bharatpur, and its environs. *J. Bombay nat. Hist. Soc.*, **89** (1) : 17-26.
- Venkataraman, K. 1992b. Cladocera of Keoladeo National Park, Bharatpur-IV. New Records 1. *Camptocercus* CF. *australis* Sars, 1896 and *Indialona globulosa* (Daday, 1898). *J. Bombay nat. Hist. Soc.*, **89** (2) : 140-142.
- Webb, D.W. 1965. Limnological features of Cedar Lake, Manitoba. *Fish. Res. Bd. Canada*, **21** (5) : 1123-1136.

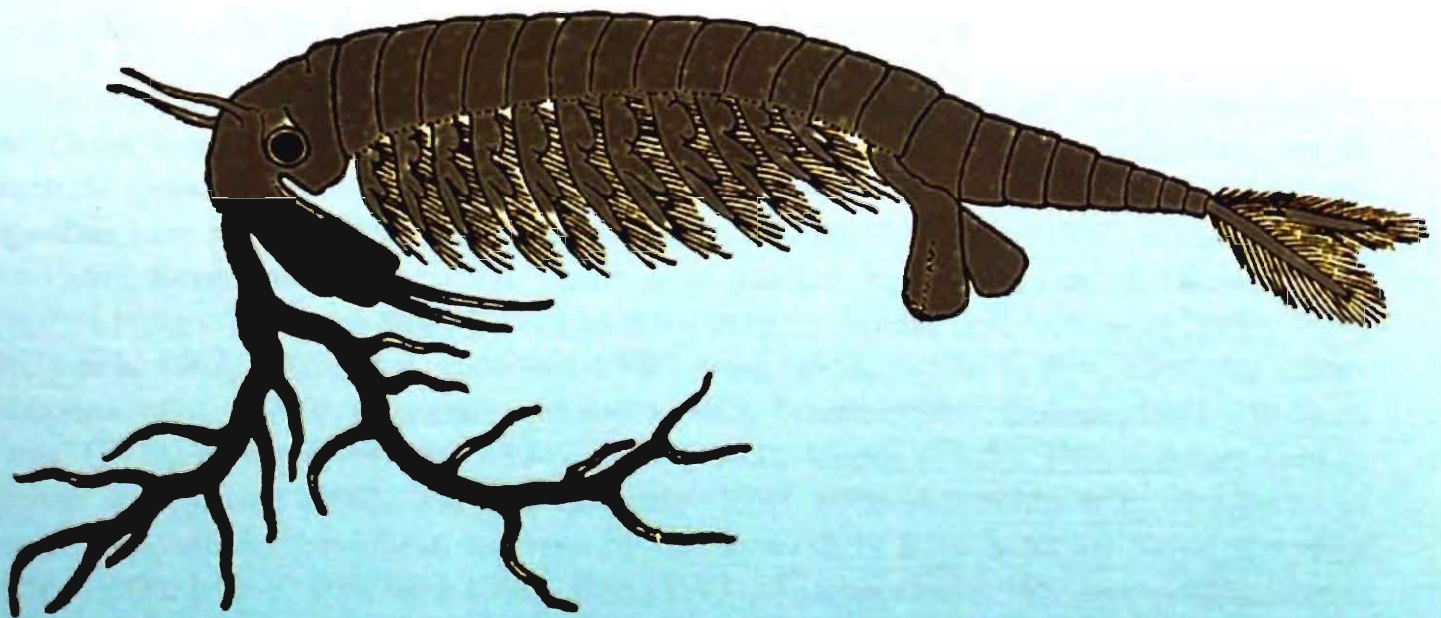


Chapter 4

Crustacea

Sanjeev Kumar

Branchinella biswasi Tiwari - A dominant saline species of Sambhar Lake



INTRODUCTION

Crustaceans are dominant aquatic arthropods, majority being marine or establish themselves in brackish waters with high salinity. They are also a very old group, with fossils back to Cambrian times and still retain many primitive living forms. Though the crustaceans are known from the Cambrian period, but the origin of the group and its phylogenetic relation to mandibulates is not clear. It is assumed that the ancestral crustaceans were small, pelagic animals which had a body consisting of a linear array of similar segments each bearing a pair of biramous appendages which served the functions of food capture, locomotion and respiration. Only the Anostraca among living crustaceans approximate these conditions. The major evolutionary trends in crustaceans have thus been towards increased tagmatization, fusion of segments, specialization of the limbs and with few exceptions benthic existence (Storer, *et al.*, 1983).

The crustaceans found in such harsh arid conditions are representatives mainly of entomostracous crustaceans, which are able to survive prolonged dry spells by development of drought resistant eggs, tough non-permeable eggshell preventing desiccation. These cysts produce new hatchlings with the fresh arrival of water.

Among crustaceans, Branchiopods with several pairs of leaf like respiratory legs are the most dominant in Rajasthan waters both in density and diversity. Sambhar Lake harbours a fairly rich quota of Cladocera having maximum species richness and density, with high tolerance towards variable salinity. The presence of group Anostraca may be of interest to the Palaeontologists in estimating the era and formation of the lake. From this angle also the disappearance of brine shrimp *Artemia salina* from this lake holds tremendous importance.

The work on Crustacea dates backs with fossil records of Ostracoda and Decapoda from "the Great Indian Desert" A total of 69 crustaceans are reported from Rajasthan, out of which 34 species are found in and around Sambhar and its vicinity. Fossil crustaceans from Rajasthan have been dealt by Imprey (1862), Adam (1899), Lindberg (1942), Barooah (1946 and 1950), Jacob and Sastri (1950), Jacob, *et al.* (1952), Kaul (1951) and Lubinova, *et al.* (1960). Living crustaceans from Rajasthan were dealt by Brehm (1951), Tiwari (1951, 1958, 1962a & b, 1963, 1965a & b, 1966 and 1996), Baid (1958, 1959a, b, & c, 1962 and 1969), Subbotina, *et al.* (1960), Glaessner and Rao (1960), Prasad (1961), Biswas (1964, 1965a, & b and 1971), Nayar (1965 and 1971), Deb (1973), Gupta (1975), Ramakrishna (1975), Michael and Sharma (1988) and Venkataraman (1988, 1990 and 1992a & b). A total of 27 species of Crustacea have been reported by earlier workers from Sambhar Salt Lake: Baid (1958, 1959a, b & c, 1962 and 1969), Deb (1973), Sharma (1980), Sharma (1980), Jakher, *et al.* (1981), Jakher, *et al.* (1990), Bhargava and Jakher (1994), Gopal and Sharma (1994), Roy (1996) and Tiwari (1958 and 1996). The present paper records a total of thirty-seven species from Sambhar Lake.

The present study was undertaken to record the species diversity of crustaceans present in Sambhar Lake. The collections were made during six surveys conducted from July, 1994 to January, 1997. The samples were collected with 50 cm diameter ring net made up of bolting silk of very fine mesh size. The collections were made by hauling the net horizontally for few minutes at different collection spots already planned for such collection. The collected samples were preserved in 4-5 % neutralized formaldehyde for identification. The following species were recorded from Sambhar Lake except *Artemia salina* of which review is discussed under remarks.

SYSTEMATIC ACCOUNT

Class CRUSTACEA

Subclass BRANCHIOPODA

Order ANOSTRACA

Family ARTEMIIDAE

Genus *Artemia* Leach, 1819

Artemia salina (Linnaeus) 1758+

Remarks : Swarms of *Artemia salina* (brine shrimp) appear with the rise in salinity and survive till the water becomes brine and becomes absent when the lake is inundated in rainy season being almost fresh. This species was in abundance in fifties and sixties as mentioned by the works of ZSI scientists who surveyed the area in those times. Later the complete disappearance of *Artemia* from Sambhar was reported by Alam (1980), which was further supported by Jakher, *et al.* (1990) and Bhargava and Jakher (1994) who reported its absence from Sambhar Lake. However, its presence in another saline lake Didwana was reported by Gopal and Sharma (1994) and Jakher, *et al.* (1990). The reasoned assigned mentions that due to the heavy floods in 1970 and sudden change in the alkalinity of the Saline Lake the *Artemia salina*, brine shrimp which was observed in plenty once in the past has disappeared and yet not recolonized in the lake even after attempts being made to reintroduce it artificially. Bhargava, *et al.* (1987) recommended to the extend that rearing of *Artemia* in such salt pans is not possible due to high evaporation rate causing a rapid increase in salinity which in turn results in low levels of dissolved oxygen and also the major cause of disappearance of *Artemia salina*.

In the present studies, *Artemia salina* was not found in the lake though many and vigorous attempts were made throughout the lake when inundated. The disappearance of *Artemia salina*, the only salt tolerant species of fresh water genus *Artemia*, from Sambhar Lake is a matter of serious biological concern and needs detailed taxo-ecological studies as this is a species characteristic of saline lakes universally and well adapted to sustain and over come the adverse climatic conditions by the formation of hard walled cysts.

SYSTEMATIC ACCOUNT

Family STREPTOCEPHALIDAE

Genus *Streptocephalus* Baird, 1852*Streptocephalus simplex* Gurney, 1907 + *

Remarks : Common in tanks and ponds in Sambhar with low salinity.

Family THAMNOCEPHALIDAE

Genus *Branchinella* Sayche, 1903*Branchinella biswasi* Tewari, 1958 + *

Remarks : Common in Sambhar Lake, Rajasthan. Also reported from Didwana Lake Rajasthan. It is a freshwater genus with high salt tolerant capacity.

The family of Artemiidae to which *Artemia* belongs might be in close affinity with family Thamnocephalidae taxonomically as both are high salt tolerant species. This species also resembles to *B. ornata* of South Africa.

Order CONCHOSTRACA

Family CAENESTHERIIDAE

Genus *Eocycticus* Daday, 1915 (= *Estheria*)*Eocycticus politus* (Baird, 1850) *

Family CYZICIDAE

Genus *Bairdestheria* Raymond, 1946*Bairdestheria boysii* (Baird, 1850) + *

Remarks : It is found when the water in the Lake is almost fresh. This species was only recorded in 1994-1995.

Family LEPTESTHERIIDAE

Genus *Leptestheriella* Sars, 1898*Leptestheriella sp. prox. gigas* Karande and Inamdar, 1960 + *

Remarks : A species surviving well till the salinity is low. Abundant in Sambhar Lake.

Family LEPTESTHERIIDAE

Genus *Leptestheria* Sars, 1898

Leptestheria biswasii Tiwari, 1965 +

Leptestheria laevis Gurney +

Remarks : Not recorded.

Genus *Sevellestheria* Sars, 1898

Sevellestheria sambharensis Tiwari, 1966 + *

Remarks : It is a species, which has a short life cycle and survives well in Sambhar Lake in abundance.

Order CLADOCERA

Family SIDIDAE

Genus *Latonopsis* Sars, 1888

Latonopsis australis Sars, 1888 *

Remarks : In abundance at Gudha Kyars. Collected from the lake in the month of July 1995.

Genus *Diaphanosoma* Fisher, 1850

Diaphanosoma sarsi Richard, 1894 *

Diaphanosoma excisum Sars, 1885 *

Remarks : A fresh water form collected from main Sambhar lake area.

Family DAPHNIDAE

Genus *Daphnia* Müller, 1785

Daphnia carinata King, 1853 *

Daphnia lumholtzi Sars, 1885 *

Remarks : Collected from the lake in the month of July 1995.

Genus *Ceriodaphnia* Dana, 1853

Ceriodaphnia cornuta Sars, 1885 *

Ceriodaphnia rigaudi Richard, 1845 +*

Remarks : Collected from the lake in the month of July 1995. A less saline tolerant species.

Genus *Scapholeberis* Schoedler, 1853

Scapholeberis kingi Sars, 1903*

Remarks : Collected throughout the period of study from Gudha Kyar, Nawa area and main Salt Lake.

Genus *Simocephalus* Schoedler, 1853

Simocephalus vetulus (O.F. Muller, 1776) + *

Remarks : A fresh water form collected from main Sambhar lake area.

Family MOINIDAE

Genus *Moina* Baird, 1850

Moina micrura Kurz, 1874 + *

Remarks : Common in Sambhar Lake and Gudha Kyars. High salt tolerant species.

Moina macrocopa (Straus, 1820) + *

Remarks : Very commonly found in the Lake. High salt tolerant species.

Moina brachiata (Jurine, 1820) + *

Remarks : Common with low to high salt tolerance.

Family MACROTHRICIDAE

Genus *Macrothrix* Baird, 1843

Macrothrix spinosa King, 1853 + *

Remarks : Found in abundance at high salinity in the Lake.

Genus *Ilyocryptus* Sars, 1862

Ilyocryptus spinifer Herrick, 1882 + *

Family CHYDORIDAE

Subfamily CHYDORINAE

Genus *Chydorus* Leach, 1816

Chydorus ventricosus Daday, 1898 + *

Chydorus reticulatus Daday, 1898 +

Chydorus denticulatus Henry, 1918 + *

Genus *Dunhevedia* King, 1853

Dunhevedia crassa King, 1853 + *

Subfamily ALONINAE

Genus *Alona* Baird, 1843

Alona pulchella King, 1853 *

Alona rectangula richardi (Stingelin, 1853) *

Alona sp. *

Remarks : Collected from Nawa and Gudha Kyar, Sambhar Lake.

Genus *Leydigia* Kurz, 1875

Leydigia acanthocercoides (Fischer, 1854) + *

Leydigia laevis Gurney, 1927 +

Leydigia sp. *

Remarks : All above chydorans collected from Gudha Kyars.

Subclass OSTRACODA

Order PODOCOPA

Family CYPRIDAE

Genus *Ilyocypris* Brady and Norman, 1889

Ilyocypris biplicate (Koch, 1838) *

Remarks : Collected from Nawa, Salt Lake area.

Family CYCLOCYPRIDIDAE

Genus *Physocypris* Vavra, 1897

Physocypris megalops (Sars) +

Physocypris crenulate (Sars) +

Family CYPRIDAE

Genus *Cyprinotus* Brady, 1885

Cyprinotus megalops (Sars) + *

Cyprinotus makua Tressler + *

Cyprinotus gunningi + *

Cyprinotus ovatus (Sars) + *

Cyprinotus sulinus (Brady) +

Remarks : Collected from Gudha Kyars, Sambhar Salt Lake.

Genus *Cypris* O.F. Müller, 1776

Cypris sp. + *

Remarks : A fresh water form collected from main Sambhar Lake area.

Genus *Heterocypris* Brady and Norman, 1889

Heterocypris sp. + *

Remarks : A fresh water form collected from main Sambhar Lake area.

Genus *Centrocypris* Sars, 1890

Centrocypris sp. +

Genus *Stenocypris* Sars, 1890

Stenocypris fulleborni Daday +

Family CYPRIDOPSIDAE

Genus *Cypridopsis* Brady, 1867

Cypridopsis newtoni Brady and Robertson +

SUMMARY

Our knowledge on Crustacean of Sambhar Lake is very limited. Only 37 species are reported from Sambhar Lake. The reported species are mainly low to high saline tolerant. More intensive surveys may reveal a diverse range of species. The studies on most primitive

group Anostraca present in Sambhar Lake may lead to new Paleontological theories to support about its origin and time of formation.

The group should be taxonomically reviewed with particular reference to correlation of species with salinity, based on sound reliable known taxonomic characters as there are possibilities of more pronounced physical adaptations which might be taken as morphological differences displaying large fluctuations in characters at the time of describing a new species.

Describing a new species is becoming a common practice but the species described as new should be based on minimum of 50 such specimens collected from the same locality, preferably throughout the year or at least from the same place in different seasons so as to prevent its synonymization. The species *Branchinella biswasi* Tewari seems to be *Branchinella ornata* Daday to which it resembles, as there is no clear cut differences mentioned in the frontal appendages on the basis of which the species are differentiated. Due to lack of literature on African species however doubt remains.

Surveys should however be conducted throughout the year with more emphasis to search for the eggs, which remain embedded in the mud to tide over the adverse conditions, and later hatch them in laboratory to get the adult. The mass multiplication of these saline crustaceans in Sambhar Lake especially of those with short life cycle will multiply fast and may be utilized as food source for human and brackish aquatic fauna. Efforts should also be made to re-introduce *Artemia* sp. as nutritive feed for young fishes and prawns.

ACKNOWLEDGEMENTS

The author is thankful to Dr. J.R.B. Alfred, Director, Zoological Survey of India and Dr. Q.H. Baqri, Additional Director, Desert Regional Station, Zoological Survey India, Jodhpur for help to carry out this work. Thanks are also due to Dr. P. Mathur, M.D.S. University, Ajmer for confirming the species identification and suggestions for preparation of the manuscript.

REFERENCES

- Adam, A. 1899. *The western Rajputana States*. A Medico-Tropographical and Central account of Marwar, Sirohi and Jaisalmer. *Junior Armyad Navy Stores Ltd. Lorda*. pp. 1- 455.
- Alam, M. 1980. Limnological studies of Sambhar Lake. *J. Bombay nat. Hist. Soc.* **79** (1) : 194-195.
- Baid, I.C. 1958. On the occurrence of *Artemia salina* in Sambhar Lake, Rajasthan. *Curr. Sci.*, **27** (2) : 58-59.
- Baid, I.C. 1959a. Some observations on the population of *Artemia salina* in Sambhar Lake, Rajasthan. *Proc. National Academy of Sciences, India*. **28** : 416.

- Baid, I.C. 1959b. Occurrence of neoteny in the genus *Artemia*. *Nature* (London), **184** : 75.
- Baid, I.C. 1959c. Some preliminary notes on the insect life in Sambhar Lake. *J. Bombay nat. Hist. Soc.*, **56** (2) : 361-363.
- Baid, I.C. 1962. Ecological studies on crustacean and insect fauna of Sambhar Lake, Rajasthan, with special reference to *Artemia salina* L. Ph.D. Thesis, *University of Rajasthan, Jaipur*.
- Baid, I.C. 1969. The arthropod fauna of Sambhar salt lake Rajasthan, India. *Oikos*, **19** (2) : 292-303.
- Barooah, S.K. 1946. The Occurrence of the Laki series in Jodhpur State. *Curr. Sci.*, **15** (11) : 317.
- Barooah, S.K. 1950. Fossil fish and crabs in the Fuller's earth bed at Kapurdi, Jodhpur, Rajasthan. *Curr. Sci.*, **19** (5) : 165.
- Bhargava, S.C. and Jakhar, G.R., 1994. Planktonic composition of two saline lakes. In: *Meeting of Experts on Gaps in Researches on the Faunal Diversity in the Thar Desert*. (Abstract) DRS, ZSI. Jodhpur, 3-4 pp.
- Bhargava, S.C., Jakher, G.R., Saxena, M.M. and Sinha, R.K. 1987. Rearing *Artemia* in a saltpan near Sambhar Lake (India). *Artemia Research and its Applications*. 3: 271-274. Vol. 3. Ecology, Culturing, Use in aquaculture. P. Sorgeloos, D.A. Bengtson, W. Decler and E. Jaspers (eds.). *Universa Press, Wetteren, Belgium*, 556 pp.
- Biswas, S. 1964. A new species of the Cladoceran genus *Latona* Straus, 1820 (Crustacea: Cladocera: Sididae) from Rajasthan, India. *Proc. Zool. Soc. Calcutta* **17** : 149-152.
- Biswas, S. 1965a. Fauna of Rajasthan, India, Part I. Crustacea: Cladocera, *Rec. zool. Surv. India*, **63** (1-4) : 96-139.
- Biswas, S. 1965b. A new species of the genus *Chydorus* Leach, 1843 (Crustacea: Cladocera: Chydoridae) from Rajasthan, India, *Crustaceana*, Leiden, **11** (2) : 113-114.
- Biswas, S., 1971. Fauna of Rajasthan, India. Part II (Crustacea : Cladocera). *Rec. zool. Surv. India*, **63** (1-4) [1965] : 95-141.
- Brehm, V. 1951. Contribution to the freshwater fauna of India, Part II. *Rec. Indian Mus.*, **48** (1) [1950] : 9-28.
- Deb. M. 1973. Fauna of Rajasthan, (India) : Crustacea-Ostracoda. *Rec. zool. Surv. India*, **67** [1969] : 233-259.
- Glaessner, M.F. and Rao, V. Raghavendra. 1960. A new species of Crab from the early tertiary Fuller's earth deposits of Kapurdi, Rajasthan (India). *Rec. zool. Surv. India*, **68** : 383- 451.

- Gopal, Brij, and Sharma, K.P. 1994. Ramsar sites of India : Sambhar Lake. *WWF for Nature, India, New Delhi*. 1-37.
- Gupta, P.D. 1975. Fifty Years (1920-1929) of faunistic survey of Rajasthan (India). *Rec. zool. Surv. India*, **68** : 383-413.
- Imprey. 1862. Discovery of ammoniferous limestone near Jaisalmer in the Great Desert. *J. Roy. Asiatic Soc. Bombay Br.*, **6** (21) : 161-206.
- Jacob, K. Sastry, M.V.A. and Sastri, V.V. 1952. A note on the microfossils of the impure gypsum from the Jamsermine, Bikaner and on the possible origin of gypsum. *Bull. Natn. Inst. Sci. India*, No. **1** : 68-69.
- Jacob. K. and Sastri, V.V. 1950. Some new microforaminifera from the Fuller's earth Bikaner, Rajputana. *Sci. Cult.*, **16** : 80-82.
- Jakher, G.R., Bhargava, S.C. and Sinha, R.K. 1990. Comparative limnology of Sambhar and Didwana lakes (Rajasthan, India). *Hydrobiologia*, **197** : 245-256.
- Jakher, G.R., Dey. T., Misra, S.D. and Bhargava, S.C. 1981. Diurnal Variations in Physico-Chemical factors and zooplankton population in Balsamand Lake, Jodhpur. *Geobios*, **8** (3) : 119-122.
- Kaul, K.N. 1951. A fossil Nariel from Rajputana Desert. *Agriculture and Animal Husbandry. U.P.*, **2** (3) : 9-11, 1 pl.
- Lindberg, K. 1942. Crustaces del'etat de djodhpour (Rajpoutana) *Rec. Indian Mus.*, **44** (3) : 341-345.
- Lubinova, P.S. Guha, D.K. and Mohan, M. 1960. Ostracoda of Jurassic and Tertiary deposits from Kutch and Rajasthan (Jaisalmer) India. *Bull. Geol. Min. Soc. India*, No., **22** : 1-60.
- Michael R. George and Sharma, B.K., 1988. Indian Cladocera (Crustacea: Branchiopoda: Cladocera). *Fauna of India* : XVII : 1-262.
- Nayar, C.K.G., 1965. Three new species of Conchostraca (Crustacea: Branchiopoda) from Rajasthan. *Bull. Syst. Zool. Calcutta*, **1** (1) : 19-24.
- Nayar, C.K.G., 1971. Cladocera of Rajasthan. *Hydrobiologia*, **37** (3-4) : 509-519.
- Prasad, K.N. 1961. Decapoda : Crustacea from the Fuller's earth deposits of Kapurdi, Rajasthan. *India Min. (Calcutta)*, **15** : 435.
- Ramakrishna, G. 1975. Results of fifty years of faunistic survey on Indian Isopods. *Rec. zool. Surv. India*, **68** : 297-303.

- Roy, T. 1996. The crustacean fauna of the Thar Desert. In : *Faunal Diversity in the Thar Desert: Gaps in Research*. (eds.) A.K. Ghosh, Q.H. Baqri, and I. Prakash, Scientific Publishers, Jodhpur, India. **12** : 107-112.
- Sharma, L.L. 1980. Some limnological aspects of Udaipur waters in comparison to selected waters of Rajasthan. A Ph.D Thesis from University of Udaipur, Udaipur. pp. 1-251.
- Sharma, M.S. 1980. Studies on Plankton and productivity of Udaipur waters in comparison to the selected waters of Rajasthan. A Ph.D Thesis from University of Udaipur, Udaipur. pp. 1-277.
- Storer, T.I., Usinger, R.L., Stebbins, R.C. and Nybakken, J.W. 1983. General Zoology. Class Crustacea: Crustaceans. Sixth Ed. Tata McGraw-Hill publishing Company Limited, New Delhi. pp. 541-562.
- Subbotina, N.N. Datta, A.K. and Srivastava, B.N. 1960. Foraminifera from the upper Jurassic deposits of Rajasthan (Jaisalmer) and Kutch, India. *Bull. Geol. Min. Soc. India*, No. **23** : 1-48.
- Tiwari, K.K. 1951. Indian species of the genus *Apus* (Crustacea: Branchiopoda) with description of two new species. *Rec. Indian Mus.*, **49** (2) : 197-205.
- Tiwari, K.K. 1958. Diagnosis of a new species of the genus *Branchinella* Sayce (Crustacea : Branchiopoda: Anostraca) from Sambhar Lake, Rajasthan. *J. Bombay nat. Hist. Soc.*, **55** (3) : 585-588.
- Tiwari, K.K. 1962a. Occurrence of a fossil Penaeid prawn in the fuller's earth deposits of Kapurdi (Barmer District), Rajasthan. *Sci. Cult.*, **28** (5) : 244-245.
- Tiwari, K.K. 1962b. New species of *Conchostraca* (Crustacea: Phyllopora) from Rajasthan. *Proc. First. All-India Congr. Zool.*, 1959. Part 2 : 180-190.
- Tiwari, K.K. 1963. Lower tertiary penaeid shrimps from Kapurdi (Barmer District) Rajasthan, India. *Crustaceana*, **5** (3) : 205-212, 2 pls.
- Tiwari, K.K. 1965a. New species of *Leptestheria* Sars (Crustacea : Conchostraca) from India. *Zool. Anz.*, **174** (3) : 209-214.
- Tiwari, K.K. 1965b. *Branchinella kugenumaensis* (Ishikawa, 1894) (Phyllopora: Anostraca) in Rajasthan. Western India. *Crustaceana*, **9** (2) : 220-221.
- Tiwari, K.K. 1966. A new genus and species of clam shrimp (Crustacea: Branchiopoda: Conchostraca) from the Sambhar Lake, Rajasthan *Proc. Zool. Soc. Calcutta*, **19** : 67-76.
- Tiwari, K.K. 1996. Branchiopod: Crustacea of Rajasthan Desert. In: *Faunal Diversity of the Thar Desert : Gaps in Research*, (eds.) A.K. Ghosh, Q.H. Baqri, and I. Prakash, Scientific Publishers, Jodhpur. **13** : 113-129.

- Venkataraman, K. 1988. Cladocera of Keoladeo National Park, Bharatpur, Rajasthan II. New Records 1. *Moinodaphnia machleayii* (King 1853) and *Bosminopsis deitersi* (Richard, 1895). *J. Bombay nat. Hist. Soc.*, **85** (1) : 229-233.
- Venkataraman, K. 1990. New records of Cladocera of Keoladeo National Park, Bharatpur, III. *J. Bombay nat. Hist. Soc.*, **87** (1) : 166-168.
- Venkataraman, K. 1992a. I. Cladocera of Keoladeo National Park, Bharatpur, and its environs. *J. Bombay nat. Hist. Soc.*, **89** (1) : 17-26.
- Venkataraman, K. 1992b. Cladocera of Keoladeo National Park, Bharatpur-IV. New Records 1. *Camptocercus* CF. *australis* Sars, 1896 and *Indialona globulosa* (Daday, 1898). *J. Bombay nat. Hist. Soc.*, **89** (2) : 140-142.

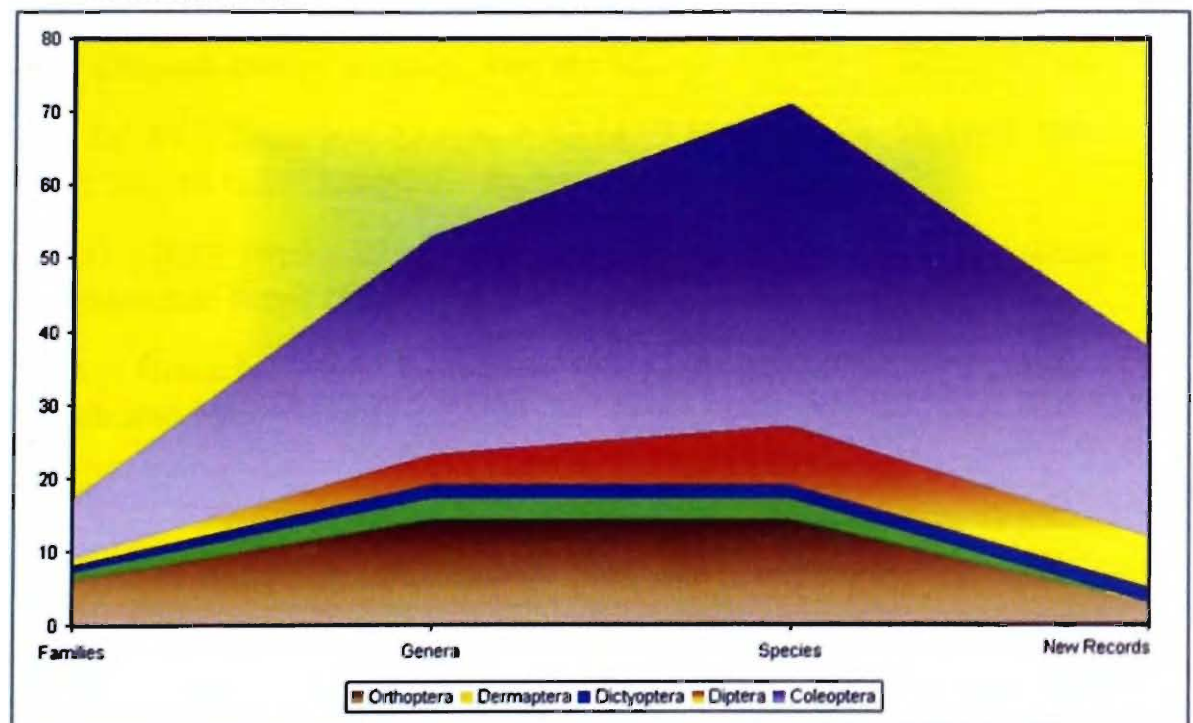


Chapter 5

Insecta :

- Orthoptera : M.S. Shishodia
- Dermoptera : G.K. Srivastava
- Dictyoptera : M.S. Shishodia
- Diptera : Sanjeev Kumar
- Coleoptera : P. Mukhopadhyay *et. al.*
- Coleoptera (Scarabaeidae) : S.K. Chatterjee & P. Mukhopadhyay

Entomofauna of Sambhar Lake



INSECTA : ORTHOPTERA

There is no account available on the orthoptera fauna of any wetland ecosystem of Rajasthan, except of Pichhola Lake, Udaipur (Shishodia, In press). The present account of Sambhar Lake, Jaipur is the second on the wetland ecosystem fauna of Rajasthan. However, Bhargava (1990 and 1996), Bhowmik (1967, 1969, 1971, 1977 and 1985), Choprad (1969), Gunther (1937), Kushwaha and Bharadwaj (1977), Parihar (1987 and 1996), Shishodia (2004), Tandon and Shishodia (1976) and Venkatesh (1977) have recorded a total of 114 species of orthoptera from Rajasthan. Present study is based on the small collection of orthoptera collected by Scientists of Desert Regional Station, Zoological Survey of India, Jodhpur, from Sambhar Lake, Jaipur, Rajasthan. In the present study a total of 14 species of Orthoptera are recorded from Sambhar Lake, Jaipur, of which 3 species marked by single asterisk (*) are reported for the first time from Rajasthan.

SYSTEMATIC ACCOUNT

Order ORTHOPTERA

Family GRYLLIDAE

Acheta domesticus Linnaeus

1758. *Gryllus acheta domesticus* Linnaeus, *Sys. Nat.* (ed. X) 1 : 428.

1967. *Acheta domesticus* : Chopard, *Orthopt. Catalog.*, Part 10 : 62.

Material examined : 3♂, 5♀, 12.vii.1994; 27♂, 56♀, 13,14.vii.1994; 2♂, 2♀, 15,17.vii.1994; 3♂, 2♀, 15,16.vii.1994; 2♀, 16.xi.1995, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : Body depressed and pubescent; head with wide frontal rostrum; vertex with a yellow transverse band; tegmina well developed.

Distribution : India : Himachal Pradesh, Jammu and Kashmir, Kerala, Maharashtra, Rajasthan, Uttar Pradesh and West Bengal.

Elsewhere : Pakistan.

Plebeigryllus guttiventris (Walker)

1871. *Gryllus guttiventris* Walker, *Cat. Derm. Salt. Brit. Mus.*, 5 : 6.

1964. *Plebeigryllus guttiventris* : Randell, *Can. Ent.*, 96 (12) : 1598.

Material examined : 4♂, 4♀, 15,19.xi.1995, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : General shape short and depressed; head blackish above with short, light yellow lines on occiput; posterior femora short and thick, feebly striated with brown.

Distribution : India : Bihar, Delhi, Goa, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Orissa, Pondicherry, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal.

Elsewhere : Myanmar and Srilanka.

***Modicogryllus confirmatus* (Walker)**

1859. *Acheta confirmata* Walker, *Ann. Mag. Nat. Hist.*, (3) 4 : 221.

1964. *Modicogryllus confirmata* : Randell, *Can. Ent.*, 96 : 1584.

Material examined : 1♀, 13.vii.1994; 1♂, 3♀, 14.vii.1994; 2♀, 15.vii.1994, 1♂, 2♀, 15,16.vii.1994; 1♂, 1♀, 16,19.xi.1995, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : Head brown with narrow yellow band connecting the lateral ocelli; mirror longer than broad, divided by a curved vein; 2 oblique veins; lateral field of tegmina with widely separated veins.

Distribution : India: Andaman and Nicobar Islands, Arunachal Pradesh, Assam, Bihar, Delhi, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Orissa, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal.

Elsewhere : Bangladesh, Indo-China, Israel, Malaya, Myanmar, Nepal, Srilanka and Thailand.

Gymnogryllus minor* Chopard

1959. *Gymnogryllus minor* Chopard, *Stuttg. Beitr. Z. Naturk.*, : 1.

1967. *Gymnogryllus minor*: Chopard, *Orthopt. Catalog.*, Part 10 : 19.

Material examined : 1♀, 16.vii.1994, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : Ocelli placed in triangle position; anterior metatarsi moderate anterior tibiae ciliated with long hairs; very similar to *G. erythrocephalus* except body size.

Distribution : India : Assam, Bihar, Goa, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Pondicherry, Tamil Nadu and West Bengal. It is also studied from Haryana, Orissa and Rajasthan.

Elsewhere : Afghanistan, Iran, Java, Myanmar, Pakistan and South Vietnam.

Family GRYLLOTALPIDAE

Gryllotalpa africana Beauvois

1805. *Gryllotalpa africana* Beauvois, *Ins. Afr. Amer.*, : 229.

1967. *Gryllotalpa africana* : Chopard, *Orthopt. Catalog.*, Part 12 : 449.

Material examined : 8♂, 11♀, 15,16,18.xi.1995 and 21.xi.1996, coll. S. Kumar.

Diagnostic characters : Anterior legs short, modified for digging purposes; anterior tibiae armed with four dactyls; colour of body dark-brown.

Distribution : India : Andaman and Nicobar Islands, Arunachal Pradesh, Assam, Bihar, Delhi, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Meghalaya, Orissa, Pondicherry, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal.

Elsewhere : Africa, Australia, Bhutan, Iran, Madagascar, Malaya, Myanmar, Nepal, Singapore, S. Spain and Sri Lanka.

Family ACRIDIIDAE

Truxalia sp.

Material examined : 1♂, 15.vii.1994, coll. S. Kumar and R.N. Bhargava.

Distribution : The genus is distributed in Africa, Europe and Mediterranean Islands. In Asia, it is found in all Middle East countries, Arabia, Middle Asia, India, Sri Lanka, Myanmar, and Thailand etc.

Remarks : Basal colour of hind wing disappeared due to its preservation in spirit. Hence the specific identification was not possible.

Leva indica (Bolivar)

1902. *Gymnobothrus indica* Bolivar, *Annl. Soc. ent. Fr.*, 70 : 596.

1914. *Leva indica* : Bolivar, *Trab. Mus. nec. Cienc. nat. Madr.*, (Ser. Zool.) No. 20 : 64.

Material examined : 5♂, 15.vii.1994, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : Size small; fastigium of vertex angular with acute apex; lateral carinae of pronotum parallel in prozona divergent in metazona.

Distribution : India : Delhi, Orissa, Rajasthan, Tamil Nadu and West Bengal.

Aiolopus thalassinus tamulus (Fabricius)

1798. *Gryllus tamulus* Fabricius, *Ent. Syst. Suppl.*, : 195.

1968. *Aiolopus thalassinus tamulus* : Hollis, *Bull. Br. Mus. Nat. Hist. (Ent.)*, **22** (7) : 347.

Material examined : 5♂, 15.vii.1994, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : Fastigium with forward angle more acute; foveolae narrowly trapazoid, twice as long as wide; frontal ridge gradually narrowing and almost angular towards fastigial end, sparsely punctured; pronotum saddle shaped, posterior margin rounded; posterior tibiae usually red in apical fourth and broadly separated from black band by a wide bluish grey band.

Distribution : India : Andaman and Nicobar Islands, Andhra Pradesh, Bihar, Delhi, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Meghalaya, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal.

Elsewhere : Australia, Bangladesh, Borneo, China, Hainan, Japan, Java, Malaya, New Guinea, Singapore, Sri Lanka, Sumatra and Taiwan.

Acrotylus humberianus Saussure

1884. *Acrotylus humberianus* Saussure, *Mem. Soc. Phys. nat. Geneva*, **28** (9) : 189.

1914. *Acrotylus humberianus* : Kirby, *Fauna British India, Orthopt. (Acridiidae)* : 153.

Material examined : 5♂, 7♀, 15.vii.1994, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : Face nearly or quite vertical; median carina of pronotum cut by two grooves, without very distinct crest, short, broadly rounded behind; wings yellow at base, with a wide incomplete dark band, entirely or nearly reaching the anal veins.

Distribution : India : Arunachal Pradesh, Bihar, Delhi, Goa, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu and West Bengal.

Elsewhere : Afghanistan, Bangladesh, Nepal, Pakistan and Sri Lanka.

Locusta migratoria migratorioides (R. & F.)

1859. *Oedipoda migratorioides* Reiche and Faimair, *Voy. Abyssini*, **3** : 430.

1902. *Locusta migratorioides* : Kirby, *The Uganda Protectorate*, **1** : 168.

1951. *Locusta migratoria migratorioides* : Uvarov, *Bull. off. nat. anti-Arid, Paris No. 1* : 1-4.

Material examined : 1♂, 15.vii.1994, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : Pronotum tectiform or saddle shaped; lateral lobes of pronotum higher than its length; metazona angular posteriorly tegmine mottled and reticulated with brown; wings hyaline; hind femora rather long, not much thickened at base; hind tibiae reddish; this species occurs in two forms (solitaria and gregaria). The two forms are very

sharply different, but intermediate form also exists.

Distribution : This species occurs in the whole Ethiopian region and whole of eastern hemisphere except arctic and northern region. In India, it is reported from Delhi, Maharashtra, Meghalaya, Orissa and Rajasthan.

Family PYRGOMORPHIDAE

Pyrgomorpha bispinosa deserti Bei-Bienko

1951. *Pyrgomorpha conica deserti* Bei-Bienko, *Opred. Faune SSSR*, **39** : 272.

1974. *Pyrgomorpha bispinosa deserti* : Kevan, *Journal Ent.*, (B) **42** (2) : 154.

Material examined : 1♂, 6♀, 15.vii.1994, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : Antennae 15-16 segmented; vertex without a constriction at the anterior margin of eyes; median carina of pronotum distinct; lateral carinae in the metazona not obsolete; postero-ventral angle of lateral lobes of pronotum obliquely truncate.

Distribution : Bangladesh, N.W. India to Soviet Central Asia, Transcaucasia, and S.W. Asia.

Family TETRIGIDAE

Euparatettix tenuis Hancock*

1912. *Euparatettix tenuis* Hancock, *Mem. Dep. Agric. India ent. Ser.*, **4** : 153.

Material examined : 2♂, 12.vii.1994; 3♂, 15.vii.1994, 1♂, 16.vii. 1994, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : Body slender; head exserted above the surface of pronotum; vertex narrower than an eye; frontal costa moderately sulcated; antennae placed on the lower margin of eyes; pronotum extended beyond the middle of posterior tibiae; dorsum not convex between the shoulders; median carina nearly straight; wings extend beyond the pronotal apex.

Distribution : India : Arunachal Pradesh, Assam, Bihar, Delhi, Manipur, Meghalaya, Sikkim, Tripura, Uttar Pradesh and West Bengal.

Elsewhere : Bangladesh and Myanmar (Blackith, 1992).

Hedotettix gracilis (De Haan)*

1842. *Acridium (Tettix) gracile* De Haan, Temminck, *Verhandel., Orth.*, : 167.

1887. *Hedotettix gracilis* : Bolivar, *Annl. Soc. ent. Belg.*, **31** : 284.

1914. *Hedotettix gracilis* : Kirby, *Fauna British India, Orth.*, : 72.

Material examined : 1♀, 16.vii.1994, coll. S. Kumar and R.N. Bhargava.

Diagnostic characters : Head not exserted above the pronotum; vertex equal to or narrower than an eye, frontal margin rounded; frontal costa widely sulcated, the rami widened between the antennae; pronotum and wings extended up to the apex of hind femora beyond; dorsum finely granulose; humeral angle obtusely rounded.

Distribution : India : Andaman & Nicobar Islands, Arunachal Pradesh, Assam, Madhya Pradesh, Maharashtra, Manipur, Madras, Meghalaya, Orissa, Sikkim, Tripura, Uttar Pradesh and West Bengal.

Elsewhere : Bangladesh, Celebes, Java, Myanmar, Pakistan, Sri Lanka, Sumatra, Taiwan, Thailand and Vietnam.

Family TETTIGONIIDAE

Euconocephalus incertus (Walker)

1869. *Conocephalus incertus* Walker, *Cat. Derm. Salt. Brit. Mus.*, 2 : 32.

1912. *Euconocephalus incertus* : Karny, *Gen. Ins.*, 2 (139) : 35.

Material examined : 1♂, 11.xi.1996, coll. S. Kumar.

Diagnostic characters : Fastigium produced conically and longer; radial sector 2 arises much before the middle of tegmina; length of ovipositor subequal to the body length.

Distribution : India : Andaman and Nicobar Islands, Meghalaya, Orissa, Rajasthan, Sikkim, Tripura and West Bengal. It is also studied from Madhya Pradesh and Tamil Nadu.

Elsewhere : Java and Sri Lanka.

SUMMARY

Fourteen species of Orthoptera are studied herewith. Distributional range in India and abroad, taxonomic characters have been provided. Three species of Orthoptera are newly recorded from Rajasthan.

ACKNOWLEDGEMENTS

I am thankful to Dr. J.R.B. Alfred, Director, Zoological Survey of India, Calcutta, for laboratory facilities. I am also grateful to the Officer-in-Charge of Desert Regional Station, Zoological Survey of India, Jodhpur, for handing over the material to me for study. My thanks are also due to Dr. S.K. Mitra, Officer-in-Charge, Entomology Division, Zoological Survey of India, Calcutta, for encouragement.

REFERENCES

- Bhargava, R.N. 1990. First record of the genus *Arachnocephalus* Costa from India and description of the female *Loxoblammus animae* Bhowmik (*Insecta* : *Grylloidea*). *Hexapoda*, **3** (1 & 2) : 75-78.
- Bhargava, R.N. 1996. *Grylloid fauna of the Thar Desert*. In : Faunal Diversity in the Thar Desert : Gaps in Research. *Scientific Publishers*, Jodhpur, India. **16** : 151-154.
- Bhowmik, H.K. 1967. *Gryllopsis rajasthanensis* Bhowmik, *Proc. Indian Sci. Cong. Assoc.*, Banaras, Part **B** : 491.
- Bhowmik, H.K. 1969. Studies on Indian crickets (*Orthoptera* : *Insecta*). *Zool. Anz., Bd.* 182, Helft ½ : 143-152.
- Bhowmik, H.K. 1971. Two new species of *Grylloidea* (*Orthoptera*) from India. *Oriental Ins.*, **5** (4) : 503-506.
- Bhowmik, H.K. 1977. Studies on some Indian crickets with new distributional records of the subfamily *Gryllinae* (*Gryllidae* : *Orthoptera*). *Rec. zool. Surv. India*, **73** : 229-238.
- Bhowmik, H.K. 1985. Contributions to the gryllid fauna of the Western Himalayas (*Orthoptera* : *Gryllidae*). *Rec. zool. Surv. India, Occ. Paper*, **73** : 1-85.
- Blackith, R.E. 1992. The tetrigidae (*Insecta*: *Orthoptera*) of South-East Asia. *Catalogue of S. E. Asian Tetrigidae* : 1-248 (*Japaga 'Rockbottom' Ashford Co. Wicklow, Ireland*).
- Chopard, L. 1969. *The Fauna of India and the adjacent countries*, *Orthoptera, Grylloidea*, **2** : 1-421.
- Gunther, K. 1937. *Orthoptera Celebica sarasiniana*. Fam. *Acrididae*, subfam. *Acrydiinae*.
- Kushwaha, K.S. and Bharadwaj, S.C. 1977. *Forage and pasture insect pests of Rajasthan* (ICAR, New Delhi) : 1-86.
- Parihar, D.R. 1987. Grasshopper pest of grazing-land vegetation and their management in Indian desert. *CAZRI, Monograph No.* **29** : 56 pp.
- Parihar, D.R. 1996. *Species richness of Orthoptera and Coleoptera in the Thar Desert*. In : Faunal Diversity in the Thar Desert : Gaps in Research, *Scientific Publishers*, Jodhpur, India. **17** : 155-166.
- Shishodia, M.S. 2004. *Insecta : Orthoptera. Fauna of Desert National Park, Rajasthan, Conservation Area Series*, **19** : 59-65 (Edited and Published by the Director, *Zool. Surv. India*, Kolkata).

Shishodia, M.S. Fauna of Pichhola Lake : Orthoptera. *Wetland Ecosystem Series*. (In press).

Tandon, S.K. and Shishodia, M.S. 1976. On a collection of Acridoidea (Orthoptera) from Rajasthan, India. *Newsl. zool. Surv. India*, **2** (1) : 7-11.

Venkatesh, M.V. 1977. *Some grasshoppers and locusts of Rajasthan*. In : Roonwal's Natural Resources of Rajasthan. (ed.) M. L. Roonwal, *Jodhpur University Press*, Jodhpur : 353-562.

INSECTA : DERMAPTERA

The present paper deals with three species of Dermaptera, which were collected from Sambhar Lake, Jaipur. All the species are distributed world wide, except *Forcipula quadrispinosa* (Dohrn), which occurs in various parts of Oriental Region. The species recorded here commonly occur under stones, where a little moisture is available or on the edge of river and water bodies. The members of the genus *Forcipula* Bolivar are known to swim for short distance in water.

SYSTEMATIC ACCOUNT

Family LABIDURIDAE

Subfamily NALINAE

Genus *Nala* Zacher

1910. *Nala* Zacher, *Ent. Rdsch.*, : 29 (Type *Labidura lividipes* H. Luc.=*Forficula lividipes* Dufour, 1828).

1910. *Paralabidura* Burr, *Trans. R. ent. Soc. Lond.*, (Type : *Forficula lividipes* Dufour, 1828).

Nala lividipes (Dufour)

1820. *Forficula pallipes* Dufour, *Ann. gener. des Phys. Bruxelles*, 4 : 316, pls. 116 fig. 7, 7a and 7b (Male, Female : Lower Catalonia, Spain).

1828. *Forficula lividipes* Dufour, *Ann. Sci. Nat.*, 13 : 340 (New name proposed).

1911. *Nala lividipes* : Burr *Genera Insect.*, 122 : 36.

1997. *Nala lividipes*; Srivastava, *Zool. Surv. India, State Fauna Series 6 : Fauna of Delhi* : 204.

Material examined : 1 ♂, 1 ♀, 15.xi.1958, coll. S. Biswas.

Distribution : Worldwide, more common in tropical parts of the world.

Remarks : Variations in the body colour and in the inner armature of male forceps are quite common. It occurs in a variety of habits and often attracted to light in large number, especially in post monsoon period.

Subfamily LABIDURINAE

Genus *Labidura* Leach

1815. *Labidura* Leach, *Edin. Encyl.*, 9 (1) : 48 (Type *Forficula riparia* Pallas, 1773).

***Labidura riparia* (Pallas)**

1773. *Forficula riparia* Pallas, *Reise Russ, Reichs*, 2 : 727 (Sex ?; Shores of Irtysh River, Western Siberia).

1863. *Labidura riparia* : Dohrn, *Stettin ent. Ztg.*, 24 : 313.

1997. *Labidura riparia* : Srivastava, *Zool. Surv. India, State Fauna Series 6 : Fauna of Delhi* : 204.

Material examined : 4 ♂, 5 ♀, 15.iii.1962, coll. K.K. Mahajan, 2 nymphs, 30.v.1958; 2 ♂, 1a 26.ix.1958, coll. S. Biswas, 11 ♂, 13 a and 3 nymphs, 8.i.1995, 1 nymph, 11.i.1995, coll. S. Kumar.

Distribution : Worldwide. It is a species of arenicolous habit and occurs on riverbanks, beaches and other areas where there is plenty of sand and at least some moisture (Hincks, 1957).

Genus *Forcipula* Bolivar

1897. *Forcipula* Bolivar, *Ann. Soc. ent. Fr.*, 66 : 282 (Type *Labidura quadrispinosa* Dohrn, 1863-designated by Kurby, 1904).

1974. *Genitalata* Kapoor, *Zool. J. Linn. Soc.*, 55 (1) : 83, figs. 1-4 (Type *Genitalata mahajani* Kapoor, 1974).

***Forcipula quadrispinosa* (Dohrn)**

1863. *Labidura quadrispinosa* Dohrn, *Stettin ent. Ztg.*, 24 : 311 (Male; India : Tranquebar and Ceylon).

1974. *Genitalata mahajani* Kapoor, *Zool. J. Linn. Soc.*, 55 (4) : 83, figs. 1-4, nymphs not male; India : Himachal Pradesh).

1986. *Forcipula quadrispinosa* : Srivastava, *Rec. zool. Surv. India, Occ. Paper No. 89* : 28.

Material examined : 3 nymphs, 16.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : In India it has been recorded from West Bengal (Calcutta and Darjeeling dist.), Tamil Nadu, Uttar Pradesh, Bihar and Assam.

Elsewhere : Nepal, Bhutan, Myanmar, Sri Lanka, Thailand, Indo-China, Java, Philippines Isls. Reunion and Mauritius.

SUMMARY

The present paper reports three salt tolerant species under three genera of Dermaptera.

ACKNOWLEDGEMENT

My thanks are due to the Director, Zoological Survey of India, Calcutta, for providing necessary facilities during the course of present work.

REFERENCE

Hincks, W.D. 1957. The Earwigs of South Africa. *South African Animal Life*, 4 : 33-94

INSECTA : DICTYOPTERA : MANTODEA

There is no account available on the Mantodea fauna of any wetland ecosystem of Rajasthan except of Pichhola Lake, Udaipur (Shishodia, In press). The present account of Sambhar Lake, Jaipur is the second on the wetland ecosystem fauna of Rajasthan. However, Mukherjee *et al.* (1995) has recorded a total of seven species of Mantodea from Rajasthan. Present study is based on a small collection of Mantodea collected by the scientists of Desert Regional Station, Zoological Survey of India, Jodhpur from Sambhar Lake, Rajasthan.

In the present study two species of Mantodea are recorded from the saline wetland and marked by an asterisk (*) as recorded for the first time from Rajasthan.

SYSTEMATIC ACCOUNT

Order DICTYOPTERA

Suborder MANTODEA

Hierodula (Hierodula) bipapilla (Servilla)*

1839. *Mantis bipapilla* Serville, *Hist. Nat. Ins. Orth.*, : 188.

1927. *Hierodula (Hierodula) bipapilla* : Giglio-Tos, *Das Tierreich*, 50 : 448.

Material examined : 1 ex., 15.vii.1994, coll. S. Kumar.

Distribution : India : Bihar, Himachal Pradesh, Uttar Pradesh and West Bengal.

Elsewhere : China, Japan, Java and Taiwan.

Remarks : Body small; colour not metallic; frontal sclerite bicarinate; dilation of pronotum not reaching up to the base, metazona with two indistinct dark-brown bands; fore coxae with 2-3 verrucose pouches at base of smaller spines; both wings extended beyond the abdomen.

Humbertiella indica Saussure*

1869. *Humbertiella indica* Saussure, *Mitt. Schweiz. Entomol. Ges.*, 3 : 62.

1927. *Humbertiella indica* : Giglio-Tos, *Das Tierreich*, 50 : 65.

Material examined : 1 ex., 15.vii.1994, coll. S. Kumar.

Distribution : India : Delhi, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu and Uttar Pradesh.

Elsewhere : Sri Lanka.

Remarks : Body colour not metallic; superior margin of frontal sclerite more or less straight or a little arched; pronotal tubercles prominent; fore femora with a black longitudinal line, and divided into two; tegmina with parallel transverse veinules.

SUMMARY

Two species of Mantodea studied herewith are new records from Rajasthan. Distributional range in India and abroad along with taxonomic characters has been provided.

ACKNOWLEDGEMENTS

I am thankful to Dr. J.R.B. Alfred, Director, Zoological Survey of India, Calcutta for laboratory facilities. I am grateful to the Officer-in-Charge, Desert Regional Station, ZSI, Jodhpur, for handing over the material to me for study. My thanks are also due to Dr. S.K. Mitra, O/C Entomology Division, ZSI, Calcutta for encouragement.

REFERENCES

- Mukherjee, T.K., Ghosh, A.K. and Hazra, A.K. 1995. Mantid Fauna of India. (Insecta : Mantodea). *Oriental Ins.*, **29** : 185-358.
- Shishodia, M.S. Insecta : Fauna of Pichhola Lake : Orthoptera and Mantodea. *Wetland Ecosystem Series*. (In press).

INSECTA : DIPTERA : CHIRONOMIDAE

The saline Sambhar wetland holds mainly deserticolous characteristic and fauna typical of Palaearctic and Oriental biogeographical realms as it is situated on the fringe line of the Thar Desert.

The Diptera species reported so far from the Thar belongs to diverse habitat most of which are flower visitor, parasites and dirt dwellers [Baid (1959), Kumar and Kumar (1996); Joseph and Parui (1998); Nandi (2002)]. Not much emphasis has been given to study the species associated or dependant on most moist or aquatic environs. Although numbers of such families are seen abundantly inhabiting various tanks, ponds, seepage areas, stagnated pools etc. Arrival of water through IGNP, one of the largest irrigation systems of dry areas in the world has opened up yet another ground for mass colonization of large number of water dependant families of Diptera. High density of littoral benthic chironomid larvae represented by one species (Baid, 1959) and two species (Sharma, 1980) have been reported from Sambhar Lake.

Larvae of family Chironomidae forms a significant portion of the micro-invertebrate fauna in most diverse water habitats from the cold desert high altitude lakes [Hutchinson (1933); Kaisila (1952); Singh, (1958, 1986 and 1988); Mani and Singh (1961); Oliver, (1964); James and Hubbick (1969); Alfred (1972 and 1973); Danks and Oliver (1972a & b); Aliev (1982); Beattie (1982) and Kumar (1987)] to the inland water bodies of the plains [Brunetti (1920); Buscemi (1961); Hilsenhoff (1975); Beck (1976); Kulshrestha (1977); Singh and Kulshrestha, (1977) and Sathiamoorthy (1980)].

The general adaptability of chironomid midges to all sorts of limnetic habitats is amazing due to their highly specialized larval stages (Brundin, 1966). They survive in deficient oxygen or anaerobic conditions by presence of ventral finger like osmoregulatory gills on the penultimate abdominal segments. The chironomid larvae not only forms important food of cultured fishes (Vaas and Vaas Vanoven, 1959) but by examining the remains of chironomid larvae in the stomach of feeding animals it is possible to decide the depth of the water zone in which they have been feeding (Chernowski, 1949).

The chironomid larvae are reported to be the food of birds (Kumar, 1987) and especially flamingos (Abdulali, 1964). They are an important link in the food chain between algae and micro invertebrates and large macro vertebrates, fish and aquatic birds. Their presence in large number in Sambhar Lake is indicative of high productivity (Sharma, 1980). Though no species of fish was reported in the present survey but still the presence of chironomid larvae in high density is indicative that till the salinity increases or lake margin shrinks due to drying of lake water the fishes coming along with the inflow of monsoon water must be surviving on these chironomid larvae which are in abundance. Fishes with short life span can be reared on these larvae or small fry for mass production for fish farms.

The sampling of adult chironomid was carried out by executing sweeps of butterfly net in the air just above the water surface near the lakeshore. The collection was sorted out, counted and representative specimens were dissected and mounted in Canada balsam for proper identification. Standard plankton nets made of very fine mesh bolting cloth was used to collect the chironomid larvae and later preserved in Pampel's fluid.

The chironomid fauna of Sambhar Lake is represented by eight species under four genera. Seven species are new record from Rajasthan marked with an asterisk*. The systematic account is given below :

SYSTEMATIC ACCOUNT

Order DIPTERA

Family CHIRONOMIDAE

Subfamily CHIRONOMINAE

Chironomus bharati Singh and Kulshrestha, 1976*

1976. *Chironomus bharati* Singh and Kulshrestha, *Oriental Ins.*, 7 : 156.

Material examined : 2 ♂, 3 ♀, on slides, 15.xi.1997, coll. S. Kumar.

Distribution : India : Uttar Pradesh.

Chironomus uttarpradeshensis Singh and Kulshrestha, 1976*

1976. *Chironomus uttarpradeshensis* Singh and Kulshrestha, *Oriental Ins.*, 7 : 157.

Material examined : 3 ♂, 3 ♀, on slides, 17.xi.1995, coll. S. Kumar.

Distribution : India : Uttar Pradesh.

Chironomus sp. *

1800. *Tendipes* Meigen, *Nouv. Class Mouches*, 17 (Type-species : *Tipula plumosa* Linnaeus, by designation of Coquillett 1910 : 612).

1803. *Chironomus* Meigen, *Magazin Insekt Kele*, 2 : 260 (Type-species : *Tipula plumosa* Linnaeus by designation of Latreille 1810 : 442).

Material examined : 7 larvae on slide, 23.xi.1996, coll. S. Kumar.

Tanytarsus ungulituberculatr Singh and Kulshrestha, 1975*

1975. *Tanytarsus ungulituberculatr* Singh and Kulshrestha *Oriental Ins.*, 9 (4) : 419.

Material examined : 2 ♀, 4 ♂, 6.i.1995, coll. S. Kumar.

Distribution : India : Uttar Pradesh.

Tanytarsus khandariensis Singh and Kulshrestha, 1975*

1975. *Tanytarsus khandariensis* Singh and Kulshrestha, *Oriental Ins.*, 9 (4) : 422.

Material examined : 4 ♀, 3 ♂, 6.i.1995, coll. S. Kumar.

Distribution : India : Uttar Pradesh.

Subfamily POLYPEDINAE

Polypedilium angustiforceps Kieffer, 1913*

1913. *Polypedilium angustiforceps* Kieffer, *Rec. Indian Mus.*, 9 : 148. (Type loc. : Katihar, Purnea District, Bihar, India).

Material examined : 3 ♂, 22.xi.1996, coll. S. Kumar.

Distribution : India : Bihar, West Bengal and Uttar Pradesh.

Subfamily TANYPODINAE

Tanypus riparius Kiffer, 1911*

1911. *Tanypus riparius* Kiffer, *Rec. Indian Mus.*, 6 : 332. (Type-loc : Barogh, nr. Simla, India, N. comb. ♂; Pelopia).

Material examined : 3 ♂, 2 ♀, 21.xi.1996, on slide, coll. S. Kumar.

Distribution : India : Himachal Pradesh, Uttar Pradesh.

Tanypus khandariensis Singh and Kulshrestha, 1975

1975. *Tanypus khandariensis* Singh and Kulshrestha, *Oriental Ins.*, 9 (4) : 422.

Material examined : 3 ♂, 2 ♀, 6.i.1995, on slide, coll. S. Kumar.

Distribution : India : Uttar Pradesh.

SUMMARY

In the present study eight species were recorded which makes it clear that Sambhar Lake does not constitute a body of sterile saline water but supports a highly specialized organic life in the form of chironomid larvae. It constitutes a good food source of aquatic

birds. The chironomid species reported are filter feeders or "biological filters" same like highly specialized flamingos. Fishes with short life span can be reared on these chironomid larvae or small fry for mass production for fish farms. More exploration of Sambhar Lake throughout the year is required to study the seasonal population density, species diversity, abundance and richness of chironomidae.

ACKNOWLEDGEMENTS

The author expresses sincere gratitude to Dr. J.R.B. Alfred, Director, Zoological Survey of India, Kolkata and Dr. Q.H. Baqri, Additional Director & Officer-in-Charge, Desert Regional Station, Z.S.I., Jodhpur for encouragement and to successfully carry out this work.

REFERENCES

- Abdulali, H. 1964. On the food and food and other habits of the Greater Flamingo (*Phoenicopterus roseus* Pallas) in India. *J. Bombay nat. Hist. Soc.*, **61** (1) : 65.
- Alfred, J.R.B. 1972. Chironomidae : in "A guide to the identification of freshwater organisms" (ed.) R. George Michael, *Supp. I. J. Maduri University*.
- Alfred, J.R.B. 1973. *Studies on the Biology of Chironomidae* (=Tendipedidae: Diptera)-Ph.D.Thesis, Madurai Kamaraj University, MADURAI.
- Aliev, R.A. 1982. Benthic fauna of Lake Nakhlykhchchala (Azerkaijan SSR, USSR). *Izv. Akad. Nauk. AZ SSR. SER Biol. Nauk.*, **6** (4) : 77-82.
- Baid, I.C. 1959. Some preliminary notes on the insect life in Sambhar Lake. *J. Bombay nat. Hist. Soc.* **56** (2) : 361-363.
- Beattie, D.M. 1982. Distribution and production of the larval chironomid populations in Tjeukemeer (The Netherlands). *Hydrobiologia*, **95** : 287-306.
- Beck, William, M. Jr. 1976. "Biology of the larval Chironomids" Technical Series. Vol. 2 No. 1, *State of Florida, Dept. of Environmental Regulation*.
- Brundin, L. 1966. Transantaric relationships and their significance, as evidenced by chironomid midges. *Kungl. Svenska Ventenskapsakademiens. Handlinger, Fjarde Serin. Bandll. Nnl* : 1-472.
- Brunetti, E. 1920. Catalogue of Oriental and South Asiatic Nemocera, *Rec. Ind. Mus.*, **XVII** : 59-79.

- Buscemi, P.A. 1961. Ecology of the bottom fauna of Parvin Lake, Colorado, *Trens. Amer. Microsc. Soc.*, **80** : 266-307.
- Chernowski, A.A. 1949. Identification of larvae of the midge family Tendipedidae (Russian) *Opred. Faune SSR* **31** : 1-186. *National Lending Library for Science and Technology Boston Spa. Yorkshire, England.*
- Danks, H.V. and D.R. Oliver. 1972a. Seasonal emergence of some high arctic chironomidae (Diptera). *Can. Ent.*, **104** : 661-686.
- Danks, H.V. and D.R. Oliver. 1972b. Diel periodicities of emergence of some high arctic chironomidae (Diptera). *Can. Ent.*, **104** : 903-916.
- Hilsenhoff, William, L. 1975. Aquatic Insects of Wisconsin-Technical Bulletin No. **89**. *Dept. of Natural Resources Madison, Wisconsin.*
- Hutchinson, G.E. 1933. Limnological studies at high altitudes in Ladakh. *Nature*, **132** (3325) : 136.
- James, A. and J. Hubbick. 1969. Studies on some high altitudes Lakes in the Hindu Kush. *Verh. Internat. Verein. Limnol.*, **17** : 362-372.
- Joseph, A.N.T. and Parui, P. 1998. *Fauna of India : Diptera (Asilidae)*, Part-I, xvi + 278 pp. (Published - Director, ZSI, Calcutta).
- Kaisila, J. 1952. Insects from the Arctic mountain snows. *Ann. Ent. Fennid*, **18** (1) : 8-25.
- Kulshrestha, A.K. 1977. *Study on the taxonomy of the Chironomidae fauna of India, with special reference to Uttar Pradesh* (Diptera : Nematocera : Chironomidae). Ph.D. Thesis, Agra University, AGRA.
- Kumar, Sanjeev. 1987. *Limnological Investigation of Dashauhar Lake (4,200 M. above M.S.L.) with Reference to Insect Fauna* (Northwest Himalaya). Ph.D. Thesis, Agra University, AGRA. pp. 1-116, plate I-XXXIV & photos 1-27.
- Kumar, Sanjeev and Kumar, S. 1996. Diptera fauna of the Thar Desert. In : *Faunal Diversity in the Thar Desert: Gaps in Research*. (eds.) A.K. Ghosh, Q.H. Baqri, and I, Prakash, Scientific Publishers, Jodhpur, India. **26** : 241-251.
- Mani, M.S. and Singh, S. 1961. Entomological Survey of Himalaya. Part XXV. A contribution to the ecology of high altitude insect life of the North West Himalaya. *Proc. Zool. Soc.*, Calcutta, **14** (2) : 61-135.
- Nandi, B.C. 2002. *Fauna of India and the adjacent countries Diptera* (Vol. X) Sarcophagidae, i-xxiv, 1-608 (Published-Director, ZSI, Kolkata).

- Oliver, D.R. 1964. A Limnological investigation of a large arctic lake, Nettilling Lake, Baffin Islands. *Arctic. Arctic*, **17** : 69-83.
- Sathiamoorthy, V.R. 1980. *Distribution of genera of Chironomidae in and around Madurai City*. M.Phil. Thesis, Madurai Kamraj University, Madurai.
- Sharma, L.L. 1980. *Some limnological aspects of Udaipur waters in comparison to selected waters of Rajasthan*. A Ph.D Thesis from University of Udaipur, Udaipur. pp. 1-251.
- Singh, Santokh, 1958. On a collection of nival Chironomidae (Diptera) from the north-west Himalaya. *Proc. Nat. Aca. Sc. (India)*, Allahabad, (B) **28** (4) : 308-314.
- Singh, Santokh, 1986. Winter snow cover as an isolating factor in speciation. In : *Recent advances in insect Physiology. Morphology & Ecology*. (ed.) S.C. Pathak, Today and Tomorrow's Printers and Publishers, New Delhi, pp. 285-289.
- Singh, Santokh, 1988. *Investigations on the taxonomy, cytotaxonomy and biology of Chironomidae (Diptera) from Indian faunal limits*. Final Progress Report. DST. New Delhi. pp. 173.
- Singh, Santokh, and Kulshrestha, A.K. 1977. *Dicrotendipes rajasthanii* n. sp. from India. *Ent. Scand.*, **8** (3) : 233-235.
- Vaas, K. F. and Vaas Vanoven, A. 1959. Studies on the production and utilization of natural

INSECTA : COLEOPTERA

India is very rich in wetland resources and exhibit significant ecological diversity because of variability in climatic conditions and the changing topography. Of the total geographical area (3,42,239 sq. km.) of Rajasthan, the total wetland area is 1,14,244 ha. of which natural wetland area is about 14,027 ha. and manmade wetlands is about 1,00,217 ha.

Sambhar Lake, the country's largest inland saline wetland is situated in Jaipur district. The lake lies between 26° 52' latitude (N) and 74° 54' longitude (E) having total area of about 7200 ha. belonging to the brackish water ecological category.

The order Coleoptera is by far the largest order of Insecta in the animal kingdom. The members of this order are commonly known as beetles and it includes nearly a quarter of a million known species, which is about 40% of the insect fauna of the world. The habit of different types of beetles are so varied or diversified that they can invade in every main type of environment suitable for their existence. They may be herbivorous, putrivorious and carnivorous and many of them are extremely injurious to our agricultural crops, horticultural and forest trees. Some of them are serious pests of stored grains and their products.

Earlier information on coleopteran insects from wetlands of Rajasthan is very little. Though Vazirani (1977), Tak and Sewak (1987) and Tak (1996) has recorded a number of aquatic species of Coleoptera from Rajasthan. Saha (1979a & b) has also recorded a number of blister beetles from Rajasthan.

The present account of coleopteran fauna of Sambhar Lake of Rajasthan is based on the material collected by the Desert Regional Station, Zoological Survey of India, Jodhpur, Rajasthan during 1994 to 1997. Altogether 26 species belonging to 19 genera under 7 families have been studied with several new records marked with a single asterisk (*).

Information regarding diversity, habitat, economic importance and general characteristics of the families has been given based on research studies by Fabricius (1781), Borelli (1809), Eschscholtz (1829), Candeze (1857), Kraatz (1859), Chaudoir (1876), Fowler (1912), Marshall (1916), Knisch (1924), d'orchymont (1928), Andrews (1930), Cameron (1930, 1931 and 1932), Arnett (1952), Guignot (1954), Vazirani (1968 and 1977), Saha and Sengupta (1979a & b), Biswas and Sengupta (1989), Vats and Chauhan (1993), Vats and Kashyap (1993) and Saha, *et al.* (1995). Collection data on the materials studied have been incorporated.

Distributional data of the species has been given from the published records as well as actual study of the specimens. First reference and recent valid name of each genus and species have been given.

SYSTEMATIC ACCOUNT

Family CARABIDAE

This is one of the largest families of the order Coleoptera. The members of the family are almost terrestrial being found under stone or bark, in moss, rotten wood etc. They are carnivorous and predaceous and few of them also eat the young seeds and growing corn.

Genus *Scarites* Fabricius, 1775

1775. *Scarites* Fabricius, *Syst. Ent.*, p. 249.

Scarites sp.

Material examined : 3 exs, 15.xi.1995, coll. S. Kumar.

Genus *Chlaenius* Dejean, 1826

1826. *Chlaenius* Dejean, *Species Generald Coleoptera*, 2 : 297.

Chlaenius bimaculatus Dejean *

1826. *Chlaenius bimaculatus* Dejean, *Spec. gne. Col.*, 2 : 301.

1979. *Chlaenius bimaculatus* : Saha and Sengupta, *Proc. Symp. zool. Surv. India*, 1 : 27-40.

Material examined : 1 ex., 15.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : West Bengal, Bihar, Orissa, Assam, Meghalaya, Manipur, Arunachal Pradesh, Sikkim, Andhra Pradesh, Madhya Pradesh, Rajasthan, Maharashtra, Tamil Nadu and Kerala.

Elsewhere : Nepal, Bhutan, Myanmar, Sri Lanka, China, Laos and Malaya Archipelago.

Remarks : This species is recorded for the first time from Rajasthan.

Family CICINDELIDAE

The members of this family are commonly known as 'tiger beetles' and belong to the suborder Adephaga of the order Coleoptera. They are predacious and some of them are usually found in open survey places where soil is sandy and also near to moist streams, ponds, lakes and seashores.

Genus *Cicindela* Linnaeus, 1735

1735. *Cicindela* Linnaeus, *Syst. Nat.*, 2 : 657.

***Cicindela catena* Fabricius ***

1775. *Cicindela catena* Fabricius, *Syst. Ent.*, p. 226.

1790. *Cicindela catena*, Oliver, *Ent.*, 2 : 20, pl. i, f. 12.

1912. *Cicindela catena*, Fowler, *Fauna British India including Ceylon and Myanmar, Coleoptera* : *Cicindelidae*, p. 426.

Material examined : 2 exs., 15.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : West Bengal, Bihar, Karnataka, Sikkim, Tamil Nadu and Rajasthan.

Elsewhere : Sri Lanka and Myanmar.

Remarks : This species is recorded for the first time from Rajasthan.

***Cicindela fuliginosa* Dejean ***

1826. *Cicindela fuliginosa* Dejean, *Spec. Col.*, 2 : 415.

1846. *Cicindela fuliginosa*, Schmidt Goebel, *Fauna Col. Birm.*, p. 5, pl. i., fig. 6.

1912. *Cicindela fuliginosa*, Fowler, *Fauna British India including Ceylon and Myanmar, Coleoptera* : *Cicindelidae*, pp. 422-23.

Material examined : 12.vii.1994, 3exs., 15.vii.1994, 2exs., coll. R.N. Bhargava and S. Kumar

Distribution : India : Rajasthan.

Elsewhere : Sri Lanka, Malay States, Indonesia, Cambodia and Cochin-China.

Remarks : This species is recorded for the first time from India : Rajasthan.

Family DYTISCIDAE

The members of this family are commonly known as 'predaceous diving beetles' They are very active swimmers and inhabit in both fresh and brackish water. They also serve as food for carnivorous or omnivorous fishes. So far 25 species under 13 genera belonging to five subfamilies viz. Noterinae, Laccophilinae, Hydroporinae, Colymbetinae and Dytiscinae are recorded from Rajasthan. In the present study 8 species under 7 genera are recorded from Sambhar Lake of Rajasthan.

Genus *Laccophilus* Leach, 1817

1817. *Laccophilus* Leach, *Zool. Misc.*, 3 : 69.

1977. *Laccophilus*, Vazirani, *Cat. Orient., Dytiscidae*, p. 9.

***Laccophilus sharpi* Regimbart**

1889. *Laccophilus sharpi* Regimbart, *Ann. Soc. ent. Fr.*, **6** (9) : 151.

1977. *Laccophilus sharpi*, Vazirani, *Cat. Orient., Dytiscidae*, p. 15.

Material examined : 1 ex., 18.xi.1995, coll. S. Kumar.

Distribution : India : Bihar, Tripura, Orissa, Uttar Pradesh, Rajasthan, Madhya Pradesh, Maharashtra, Gujarat, Tamil Nadu and Andaman Islands.

Elsewhere : Myanmar, Pakistan, Nepal, Sri Lanka, Japan, China and Iraq.

Genus *Guignotus* Houlbart, 1934

1934. *Bidessus* (*Guignotus*) Houlbart, *Fauna Ent. Ann; Hydrocanthares*, p. 54.

1945. *Guignotus*, Guignot, *Mem. Mus. nat. Hist. Nat.*, **19** : 226.

1977. *Guignotus*, Vazirani, *Cat. Orient., Dytiscidae*, p. 31.

***Guignotus flammulatus* (Sharp)**

1882. *Bidessus flammulatus* Sharp, *Sci. Trans. R. Dublin Soc.*, **2** : 359.

1954. *Guignotus flammulatus*, Guignot, *Opusc. ent. Orient, Lund*, **19** : 221.

1977. *Guignotus flammulatus*, Vazirani, *Cat. Orient, Dytiscidae*, p. 32.

Material examined : 1 ex., 18.xi.1996, coll. S. Kumar.

Distribution : India : West Bengal, Bihar, Tripura, Orissa, Gujarat, Rajasthan, Madhya Pradesh, Uttar Pradesh, Maharashtra and Tamil Nadu.

Elsewhere : Bangladesh, Myanmar, Sri Lanka, Pakistan, China, Japan, Indonesia, Thailand and Vietnam.

***Guignotus penjabensis* Guignot**

1954. *Guignotus penjabensis* Guignot, *Opusc. ent. Orient., Lund*, **19** : 221.

1977. *Guignotus penjabensis*, Vazirani, *Cat. Orient., Dytiscidae*, p. 35.

Material examined : 3 exs., 18.xi.1996, coll. S. Kumar

Distribution : India : Bihar, Rajasthan, Gujarat, Madhya Pradesh, Maharashtra and Goa.

Elsewhere : Pakistan and Bangladesh.

Genus *Hydrovatus* Motschulsky, 1855

1855. *Hydrovatus* Motschulsky, *Etudes Ent.* 5 : 82.

1977. *Hydrovatus*, Vazirani, *Cat. Orient., Dytiscidae*, p. 25.

Hydrovatus sp.

Material examined : 1 ex., 18.xi.1996; 1 ex., 22.xi.1996, coll. S. Kumar.

Genus *Eretes* Castelnau, 1833

1833. *Eretes* Castelnau, *Ann. Soc. ent. Fr.*, 2 : 397.

1977. *Eretes*, Vazirani, *Cat. Orient., Dytiscidae*, p.73.

Eretes sticticus (Linnaeus)

1767. *Dytiscus sticticus* Linnaeus, *Syst. Nat., ed. 12*, p. 666.

1833. *Eretes sticticus* Castelnau, *Ann. Soc. ent. Fr.*, (5) 8 : 450.

1977. *Eretes sticticus*, Vazirani, *Cat. Orient., Dytiscidae*, p. 73.

Material examined : 1ex., 15.vii.1994, 2exs., 16.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Kashmir, Delhi, Gujarat, Rajasthan, Goa and South Andaman Is.

Elsewhere : Nepal.

Genus *Hydaticus* Leach, 1817

1817. *Hydaticus* Leach, *Zool. Miscell.*, 3 : 69, 72.

1977. *Hydaticus*, Vazirani, *Cat. Orient., Dytiscidae*, p. 75.

Hydaticus vittatus (Fabricius) *

1775. *Dytiscus vittatus* Fabricius, *Syst. Ent., App.*: 825.

1838. *Hydaticus vittatus*, Aube, in *Dejeans species Coleopteres*, 6 : 208.

1977. *Hydaticus vittatus*, Vazirani, *Cat. Orient., Dytiscidae*, p. 81.

Material examined : 1 ex., 15.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : West Bengal, Tripura, Gujarat, Rajasthan, Uttar Pradesh and Tamil Nadu.

Elsewhere : Myanmar, Sri Lanka, Pakistan, Nepal, Bangladesh, China, Formosa, Japan and Indonesia.

Remarks : This species is recorded for the first time from Rajasthan.

Genus *Cybister* Curtis, 1827

1827. *Cybister* Curtis, *Brit. Ent.*, **4** : 151.

1977. *Cybister*, Vazirani, *Cat. Orient., Dytiscidae*, p. 86.

Cybister tripunctatus asiaticus Sharp

1882. *Cybister asiaticus* Sharp, *Sci. Trans. R. Dublin Soc.*, **2** : 731.

1899. *Cybister tripunctatus asiaticus*, Regimbart, *Ann. Soc. ent. Fr.*, **68** : 352.

1977. *Cybister tripunctatus asiaticus*, Vazirani, *Cat. Orient., Dytiscidae*, p. 92.

Material examined : 1 ex., 12.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Tripura, Gujarat, Rajasthan, Sikkim, Tamil Nadu and Andaman Is.

Elsewhere : Pakistan, Sri Lanka, Myanmar, Nepal, Bangladesh and Afghanistan.

Family HYDROPHILIDAE

The family Hydrophilidae belongs to the superfamily Hydrophiloidea of the Suborder Polyphaga: Coleoptera and are commonly known as 'water scavenger beetle' Majority of them are truly aquatic and few of them are terrestrial and found in moist places. These insects vary from small to large in size and can be easily distinguished by its maxillary palpi, which may be mistaken as antennae.

Subfamily HYDROPHILINAE

Tribe Hydrobiini

Genus *Enochrus* Thomson, 1859

1859. *Enochrus* Thomson, *Skand. Col.*, **1** : 18.

1924. *Enochrus* Thomson, *Col. Cat.*, **14** (79) : 200-219.

Enochrus escuriens (Walker) *

1858. *Philhydrus escuriens* Walker, *Ann. Mag. Nat. Hist.* (3) **2** : 209

1924. *Enochrus escuriens* Knisch, *Col. Cat.*, **14** (79) : 209

Material examined : 1ex., 7.i.1995, coll. S. Kumar.

Distribution : India : West Bengal, Rajasthan and Nicobar Is.

Elsewhere : Queensland, Australia, Philippines, Indonesia, F.M.S., Siam, Annam, Tonkin, Cochin-China, Sri Lanka, Indonesia, Sunda Island and Vietnam.

Remarks : This species is recorded for the first time from Rajasthan.

Tribe **Hydrophilini**

Genus *Hydrophilus* Muller, 1764

1764. *Hydrophilus* Muller, *Fauna Ins. Fridrish Sdalina*, 16.

1815. *Hydrophilus* Leach, *Brewster's Edinb. Enc.*, 9 : 96.

Hydrophilus olivaceus Fabricius *

1781. *Hydrophilus olivaceus* Fabricius, *Spec. Ins.*, 1 : 289.

Material examined : 1 ex., 12.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : West Bengal, N. India, Maharashtra, Rajasthan and Gujarat.

Remarks : This species is recorded for the first time from Rajasthan.

Tribe **Berosini**

Genus *Berosus* Leach, 1817

1817. *Berosus* Leach, *Zool. Misc.*, 3 : 92.

1914. *Berosus* Leach, *Col. Cat.*, 14 (79) : 261-276.

Berosus fairmairei Zaitzev *

1908. *Berosus fairmairei* Zaitzev, *Hor. Soc. Ent. Ross.*, 38 : 355.

Material examined : 3 exs., 22.xi.1996, coll. S. Kumar.

Distribution : India : West Bengal, Bihar and Rajasthan.

Elsewhere : Indonesia, Indo-China, Tonkin, Laos, Annam, Siam, F.M.S. and Philippines.

Remarks : This species is recorded for the first time from Rajasthan.

***Berosus indicus* Motschulsky ***

1861. *Berosus indicus* Motschulsky, *Bull. Soc. Nat. Mosc.*, **34** (1) : 110.

Material examined : 2 exs., 22.xi.1996, coll. S. Kumar.

Distribution : India : West Bengal, Bihar and Rajasthan.

Elsewhere : Indonesia, China, Philippine Is., F.M.S., Cambodia, Laos, Annam, Indo-China, Tonkin, Siam, Myanmar, Sri Lanka, Sunda Is.

Remarks : This species is recorded for the first time from Rajasthan.

***Berosus pulchellus* M'Leay**

1825. *Berosus pulchellus* M'Leay, *Annual. Jav.*, : 35.

Material examined : 6 exs., 22.xi.1996, coll. S. Kumar.

Distribution : India : West Bengal, Bihar, Maharashtra, Rajasthan, Haryana, Uttar Pradesh, Karnataka and Kerala.

Elsewhere : Australia, Indo-China, Annam, Formosa, Philippine Is., Indonesia, Tonkin, Myanmar, Sri Lanka.

***Berosus nigriceps* (Fabricius)**

1801. *Hydrophilus nigriceps* Fabricius, *Syst. Ekuth.*, **1** : 254.

Material examined : 2 exs., 22.xi.1996, coll. S. Kumar.

Distribution : India : West Bengal, Delhi, Rajasthan, Uttar Pradesh and Tamil Nadu.

Elsewhere : Pakistan, Bangladesh, Sri Lanka and Egypt.

Family STAPHYLINIDAE

The member of the family are commonly known as 'rove beetles' and is also one of the largest family of the order Coleoptera. The habits of Staphylinidae are very varied and found usually in dung, decaying vegetable refuse, dead birds and animals, moss moist dead leaves etc. They are mostly carnivorous, some of them are vegetable feeders and large number of them are found in fungi and in sap, flowers, decaying wood, burrows on the bank of pond, river, lake and seashore etc. They feed on the various small insects, larvae, pupae etc. and also found to be associated with ants. Some are very conspicuous, brilliantly coloured and widely distributed throughout the world.

Subfamily OXYTELINAE

Genus *Bledius* Leach, 1819

1819. *Bledius* Leach, *The entomologists useful compendium.*, London, p. 496.

Bledius (*s. str.*) *marusthanicus* Biswas and Sengupta

1989. *Bledius* (*s. str.*) *marusthanicus* Biswas and Sengupta, *Rec. zool. Surv. India, Occ. Paper no. 122* : 1-46, Figs 1-133.

Material examined : 13exs., 16.vii.1994, coll. R.N. Bhargava and S. Kumar, 14exs., 6.i.1995, coll. S. Kumar.

Distribution : India : Rajasthan.

Bledius (*Pucerus*) *gracilicornis* Kraatz *

1859. *Bledius* (*Pucerus*) *gracilicornis* Kraatz, *Arch. Naturgesch.*, **25** (1) : 169.

1989. *Bledius* (*P.*) *gracilicornis* : Biswas and Sengupta, *Rec. zool. Surv. India, Occ. Paper No. 122* : 1-46, figs 1-133.

Material examined : 2 exs., 16.vii.1994, coll. R.N. Bhargava and S. Kumar, 5 exs., 6.i.1995, 3 exs., 21.xi.1996, coll. S. Kumar.

Distribution : India : Rajasthan and Tamil Nadu.

Elsewhere : Sri Lanka.

Remarks : This species is recorded for the first time from Rajasthan.

Subfamily STAPHYLININAE

Genus *Neobisnius* Ganglb., 1895

1895. *Neobisnius* Ganglb., *Kaf. Mitt. Eur.*, **2** : 464.

Neobisnius sp.

Material examined : 5 exs., 25.xi.1996, coll. S. Kumar.

Distribution : India : Rajasthan.

Genus *Philonthus* Curtis, 1825

1825. *Philonthus* Curtis, *Brit. Ent.*, **13** : 610.

***Philonthus poephagus* Cameron ***

1928. *Philonthus poephagus* Cameron, *Ann. Mag. Nat. Hist.*, **2** (10) : 562.

1932. *Philonthus poephagus* Cameron, *Fauna British India*, **3** : 79-80.

Material examined : 1 exs., 25.xi.1996, coll. S. Kumar.

Distribution : India : Rajasthan.

Elsewhere : Tibet.

Remarks : This species is recorded for the first time from India: Rajasthan.

Family ELATERIDAE

Elateridae is one of the largest families under the Superfamily Elateroidea of the order Coleoptera. The members of this family are commonly known as 'click beetles' The larvae of these beetles are commonly known as wireworms and are mainly root feeders. They are widely distributed throughout the world.

Subfamily AGRYPNINAE

Genus *Lanelator* Arnett, 1952

1952. *Lanelator* Arnett, *Wasmann J. Biol.*, **10** : 105.

***Lanelator fuscipes* (Fabricius) ***

1775. *Elater fuscipes* Fabricius, *Syst. ent.*, : 211.

1952. *Lanelator fuscipes* (Fabricius), Arnett, *Wasmann J. Biol.*, **10** : 105.

1996. *Lanelator fuscipes* (Fabricius), Chakraborty *et al.*, *Rec. zool. Surv. India, State Fauna Series 6, Fauna of Delhi, Coleoptera* : 346.

Material examined : 1 ex., 12.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : West Bengal, Delhi, Rajasthan, Uttar Pradesh, Karnataka and Tamil Nadu.

Remarks : This species is recorded for the first time from Rajasthan.

Genus *Agrypnus* Eschscholtz, 1829,

1829. *Agrypnus* Eschscholtz, in Thon, *Entomologisches Archiv.*, **2** (1): 32.

1973. *Agrypnus*, Von Hayek, *Bull. Br. Mus. Nat. Hist. (Ent.) Suppl.*, **20** : 113.

Agrypnus holontelius Vats and Kahsyap

1992. *Agrypnus holontelius* Vats and Kashyap, *J. Ent. Res.*, **16** (2) : 121.

Material examined : 3 exs., 15.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Uttar Pradesh, Himachal Pradesh and Rajasthan.

Subfamily DICROPIDINAE

Genus ***Dicronychus*** Castelnau, 1840

1840. *Dicronychus* Castelnau, *Hist. Nat. Ins.*, **1** : 251.

1891. *Dicronychus*, Candeze, *Cat. methodique des Elaterides* : 53.

Dicronychus sp.

Material examined : 4 exs., 15.vii.1994, coll.: R.N. Bhargava and S. Kumar.

Remarks : Due to lack of literature the material cannot be identified upto species level.

Family CURCULIONIDAE

The member of the family Curculionidae are commonly known as weevils and is one of the largest families of the order Coleoptera. So far this family includes 50,000 species under 4500 genera spreading over 72 Subfamilies from all over the world, of which 36 Subfamilies are recorded from India. They can be easily distinguished by the pronounced rostrum and geniculate antennae. Though there are few exceptions where rostrum is so short as to be almost absent. They are mainly vegetable feeders. Some of them are serious pests of stored grains, fruits, agricultural crops and forest trees.

Subfamily OTIORRHYNCHINAE

Genus ***Myllocerus*** Schonherr, 1826

1826. *Myllocerus* Schonherr, *Disp. Meth.*, p. 178.

Myllocerus transmarinus Hbst. *

1795. *Curculio transmarinus* Hbst., *Kaf.*, **6** : 213, pl. 75, fig. 1.

1914. *Myllocerus transmarinus*, Stebbing, *Indian Forest Insects*, p. 402.

1916. *Myllocerus transmarinus*, Marshal, *Fauna of British India including Ceylon and Myanmar, Col.* : *Rhyncophora* : *Curculionidae*, pp. 337-338.

Material examined : 2 exs., 12.vii. 1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : West Bengal, Bihar, Punjab, Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra and Tamil Nadu.

Remarks : This species is recorded for the first time from Rajasthan.

Mylocerus subfasciatus Guer. *

1843. *Mylocerus subfasciatus* Guer., *Voy. Deless.*, 2 : 54.

1916. *Mylocerus subfasciatus*, Marshall, *Fauna of British India including Ceylon and Myanmar, Col.: Rhynchophora : Curculionidae*, pp. 345-346.

Material examined : 2 exs., 15.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Maharashtra, Rajasthan, Pondicherry, Madhya Pradesh and Tamil Nadu.

Remarks : This species is recorded for the first time from Rajasthan.

SUMMARY

The present paper deals with 26 species belonging to 19 genera under 7 families. Of which 13 are new records: two species viz. *Cicindela fuliginosa* Dejean (Cicindelidae) and *Philonthus poephagus* Cameron (Staphylinidae) are recorded for the first time from India and 11 species under 9 genera belonging to 7 families are recorded here for the first time from Rajasthan. First reference and recent valid names of genera and species have been given. Distributional data of each species has been given from the published records as well as actual study of the specimens. Selected synonyms, collection data of each species have also given.

ACKNOWLEDGEMENTS

Authors are highly indebted to Dr. J.R.B. Alfred, Director, Zoological Survey of India, for giving laboratory facilities. Thanks are also due to Dr. G.K. Srivastava, Additional Director (Retd.) and Dr. S.K. Mitra, Joint Director (Retd.) for suggestions and encouragement to complete the work and to Dr. Q.H. Baqri, Joint Director and Officer-in-Charge, Desert Regional Station, Jodhpur for sending the material for the present study.

REFERENCES

- Andrews, H.E. 1930. *Catalogue of India Insects*, Part **18** : Carabidae, pp.1- 388.
- Arnett, R.H. 1952. A review of the Nearctic Adelocerinae (Coleoptera: Elateridae). *The Wasmann Journal of Biology*, **10** : 103-126.
- Biswas, D.N. and Sengupta, T. 1989. Revision of the Indian *Bledius* Leach (Coleoptera: Staphylinidae). *Rec. zool. Surv. India, Occ. Paper No. 122* : 1-46, figs 1-133.
- Borelli, F.A. 1809. Observations entomologiques (Caraben). *Memorie Acad. Sci. Torino*, **18** : 21-78.
- Cameron, M. 1930. *The Fauna of British India including Ceylon and Myanmar*, Coleoptera : Staphylinidae, Vol. I, London, V + 463 pp., 3 pl.
- Cameron, M. 1931. *The Fauna of British India including Ceylon and Myanmar*, Coleoptera : Staphylinidae, Vol II, London, iii + 257 pp., 2 pl.
- Cameron, M. 1932. *The Fauna of British India including Ceylon and Myanmar*, Coleoptera : Staphylinidae, Vol. III, London, V + 433. pp., 4 pl.
- Candeze, E. 1857. Monographie des Elaterides I. *Mem. Soc. R. Sci. Liege*, **12** : 1- 400.
- Chaudoir, B.M. 1876. Monographie des chleniens, *Annali Mus. Civ. Stor. nat. Giacomo Doria*, **8** : 1- 315.
- d'orchymont, A. 1928. *Catalogue of Indian Insects*, Part **14** : 1-146, Govt. of India Publication, Hydrophilidae : Coleoptera.
- Eschscholtz, J.F. 1829. Eintheilung der Elateriden in Gattungen, in *Thon. Archiv.*, **2** (1) : 31-35.
- Fabricius, J.C. 1781. *Species Insectorum. Hamburgi & Kilonii*, **1** : viii + 552.
- Fowler, W.W. 1912. *The Fauna of British India including Ceylon and Myanmar*, Coleoptera: Genl. Introduction and Cicindelidae and Paussidae, pp. 529 (Taylor and Francis, London).
- Guignot, F. 1954. *Dytiscidae recolte's par la yale North India Expedition on Kashmir et an Punjab*.
- Knisch, A. 1924. *Coleopterorum Catalogus*, (S. Schkling edited), **14** (79) : 306.
- Kraatz, G. 1859. Staphylinen-Fauna Von Ostindien insbesondere der Insel Ceylon. *Archiv fur Naturgeschichte*, **25** : 1-193, 3 pl.

- Marshall, G.A.K. 1916. *The Fauna of British India including Ceylon and Myanmar*, Coleoptera : Rhynchophera : Curculionidae, pp. 1-367.
- Saha, S.K. and Sengupta, T. 1979a. Aspects of intra-specific variation in *Chlaenius bimaculatus* Dejean (Carabidae : Chlaeniini : Coleoptera). *Proc. Symp. Zool. Surv. India*, **1** : 27-40.
- Saha, S.K. and Sengupta, T. 1979b. On a collection of India *Chlaenius* Bonelli (Chlaeniini) : Carabidae: Coleoptera) in Museum d'Histoire naturelle de Geneve with description of three new species. *Revue Suisse zool.*, **86** (2) : 419-425.
- Saha, S.K., Halder, S.K. and Biswas, S. 1995. Insecta: Coleoptera : Adephaga : Family : Rhysodidae, Paussidae and Cicindelidae. *Zool. Surv. India, State Fauna Series 3 : Fauna of West Bengal*, part **6** (A) : 1-51.
- Tak, N. 1996. Aquatic beetles of Thar Desert. In : *Faunal Diversity in the Thar Desert : Gaps in Research*, (eds.) A.K. Ghosh, Q.H. Baqri and I. Prakash, Scientific Publishers, Jodhpur, India. **24** : 221-226.
- Tak, N. and Sewak, R. 1987. On the Collection of aquatic beetles (Coleoptera) from Lake Kailana (Jodhpur, India). *Oikoassay*, **4** (2) : 33-38.
- Vats, L.K. and Chauhan, R.L. 1993. Species of *Lanelater* Arnett from North India (Elateridae : Coleoptera). *Ind. J. For.*, **16** (3) : 214-222.
- Vats, L.K. and Kashyap, S.K. 1993. Forty-eight species of *Agrypnus* Eschscholtz including forty new additions from North East India (Coleoptera : Elateridae). *J. Ent. Res.*, **16** (2) : 87-154.
- Vazirani, T.G. 1968. Contribution to the study of Aquatic beetles (Coleoptera). 2. A review of the Subfamilies Noterinae, Laccophilinae, Dytiscinae and Hydroporinae (in part) from India. *Ori. Ins.*, **2** (3-4) : 217-341.
- Vazirani, T.G. 1977. Catalogue of Oriental Dytiscidae. *Rec. zool. Surv. India, Occ. Paper No.*, **6** : 1-111.

INSECTA : COLEOPTERA : SCARABAEIDAE

The members of the family Scarabaeidae are commonly known as dung beetles and belong to the superfamily Scaraboidea (Lamellicornia) of the order Coleoptera. Though they are widely distributed and found almost all over the world, they are more common in tropics than in temperate region. These beetles feed on vegetation, roots and dung of various animals. Some of the species are highly injurious to cultivated plants, forests and horticultural trees. It is also a very useful clearing agent of excrement and others offensive materials and is known to help in the enrichment of soil.

The knowledge of Indian scarabaeidae is based on monographic works "Fauna of British India" by Arrow (1910, 1917 and 1931) and Von Dalla Torre (1912).

Present study is based on the materials collected from Sambhar Lake, Rajasthan by members of Desert Regional Station and also the collection present in the National Collection of Z.S.I., Calcutta. Altogether 18 species under 11 genera belonging to 6 subfamilies are dealt with in this paper and 9 species are first time recorded from Rajasthan marked with an asterisk (*).

SYSTEMATIC ACCOUNT

Family SCARABAEIDAE
Subfamily DYNASTINAE
Genus *Pentodon* Hope

1894. *Pentodon* Hope, *Coleopterist's Manual*, 1 : 92.

Pentodon bispinifrons Reitter *

1894. *Pentodon bispinifrons* Reitter, *Deutsche Ent. Zeitscher.*, p. 45.

1910. *Pentodon bispinifrons* Reitter, Arrow, *Fauna Brit. India. (Lamellicornis : Dynastinae)*, 1 : 303.

Material examined : 3 exs., 12 and 16.vii.1994, Coll. R.N. Bhargava and S. Kumar.

Distribution : India : Punjab and Rajasthan (Jaipur).

Elsewhere : Pakistan, Baluchistan and Turkistan.

Remarks : This species is recorded for the first time from Rajasthan.

Subfamily RUTELINAE

Genus *Anomala* Samouelle

1819. *Anomala* Samouelle, *The Entomologist's Useful companion*, p. 191.

Anomala dorsalis (Fabricius) *

1775. *Melolontha dorsalis* Fabricius, *Syst. Ent.*, p. 35.

1844. *Anomala dorsalis* Burmeister, *Handb. Ent.*, 4 (1) : 232.

1917. *Anomala dorsalis*, Arrow, *Fauna Brit. India (Lamellicornia : Rutelinae)*, 2 : 136-137.

Material examined : 2 exs., 12 and 16.vii.1994, coll. R.N. Bargava and S. Kumar.

Distribution : India : Maharashtra, Karnataka, Uttar Pradesh, Bihar, West Bengal, Assam, Sikkim, Andaman Island and Rajasthan (Jaipur).

Remarks : This species is recorded for the first time from Rajasthan.

Anomala ruficapilla Burmeister *

1855. *Anomala ruficapilla* Burmeister, *Handb. Ent.*, 4 (2) : 499.

1917. *Anomala ruficapilla*, Arrow, *Fauna Brit. India (Lamellicornia: Rutelinae)*, 2 : 153-154.

Material examined : 1 ex., 12.vii.1994, coll. R.N. Bargava and S. Kumar.

Distribution : India : Maharashtra, Karnataka, Rajasthan and Sri Lanka.

Remarks : This species is recorded for the first time from Rajasthan.

Genus *Adoretus* Castelnau

1840. *Adoretus* Castelnau, *Hist. Nat. Ins.*, 2 : 142.

Adoretus sp. 1.

Material examined : 1 ex., 16.vii.1994, coll. R.N. Bargava and S. Kumar.

Adoretus sp. 2.

Material examined : 1 ex., 16.vii.1994, coll. R.N. Bhargava and S. Kumar.

Subfamily COPRINAE

Genus *Copris* Geoffroy

1762. *Copris* Geoffroy, *Ins. Des. Env. de paris*, p. 87.

Copris andrewesi Wat. *

1891. *Copris andrewesi* Wat., *Ann. Mag. Nat. Hist.*, 7 (6) : 521.

1931. *Copris andrewesi*, Arrow, *Fauna Brit. India (Lamellicornia : Coprinae)*, 3 : 127.

Material examined : 1 ex., ♂, 12.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Maharashtra, Karnataka, Orissa and Rajasthan.

Remarks : This species is recorded for the first time from Rajasthan.

Copris punjabensis Gillet *

1921. *Copris punjabensis* Gillet, *Ann. Soc. Sci. Brux.*, p. 126.

1931. *Copris punjabensis* Arrow, *Fauna Brit. India (Lamellicornia : Coprinae)*, 3 : 128.

Material examined : 2 exs., 12.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Punjab and Rajasthan.

Remarks : This species is recorded for the first time from Rajasthan.

Copris sp.

Material examined : 1 ex., 16.vii.1994, coll. R.N. Bhargava and S. Kumar.

Genus *Onthophagus* Latralle

1802. *Onthophagus* Latralle, *Hist. Nat. Crust. et Ins.*, 3 : 141.

1883. *Proagoderus* Lansberge, *Notes Leyd. Mus.*, 5 : 15.

1931. *Onthophagus* Arrow, *Fauna Brit. India (Lamellicornia : Coprinae)*, 3 : 159-162.

Onthophagus catta (Fabricius)

1787. *Scaraboeus catta* Fabricius, *Mant. Ins.*, 1 : 12.

1787. *Scaraboeus gazella* Fabricius, *Mant. Ins.*, 2 : 377.

1931. *Onthophagus catta*, Arrow, *Fauna Brit. India (Lamellicornis : Coprinae)*, 3 : 230-231.

Material examined : 4 exs., 12.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Maharashtra, Tamil Nadu, Punjab, Bihar and Rajasthan

Elsewhere : Pakistan and Saudi Arab.

***Onthophagus bonasus* (Fabricius)**

1775. *Scarabaeus bonasus* Fabricius, *Syst. Ent.*, p. 23.

1931. *Onthophagus bonasus* Arrow, *Fauna Brit. India (Lamellicornia : Coprinae)*, 3 : 231-232.

Material examined : 1 ex., 15.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Maharashtra, Uttar Pradesh, Tamil Nadu, Karnataka, Bihar, Punjab, West Bengal and Rajasthan.

Elsewhere : Pakistan, Myanmar, Vietnam, Thailand, Cambodia and Sri Lanka.

Subfamily CHIRONINAE

Genus *Chiron* M'Leay

***Chiron cylindrus* Fabricius ***

Material examined : 1 ex., 11.vii.1952, coll. A.K. Mukherjee; 1 ex., 16.vii. 1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Orissa, Uttar Pradesh and Rajasthan.

Remarks : This species is recorded for the first time from Rajasthan.

Genus *Hybosorus* M'Leay

***Hybosorus orientalis* Westwood ***

Material examined : 2 exs., 11.vii.1958, coll. A.K. Mukherjee; 4 exs., 15. vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : West Bengal, Sikkim, Orissa, Uttar Pradesh and Rajasthan (Jaipur).

Remarks : This species is recorded for the first time from Rajasthan.

***Hybosorus* sp.**

Material examined : 20 exs., 15-16.vii.1994, coll. R.N. Bhargava and S. Kumar.

Subfamily MELOLONTHINAE

Genus *Serica* M'Leay

1819. *Serica* M'Leay, *Horae ent.*, **1** : 146.

1897. *Serica* Brenske, *Berl. Ent. Zeitschr.*, **42** : 356-357.

Serica sp.

Material examined : 9 exs., 12, 15, 16.vii.1994, coll. R.N. Bhargava and S. Kumar.

Genus *Apogonia* Kirby

1818. *Apogonia* Kirby, *Trans. Linn. Soc. London*, **12** : 401.

1899. *Apogonia* Kolbe, *Ent. Nachr.*, **25** : 198-204.

Apogonia ferruginea (Fabricius)*

1781. *Melolontha ferruginea* Fabricius, *Spec. Ins.*, **1** : 41.

1912. *Apogonia ferruginea*, Von Dalla Torre, *In Junk's Coleopt. Cat. (Scarabaeidae : Melolonthinae)*, **20** : 138.

Material examined : 4 exs., 12.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Tamil Nadu and Rajasthan.

Elsewhere : Guinea.

Remarks : This species is recorded for the first time from Rajasthan.

Apogonia cribricollis Burmeister *

1855. *Apogonia cribricollis* Burmeister, *Haudb. Ent.*, **4** (2) : 256.

1912. *Apogonia cribricollis*, Von Dalla Torre, *In Junk's. Coleopt. Cat. (Scarabaeidae : Melolonthinae)*, *Pars.*, **49** : 139.

Material examined : 2 exs., 15, 16.vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Assam and Rajasthan (Jaipur).

Elsewhere : Vietnam and Hong Kong.

Remarks : This species is recorded for the first time from Rajasthan.

Genus *Holotrichia* Hope

1837. *Holotrichia* Hope, *Col. Man.*, 1 : 100.

1912-13. *Holotrichia*, Von Dalla Torre, *Coleopt. Cat. Junk (Scarabaeidae: Melolonthinae)*, 20 (49) : 200.

Holotrichia consanguinea Blanchard

1850. *Holotrichia consanguinea* Blanchard, *Cat. Coll. Ent.*, 1 : 130.

1912-13. *Holotrichia consanguinea*, Von Dalla Torre, *Coleoptera. Cat. Junk (Scarabaeidae : Melolonthinae)*, 20 (49) : 202.

Material examined : 2 exs., 5.vii.1958, coll. A.K. Mukherjee; 8 exs., 12, 15, 16. vii.1994, coll. R.N. Bhargava and S. Kumar.

Distribution : India : Kerala, Madhya Pradesh and Rajasthan (Jaipur).

Subfamily APHODIINAE

Genus *Aphodius* Illiger*Aphodius* sp.

Material examined : 15 exs., 15-16.vii.1994, coll. R.N. Bhargava and S. Kumar.

SUMMARY

Present paper records 18 species belonging to 11 genera and 6 subfamilies from Sambhar Lake, Rajasthan most of the species (9) are recorded for the first time from Rajasthan. Distributional data of each species has been given from the published records as well as the actual study of the specimens. Selected synonyms and collection data of each species have also been given.

ACKNOWLEDGEMENTS

Authors are highly indebted to Dr. J.R.B. Alfred, Director, Zoological Survey of India for giving laboratory facilities. Thanks are also due to Dr. G.K. Srivastava, Additional Director (Retd.) and Dr. S.K. Mitra, Joint Director (Retd.), for suggestions and encouragement to complete the work and to Dr. Q.H. Baqri, Joint Director and Officer-in-Charge, Desert Regional Station, Jodhpur for sending the material for the present study.

REFERENCES

- Arrow, G.J. 1910. *The Fauna of British India, including Ceylon and Burma*. Coleoptera : Lamellicornia (Cetoniinae and Dynastinae). *Taylor and Francis, London*, **1** : 1-322, 2 pls.
- Arrow, G.J. 1917. *The Fauna of British India, including Ceylon and Burma*. Coleoptera : Lamellicornia (Rutelinae). *Taylor and Francis, London*, **2** : 1-387, 5 pls.
- Arrow, G.J. 1931. *The Fauna of British India, including Ceylon and Burma*. Coleoptera : Lamellicornia (Coprinae). *Taylor and Francis, London*, **3** : I-xii +428 pp. 13 pls.
- Von Dalla Torre, K.W. 1912. *In Junk's Coleopterorum Catalogus* (Scarabaeidae : Melolonthinae), *Pars.* **45** (1) : 1-385.

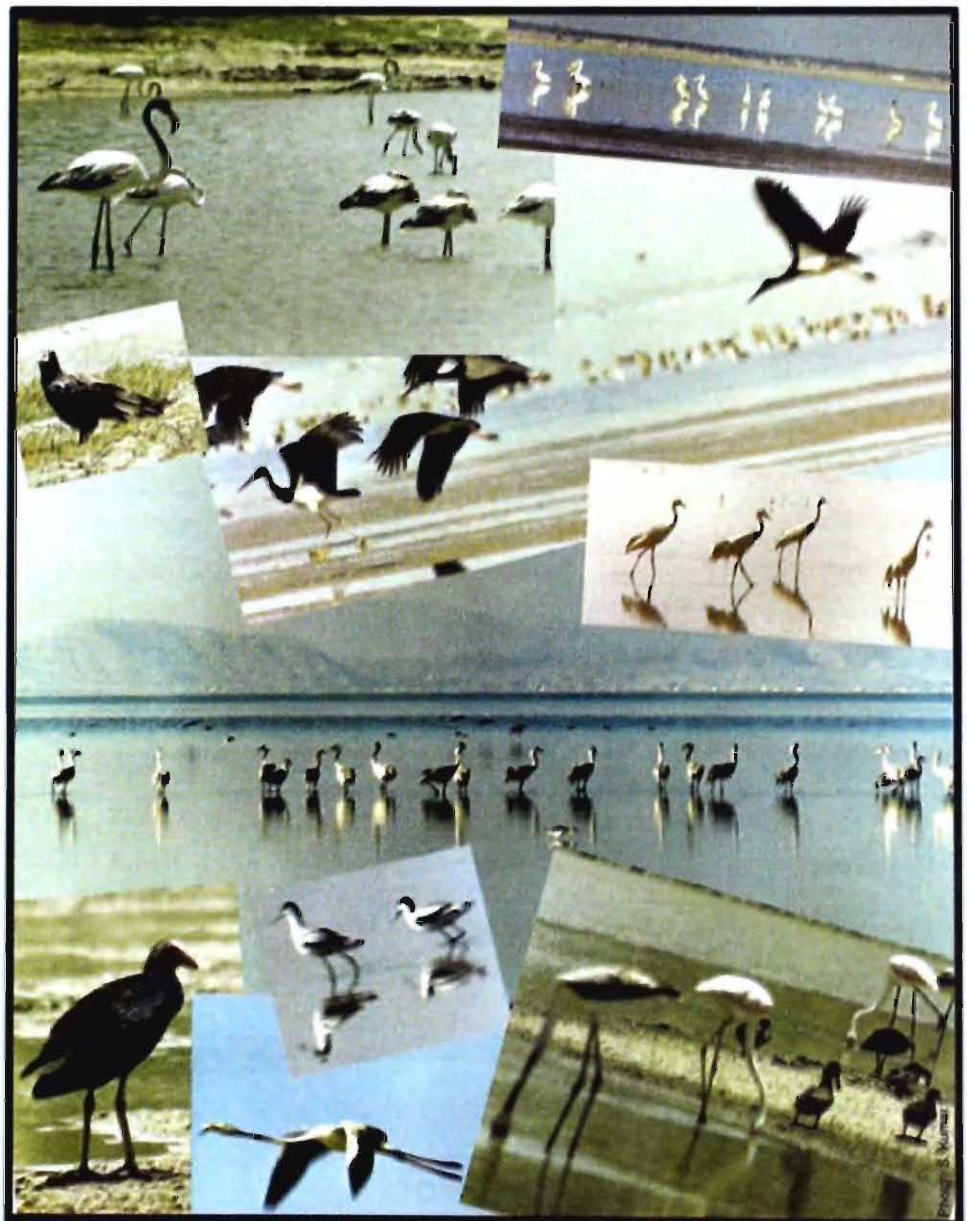


Chapter 6

Aves

Sanjeev Kumar

Avian diversity of Sambhar Lake



INTRODUCTION

The stretches of fire flames at a distant end of the open waters mesmerize man to think what it could be a red flame rising out of water. This is none other than lined population of flamingos appears as a flame inspite of the misty haze in the atmosphere at Sambhar Lake, which attracts the attention. Sambhar Lake is an ideal habitat for water birds. Its vast spread of open waters allows most aquatic birds to land in flocks and find for themselves enough space to remain aloof and separated with no resource competition. The algal blooms of *Spirulina* and variety of zooplankton fauna make it more sumptuous to birds to feed in the lake for long hours without any disturbance and interference.

Though devoid of any submerged or emergent vegetation, Sambhar Lake invites large number of wetland avian species to over winter every year. It holds a second largest congregation of flamingos after the Great Rann of Kutch, which is also said to be the "motherland of flamingos" in India.

Our knowledge on birds of Sambhar Lake is available from the studies made by Adam (1873 and 1874), McCann (1939), Alam (1982), Kumar (1996a & b and 1998), Kumar and Bhargava (1996), Rahmani (1997), Rahmani and Soni (1997) and Sangha (1998). Gopal and Sharma (1994) have documented 42 species of wetland birds from the Sambhar lake waters.

In our present attempt to study the avian fauna of Sambhar Lake, the birds were mostly observed in open waters and different sub-habitat of the lake during morning, day, evening and at night. The birds associated with the water or wetland territory were only recorded. Some of the species though not solely depended on the wetland habitat but were taking refuge during some part of the day and locally migrating to near by ponds and smaller wetland for feeding etc. were also recorded. Since the Sambhar Lake area is too large and interiors of the lake margins remains undisturbed, the birds were mostly found resting in the desolate locations for long. The frequency of their sighting, diversity at one point of time, species density and groups abundance were recorded and based on these data, their status at the Sambhar Lake have been mentioned (Table 1.).

Though most of the species were observed for their whole time activities, the two species of Flamingos : *Phoenicopterus ruber* (Linnaeus, 1758), Greater Flamingo and *Phoenicopterus minor* (Geoffroy, 1798) Lesser Flamingo were observed more closely due to their large population and major dependence on the wetland.

The avian diversity recorded during 1994-1997 is based on seven survey conducted by the author in this region during different seasons twice every year. Only direct sightings in the field were recorded and birds identified with the help of Ali and Ripley (1983) and Woodcock (1983). Specific details were observed with the help of 10 x 50 binocular and

wherever possible, photographs were taken with the help of 70-210 mm zoom lens with 2x converter on a 35 mm format SLR camera. The classification followed as Roberts (1991) and supplemented later with Manakadan and Pittie (2001). Systematic account of Aves along with their status is given below in Table 1 :

Table 1. Avian fauna of Sambhar Wetland.

Scientific name	Common name	Habitat	Status
Family PODICIPEDIDAE			
Grebes			
<i>Tachybaptus ruficollis</i> (Pallas, 1764)	Little Grebe	Ow	S, M
<i>Podiceps cristatus</i> (Linnaeus, 1758)*	Great Crested Grebe	Ow	S, M
Family PELECANIDAE			
Pelicans			
<i>Pelecanus onocrotalus</i> Linnaeus, 1758	Great White Pelican	Ow, Lm	S, M
Family PHALACROCORACIDAE			
Cormorants			
<i>Phalacrocorax niger</i> (Vieillot, 1817)	Little Cormorant	Ow, Lm	A, Re
<i>Phalacrocorax carbo</i> (Linnaeus, 1758)	Great Cormorant	Ow, Lm	S, Re
Family ANHINGIDAE			
Daters			
<i>Anhinga melanogaster</i> Pennant, 1769	Darter	Ow	Vr
Family ARDEIDAE			
Herons and Egrets			
<i>Egretta garzetta</i> (Linnaeus, 1766)	Little Egret	Lm, H	A, Re
<i>Ardea cinerea</i> Linnaeus, 1758	Grey Heron	Lm, H	R, Re
<i>Ardea purpurea</i> Linnaeus, 1766	Purple Heron	Sw, Lm	S, M
<i>Casmerodius albus</i> (Linnaeus, 1758)*	Large Egret	Lm, Sw	A, Re
<i>Mesophoyx intermedia</i> (Wagler, 1829)*	Median Egret	Lm	S, Re
<i>Bubulcus ibis</i> (Linnaeus, 1758)	Cattle Egret	Lm, H	A, Re
<i>Ardeola grayii</i> (Sykes, 1832)	Indian Pond Heron	Lm, H	R, M
<i>Nycticorax nycticorax</i> (Linnaeus, 1758)*	Night Heron	Lm, H	Vr, M
Family CICONIIDAE			
Storks			
<i>Mycteria leucocephala</i> (Pennant, 1769)	Painted Stork	H	R, M
<i>Ciconia nigra</i> (Linnaeus, 1758)	Black Stork	Lm	R, M
Family THRESKIORNITHIDAE			
Ibises and Spoonbills			
<i>Plegadis falcinellus</i> (Linnaeus, 1788)*	Glossy Ibis	Lm	R, M

Scientific name	Common name	Habitat	Status
<i>Platalea leucorodia</i> Linnaeus, 1758*	Eurasian Spoonbill	Lm, H	R, M
Family PHOENICOPTERIDAE	Flamingos		
<i>Phoenicopterus ruber</i> Linnaeus, 1758	Greater Flamingo	Sw, Lm	A, M
<i>Phoenicopterus minor</i> (Geoffroy, 1798)	Lesser Flamingo	Sw, Lm	A, M
Family ANATIDAE	Geese and Ducks		
<i>Anser anser</i> (Linnaeus, 1758)	Greylag Goose	Ow, Sw	Vr, M
<i>Anser indicus</i> (Latham, 1790)	Bar-headed Goose	Ow, Sw	Vr, M
<i>Tadorna ferruginea</i> (Pallas, 1764)*	Brahminy Shelduck	Ow, Sw	Vr, M
<i>Nettapus coromandelianus</i> (Gmelin, 1789)*	Cotton Teal	Ow	S, M
<i>Anas strepera</i> Linnaeus, 1758*	Gadwall	Ow	R, M
<i>Anas penelope</i> Linnaeus, 1758*	Eurasian Wigeon	Ow	R, M
<i>Anas platyrhynchos</i> Linnaeus, 1758*	Mallard	Ow	Vr, M
<i>Anas poecilorhyncha</i> J.R. Forester, 1781	Spot-billed Duck	Ow, Lm	Vr, M
<i>Anas clypeata</i> Linnaeus, 1758	Northern Shoveler	Ow	R, M
<i>Anas acuta</i> Linnaeus, 1758	Northern Pintail	Ow	S, M
<i>Anas querquedula</i> Linnaeus, 1758*	Garganey	Ow	Vr, M
<i>Anas crecca</i> Linnaeus, 1758	Common Teal	Ow	S, M
<i>Rhodonessa rufina</i> (Pallas, 1773)	Red-crested Pochard	Ow	S, M
<i>Aythya ferina</i> (Linnaeus, 1758)	Common Pochard	Ow	R, M
<i>Aythya fuligula</i> (Linnaeus, 1758)	Tufted Pochard	Ow	Vr, M
Family ACCIPITRIDAE	Vultures		
<i>Neophron percnopterus</i> (Linnaeus, 1758)	Egyptian Vulture	Ar, Lm	R, Re
Family GRUIDAE	Cranes		
<i>Grus antigone</i> (Linnaeus, 1758)*	Sarus Crane	Lm	R, Re
<i>Grus virgo</i> (Linnaeus, 1758)	Demoiselle Crane	Lm	A, M
<i>Grus grus</i> (Linnaeus, 1758)*	Common Crane	Lm	S, M
Family RALLIDAE	Moorhens and Coots		
<i>Porphyrio porphyrio</i> (Linnaeus, 1758)	Purple Moorhen	Ow, Lm	S, M
<i>Fulica atra</i> Linnaeus, 1758	Common Coot	Ow	A, M
Family CHARADRIIDAE	Plovers and Lapwings		
<i>Pluvialis apricaria</i> (Linnaeus, 1758)*	European Golden Plover	Lm	R, M

Scientific name	Common name	Habitat	Status
<i>Charadrius dubius</i> Scopoli, 1786	Little Ringed Plover	Lm	R, M
<i>Charadrius alexandrinus</i> Linnaeus, 1758	Kentish Plover	Lm	R, M
<i>Charadrius leschenaultii</i> Lesson, 1826*	Greater Sand Plover	Lm	R, Re
<i>Vanellus malabaricus</i> (Boddaert, 1783)*	Yellow-wattled Lapwing	Lm	R, Re
<i>Vanellus duvaucelii</i> (Lesson, 1826)	River Lapwing	Lm	R, M
<i>Vanellus indicus</i> (Boddaert, 1783)	Red-wattled Lapwing	Lm	S, Re
Family SCOLOPACIDAE	Sandpipers, Stints, Snipes, Godwits & Curlews		
<i>Gallinago stenura</i> (Bonaparte, 1830)*	Pintail Snipe	Lm	R, M
<i>Gallinago gallinago</i> (Linnaeus, 1758)*	Common Snipe	Lm	S, M
<i>Limosa limosa</i> (Linnaeus, 1758)*	Black-tailed Godwit	Lm	R, M
<i>Numenius phaeopus</i> (Linnaeus, 1758)*	Whimbel	Lm	R, M
<i>Numenius arquata</i> (Linnaeus, 1758)*	Eurasian Curlew	Lm	S, Re
<i>Tringa tetanus</i> (Linnaeus, 1758)	Common Redshank	Lm	S, M
<i>Tringa stagnatilis</i> (Bechstein, 1803)*	Marsh Sandpiper	Lm	S, M
<i>Tringa nebularia</i> (Gunner, 1767)	Common Greenshank	Lm	R, M
<i>Actitis hypoleucos</i> Linnaeus, 1758	Common Sandpiper	Lm	S, M
<i>Calidris alba</i> (Pallas, 1764)*	Sanderling	Lm	Vr, M
<i>Calidris minuta</i> (Leisler, 1812)	Little Stint	Lm	S, M
<i>Calidris temminckii</i> (Leisler, 1812)	Temminck's Stint	Lm	R, M
<i>Calidris ferruginea</i> (Pontoppidan, 1813)*	Curlew Sandpiper	Lm	S, M
<i>Philomachus pugnax</i> (Linnaeus, 1758)	Ruff (& Reeve)	Lm	Vr, M
Family RECURVIROSTRIDAE	Ibisbill, Avocets and Stilts		
<i>Ibidorhyncha struthersii</i> Vigors, 1832*	Ibisbill	Sw, Lm	R, M
<i>Himantopus himantopus</i> (Linnaeus, 1758)	Black-winged Stilt	Lm	A, Re
<i>Recurvirostra avosetta</i> Linnaeus, 1758	Pied Avocet	Lm	S, Re
Family GLAREOLIDAE	Pratincoles		
<i>Glareola pratincola</i> (Linnaeus, 1758)	Collared Pratincole	Lm	R, M
Family LARIDAE	Gulls & Terns		
<i>Larus cachinnans</i> Pallas, 1811	Yellow-legged Gull	Ow, Lm	R, M
<i>Larus brunnicephalus</i> Jerdon, 1840	Brown-headed Gull	Ow, Ar	R, M
<i>Larus ridibundus</i> Linnaeus, 1766	Black-headed Gull	Lm, Ar	R, M
<i>Sterna aurantia</i> J. E. Gray, 1831*	River Tern	Ar	S, Re
<i>Chlidonias hybridus</i> (Pallas, 1811)	Whiskered Tern	Ar	R, M

ABBREVIATIONS USED IN THE TABLE

Ow = Open waters, Sw = Shallow waters, Lm = Lake margins, Ar = Aerial, H = Heronry, A = Abundant, S = Sizeable, R = Rare, Vr = Very rare, Re = Resident, M = Migrant and * = New Records.

A total of 71 species of wetland birds have been recorded. Anatids were largest in number and 27 species have been sighted for the first time from the lake waters. Under Ramsar definition, some twenty families of water birds have been designated as birds ecologically dependent on wetland. Out of 20 families recognized, 15 families are recorded from Sambhar Lake. The other two families also form the part of wetland dependent birds. All the 17 families recorded from Sambhar Lake are taxonomically categorized to define clearly the nature of dependence and status of wetland birds. The taxonomic status of Waterfowls, Shore and Upland birds of Sambhar Lake is separately given in Fig. 1. & 2.

Grebes, Cormorant and Darters were seen to mark their presence in the lake but their population was not very high except Grebes. Pelicans though never found feeding in the lake were observed to flocking the waters in large numbers mostly in the interior of the lake towards southwestern side. Their periodic absence indicated that the flock migrates to nearby wetlands and frequents between the two. The birds represented by Ardeidae family were seen in abundance through out the lake in almost all possible niches available in the wetland. Their population too was moderate to high and very high in different years. Storks, Ibis and Spoonbills were regular visitors to this lake during winter and their presence was recorded both singly and in flocks. The most dominant component of avian fauna of this lake was the congregation of Flamingos. Both Greater and Lesser Flamingos were observed arriving as early as in the month of June when water in the smaller ponds located in close proximity of the Sambhar Lake become abundant due to timely arrival of monsoon.

It will not be out of place to mention that, Lesser Flamingos were found breeding at Sambhar Lake in year 1995-1997 (Kumar, 1996a & b and 1998) and (Kumar and Bhargava, 1996). Some fifteen species of anatids were recorded from the lake with varying degree of population showing absolute to partial dependence on the lake. These waterfowls were observed both in open waters as well as taking refuge in the shallow margins of the lake having elevated land zones, which get exposed due to receding of water level. There are two species of crane arriving in this desert land: Demoiselle Crane and Common Crane. Their presence can be seen in the agriculture fields but large flocks of these cranes were observed landing on the drier margins of the lake, sometimes staying back for hours together again to take flight to settle somewhere else again on the margins of the lake. Sarus crane though resident but seen casually.

The most abundant and commonly seen floating units were coots. Their presence was universal in open waters registering flocks of very high to medium population mostly in the northeastern side of the lake waters. When disturbed their shifting was very local owing to the magnitude of openness and vast spread of water.

Fig. 1. Taxonomic Status of Waterfowls of Sambhar Lake.

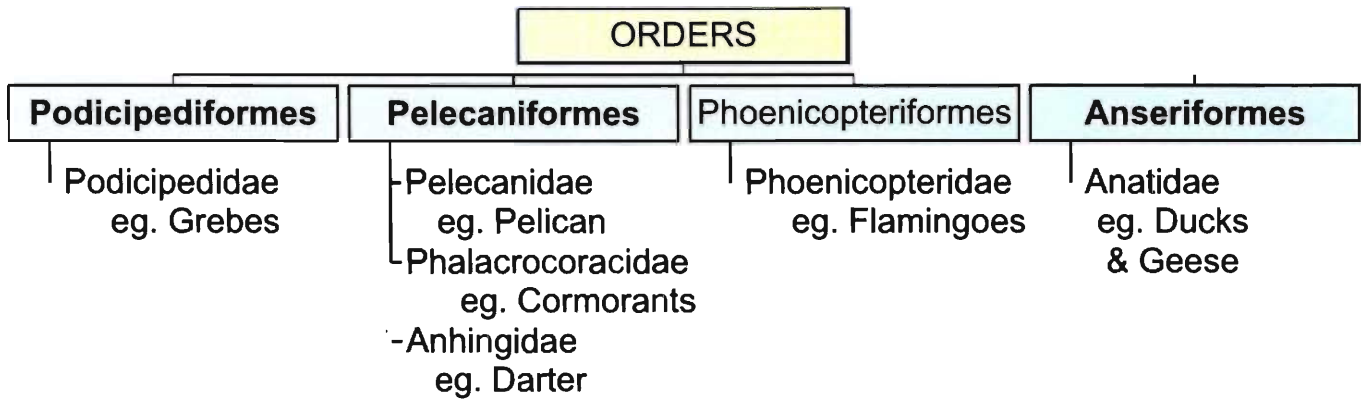
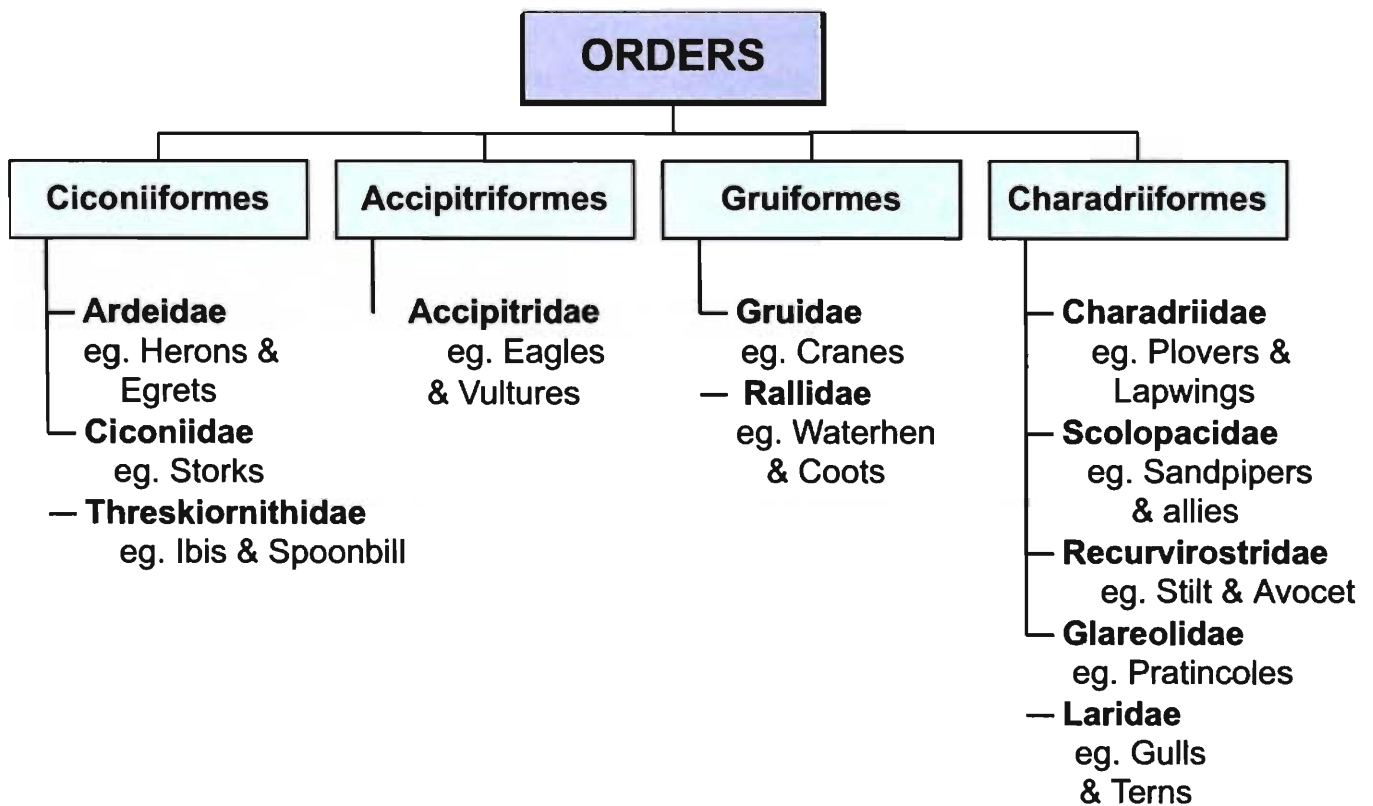


Fig. 2. Taxonomic Status of Shore and Upland birds of Sambhar Lake.



Plover and lapwing were observed mostly on the marginal drier lands of the lake with varying degree of presence especially, in the afternoon hours. Their dependence seems to be greater than the most other birds of this niche.

The family Scolopacidae was found to throng the marginal to shallow regions of the lake, most of which were seen busy feeding and taking quick look at the site with an abrupt change of place within small distances. These waders were the invisible fliers of the lake quickly abandoning the area due to foreign presence and dispersing themselves in a manner that they were never together before. The most distinctly billed Ibis bill and Avocet were seen visiting the shallow lake margins and enquiring and searching the margins vigorously. Once occupied the territory, they remain there for long with other birds. Their characteristic peculiarity lies in their wading the margins in a wider area and becoming conspicuous feeder of the shallow zones. Gulls and Terns though mostly seen flying high in the air were seen sometimes resting on objects and high raised margins of the lake. Terns though remained aerial showed their presence regularly especially during and midday over the lake. Their aerial surveillance of the lake makes it more lively and wild. The only bird of prey seen was pariah kite with no attempt to fetch the kill.

Sambhar Lake is a paradise of wetland birds in a desolate serene environment away from disturbances and competition but not free from human attention of poachers.

SUMMARY

The present paper records 71 species of wetland or wetland dependent birds belonging to 17 families under 8 orders. 27 species are recorded for the first time from Sambhar Lake.

ACKNOWLEDGMENTS

The author is thankful to Dr. J.R.B. Alfred, Director, Zoological Survey of India, Calcutta and Dr. Q.H. Baqri, Additional Director and Officer-in-Charge, Desert Regional Station, Jodhpur for providing facilities to carry out this work.

REFERENCES

- Adam, R.M. 1873. Notes on the birds of Sambhar Lake and its vicinity. *Stray Feathers*, **1** (5) : 361-404.
- Adam, R.M. 1874. Additional notes on the birds of Sambhar Lake and its vicinity. *Stray Feathers*, **2** (4) : 337-341.
- Alam, M. 1982. The flamingoes of Sambhar Lake. *J. Bombay nat. Hist. Soc.*, **79** : 194-195.

- Ali, Salim and Ripley, S.D. 1983. Birds of India and Pakistan. *Oxford University Press, Oxford*. pp. 1-733.
- Gopal, Brij, and Sharma, K.P. 1994. Ramsar sites of India: Sambhar Lake. *World Wide Fund for Nature, India, New Delhi*. 1-37.
- Kumar, Sanjeev. 1996a. New Flamingo Breeding Ground at Sambhar Lake. *Hornbill*, No. 1 : 26-27.
- Kumar, Sanjeev. 1996b. Conservation of New Breeding grounds of Flamingoes at Sambhar Lake, India. In : *Salim Ali Centenary Seminar on Conservation of Avifauna of Wetlands and Grasslands, BNHS, Bombay*, February 12-15, 1996. Abstract : 45-46.
- Kumar, Sanjeev. 1998. Biodiversity of Sambhar Lake, A Ramsar site and its sustainable development. In : *International Conference on Asian Wetlands, New Delhi/Bharatpur*. January 29-31, 1998. Abstract : 7.
- Kumar, Sanjeev and Bhargava, R.N. 1996. Sambhar Lake A new Breeding ground of flamingoes in India. *Sanctuary Asia*, XVI (2) : 59.
- Manakadan, R and Pittie, A. 2001. Standardised common and scientific names of the birds of the Indian Subcontinent. *Buceros*, 6 (1) : i-ix, 1-37.
- McCann, Charles. 1939. The Flamingoes (*Phoenicopterus ruber antiquorum* Temmi.) *J. Bombay nat. Hist. Soc.*, 44 (1) : 12-38.
- Rahmani, Asad R. 1997. Wildlife in the Thar. *Published by World Wide Fund-India*, New Delhi, pp. 1-97.
- Rahmani, Asad R. and Soni, R.G. 1997. Avifaunal changes in the Indian Thar Desert. *J. Arid Environ.*, 36 : 687-703.
- Roberts, T.J. 1991. Birds of Pakistan. Non-passeriformes. Vol. I. *Oxford University Press, New York*. pp. 1-598.
- Sangha, H.S. 1998. Flamingo surveys at Sambhar Lake (Rajasthan), India. *Flamingo Specialist Group Newsletter*, 8 : 24-25.
- Woodcock, Martin W. 1983. Collins Handguide to the birds of the Indian Sub-Continent. *Printed by Wm Collins Sons and Co Ltd, Glasgow*. pp. 1-170.



Chapter 7

Flamingos and Breeding

Sanjeev Kumar

Breeding Ground of Flamingos at Sambhar Lake



INTRODUCTION

One of the greatest and the most colourful wildlife creatures on earth are the flamingos seen around the shores of lake Sambhar, the largest inland saline wetland in India. Sometimes there can be more than 50,000 birds mainly Lesser Flamingos (*Phoenicopterus minor*) that forms a pink ribbon around the periphery of saline lake. The best general view can be obtained from the top of hill at Shakambari Mata temple above the northwestern shore, where one can fully appreciate the incredible numbers. Down by the muddy lake shore the air is full of their calls as they preen and fly in small flocks to and from other parts of the lake. Standing taller than the multitude, but in same numbers are, the paler Greater Flamingos (*Phoenicopterus ruber*), occasionally lifting their heads to show that their angled bill is largely pink, unlike the dark red of the Lesser Flamingos. There is nothing like a flamingo with its very long legs, long neck and peculiar angled bill used to filter algae, shrimps and other plankton forms that makes up the diet. Amongst birds, flamingo has the unique filter feeding system, which is comparable with the great baleen whales *Mysticeti*, which have evolved this sort of specialized feeding method.

Today the relationship between flamingos and other bird families is not clear. It is generally accepted that they should be placed with storks like birds but exactly this is still a matter of debate. They share anatomical similarities with both ibises and the storks but one school of thought place them closer to herons-Ardeidae. Behavioural studies on the other hand linked them with wildfowl Anseriformes and yet another proposition is that there is a close tie with the shore birds. McCanns, (1939) has very rightly remarked that flamingos hold almost the same problematic position in the feathered bird as does the camel among the mammals-both composition of spare parts left over after creation. They are well known, yet strangers in every sense- a patch work of nature.

What ever may be the confusion but it is certain that these large long legged wading birds are the miracle of nature. Still organizing a very primitive pattern of nesting on mud mounds at the floor of the shallow saline wetland. Earlier five species of flamingos were known to the world (Fig.1). They were divided into three genera and five species and two subspecies. Presently five species are known under two genera only. They are Greater Flamingo (*Phoenicopterus ruber*), Lesser Flamingo (*Phoenicopterus minor*), Chilean Flamingo (*Phoenicopterus chilensis*), James Flamingo (*Phoenicoparrus jamesi*) and Andean Flamingo (*Phoenicoparrus andinus*).

The Greater Flamingo occurs from northern South America and the Caribbean to southern Europe, Africa, Central Asia and India. From Peru and Uruguay in South America it is replaced by Chilean Flamingo, which occurs up to the height of 4500 m. in the Andes. The smallest species is the Lesser Flamingo of Africa and north-west India. The other two species are the Andean and James Flamingo found in Peru, Chile, Bolivia and Argentina. The

two species *Phoenicopterus ruber* and *P. minor* are found in the Indian sub-continent and becoming resident to this place. Being colonial in nesting flamingos breed in alkaline or salt lakes, where their number can run into tens of thousands in a shallow flooded wetland.

SYSTEMATIC ACCOUNT

Class AVES
 Order PHOENICOPTERIFORMES
 Family PHOENICOPTERIDAE
 Genus *Phoenicopterus* Linnaeus, 1758

Key to species

Large, 145cm, plumage dull pinkish white; beak mainly pale pink with tip black, upper mandibles overlapping lower; throat bare; iris yellowish-white to pale pink; primaries and secondaries jet black, upper coverts pink, lesser and medium coverts uniform pink, tail feathers whitish pink; legs pale pink *ruber*.

Smaller, 100 cm, plumage deep rose pink; beak dark red (appearing black) with tip black, upper mandibles not overlapping lower; throat feathered; iris deep red; primaries and secondaries black, upper coverts whitish-pink, lesser and medium coverts dark red, tail feathers pink; legs dark pinkish red *minor*.

Measurements

Species	Body length (cm)	Wing span (cm)	Bill length (mm)	Tarsus (mm)	Overall length (cm)
<i>ruber</i>	125-145	140-165	139-164	311-327	155
<i>minor</i>	80-90	95-100	100-118	190-242	100

Phoenicopterus ruber Linnaeus 1758, Greater Flamingo

1758. *Phoenicopterus* Linnaeus, *Syst. Nat.*, ed. 10 : 139 Type, by monotype, *Phoenicopterus ruber* Linnaeus.

Material examined : 1♀, 20.xi.1995, coll. S. Kumar.

Diagnostic characters : Large, coral pink long legged, enormously long neck, base of bill pink with tip black down curved about half of its length, plumage rosy white with scarlet and black wings; sexes: female smaller than male.

Distribution : India : State wise details given as block information under distribution of flamingos in India. Elsewhere: Pakistan, Northern South America, South France, South Spain, North and East Africa, Middle East, Caspian to West Siberia, Afghanistan and Central Asia.

Remarks : At Sambhar Lake population of more than 50,000 was seen in the year 1995, 1996 and little less in the year 1997.

***Phoenicopterus minor* (Geoffroy 1798)**

Lesser Flamingo

1798. *Phoenicopterus minor* Geoffroy, *Bull. Soc. Phil. Paris*, **1** : 98 (East Africa); Baker, FBI No. 2242, Vol. **6** : 375

Material examined : 1♂, 27.xi.1996, coll. S. Kumar.

Diagnostic characters : Smaller than greater flamingo, neck and body with dark rose pink plumage; bill base red with tip black, slightly down-curved, legs dark pink; Sexes alike.

Distribution : India : Sambhar Lake, Rajasthan; Great and Little Rann of Kutch, Gujarat and Chilika Lake, Orissa. Elsewhere: Pakistan and Africa.

Remarks : Nearly one lac population was recorded in the year 1995 and 1996 and also found breeding at Sambhar Lake.

Flamingos in India : In the last later half of the century various workers have reported flamingo distribution, breeding biology, diseases, behaviour and feeding in India in a wide geographical locations varying from coastal to inland saline and fresh water habitats. Some of the noteworthy contributions are of Feilden (1868); Adam (1873 and 1874); Barnes (1891); Lester (1894 and 1897); Blandford (1898); Mason (1898); Rao (1904); Baker (1908 and 1929); Inglis (1908 and 1919); Khengarji (1909); Fenton (1910); Mosse (1910); Osmaston (1922), Whistler (1923); Acharya (1935 and 1936); Billimoria (1936); Eates (1937); McCann (1939); Akhtar (1946); Ali, (1944, 1945, 1960 and 1974); Ali (1947); Ridley (1954); Sanjeevaraj (1958); Shivraj Kumar, *et al.* (1960); Abdulali (1964); Dangre (1964); Bhaduri, *et al.* (1965); Mukherjee (1968); Melliush (1968a & b and 1969); Ketkar and Gray (1971); Creado (1974); Krupanidhi (1978); Rahmani (1978); Rao and Choudary (1980), Sankhala (1981); Thakker (1982); Alam (1982); Latif (1983); Hoffmann (1983); Neelakantan (1983); Mundkur (1984); Sharma and Mathur (1984); Kumar (1986); Samarasekera (1986); Shivraj Kumar (1986); Uttangi (1986); Perera (1987); Singh (1987); Bharucha (1986 and 1988); David (1988); Reuben (1988); Rajendran (1989); Mundkur, *et al.* (1990); Bapat (1991 and 1993); Hussain (1991); Himmatsinhji (1991); Negi (1993); Singh and Yazdani (1991); Kurup, *et al.* (1993); Anon. (1994 and 1998); Gopal and Sharma (1994); Misra and Bakre (1994); Mulchandani (1994); Sowrirajan (1994); Kehimkar (1995); Manakadan (1995); Mukherjee (1995); Kumar (1996a & b and 1998); Kumar and Bhargava (1996) Devadhar, *et al.* (1997); Tatu (1997); Sangha (1998); Taher (2000); Khacher (2001) and Seksharia (2001).

DISTRIBUTION OF FLAMINGOS IN INDIA	
State	Sites
Andhra Pradesh	Pulicate Lake; Pocharam (Medak District); Madurantakam Tank and Tanks in Rollapadu area.
Delhi	Okhla Barrage and Okhla Bird Sanctuary.
Diu	Diu Salt Works.
Gujarat	Alansagar Lake, Bhadar River, Malgadh, Rajavadha Lake, Charakla Salt Works, Kiu Point, Arambda Salt Works, Sagar Salt condensers, Fofer Dam, Rudramata Dam, Topan Sar, Muli Reservoir, Gauri Shankar Lake, Shitla Tail Tank, Salt Pans-New Port, Mathal Dam Reservoir, Nakti Creek, Don Dam Reservoir, Rukmavati Creek, Ganga Creek, Laeja Creek, Lambhvel Sewage, Kaneval, Khari Reservoir, Thoriali, Sukhbhadar, Sayla Pond, Moti Moladi, Brahmani, Charadwa, Munjiasar Reservoir, Jafrabad Creek, Nawab Khan Salt Works, Khodiyar Reservoir, Macchundari, Nyari-II, Nyari, Aji, Aji II Reservoir, Mitana Reservoir, Anandpur, S.A.I. Salt Works, Halar Salt Works, Vastrapur Village Tank, Jaspur Chikli Talav, Okla, Nalsarovar, Narayan-Sarovar Sanctuary and Lakhota Lake.
Haryana	Banks of Yamuna River, Drain Number 8 Sonipat, Sultanpur Jheel Bird Sanctuary and Bhindawas Lake Bird Sanctuary.
Karnataka	Karanji, Kukkarahalli and Lingambudhi Lakes of Mysore City.
Madhya Pradesh	National Chambal Sanctuary, Morena, Dihaila Jheel and Wetlands of Karera.
Maharashtra	Nath Sagar Dam and Ujjani Dam (Bhima River).
Orissa	Chilika Lake and Daya and Bargavi tributaries of Mahanadi River Bhitarkanika Wildlife Sanctuary.
Punjab	Harike Lake, Lehal Kalan, Ropar and Nangal.
Rajasthan	Deedwana; Pachpadra; Phulera and Sambhar Lakes; Gudha Bishnoi (Kakani-Nibala enient), Jodhpur, Kailana Lake, Jodhpur; Meja and Sareri Dams (Bliwara); Ana Sagar Lake, Ajmer; Suratgarh Lake (Hanumangarh); National Chamba River Sanctuary, Kota; Sawai Madhopur and Dholpur; Keoladeo National Park, Bharatpur, Pichhola Lake, Udaipur and Alnia Dam, Kota.
Tamil Nadu	Point Calimere Wildlife Sanctuary, Sagar Sadan Lagoon, Point Calimere and Vedaranyam Salt Swamp.
Uttar Pradesh	Bahosi Lake, Etawah Wetlands and Marshy areas of Noida.

Some of the noteworthy contributions on various aspects of flamingos in the world are of Blanford (1898); Ticehurst (1923); Baker (1929); Huxley (1933); Akhtar (1947); Gallet (1950); Zahl (1953); Brown (1955, 1959 and 1962); Ridley, *et al.* (1955), Allen (1956 and 1957); Jenkins (1956-1957); Carlisle (1962); Johnson (1973, 1990, 1991a & b, 1992, 1994 and 1995); Glunder (1983); Wadsworth, *et al.* (1983); Ferreira-Garcia and Schonhofen (1984); Lopez and Merino-Moncada (1986); Murata (1986 and 1989); Samarasekera (1986); Anónimo (1989 and 1990); Puerta, *et al.* (1989); Cave-D, *et al.* (1990); Johnson and Green (1990); Albrecht (1991); Amiard-Triquet, *et al.* (1991); Arai, *et al.* (1991); Arnhem (1991); Asensio and Cantos (1991); Boutin *et al.* (1991); Christensen (1991 and 1992); Dakki, *et al.* (1991); Farinha, *et al.* (1991); Heldstab (1991); Kirwan (1991a & b and 1992); Künzel (1991); Johnson, *et al.* (1991); Junta (1991); Maksimova (1991); Martinez Vilalta (1991); Mohamed (1991); Paterson (1991); Perennou (1991a & b and 1992); Noli-Peard and Williams (1991); Richter, *et al.* (1991); Robert and Gabrion (1991); Rozsa (1991); Senra, *et al.* (1991); Simion (1991); Stevens (1991); Studer-Thiersch (1991); Vatev (1991); Anon (1992a & b); Aves (1992); Bayle (1992); Behrouzi-Rad (1992); Brayton (1992); El Agbani and Dakki (1992); Estrada, *et al.* (1992); Peinado, *et al.* (1992); Cézilly and Johnson (1992); Cremers (1992); Greenwood (1992); Hafner and Fasola (1992); Hara (1992); Hellio and Van Ingen (1992); ICONA (1992); Lebreton, *et al.* (1992) Luke (1992); Pickering (1992); Pickering, *et al.* (1992); Pickering and Duverge (1992); Préfecture (1992); Rösing (1992); Ruiu (1992); Siki and Öktem (1992); Tourenq (1992); Velasquez (1992); Aragoneses, *et al.* (1993); Bildstein, *et al.* (1993); Castro (1993); Meininger *et al.* (1993); Mundkur and Taylor (1993); Panzera and Durante (1993); Petit (1993); Taylor (1993); Taylor and Rose (1993 and 1994); Tourenq *et al.* (1993); Trujillo (1993); Agencia (1994); Andre and Delverdier (1994); Aspinall and Hirschfeld (1994); Baccetti, *et al.* (1994); Bucher (1994); Buissink (1994); Casler, *et al.* (1994); Cézilly, *et al.* (1994a & b); Collar, *et al.* (1994); Delannoy (1994); Groen and Zomerdijk (1994); Hellyer (1994); Howard (1994 a & b); Kairu (1994); Kivit, *et al.* (1994); Lassey (1994); Lipu (1994); Johnson and Bennun (1994); Magnin and Yarar (1994); Maier, *et al.* (1994); Marquez (1994); Muñoz and Escandell (1994); Murimi (1994); Patel (1994); Platt (1994); Perennou, *et al.* (1994); Treep (1994); Triplet and Yésou (1994); Vrignaud (1994) and Walmsley (1994).

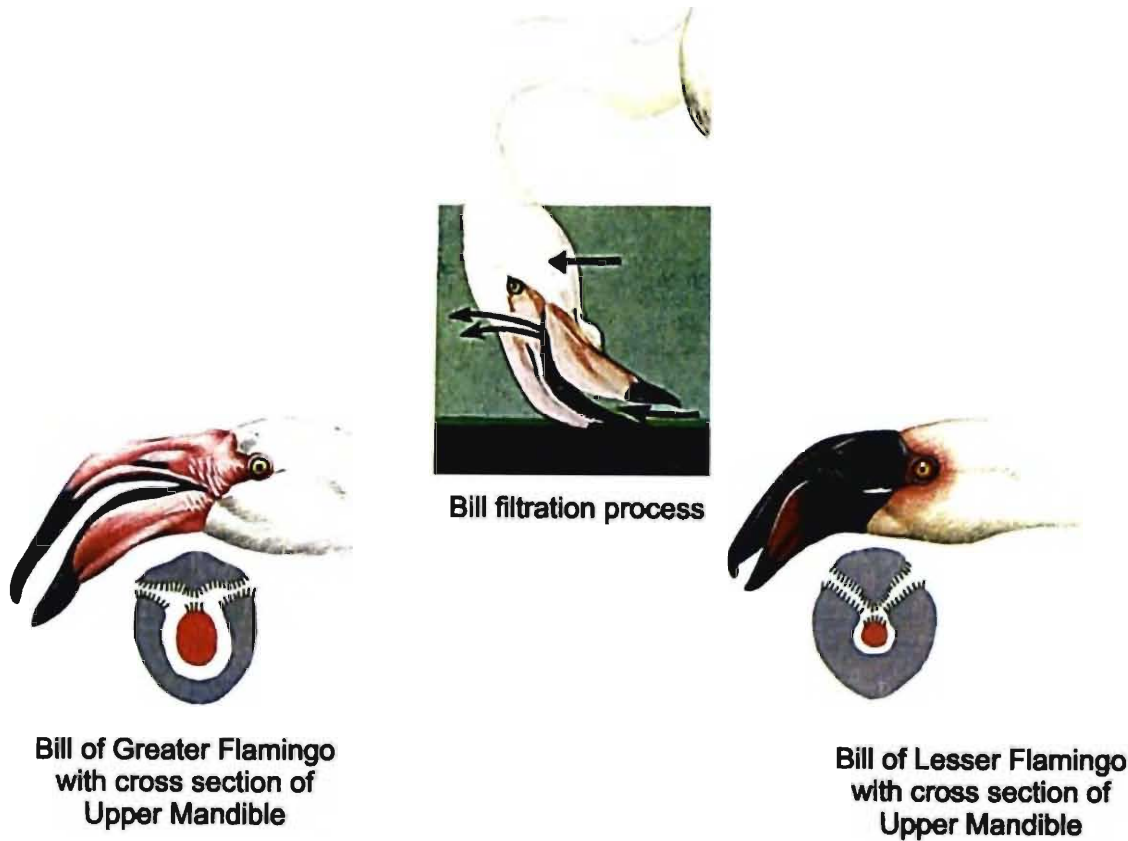
BEHAVIOUR

Flamingo is highly gregarious in nature and flocks move erratically as and when preferred or induced by the local conditions. They remain for long period of time sometimes over several months, in one feeding area. The preferred habitats are shallow brackish lakes, coastal mud flats, tidal creeks and large inland lakes both freshwater and saline with shallow margins. The feeding congregations can be seen honking throughout the day and night as if busy with natural discussion. They frequently feed and sleep at intervals throughout the day but become more active at dusk and during night, feeding hours together in the darkness. Swimming flamingos look like Swan but such occasions are rare, as they prefer to wade the margins of the lake in most parts of their lives.

Fig. 1. Flamingo diversity of the world



Fig. 2. Bill Structure & Feeding Process



Flamingos are normally very shy animals and wait, watch and fly when approached. They leap forward extending the legs striking repeatedly with water surface before becoming air borne and take off high gradually and hover over in the sky in search of a suitable safe landing sight. When flying long distances they fly low making a 'V' formation. On a inland water floor, if a congregation is approached by a human being, it has been observed that they retreat with the pace of the human approach forming a invertedΛ shaped gap till their retreat get obstructed or approach becomes distant from the foreign element, a distance permissible to remain away from such intruders. They only fly when forced by a closer presence. Solitary presence of a flamingo is a rare sight. Most of the time disease or injury makes the bird unable to fly with the moving flock.

FOOD AND FEEDING

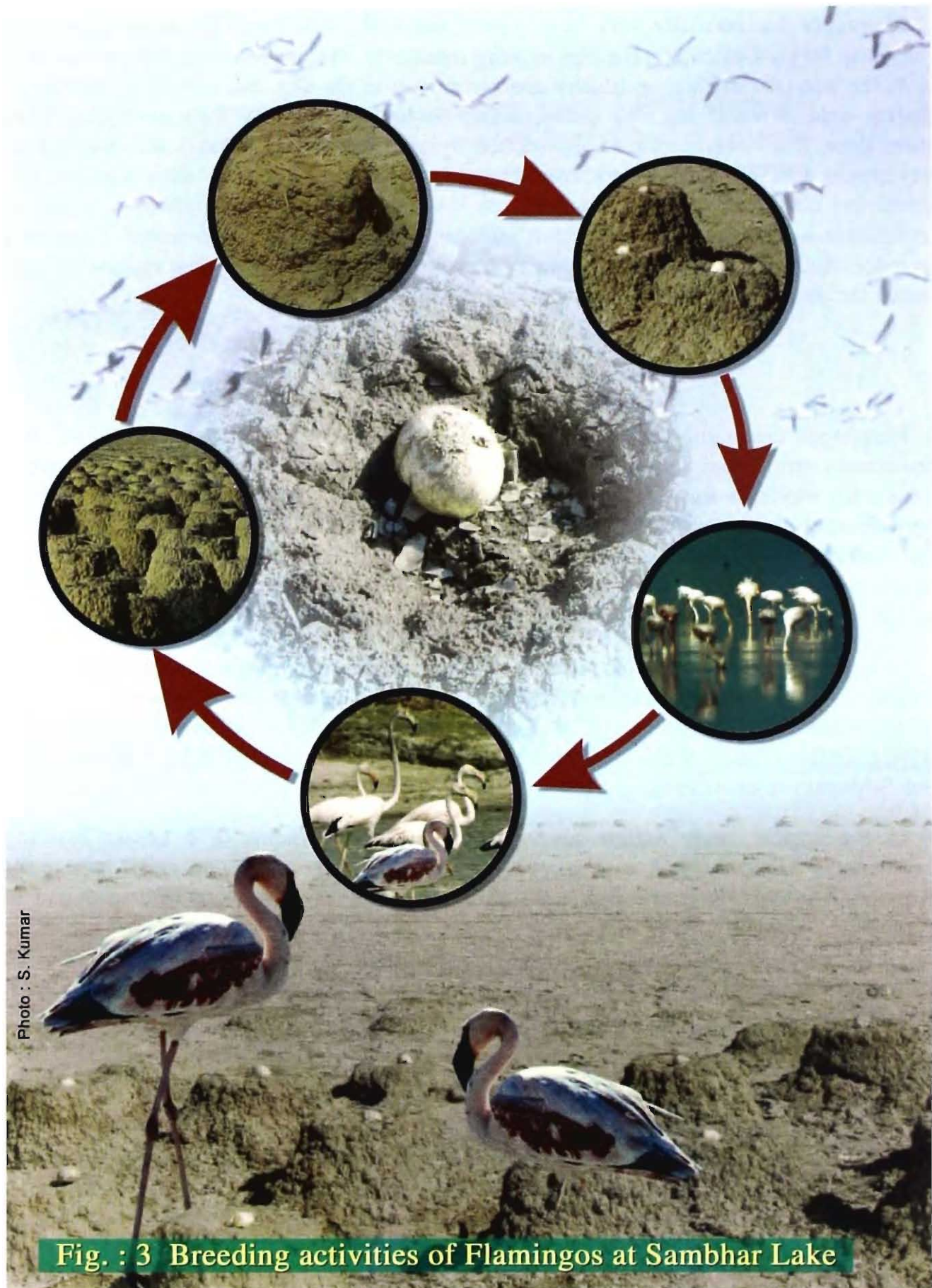
Flamingos are highly specialized filter feeders. The food consists mainly of small crustaceans, worms and insects with their larvae, ova, organic slime, algae, diatoms, vegetable seeds tinny molluscs and the brine shrimp *Artemia salina*. The two species found in Indian sub-continent have selective feeding preferences for feeding amongst food mentioned above. The fleshy tongue works back and forth like a piston sucking in the water and mud, from which minute organisms are strained out by the lamellae along the edges of the bill. It scoops or scraps the bottom ooze with the help of upper mandibles (Fig.2).

Various workers have documented information on food of flamingos. Some of the notable contributions are Blanford (1898); Baker (1908 and 1929); Ticehurst (1923); Ali (1945); Akhtar (1947); Ridley (1954); Ridley, *et al.* (1955); Allen (1956 and 1957); Carlisle (1962); Gallet (1950); Jenkins (1956-1957); Brown (1959); Zahl (1953); Abdulali (1964) and Bildstein, *et al.* (1993).

In the present study author has examined the gut contents of a Lesser Flamingo (accidentally killed by striking a electric wire near Gudha) and found small crustaceans, chironomid larvae, blue-green algae and diatoms (Bacillariophyceae) along with small quantity of mud. The present investigation confirms earlier valid findings to some extent and not all the other reports on this subject. The pinkish colour of flamingo may be due to the feeding of *Dunaliella salina* and *Spirulina*, which have a red orange carotenoid pigment responsible for imparting this pink gloss, which becomes all the more shining during breeding season.

BREEDING

The evidence of flamingo breeding in Kutch, India dates back to 5th Oct, 1893 when his highness Maharao of Kutch, addressed a letter to Lieutenant C.D. Lester (1894, *BNHS* Vol. VIII, p.553) about the breeding of flamingos in Kutch, India. This was further confirmed by his highness with a photograph of the site (*BNHS*, Vol. XV, 706). In this way His Highness became first to discover the Indian nesting sites of flamingos. Later many workers



such as McCann (1939); Ali (1944, 1945, 1960 and 1974) reported more about flamingo breeding in this region. The birds have been reported to show unpredictable breeding pattern. Some of the Ornithologists have reported about the irregular nature of breeding attempts at other breeding grounds in Africa Continent with gaps ranging from one year to several years without any breeding activity (Johnson, 1973). Details of breeding by Lesser and Greater Flamingos are given for 16 sites in 10 countries by Johnson, (1995). Lesser flamingos bred massively at lake Natron in 1991-1992, the most important breeding site for the species in the World. However, the Lesser Flamingo is classified as near threatened in many countries where the species occur including India (Johnson, 1995).

Attempt of breeding or rather nest building by flamingos at places other than Kutch was reported by Thakker (1982) and Tatu (1997). In the meantime it was reported that flamingo breeding has discontinued for over a spell of 13 years (Negi, 1993) and brief account of this was also reported by Johnson (1995). The presence of flamingo at Sambhar Lake has been reported as early as 1873 (Adam, 1873) and over the century their almost regular arrival reported time and again by various workers (McCann, 1939; Alam, 1982; Mukherjee, 1968 and Gopal and Sharma, 1994).

In a recently conducted survey of Sambhar Lake during the winter season of 1994-1995, a nesting colony was found in an area of about one hectare in the southern side of the lake (Ch. 1. Fig. 2. pg. 8). Nearly 11,000 mud nests in about 18 clusters (Table 1.) most of them were found to have hatched eggshells giving ample evidence that the bird has certainly bred when the area was inundated.

This revealed a historical event of Natural History - the breeding ground of flamingos at Sambhar Lake. In the following years 1995-1996 and 1996-1997 large-scale nest building process was recorded in an area of about 10 km long stretch and a population of about 1500 juveniles were closely monitored in January 1996. Since the project was later concluded no further observations were made of their breeding in the lake (Fig.3.). With the discovery of a new breeding ground and successive nest building process recorded, it becomes amply evident that flamingos have searched an alternate and more suitable breeding ground in India other than the Great Rann of Kutch in Gujarat. It is reported that due to various factors, breeding of flamingos in Rann of Kutch has either stopped or diminished due to erratic inundations of their habitat and inflow of toxic waste in the region.

The vast expanse of Sambhar Lake and availability of food has given opportunity to this bird to breed in this region. It seems from the nest building process in such a large area that flamingo was breeding at Sambhar Lake for quite a long time but it was recorded only in the year 1995. Since the water recedes very quickly in the Sambhar Lake, the flamingos have also adapted to simplify the nest building process. The birds scoop the soil in a circular form thereby leaving central place as elevated portion for laying eggs.

As has been mentioned earlier that flamingo nesting is a primitive character but it is a miracle of the nature that mud mounds are constructed by this bird on a shallow floor

Table 1. Flamingo nest count at Sambhar Lake (One Ha. Area) in 1995

Groups	No. of Nest Mounds	No. of Hatched Eggs	Height of Mounds (Range in cm)
I	21	10	20-30
II	31	20	20-35
III	26	05	15-30
IV	86	23	10-23
V	01	01	13-00
VI	08	02	13-20
VII	28	15	10-28
VIII	56	26	10-38
IX	430	155	10-46
X	0	66	10-20
XI	20	08	10-25
XII	170	108	10-20
XIII	65	32	15-36
XIV	08	02	10-18
XV	16	04	10-20
XVI	32	18	10-25
XVII	10	03	03-05
XVIII	15	-	05-14

depending upon the thin level of water below raising the height of the mud mound up to a maximum of 18 inches or (48 cm.) from the ground level. It is beautifully constructed in a cluster with equal distance from others that it formed a colony setting in a given area. The mounds are build by scooping the mud and placing it on one upon another in between it is reinforced with the feathers of the bird to get strength in gaining height. Charles McCann (1939) mentioned that feathers found in the mounds are accidental but it was not found so. The cross-section of many mud mounds was made just to see the presence of feathers at different layers. And it was found that feathers were placed only after gaining certain height and not in the base. Large numbers of mounds were examined and it was concluded that bird is definitely placing them for reinforcement while constructing the mound.

The semi-solid mud is collected in the bill scooped by the side of the constructing mounds and pile up in a heap. In this process excess water oozes out form the mound giving the outer wall a rough surface with minute irregular channels moving down up to

the bottom. The conical shape having broad base and a truncated cone with saucer shaped depression is a result of natural phenomenon in such a construction using semi-solid soil. Accordingly, it can be inferred that height is depended on the soil moisture and the effort made at that point of time by the birds sensing the receding water level.

Nests are sometimes interconnected or have clear spaces between them, as is quite evident from the hollow scooped area lying in between them. The cluster of nests forming a colony were found as a unit at a little distance from others in a ten km long and half km wide area on the southwestern shore of the Sambhar Lake. At some distance from shore inside the lake, only hollow scoops were seen on the lake floor in a big area giving shape of a colony. This might be made by the bird at the early stage sensing fast receding water and utilizing the surface elevated due to hollowing of the area, giving them opportunity to even lay eggs on these elevated areas inside the lake with thin water level existing in the region similar to that of constructed mud mounds. This phenomenon seems to be an adaptation to cope up with fast receding of water at Sambhar Lake where evaporation rate is very high and inundation of water is restricted to only early monsoon months. Though no breeding was observed in this area, large scale scooping of lake floor gave ample evidence that bird must have certainly used the floor for laying egg and incubated it to get a young one.

Eggs of Lesser flamingos are similar in shape and colour with those of Greater flamingos but slightly smaller in size. A dropped egg was found in an abandoned colony inside the water having oval shape, dull white colour with outer rough surface. Similar data was recorded with other dropped eggs found on the lake floor. The egg size was recorded in mm as length and width 78.8 x 44.5, 73 x 49.0, 73 x 47.5, and 81 x 48.2.

The chicks were observed in different stages of development. The freshly hatched chicks have swollen dark reddish colour legs. The colour slowly changes to brownish gray. The beak of the juveniles is straight and grayish much different from that of specialized filter beak of the adults, which gradually takes the shape of the adult beak. The hatching period is reported to be 30 to 32 days though no such observation was recorded during the survey. The downy chicks very soon are able to fend themselves. Parental care is well marked, chicks being fed by parents till they are able to move along with the adult flock. The juveniles are kept under the safe protective cover of the flocks. The grayish brown colour of the immature slowly changes to that of the adult with juveniles having mainly gray-brown head, neck and beak resembling their parents.

With the discovery of the new breeding ground and successive nest building recorded over the period it has become important to focus attention on conservation of this saline wetland. Sambhar Lake has a great potential to support large population of flamingos and other water birds. To implement any conservation measures on this wetland it is important to have a sound legal policy and framework to protect such wetlands from over exploitation by different agencies. This has become all the more necessary because Sambhar Lake is facing a serious threat due to large scale top soil removal by private salt industries, heavy

vehicular trespass by villagers, small dam construction in the catchment area restricting the water supply of the lake, mushrooming of private salt industries on the northern belt of the lake from Nawa to Gudha in Nagaur district, air and noise pollution due to these industries and biotic interference including human pressure. The poaching during winter months is very high and estimated to be more than 100 aquatic birds poached almost every day and marketed at Jaipur, which is only 60 km away from the lake. These threats are rather steadily affecting not only the process of establishment of breeding ground but also disturbing the feeding population of flamingos and other water birds.

To develop or to promote favourable ecological niche for breeding of flamingos in this lake, the International Scientific Community should take up this issue at the highest level to implement conservation measures to safe guard the unique saline waterfowl habitat.

SUMMARY

The paper includes taxonomic position, identification, distribution, behaviour, food and feeding, breeding of flamingos and their conservation at Sambhar Lake. With the discovery of the new breeding ground and successive nest building recorded over the period, it has become important to focus attention on conservation of this saline wetland. Sambhar Lake has a great potential to support large population of flamingos and other water birds. It is important to have a legal framework to protect this wetland from excessive exploitation and damage caused by different agencies. The International Scientific Community should also take up the issue of safe guarding this saline wetland, an important Ramsar site of India.

ACKNOWLEDGEMENTS

The author is grateful to Dr. J.R.B. Alfred, Director Zoological Survey of India, Calcutta and Dr. Q.H. Baqri, Additional Director, Zoological Survey of India, Jodhpur for providing facilities and encouragement to carry out such a megha investigation on Ramsar site. Thanks are also due to Late Dr. I. Prakash and Dr. N.S. Rathore for their constant encouragement and lucid suggestions throughout the period of investigation.

REFERENCES

- Abdulali, Humayun 1964. On the food and other habits of the Greater Flamingo (*Phoenicopterus roseus Pallas*) in India. *J. Bombay nat. Hist. Soc.*, **61** (1) : 60-68.
- Acharya, H.N. 1935. Occurrence of the Flamingo *Phoenicopterus ruber antiquorum* (Temm.) in north Gujarat. *J. Bombay nat. Hist. Soc.*, **38** (2) : 404.

- Acharya, Hari Narayan. 1936. Migration of Flamingo (*Phoenicopterus ruber antiquorum* Temm.) from North Gujarat. *J. Bombay nat. Hist. Soc.*, **39** (1) : 182.
- Adam, R.M. 1873. Notes on the birds of the Sambhar Lake and its vicinity. *Stray Feathers*, **1** (5) : 361-404.
- Adam, R.M. 1874. Additional note on the birds of the Sambhar Lake and its vicinity. *Stray Feathers*, **2** (4) : 337-341.
- Agencia de Medio Ambiente. 1994. El flamenco vuelve a criar en la laguna de Fuente de Piedra. *Quercus*, **103** : 47.
- Akhtar, S.A. 1946. Babar the Great on Flamingoes. *J. Bombay nat. Hist. Soc.*, **46** (3) : 545-547.
- Akhtar, S.A. 1947. Ab-Istadeh, a breeding place of the Flamingo *Phoenicopterus roseus* (Pallas) in Afghanistan. *J. Bombay nat. Hist. Soc.*, [1947] **47** (2) : 308-314.
- Alam, Mohd. 1982. The Flamingos of Sambhar Lake. *J. Bombay nat. Hist. Soc.*, **79** (1) : 194-195.
- Albrecht, S. 1991. News and Information; Flamingos killed by hailstones in Turkey. *Bull. OSME*, **26** : 36-37.
- Ali, Hamid 1947. The Persian name for the Flamingo. *J. Bombay nat. Hist. Soc.*, **47** (1) : 164.
- Ali, Salim 1944. The Common Flamingo (*Phoenicopterus ruber*) : An appeal. *J. Bombay nat. Hist. Soc.*, **44** (3) : 476-477.
- Ali, Salim 1945. More about the Flamingo *Phoenicopterus ruber* (Pallas) in Kutch. *J. Bombay nat. Hist. Soc.*, **45** (4) : 586-593.
- Ali, Salim 1960. 'Flamingo City' re-visited: nesting of the Rosy Pelican (*Pelecanus onocrotalus* Linnaeus) in the Rann of Kutch. *J. Bombay nat. Hist. Soc.*, **57** (2) : 412-415.
- Ali, Salim 1974. Breeding of the Lesser Flamingo, *Phoeniconaias minor* (Geoffroy) in Kutch. *J. Bombay nat. Hist. Soc.*, **71** (1) : 141-144.
- Allen, R.P. 1956. The Flamingos their life history and survival. With special reference to the American or West Indian Flamingo (*Phoenicopterus ruber*). *Res. Rep. nat. Audubon Soc.*, **5** : 1-285.
- Allen, R.P. 1957. On the Trail of Vanishing Birds. *McGraw Hill*, New York.
- Amiard-Triquet, C., Pain, D. and Delves, H.T. 1991. Exposure to trace elements of flamingos living in a Biosphere Reserve, the Camargue (France). *Envir. Pollution*, **69** : 193-201.

- Andre, J.P. and Delverdier, M. 1994. Haemosiderosis or haemochromatosis? A study in cage birds. *Revue-de-Medecine. Veterinaire*, **145** (1) : 37-41.
- Anon. 1992a. Flamingos flown in. *Oryx*, **26** : 198.
- Anon. 1992b. Shielded by Volcanoes, Flamingos Still Need Help. *National Geographic (August)*.
- Anon. 1994. Flamingos nesting in Gujarat City. *Hornbill* (1) : **14** (photo 16-17).
- Anon. 1998. An ill-wind this way blows. *Sanctuary Asia*, **18** (4) : 62-63.
- Anónimo. 1989. *Phoenicopterus ruber* in Notes. *Butlletí del Parc Natural del delta del'Ebre*, **4** : 45.
- Anónimo. 1990. *Phoenicopterus ruber* in Notes. *Butlletí del Parc Natural del delta del'Ebre*, **5** : 39-40.
- Aragoneses, J., Martinez, F. and Ruiz, J.B. 1993. En las Salinas de Santa Pola se producen 6,000 atropellos de vertebrados cada ano. *Quercus* **83** : 20-21.
- Arai, S., Arai, C., Fujimaki, M., Iwamoto, Y., Kawarada, M., Saito, Y. Nomura, Y and Suzuki, T. 1991. Cutaneous Tumour-like Lesions due to Poxvirus Infection in Chilean Flamingos. *J. Comp. Path.*, **104** : 439-441.
- Arnhem, R. 1991. Le Traffic des Oiseaux Exotiques : Assez de drames. *Des actes! L'Homme et l'Oiseau*, **29** : 87-98.
- Asensio, B. and Cantos, F.J. 1991. Informe sobre la Campana de Anillamiento de Aves en España. Ano 1990. *Ecologia*, **5** : 275-319.
- Aspinall, S. and Hirschfeld, E. 1994. Greater Flamingos breed in the United Arab Emirates in 1993. *Phoenix*, **10** : 14-15.
- Aves, J. 1992. Flamingoes in a changing world. *Marunga*, **10** (60) : 19-21.
- Baccetti, N., Cianchi, F., Dall`Antonia, P., De Faveri, A. and Serra, L. 1994. Nidificazione di Fenicottero, *Phoenicopterus ruber*, nella Laguna di Orbetello. *Riv. Ital. Orn., Milano*, **64** (1) : 86-87.
- Baker, E.C. Stuart, 1908. The Indian Ducks and their allies. XI + 292 pp., 30 col. Pls.-London (*Bombay nat. Hist. Soc.*).
- Baker, E.C. Stuart, 1929. *The Fauna of British India, including Ceylon and Burma. Birds* (2nd ed.), Vol. **6**, xxxvi + 500 pp., 3 pls. London (*Taylor & Francis Ltd.*).
- Bapat, N.N. 1991. Greater Flamingo in Kutch. *Newsletter for Birdwatchers*, **31** (1 & 2) : 11-12.

- Bapat, Navin N. 1993. A visit to the 'Flamingo City' in the Great Rann of Kutch, Gujarat. *J. Bombay nat. Hist. Soc.*, [1992] **89** (3) : 366-367.
- Barnes, H.E. 1891. Nesting in western India. *J. Bombay nat. Hist. Soc.*, **6** (3) : 285-317.
- Bayle, P. 1992. EDF neutralize la ligne de Fos-sur-Mer. *L'Oiseau Magazine*, **27** : 11.
- Behrouzi-Rad, B. 1992. On the movements of the Greater Flamingo, *Phoenicopterus ruber*, in Iran. *Zoology in the Middle East*, **6** : 21-27.
- Bhaduri, J.L., De, A. and Biswas, B. 1965. The main thoracic and cervical arteries of the Flamingo, (*Phoenicopterus roseus*) Pallas. *Proceedings of the Zoological Society of Calcutta*, **18** : 167-172.
- Bharucha, E. 1986. Bhigwan flamingo haven. *Sanctuary Asia*, **6** (2) : 144-150; 170-171.
- Bharucha, E. 1988. Some aspects of behaviour observed in the Greater Flamingo at Bhigwan. *J. Bombay nat. Hist. Soc.*, **84** (3) : 677-678 (1987).
- Bildstein, L., Golden, C.B., McCraith, B.J., Bohmke, B.W. and Sibels, R.E. 1993. Feeding behaviour, aggression and the conservation biology of flamingos: integrating studies of captive and free-ranging birds. *Amer. Zool.*, **33** : 117-125.
- Billimoria, N.M. 1936. Flamingoes in India. *J. Sind nat. Hist. Soc.*, **2** (4) : 22-26.
- Blanford, W.T. 1898. *Fauna of British India, including Ceylon and Burma*. Birds 4, XXII+500 + 2 (unnumbered) pp. London (*Taylor & Francis Ltd.*).
- Boutin, J., Chérain, Y. and Vandewalle, P. 1991, Suivis de populations naturelles, compte rendu ornithologique camarguais pour les années 1988-1989. *Rev. Ecol. (Terre Vie)*, **46** : 263-289.
- Brayton, C. 1992. Amyloidosis, Hemochromatosis and Atherosclerosis in a roseate flamingo (*Phoenicopterus ruber*). *Annals New York Academy Sci.*, **653** : 184-190.
- Brown, Leslie 1955. The Breeding of Lesser and Greater Flamingos in East Africa. *J. E. Africa nat. Hist. Soc.*, **22** : 159-162.
- Brown, Leslie 1959. The mystery of the Flamingos. *Country Life Ltd.*, London.
- Brown, Leslie 1962. A note on the Flamingo situation at Megodi, Kenya. *I.U.C.N. Bulletin (New Series)*, **5** : 7.
- Bucher, E.H. 1994. Population and Conservation Status of Flamingos in Mar Chiquita, Cordoba, Argentina. *Colonial Waterbirds*, **15** (2) : 179-184.
- Buissink, F. 1994. De roze parade. *Grasduinen*, **8** (Aug) : 4-11.
- Carlisle, D.B. 1962. The Times Science Review, Winter 1962, p. 10.

- Casler, C.L., Esté, E.e. and Pardo, H.M. 1994. Breeding of the Greater Flamingo in western Venezuela. *Colonial Waterbirds*, **17** (1) : 28-34.
- Castro, H. 1993. Las Salinas de Cabo Gata. *Inst. de Estudios Almerienses*, Almeria.
- Cave-D, di, Cirillo, L. D-Ettori, C. Mura, G. and Di-Cave, D. 1990. In: XVI Congresso nazionale della Societa Italiana di Parassitologia, Cagliari, S. Margherita di Pula, 7-11 Maggio 1990. *Parassitologia*. **32** : Supplemento, 90.
- Cézilly, F. and Johnson, A.R. 1992. exotic Flamingo in the Western Mediterranean Region; A Case for Concern. *Colonial Waterbirds*, **15** : 261-263.
- Cézilly, F., Gowthorpe, P., Lamarche, B. and Johnson, A.R. 1994a. Observation on the Breeding of the Greater Flamingo, *Phoenicopterus ruber roseus*, in the Banc d'Arguin National park, Mauritania. *Colonial Waterbirds* **17** : 181-183.
- Cézilly, F., Tourenq, C. and Johnson, A.R. 1994b. Variation in parental care with offspring age in the Greater Flamingo. *The Condor*, **96** : 809-812.
- Christensen, R. 1991. Artsbestemmelse af flamingoer. *Dansk. orn. Foren. Tidsskr.*, **85** : 97-100.
- Christensen, R. 1992. Flamingoernes forekomst in Danmark. *Dansk. Orn. Foren. Tidsskr.*, **86** : 123-127.
- Collar, N.J., Crosby, M.J. and Stattersfield, A.J. 1994. Status of two South-American flamingos Species. In : *Birds to Watch 2 : The World List of Threatened Birds*. BirdLife Conservation Series No. 4. Bird Life International, Cambridge. pp. 46.
- Creado, W. 1974. Flamingoes at Juhu. *Newsletter for Birdwatchers*, **14** (10) : 8.
- Cremers, H.C. 1992. Flamingos flourish in northern Germany. *New Scientist*, (3 October) : 4.
- Dakki, M., Baouab, R.E. and El Agbani, M-A. 1991. Recensement hivernal d'oiseaux au Maroc: janvier 1991. *Doc. Inst. Sci., Rabat*, **14** : 1-30.
- Dangre, B.J. 1964. Flamingos at Kapurwadi Tank near Ahmednagar, Maharashtra State. *Newsletter for Birdwatchers*, **4** (10) : 9-10.
- David, Reuben 1988. Ahmedabed (sic!) Zoo leader in flamingo breeding. *Zoos' Print*, **3** (7) : 16.
- Delannoy, P. 1994. Les dandies du ciel. *Grands Reportages* 154 (Novembre) : 14-24.
- Devadhar, J.G.; Devadhar, Madhuri; Neginhal, S.G. and Uttangi, J.C. 1997. Flamingo flocks near Haveri. *Newsletter for Birdwatchers*, **37** (2) : 30.

- Eates, K.R. 1937. Leaves from my notebook. *J. Sind nat. Hist. Soc.*, **3** (3) : 4-11.
- El Agbani, M-A and Dakki, M. 1992. Recensement hivernal d'oiseau au Maroc: janvier. *Doc. Inst. Sci., Rabat*, **15** : 1-32.
- Estrada, J., Marti, R.Y. and Martinez Vilalta, A. 1992. *Phoenicopterus ruber* in Notes floristiques I faunistiques. *Butlleti del parc Natural del delta del'Ebre*, **7** : 46.
- Farinha, J.C. Serra Guedes, R. and Croft de Moura, R. 1991. Recenseamento e distribuicao do Flamingo, *Phoenicopterus ruber roseus*, em Portugal em 1990. *Airo (CEMPA)*, **2** (2) : 49-51.
- Feilden, H.W. 1868. Letter about three specimens of a flamingo. *Ibis* (2) **4** : 496.
- Fenton, L.L. 1910. Occurrence of the Lesser Flamingo (*Phoeniconaias minor*) in Kathiawar. *J. Bombay nat. Hist. Soc.*, **20** (1) : 221.
- Ferreira-Garcia, R.G. and Schonhofen, C.A. 1984. Aspergillus bronchopneumonia in Flamingo. *Arquivos de Biologia e Tecnologia.*, **27** (3) : 341-342.
- Gallet, Etienne 1950. The Flamingos of the Camargue. *Basil Blackwell*, Oxford.
- Glunder, G. 1983. Actinobacillus-like bacteria associated with joint disease in a flamingo. *Tagung der fachgruppe Geflugelkrankheiten.*, **3** (4) : 178-183.
- Gopal, Brij and Sharma, K.P. 1994. Ramsar Sites of India : Sambhar Lake, *WWF-India*, 1994. pp. 37.
- Greenwood, A.G. 1992. Laparoscopic salpingectomy in a hybrid flamingo. *Vet. Rec.*, **131** (15) : 349.
- Groen, N.M. and Zomerdijk, P.J. (eds). 1994. Waders and waterbirds along part of the Atlantic coast of Morocco, Autumn 1991-Spring 1992. *WIWO Report No.* **47**.
- Hafner, H. and Fasola, M. 1992. Workshop on Colonial Waterbirds in the Mediterranean: A Summary. *Colonial Waterbirds*, **15** (1) : 159-160.
- Hara 1992. Flamingos: a photographer's odyssey. *Abrams Inc.*, New York.
- Heldstab, A. 1991. Flamingos- Medizinischer "Check" beim Umzug. *Zolli (Bull. Zool. Garden Basel)*, **67** : 10-11.
- Hellio, J-F. and Van Ingen, N. 1992. Le flamant rose, prince de la Camargue. *Patte à patte, Editions Milan*, Toulouse.
- Hellyer, P. 1994. Greater Flamingos: first time breeding in the UAE. *Arabian Wildlife*, **1** : 11.

- Himmatsinhji, M.K. 1991. The 'flamingo city' in the Rann of Kutch. *Newsletter for Birdwatchers*, **31** (5-6) : 3-4.
- Hoffmann, T.W. 1983. The 1983 mid-January duck (and flamingo) count in Sri Lanka. *Loris*, **16** (3) : 116-123.
- Howard, G.W. (Ed.). 1994a. Understanding wetland biodiversity in East Africa. *Proceedings of the Workshop on Wetland Biodiversity*, Nakuru, Kenya, 9-13 November 1993. IUCN, Gland.
- Howard, G.W. 1994b. East African Flamingos surveyed. *IUCN Wetlands Programme Newsletter*, (10 November) : 5.
- Hussain, S.A. 1991. Flamingo breeding conservation action needed. *Newsletter for Birdwatchers*, **31** (3 & 4) : 5-6.
- Huxley, J.S. 1933. Africa View. *Chatto and Windus*, London.
- ICONA 1992. Lead poisoning in flamingos, *Phoenicopterus ruber*, during the spring of 1991 in Donana National Park, In : *Lead Poisoning in Waterfowl*. (ed.) D.J. Pain, pp. 91.
- Inglis, C.M. 1908. The Flamingo *Phoenicopterus roseus* in the Darbhanga District, Tirhoot. *J. Bombay nat. Hist. Soc.*, **18** (3) : 683.
- Inglis, C.M. 1919. Further occurrence of the Rose Coloured Starling (*Pastor roseus*) and the Flamingo (*Phoenicopterus roseus*) in the Darbhanga District, Behar. *J. Bombay nat. Hist. Soc.*, **26** (3) : 853.
- Jenkins, P.M. 1956-1957. The Filter Feeding and Food of Flamingos (*Phoenicopterus*). *Phil. Trans. R. Soc. Lond. Ser. B.* **240** : 401-492.
- Johnson, A.R. 1973. Camargue flamingos, East Africa, International of Flamingo Symposium (ed). L. Brown. *Slimbridge* 10-12 July.
- Johnson, A.R. 1990. Taking a closer look at the flamingos on Cyprus in winter. *Gli Ucelli d'Italia*, **15** : 5-10.
- Johnson, A.R. 1991a. An overview of the distribution, numbers and movements of Flamingos in the Western Mediterranean and North-West Africa. *Reunión técnica sobre la situación y problemática del Flamenco rosa Phoenicopterus ruber roseus en el Mediterráneo Occidental y Africa Noroccidental* : 63-81.
- Johnson, A.R. 1991b. Conservation of breeding flamingos in the Camargue (Southern France) *Species*, **17** : 33-34.
- Johnson, A.R. 1992. Les Flamants de Camargue. *PNRC, Imp.du Collège*, Marseille.

- Johnson, A.R. 1994. Flamant rose *Phoenicopterus ruber roseus*. In : Atlas des Oiseaux Nicheurs de France. (eds.). D. Berthelot-Yeatman, and G. Jarry, Soc. Orn. De France, Paris. pp. 114-115.
- Johnson, A.R. 1995. Annual report 1991-1994. *IWRB Flamingo Specialist Group Newsletter* No. 7. France.
- Johnson, A. and Bennum, L. 1994. Lesser Flamingos : concern over Lake Natron. *IWRB News*, 11 : 10-11.
- Johnson, A.R. and Green, R.E. 1990. Survival and breeding of Greater Flamingos, *Phoenicopterus ruber roseus*, in the wild after a period of care in captivity. *Wildfowl*, 41 : 117-121.
- Johnson, A.R., Green, R.E. and Hirons, G.J.M. 1991. Survival rates of Greater Flamingos in the West Mediterranean Region, In : *Bird population studies: relevance to conservation and management*. (eds.) C.M. Perrins, J-D. Lebreton, and G.J.M. Hirons, 12 : 249-271.
- Junta De Andalucia. 1991. Reunion tecnica sobre la situacion y problematica del Flamenco rosa (*Phoenicopterus ruber roseus*) en el mediterraneo occidental y Africa noroccidental. *Galan*, Sevilla. pp. 238.
- Kairu, J.K. 1994. Pesticide residues in birds at Lake Nakuru, Kenya. *Int. Journ. Salt Lake Research*, 3 : 31-48.
- Kehimkar, Isaac 1995. A glimmer of hope. *Hornbill*, (3) : 1.
- Ketkar, S.M. and Gray, Lincoln 1971. Occurrence of the Flamingo in interior Maharashtra. *J. Bombay nat. Hist. Soc.*, 68 (1) : 241-242.
- Khacher, Lavkumar 2001. Letter, dated 1st May 2001. *Newsletter for Birdwatchers*, 41 (3) : 38.
- Khengarji, Rao 1909. The Lesser Flamingo (*Phoenicoptera minor*) in Cutch. *J. Bombay nat. Hist. Soc.*, 19 (1) : 262.
- Kirwan, G. 1991a. Around the region (Oman : 2nd record of Lesser Flamingo). *Bull. OSME*, 26 : 62.
- Kirwan, G. 1991b. Karapinar Ovasi, a little-known Turkish IBA. *Bull. OSME*, 27 : 24-27.
- Kirwan, G. 1992. A freshwater breeding record of Greater Flamingo *Phoenicopterus ruber* in Turkey. *Sandgrouse*, 14 : 56-57.
- Kivit, H., Nijmeijer, H. and Ovaa, A. (eds.). 1994. Wader and waterfowl migration in the Cukurova deltas, South Turkey, Spring 1990. *WIWO report* No. 48.

- Krupanidhi, D. 1978. Birdwatching enroute to Sandalbet "the city of flamingoes" *Newsletter for Birdwatchers*, **18** (11) : 4-6.
- Kumar, R. Ashok 1986. Rise in global mean sea level has it affected the Flamingo breeding grounds? *J. Bombay nat. Hist. Soc.*, **83** (2) : 433-435.
- Kumar, Sanjeev 1996a. New flamingo breeding ground at Sambhar Lake. *Hornbill*, (1) : 26-27.
- Kumar, Sanjeev. 1996b. Conservation of New Breeding grounds of Flamingoes at Sambhar Lake, India. In : *Salim Ali Centenary Seminar on Conservation of Avifauna of Wetlands and Grasslands, BNHS, Bombay*. February 12-15, 1996. Abstract : 45-46.
- Kumar, Sanjeev. 1998. Biodiversity of Sambhar Lake, A Ramsar site and its sustainable development. In : *International Conference on Asian Wetlands, New Delhi/Bharatpur*. January 29-31, 1998. Abstract : 7.
- Kumar Sanjeev and Bhargava, R.N. 1996. Sambhar Lake-A new breeding ground of flamingoes in India. *Sanctuary Asia*, **XVI** (2) : 58.
- Künzel, A. 1991. Flamingos-die neue Anlage aus der Sicht des Gartenarchitekten. *Zolli (Bull. Zoll. Garden Basen)*, **67** : 6-7.
- Kurup, D.K. Narayana and Kumar, C. Mohan 1993. The Flamingo *Phoenicopterus roseus* Pallas in Kerala. *J. Bombay nat. Hist. Soc.*, **89** (3) : 365-366 (1992).
- Lassey, P.A. 1994. First record of Lesser Flamingo, *Phoenicopterus minor*, in Egypt. *Sandgrouse*, **16** (1) : 52-53.
- Latif, N. 1983. Flamingo in Husein (sic) Sagar. *Newsletter for Birdwatchers*, **23** (1-2) : 12.
- Lebreton, J-D., Burnham, K.P., Clobert, J. and Anderson, D.R. 1992. Modeling survival and testing biological hypotheses using marked animals : a unified approach with case studies. *Ecological Monographs*, **62** : 67-118.
- Lester, C.D. 1894. The Flamingo breeding in India. *J. Bombay nat. Hist. Soc.*, **8** (4) : 553-554.
- Lester, C.D. 1897. The Flamingo breeding in India. *J. Bombay nat. Hist. Soc.*, **11** (2) : 321.
- Lipu, Cagliari 1994. Fenicottero Rosa. *LIPU Ali Notizie* **29** (September) : 12.
- Lopez, A. and Merino-Moncada, M. 1986. Cholangiocarcinoma and hepatic megalocytosis in a captive flamingo, *Phoenicopterus ruber*. *Journal Zoo Animal Medicine*, **17** (4) : 147-148.
- Luke, A. 1992. Spanish pilots force flamingos to flee. *New Scientist*, (5 September) : 7.

- Magnin, G and Yarar, M. 1994. Some notes on the breeding of Greater Flamingo, *Phoenicopterus ruber roseus* and White Pelican, *Pelecanus onocrotalus*, in Turkey. *OSME Bulletin*, **32** : 28-30.
- Maier, R.T., Kelly, A. and Robinson, K.B. 1994. *Breeding of three species of Flamingos in Bolivia*. Bolivian Puna Expedition 1992/93. Final Report University of East Anglia, Norwich. NR4 7TJ-U.K.
- Maksimova, A.P. 1991. Ecology and biology of *Eurycestus avoceti* (Cestoda : Dilepididae). *Parazitologiya*, **25** (1) : 73-76.
- Manakadan, Ranjit 1995. Impact of salt works on the status, population of the Greater Flamingo *Phoenicopterus ruber roseus* and the Lesser Flamingo *Phoeniconaias minor* in the Great Vedaranyam Swamp. *J. Bombay nat. Hist. Soc.*, **92** (3) : 364-371.
- Marquez, F. 1994. Flamencos. *El Pais Semanal*, **179** : 56-63.
- Martinez Vilalta, A. 1991. El Flamenco en el Delta del Ebro. Reunion tecnica sobre la situacion y problematica del Flamenco rosa *Phoenicopterus ruber roseus* en el Mediterraneo Occidental y Africa Noroccidental. pp. 48-51.
- Mason, J.M. 1898. Occurrence of the Lesser Flamingo *Phoeniconaias minor* near Bombay. *J. Bombay nat. Hist. Soc.*, **11** (3) : 552.
- McCann, C. 1939. The Flamingo (*Phoenicopterus ruber antiquorum* Temm.). *J. Bombay nat. Hist. Soc.*, **41** (1) : 12-38.
- Meininger, P.L., Wolf, P.A., Hadoud, D.A. and Essghaier, M.F.A. 1993. Ornithological survey of the coast of Libya, July 1993. *WIWO Report*, No. **46**.
- Melluish, R.A.S. 1968a. A Flamingo-hunter's Journal: Part 1. *Newsletter for Birdwatchers*, **8** (11) : 1-4.
- Melluish, R.A.S. 1968b. A Flamingo-hunter's Journal: Part 2. *Newsletter for Birdwatchers*, **8** (12) : 4-6.
- Melluish, R.A.S. 1969. A Flamingo-hunter's Journal : Part three. *Newsletter for Birdwatchers*, **9** (1) : 2-5.
- Misra, V. and Bakre, D.P. 1994. Organochlorine contaminants and avifauna of Mahala water reservoir Jaipur, India. *Science Total Environ.*, **144** : 1-3.
- Mohamed, S.A. 1991. On the Movement and Distribution of the Greater flamingo, *Phoenicopterus ruber*, in Bahrain, Arabian Gulf. *Arab Gulf J. Scient. Res.*, **9** (3) : 133-142.
- Mosse, A.W. 1910. Occurrence of the Lesser Flamingo (*Phoeniconaias minor*) in Kathiawar. *J. Bombay nat. Hist. Soc.*, **20** (2) : 518.

- Mukherjee, R.N. 1968. Visit to Sambhar Lake area for Flamingos in November. *Newsletter for Birdwatchers*, **8** (4) : 9.
- Mukherjee, R.N. 1995. Birds of arid and semi-arid tracts, *Rec. zool. Surv. India, Occ. Paper* No. **142** : 303.
- Mulchandani, Anil 1994. Letters. *Hornbill*, (4) : 9.
- Mundkur, T. 1984. Occurrence of the Lesser Flamingo *Phoeniconaias minor* (Geoffroy) in Poona, Maharashtra. *J. Bombay nat. Hist. Soc.*, **81**(2) : 468.
- Mundkur, T. and Taylor, V. 1993. Asian Waterfowl Census 1993. *IWRD, Slimbridge, UK*. 142 pp.
- Mundkur, Taej; Pravez, Rishad; Khachar, Shivraj Kumar and Naik, R.M. 1990. Hitherto unreported nest site of Lesser Flamingo (*Phoeniconaias minor*) in the Little Rann of Kutch, Gujarat. *J. Bombay nat. Hist. Soc.*, **86** (3) : 281-285 (1989).
- Muñoz, T. and Escandell, R. 1994. Anuari Ornitologic de les Balears 1993. (Vol. 8) *Waterfowl census* : 61-65.
- Murata, K. 1986. A case report of Sarcocystis infection in a lesser flamingo. *Japanese J. Parasitology*, **35** (6) : 555-557.
- Murata, K. 1989. A serological survey of Toxoplasma gondii infection in zoo animals and other animals. *Japanese. J. Vet. Sci.*, **51** (5) : 935-940.
- Murimi, S.K. 1994. Falling water-levels in saline lakes of the central Rift Valley of Kenya : the case of Lake Elmenteita. *Int. Journ. Salt Lake Research*, **3** : 65-74.
- Neelakantan, K.K. 1983. Comment. *Mayura*, **4** (3) : 25.
- Negi, A.S. 1993. A visit to the flamingo city in the Great Rann of Kutch (Gujarat). *Indian Forester*, **113** (5) : 354-359.
- Noli-Peard, K.R. and Williams, A.J. 1991. Wetlands of the Namib Coast. *Madoqua*, **17** : 147-153.
- Osmaston, B.B. 1922. Occurrence of the Flamingo in the Central Provinces. *J. Bombay nat. Hist. Soc.*, **28** (2) : 549-550.
- Panzer, S. and Durante, M.A. 1993. Eccezionale passo di fenicottero, *Phoenicopterus ruber* L., 1758 nel Salento (Puglia). *Picus*, **19** : 67-69.
- Patel, T. 1994. French aim their sights on pink flamingos. *New Scientist*, 1994 (3 December) : 9.
- Paterson, A. 1991. Fuente de Piedra. *Birds Magazine RSPB*, **13** (6) : 52-56.

- Peinado, V.I., Polo, F.J., Viscor, G. and Palomeque, J. 1992. *Avian Pathology*, **21** (1) : 55-64.
- Perennou, C. 1991a. African Waterfowl Census 1991. Les Dénombrements Internationaux d'oiseaux d'eau en Afrique, 1991. *IWRB, Slimbridge, UK*. 88 pp.
- Perennou, C. 1991b. Les recensements Internationaux d'oiseaux eau en Afrique tropicale. *IWRD Publication*, No. **15**.
- Perennou, C. 1992. African Waterfowl Census 1992. Les Dénombrements Internationaux d'oiseaux d'eau en Afrique, 1992. *IWRB, Slimbridge, UK*. 87 pp.
- Perennou, C., Mundkur, T. and Scott, D.A. 1994. The Asian Waterfowl Census 1987-1991: Distribution and status of Asian Waterfowl. *AWB Publication No. 86, IWRB Publication*, No. **24**.
- Perera, B.L. 1987. The flamingoes at Bundala. *Loris*, **17** (6) : 236-237.
- Petit, T. 1993. Myopathie de capture chez des flamants. *Le Point Vétérinaire*, **25** : 77-80.
- Pickering, S. 1992. The comparative breeding biology of flamingos, Phoenicopteridae, at the Wildfowl and Wetlands Trust Centre, Slimbridge. *Int. Zoo. Yb.*, **31** : 139-146.
- Pickering, S., Creighton, E. and Stevens-Wood, B. 1992. Flock size and breeding success in flamingoes. *Zool. Biol.*, **11** : 229-234.
- Pickering, S.P.C. and Duverge, L. 1992. The influence of visual stimuli provided by mirrors on the marching displays of lesser flamingos, *Phoeniconais minor*. *Anim. Behav.*, **43** : 1048-1050.
- Platt, J. 1994. Greater flamingos, *Phoenicopterus ruber*, at Khor Dubai, United Arab Emirates. *Sandgrouse*, **14** : 72-80.
- Préfecture de Région Languedoc Roussillon 1992. Le comblement des étangs. *Service Maritime et de Navigation du Languedoc Roussillon*.
- Puerta, M.L. Huecas, V. and Garcia-Del-Campo-A.L. 1989. *Comp. Biochem. Phy.*, **94** (4) : 623-625.
- Rahmani, A.R. 1978. The fascinating fabulous Flamingo. *Science Reporter*, **15** : 174-176.
- Rajendran, N. 1989. Flamingo (*Phoenicopterus ruber* L.) and its nidification. *Zoos' Print'*, **4** (7) : 23-24.
- Rao, K. 1904. The Flamingo (*Phoenicopterus roseus*) breeding on the Rann of Cutch. *J. Bombay nat. Hist. Soc.*, **15** (4) : 706-707.

- Rao, M.R.K.M. and Choudary, C. 1980. Pneumomycosis in a flamingo (*Phanecopteris* [*Phoenicopterus*] *ruber* L.) [*Aspergillus* sp.]. *Indian Vet. Jour.*, **57** (9) : 774-775.
- Reuben, R. 1988. The SPIC flamingos. *Newsletter for Birdwatchers*, **28** (5-6) : 4-5.
- Richter, N.A., Bourne, G.R. and Diebold, E.N. 1991. Gender Determination by Body Weight and Linear Measurements in American and Chilean Flamingos, previously Surgically Sexed : Within-Sex Comparison to Greater Flamingo Measurements. *Zoo Biology*, **10** : 425-431.
- Ridley, M.W. 1954. Observations on the diet of Flamingoes. *J. Bombay nat. Hist. Soc.*, **52** (1) : 5-7.
- Ridley, M.W., Moss, B.L. and Percy, Lord R.C. 1955. The Food of Flamingos in Kenya Colony. *J.E. Africa nat. Hist. Soc.*, **22** (5) : 147-158.
- Robert, F. and Gabrion, C. 1991. Cestodes of birds in Camargue. Importance of *Artemia* (Crustacea, Anostraca) and host location strategies. *Annals de. Parasitologie Humaine et. Comparee.*, **66** (5) : 226-235.
- Rösing, J. 1992. Erfolgreiche Handaufzucht von drei Chile-Flamingos (*Phoenicopterus chilensis*). *Jahresbericht des Zoologischen Gartens der Stadt frankfurt Am Main*, 116-130 für 1974-1991 : 64-69.
- Rozsa, L. 1991. Points in question flamingo lice contravene Fahrenholz. *Int. Journ. Parasitology*, 151-152.
- Ruiu, D. 1992. Fenicottero: Zingaro rosa. *Oasis*, **10** (Ottubre) : 34-59.
- Samarasekera, M.J. 1986. Do flamingoes nest in Sri Lanka? *Loris*, **17** (4) : 183.
- Sangha, H.S. 1998. Flamingo surveys at Sambhar Lake (Rajasthan), India. *Flamingo Specialist Group Newsletter*, **8** : 24-25.
- Sanjeevaraj, P.J. 1958. Occurrence of the Common Flamingo (*Phoenicopterus ruber* Linn.) at Nandyal, Andhra State. *J. Bombay nat. Hist. Soc.*, **55** (1) : 171-172.
- Sankhala, K. 1981. A voyage to Flamingo Island. *The India Magazine* **1** (2) : 38.
- Seksharia, Pankaj 2001. Ucchali: Pakistan's flamingo refuge. *Sanctuary Asia*, **21** (3) : 40-41.
- Senra Martinez, A., Abeledo, J. and Ales, E.E. 1991. El Flamenco rosa (*Phoenicopterus ruber roseus*) en Andalucia: Situacion actual y problematica de conservacion. *Jornadas de Zonas Humedas Andaluzas, Fuente Piedra*, 20-22 April 1990 : 19-31.

- Sharma, S. and Mathur, K.M. 1984. A new species of *Armadoskrajabinia* (Cestode : Hymenolepididae) from Indian flamingo (*Phoenicopterus minor*). *Pavo*, **22** (1 & 2) : 80-83.
- Shivraj Kumar, 1986. Flamingo. In : Encyclopedia of Indian Natural History. (Ed. : Hawkins, R.E.) *Bombay Natural History Society & Oxford University Press*, Delhi. pp. 225-226.
- Shivraj Kumar, Naik, R.M. and Lavkumar, K.S. 1960. A visit to the flamingos in the Great Rann of Kutch. *J. Bombay nat. Hist. Soc.*, **57** : 465-478.
- Siki, M. and Öktem, N. 1992. La révision des espèces d'oiseaux de la pêcherie de homa dans la Saline de Camalti. *Journ. Fac. Sc. Ege Univ. B*, **14** : 39-51.
- Simion, L. 1991. Tra I fennicotteri della Camargue : Dove si Costruise un Futuro Rosa. *Airone* **118** (Febbraio) : 78-99.
- Singh, D.F. and Yazdani, G.M. 1991. Flamingo-fish interaction in the Ujani wetland, Maharashtra. *Geobios*, **18** (1) : 38-40.
- Singh, Gurmit 1987. Flamingo migration in Punjab. *Cheetal*, **28** (3) : 17-19.
- Sowrirajan, T.V. 1994. Are there flamingoes in Sewri? *Hornbill* (1) : 2-7.
- Stevens, E.F. 1991. Flamingo breeding: the role of group displays. *Zool. Biol.*, **10** : 53-63.
- Studer-Thiersch, A. 1991. Flamingos - Wie in Africa. *Zolli (Bull. Zool. Garden Basel)*, **67** : 3-5.
- Taher, Siraj A. 2000. Spotlight: Lesser Flamingo *Phoeniconaias minor*. *Pitta*, **111** : 4.
- Tatu, Ketan S. 1997. Nest building activities of the Flamingo (*Phoenicopterus roseus*) at Shahwadi (Ahmedabad). *J. Bombay nat. Hist. Soc.*, **94** (2) : 397-398.
- Taylor, V. 1993. African Waterfowl Census 1993. Les Dénombrements Internationaux d'oiseaux d'eau en Afrique, 1993. *IWRB, Slimbridge*, UK. 156 pp.
- Taylor, V. and Rose, P.M. 1993. Western Palearctic and South West Asia Waterfowl Census 1993. *IWRB, Slimbridge*, UK. 215 pp.
- Taylor, V. and Rose, P.M. 1994. African Waterfowl Census 1994. Les Dénombrements Internationaux d'oiseaux d'eau en Afrique, 1994. *IWRB, Slimbridge*, UK. 184 pp.
- Thakker, P.S. 1982. Flamingos breeding in Thol Lake Sanctuary near Ahmedabad. *J. Bombay nat. Hist. Soc.*, **79** (3) : 668.
- Ticehurst, C.B. 1923. The birds of Sind (Pt. V). *Ibis* **5** (11) : 438-474.

- Tourenq, C. 1992. La formation de crèche chez le Flamant rose, *Phoenicopterus ruber roseus*. Unpubl. Diploma., Université Paul Sabatier, Toulouse.
- Tourenq, C. Johnson, A. R. and Gallo, A. 1993. Le comportement agressif de l'adulte Flamant rose, *Phoenicopterus ruber roseus* : condition préalable à la formation de crèches chez cette espèce? Actes du 25eme Colloque Annuel de la SFECA, Rennes, 7-9 avil 1993 : 305-311.
- Treep, J.M. 1994. Zijn flamingo's Phoenicopoteridae blijvertjes in Nederlandse wateren? *Het Vogeljaar*, **42** (5) : 208-217.
- Triplet, P. and Yésou, P. 1994. Oiseaux d'eau dans le delta du Sénégal en janvier 1994. *Bulletin O.N.C.*, **190** : 2-11.
- Trujillo, D. 1993. Flamenco. *Ardeola*, **40** : 89.
- Uttangi, J.C. 1986. Flamingoes in Badami Taluk. *Newsletter for Birdwatchers*, **26** (11-12) : 23-24.
- Vatev, I.T. 1991. Observations du Flamant rose, *Phoenicopterus ruber*, en Bulgarie. *Alauda*, **59** : 53-54.
- Velasquez, C.R. 1992. Managing artificial saltpans as a waterbird habitat: species' responses to water level manipulation. *Colonial Waterbirds*, **15** (1) : 43-55.
- Vrignaud, Y. 1994. Chili-Sauvetage dans la Cordillère des Andes. *Vivre avec les Oiseaux*, **6** (Sept-Oct) : 34-37.
- Wadsworth, P.F., Jones, D.M. and Pugsley, S.L. 1983. Hepatic haemosiderosis in birds at the Zoological Society of London. *Avian Pathology*, **12** (3) : 321-330.
- Walmsley, J.G. 1994. An assessment of the Greater Flamingo population in Egypt in winter and spring 1989-1990. pp. 261-272. In: Meininger, P.L. and Atta, G.A.M. (eds.). *Ornithological studies in Egyptian Wetlands 1989/90*. FORE report Nr. 94-01. WIWO report Nr. 40.
- Whistler, H. 1923. The Common Flamingo *Phoenicopterus antiquorum* in the Punjab Salt Range. *J. Bombay nat. Hist. Soc.*, **29** (3) : 840.
- Zahl, P.A. 1953. Flamingo Hunt, pp 222. *Hammond*, Hammond & Co., London.



Chapter 8

Mammals

Sanjeev Kumar

Blue Bull on the dried margins of Sambhar Lake



Photo: S. Kumar

INTRODUCTION

The present knowledge on mammalian fauna of Rajasthan is available from the studies made by Alfred and Agrawal (1996), Agrawal (1967), Bahadur (1925), Bate and Harrison (1997), Biswas and Ghosh (1968), Ghosh (1976), Prakash (1959, 1974, 1975 and 1995) and Roberts (1977). So far 87 species of mammals belonging to 55 genera under 27 families have been recorded by Sharma (1999). Works on mammals and habitat ecology have been reported from Keoladeo National Park, Rajasthan (Haque and Vijayan, 1988). There is no account of mammalian species recorded or studies made on the partial dependence or association of mammals with the saline wetlands in Rajasthan.

The present studies records six species found environmentally associated and partially dependent on the wetland. The species were mainly observed during various surveys conducted from 1994-1997. The classification followed is after Ellerman and Morrison-Scott (1951) and Honaki, *et al.* (1982) along with the remarks on their activities.

SYSTEMATIC ACCOUNT

MAMMALIA

Order CARNIVORA

Family CANIDAE

Genus *Vulpes* Oken, 1816

Vulpes vulpes pusilla Blyth

Desert Fox

1854. *Vulpes pusilla* Blyth, *J. Asiat. Soc. Beng.*, **23** : 729 (Salt Range, Pakistan)

Diagnosis : When viewed from distance, it looks grayish with light speckling rusty brown hairs. A patch of black hairs on the muzzle present. Tail bushy with very long hairs at the proximal region.

Distribution : India : Rajasthan, Gujarat, Madhya Pradesh and Punjab.

Elsewhere : Iraq, Iran and Pakistan.

Remarks : Rare but seen during the survey on the southeastern dried margins of the lake. The actual dependence on the lake is not known but sighting was frequent in the year 1995 and 1996.

Family HERPESTIDAE
Subfamily HERPESTINAE

Genus *Herpestes* Illiger, 1881

Herpestes edwardsi ferrugineus Blanford
Indian Grey Mongoose

1874. *Herpestes ferrugineus* Blanford, *Proc. zool. Soc. Lond.*, pp. 661 (Larkhana, Sind, Pakistan).

Diagnosis : Very large in size long contour hairs, little paler with distinctly reddish hind foot.

Distribution : India : Gujarat, Rajasthan and Himáchal Pradesh.

Elsewhere : Pakistan, Iraq and Iran.

Remarks : The species was regularly observed in the large bushy area in the vicinity of Sambhar Lake having mountainous outcrop connected with road and also houses a temple of Shakambari Mata.

Family FELIDAE
Subfamily FELINAE

Genus *Felis* Linnaeus, 1758

Felis silvestris ornate Gray
Indian Desert Cat

1831. *Felis ornate* Gray, III. *Ind. Zool.*, 1pl. 2 (India)

Diagnosis : Body pale sandy light yellow with small clearly separated grayish black spots. Scattered spots on fore head and lower surface of paws. Tail spotted in proximal part and with four or five black rings in distal half.

Distribution : India : Rajasthan, Gujarat and Madhya Pradesh.

Elsewhere : Afghanistan and Pakistan.

Remarks : Very rarely seen and restricted distribution. The animals were spotted at night near the hill outcrop towards Aravalli's and also spotted near Shakambari Mata temple. There is no direct evidence of the dependence of this species but the location of this specific habitat remains moist and later dried which attracts variety of animals to occupy the area.

Order ARTIODACTYLA

Family BOVIDAE

Genus *Boselaphus* Pallas, 1766

Boselaphus tragocamelus (Pallas)

Blue Bull

1766. *Antelope tragocamelus* Pallas, *Misc. Zool.*, 5 (Plains of Peninsular India)

Diagnosis : Horse like appearance with stout legs, long and narrow head, a course mane of black gray and white hairs run down the hind neck and over the wither. Males with smooth and cylindrical horns and blue gray in colour. Female body reddish tan.

Distribution : India : Rajasthan, from base of Himalayas to Karnataka upto Maharashtra.

Remarks : Though considered as menace, blue bull (Roz) is found in abundance and pest of crops in this region. Number of small to large groups with varying age roams the dried margins through out the lake. Their actual dependence on the lake ecosystem is yet not known.

Order RODENTIA

Family SCIURIDAE

Subfamily SCIURINAE

Genus *Funambulus* Lesson, 1835

Funambulus pennanti Wroughton

Five-striped Palm Squirrel

1905. *Funambulus pennanti* Wroughton, *J. Bombay nat. Hist. Soc.*, 16 : 411 (Mandvi Taluka, Surat, Gujarat, India).

Diagnosis : Dorsum olive gray, divided by three conspicuous cream coloured stripes. Belly and flanks creamy gray and separated from the dorsum by indistinct creamy buff longitudinal strips Ears rounded, small and muzzle pointed. Tail bushy and creamish white at the tip.

Distribution : India : Rajasthan, Gujarat, Andaman Islands, Assam, Bihar, Delhi, Gujarat, Haryana, Jammu & Kashmir, Madhya Pradesh, Maharashtra, Meghalaya, Orissa, Punjab, Sikkim, Uttar Pradesh and West Bengal.

Elsewhere : Pakistan, Iran, Nepal and Bangladesh.

Remarks : Commonly spotted on the 5 kms. long Jhapok-Guda Dam and near the lake margins adjacent to the Aravalli hills and the fellow land towards the railway track. Also

seen frequenting the sluice gates and stone barriers erected inside the lake having continuity with the dam.

Family MURIDAE

Subfamily MURINAE

Genus *Tatera* Lataste, 1882.

Tatera indica indica (Hardwicke)

Indian Gerbil

1807. *Dipus indicus* Hardwicke, *Trans Linn. Soc. Lond.*, **8** : 279.

Material examined : 1 ♂, 11.i.1995, 2 ♀, 18.xi.1996, coll. S. Kumar.

Diagnosis : Tail longer than head and body. Tail well-furred and distal one third bears a dorsal crest of long blackish hairs ending in a tuft. Dorsal and ventral surface of tail brown with sides paler. Dorsum pale brown to reddish and venter white.

Distribution : India : Rajasthan, Gujarat, Andhra Pradesh, Bihar, Delhi, Haryana, Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh, Maharashtra, Orissa, Punjab, Uttar Pradesh and West Bengal.

Elsewhere : Pakistan, Iran and Nepal.

Remarks : Burrows were seen on the wastelands adjoining the lake margins towards northern side. Many attempts were made to collect them but twice succeeded. Their food dependence is evident as they were seen visiting the moist margins to feed on coleopteran insects emerging out from the semi-dried soil.

SUMMARY

The paper reports sighting of six species of mammals belonging to three orders under six families. Most of the species were recorded from the close proximity of the lake waters frequently visiting the moist margins of the lake.

ACKNOWLEDGEMENTS

Authors are thankful to Dr. J.R.B. Alfred, Director, Z.S.I., Calcutta and to Dr. Q.H. Baqri, Additional Director and Officer-in-Charge, D.R.S., Z.S.I., Jodhpur for providing facilities. Gratitude is expressed towards Late Prof. Ishwar Prakash for giving useful suggestions to improve the quality of this communication.

REFERENCES

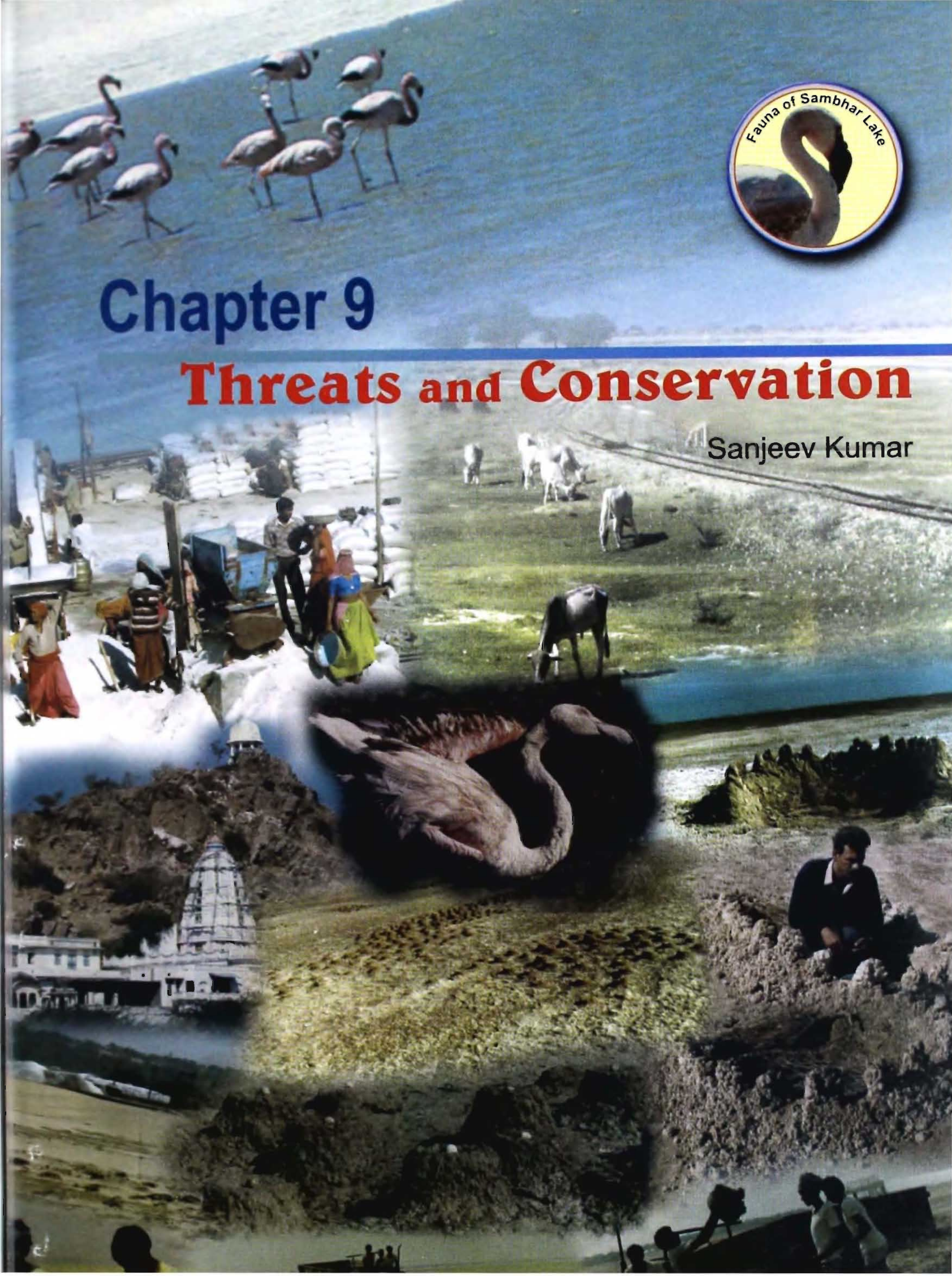
- Agrawal, V.C. 1967. New mammal records from Rajasthan. *Labdev J. Sci. Tech.*, Kanpur, **5** : 342-344.
- Alfred, J.R.B. and Agrawal, V.C. 1996. The mammal diversity of the Indian Desert. In : *Faunal Diversity in the Thar Desert, Gaps in Research*, (Eds.) A.K. Ghosh, Q.H. Baqri and I. Prakash. Scientific Publishers Jodhpur, India. **35** : 335-348.
- Bahadur, S.S. 1925. A hybrid black buck (*A. cervicapra*) and Chinkara (*G. bennetti*). *J. Bombay nat. Hist. Soc.*, **30** (4) : 922-912.
- Bate. J.J. Paul and Harrison, David L. 1997. Bats of the Indian subcontinent. pp. 9-13. *Published by Harrison Zoological Museum*. i-xvi + 1-258.
- Biswas, B. and Ghosh, R.K. 1968. New record of mammals from Rajasthan, India. *J. Bombay nat. Hist. Soc.*, **65** : 481-482.
- Ellerman, J.R. and T.C.S. Morrison-Scott. 1951. Checklist of Palearctic and Indian mammals, 1758-1946. *Br. Mus. Nat. Hist.*, London, pp. 810.
- Ghosh, R.K. 1976. Further new records of mammals from Rajasthan, India. *J. zool. Soc. India*, **26** : 149-150.
- Haque, M.N. and Vijayan, V.S. 1988. Food habits of the smooth Indian otter (*Lutra perspicillata*) in Keoladeo National Park, Bharatpur, Rajasthan. First International Asian Otter Symposium, Bangalore. October 1988. Abstract. *Asian Otter Specialist Group Newsletter*, **1** : 17.
- Honacki, J.H., Kirman, K.E. and Koepl, J.W. 1982. Mammal species of the World. *Allen Press Inc. Kanasa, USA*.
- Prakash, I. 1959. Checklist of the mammals of Rajasthan Desert. *Univ. Rajasthan Stud. (Biol. Sci.)* Jaipur, (B) **6** : 30-56.
- Prakash, I. 1974. The ecology of vertebrates of the Indian desert. In : *Ecology and Biogeography in India*. (ed.) M.S. Mani, Dr. Junk Verlag, *The Hague*, pp. 96-121.
- Prakash, I. 1975. The ecology and zoogeography of mammals. In : *Environmental Analysis of the Thar Desert*. (eds.), R.K. Gupta and I. Prakash, pp. 448-467.
- Prakash, I. 1995. Invasion of peninsula small mammals towards the Aravali ranges and the Thar Desert. *Intt. J. Ecol. Envntal. Sci.*, **21** : 17-24.
- Roberts, T.J. 1977. The mammals of Pakistan. *Earnest Benn Ltd*. London and Tonbridge.
- Sharma, S. K. 1999. Mammalian fauna of Rajasthan. *Bionature*, **19** (1) : 7 13.



Chapter 9

Threats and Conservation

Sanjeev Kumar



INTRODUCTION

Wetlands are now considered to be one of the most productive land-water ecotones on this earth exhibiting a large diversity. They have assumed significance in recent years with the growing interest in them for their role to supplement human dietary requirements and ecological significance in terms of flood control, water purification, aquatic productivity, microclimatic regulation and as habitat of rich biodiversity. Besides, wetlands have many cultural and aesthetic values to fulfil the needs of a regional geographic zone.

Among the wide variety, the inland freshwater wetlands are considered to be more useful and productive aquatic entities in comparison to inland saline wetlands, which are few and less, productive in nature.

In India there is so far no estimate made for inland saline wetlands except for those, which are coastal saline and brackish water wetlands. Salinity is one of the most characteristic features of desert lands and as a result of interaction of the two: salinity and water - India's largest saline Sambhar Lake came into existence time immemorial. Legends abound its formation but it is the interactive value of the nature's phenomenon, which resulted into establishing a unique wetland habitat in this region.

In the context of Indian scenario, the pressure on wetlands is increasingly becoming unbearable due to population explosion in the country. Natural resources of almost all types are coming under threat of over exploitation and degradation, so is the case with wetlands too. Saline lakes are also not spared from these pressures what so ever may be their contribution or ecological role to play in the natural cycle of the ecosystem.

Economically, salt lakes are important as source of minerals such as uranium, zeolites, lithium, borax and especially the halites. They also yield biochemical products such as glycerol, β -carotene from *Dunaliella* and protein from *Spirulina*. These saline habitat not only sustain species like *Artemia* but also allow to accommodate large variety of other salt tolerant arthropods and large number of wetland avian species notably flamingos due to their rich food production of various planktonic species both phyto and zooplankton, characteristic of only saline habitat. Many of these saline wetlands are of cultural significance (eg. the Dead Sea) and large number of them has high aesthetic value both as naturally attractive environment (eg. Mono Lake, California and Sambhar Lake, India) and as habitat for specific biota.

Perhaps threats to salt lakes are even greater than that of freshwater lakes because of a general perception that salt lakes are less valuable than other sorts of inland water. Best-known examples of severely damaged salt lakes are undeniably the Dead Sea, the Aral Sea, and Mono Lake. In each case, levels have dropped tens of meters and salinity risen by many g/L in the relatively recent past (Williams, 1996). For the Aral Sea, the total effects have

been catastrophic to the local human population, agricultural production, and the environment in general.

Not the least of threats are those likely from global climatic change, given the sensitivity of salt lakes to climatic events, and increased levels of UVB radiation, given that many salt lakes are shallow, already exposed to high levels of solar radiation, and have fewer refuges from light than many freshwater lakes.

Pollution of salt lakes is yet another anthropogenic activity of widespread importance, as is the ad hoc spread of exotic biota, especially *Artemia*. The global distribution of salt lakes is widespread, occurs on all continents, and are often present not far from centers of population. They are not abundant in very dry areas though, in true deserts where annual precipitation is < 25 mm, but they are otherwise widespread in dry lands. Within each continent, they are also widely dispersed and extensive.

In general, Chatrath (1992) and Tewari (1994) have sufficiently identified threats faced by wetlands in common as siltation, eutrophication, shrinkage of area, reclamation, encroachment, pollution, change in water quality, excessive tourism load, reduced arrival of migratory birds and over exploitation of fisheries resource. But this does not hold true with the saline wetlands facing location specific problems and threats, which are the result of geographical, social, economic and salt related problems.

Sambhar Lake is one such example of deteriorating saline wetland facing serious threats because of various factors which in turn resulting in rapid degradation of the aquatic environment and decrease in biological diversity of the lake. Its ecosystem is now alarmingly under pressure due to man made factors such as small check dams construction in the catchment area restricting the water supply to the lake, large scale top soil removal, heavy vehicular trespass, mushrooming of private salt industries in the vicinity, air, noise and water pollution and biotic interference including human pressure. Poaching and unregulated tourism is also adding to the degradation and health of the lake.

PHYSIOGRAPHY OF THE LAKE

Sambhar Lake is divided by a five kms dam into two unequal parts. The eastern divide of the lake is a brine reservoir covering an area of 76.8 sq. km. This area comprises number of salt pans (kyars) for the manufacture of salt through natural evaporation method, by Sambhar Salt Limited. Though the process of concentrating salt from the lake brine involves several steps, the lake water is pumped into these reservoirs through sluice gates in the dam after it has attained a certain level of salinity, which increases continuously. The western part of the lake is open water undisturbed natural lake ecosystem. It is also sometimes altered by dredging channels to obtain water for salt manufacturing. Along the southern length of open waters of the lake are situated small clusters of "Dhanis" which are distantly placed in the region. About 20 km from the dam towards south-west direction of the lake,

there is a hilly outcrop on which a temple of Mata Shakambari was constructed long back. It is a regular pilgrimage site for the people of Rajasthan.

The northwestern length of the Sambhar Lake is fragmented into three major zones. On the northern side of the dam there is a small settlement called Gudha and a railway station adjoining the lake margin. Sambhar Salt Limited has their salt yard in that area. There is a continuous railway track along the northeastern side of the lake, which is distantly placed from the margins of the lake. The land in between is raised to create a sort of bund formation (dam) to restrict water to spread beyond certain land area. From Gudha settlement onwards up-till Nawa, a zone of about 10-15 km just adjacent and along the length of the lake is occupied by small units of private salt industries. At Nawa also Sambhar Salt Limited has brine reservoirs for salt extraction. The lake still extends further with scanty shrub vegetation zone and touches the interrupted Aravalli hill-outcrops on the western end of the lake.

The south-eastern length of the lake area is little elevated and extensively used for crop cultivation by the local farmers. Sambhar Lake is scatteredly surrounded by sparse and very scanty scrub vegetation. The elevated wasteland around the Sambhar Lake harbours grassy vegetation, which is extensively grazed by high-density livestock population.

Since the actual inundation of the lakebed varies from year to year, the marginal demarcation of the lakebed remains variable. This is also accentuated due to high evaporation rate and water recedes faster shrinking the lake area leaving behind actual active zone with very shallow water.

FACTORS CAUSING DEGRADATION OF SALINE AQUATIC ECOSYSTEM

Some of the main threats faced by Sambhar Lake are as given below :

- Small dam construction in the catchment area.
- Excessive grazing in catchment area.
- Large-scale soil removal by private salt industries.
- Vehicular trespass by villagers
- Mushrooming of private salt industries.
- Air and noise pollution.
- Water pollution.
- Biotic interference including human pressure.
- Poaching of birds.
- Unregulated pilgrimage and tourism.

1. SMALL DAM CONSTRUCTION IN THE CATCHMENT AREA

The lake remains very much affected due to erratic monsoon precipitation in the catchment area of Sambhar Lake. This is all the more accentuated by construction of large number of small check dams all along the length and breadth of the catchment's area by farmers to

harvest rain-water for agriculture. It is therefore severely affecting the quantum of flow of water into the lake and even in normal monsoon years, the lake is not filled up sufficiently to attract wetland avian fauna as also not providing the healthy opportunities to micro-organisms to perpetuate and flourish well.

2. EXCESSIVE GRAZING IN THE CATCHMENT AREA

The catchment area includes area under surface run-off and adjacent lands around Sambhar Lake. It is subjected to heavy cattle grazing. Since the farmers of this region are unable to produce good yield of crops both because of scarcity of water and high salinity, the other option of livelihood depends on the maintenance of live stock population. It is because of this reason, high-density livestock population exists in this region and indiscriminate and unregulated grazing has seriously affected the floor of the catchment area and the adjoining land. This might initiate soil erosion in times to come (Photo 1).



Photo 1. : Grazing in the catchment area of Sambhar Lake

3. LARGE SCALE SOIL REMOVAL BY PRIVATE SALT INDUSTRIES

A large number of small-scale private salt industries in the Nawa-Gudha sector have come-up in last 10 years. These industries have developed quick seven days method of salt extraction by following a simple technique of fractional crystallization through solar evaporation. Initially a "kyar" is prepared by spreading topsoil brought from the lakebed of Sambhar and then sub-soil brine is pumped from the wells through generator-operated

pumps in these "kyars" The water spread in the artificially prepared salt pans is left for evaporation for six to seven days and turned over at fixed intervals. This results in the uniform crystallization of salt within seven days. This is the quickest method adopted by thousand of private salt industries all along the Nawa-Gudha sector of Sambhar Lake. In this way large amount of topsoil is removed by these industries to prepare their temporary salt "kyars" (Photo 2.). It is a popular believe that top soil substrate of these "kyars" helps brine to mature early giving them quick yield of salt for commercial purpose. Due to large-scale topsoil removal from Sambhar Lake basin, the micro-organisms inhabiting topsoil is also removed which are the basic material for perpetuating organic life after every year when monsoon rains inundates the lake. The constant removal of topsoil is resulting in nutrition loss and fast depletion of saline entities of micro flora and fauna leaving behind sterile land which on receiving water may hold less potential to produce food for organisms dependent



Photo 2. : Large scale soil removal from Lake bed.

on this wetland as also interrupting the natural food cycle of the lake ecosystem.

4. VEHICULAR TRESPASS BY VILLAGERS

The lakebed is frequently used for vehicular movement like tractor-trolley, camel carts and jeeps to move between Sambhar city and Nawa. Since this is a shortcut to reach either side, the inhabitants of these settlements are frequently trespassing the lake when water recedes and the lake water shrinks to smaller area, which allows straight passage through the Lake. This frequent movement of vehicles not only churns the lakebed surface but also destroys the flamingo mud nest colonies established by flamingos during submerged situation of the lakebed. The vehicular movement ply all along the dried margins of the lakebed adjoining water spread area, which creates aversion to waders and birds congregating on the wet margin of the lake thereby disturbing them repeatedly to the extent that they have to frequently leave their feeding niches and migrate to nearby smaller wetlands. The quantum of trespass increases as the lakebed dries and more area becomes approachable to these trespassing vehicles (Photo 3.). This continues to occupy more and more area with the pace of drying bed to the extent that whole of the lake is accessed by these vehicles, criss-crossing the entire lake basin and meandering their way to reach faster between the two populated destination of human settlements. Since these cities are commercial centers, the amount of



Photo 3. : Vehicular trespass by villagers.

trespass is very heavy and remains operational till the lake gets freshly inundated in monsoon months.

5. MUSHROOMING OF PRIVATE SALT INDUSTRIES

Over the period of last ten years thousand of small-scale private salt manufacturing units have come up in production of commercial salt for industrial use. Due to quick harvesting of salt within seven to ten days these industries have mushroomed in the area utilizing top soil of the Sambhar Lake bed and sub-soil brine pumped from deep wells in their salt units. Their existence all along the 10-15 kms length of the lake in the north western side is mounting various pressure direct or indirect on the environment of Sambhar Lake making it more vulnerable and threatened due to industrial and human activities which are also discussed in the following threats.

6. AIR AND NOISE POLLUTION

Emission of exhaust from vehicular movement and diesel generated pump sets for brine extraction from the wells and burning of fuel wood by temporary human settlements of private salt industries together amounting to create unhealthy and obnoxious environment of the lake resulting in aversion by waterfowls in the region. Constant sound pollution produced by vehicular movement and generator sets along with loud vocal presence of human beings also deterring the bird life to feel insecure in the lake environment.

7. WATER POLLUTION

Extensive agriculture practiced in the catchment's area and use of excessive pesticides for better yield, the residue of which is constantly reaching the lakebed through drainage of monsoon water into the lake. Over the period, the accumulations of such toxic residues are binding themselves in the algal blooms of the lake, reaching to bird population through food (Misra and Bakre, 1994). The defecate night soil of human population on the dried margins of lakebed cultures various parasitic forms brought in this way to the lake and later reaching to the prominent faunal dependants of the lake in the form of diseases for example leg joint disease in flamingo (Glunder, 1983).

8. BIOTIC INTERFERENCE INCLUDING HUMAN PRESSURE

Large-scale biotic pressure exists on the lake due to large-scale human activity around the lake margins especially in the Nawa-Gudha sector. Pet animal association with human beings is a common phenomenon but this affects severely when associated with wetlands like Sambhar which holds no vegetation or forest as barrier around it. The danger of such presence of man and animals which is poverty ridden and food deficient inclines to unethically exploit the environment because the wetland does not hold any fish fauna to be exploited

by the inhabitants. The birds become direct target of food source for many. Poaching of this nature becomes inevitable by both man and animal in such dependant environment.

9. POACHING OF BIRDS

Most wetlands in India are den of bird poachers. Though varying degree of poaching exists depending upon the population, species peculiarity and accessibility to such activities. Sambhar Lake is one among such wetlands having high pressure of poaching of water birds especially flamingos. During the period of study, poaching of birds was observed using



Photo 4. : Poaching activity in the Sambhar Lake.

variety of methods like slinging, netting, gun shooting etc. The poachers were found to use camouflaging techniques to come closer to the bird like flamingo by building artificial mud mound to attract and mislead flamingo for easy killing (Photo 4).

10. UNREGULATED PILGRIMAGE AND TOURISM

Although tourism in true sense has not yet developed in this region but inflow of pilgrims to worship at "Shakambari Mata" temple (Photo 5.), which is situated some 26 km southwest of the lake from Sambhar city is thronged by thousands of people throughout the year.



Photo 5. : Unregulated Pilgrimage and Tourism.

Though this temple is connected by metalled road from Sambhar city and due to long distance by this route, pilgrims and local transporters prefers to trespass through the drying margins of the lake bed thereby severely affecting the wetland basin and existing bird fauna of the lake.

CONSERVATION

By virtue of high salinity regime and shallow depth - Sambhar Lake is being considered a place of desolate nature with no human activity and a place of no benefit except salt. It is a myth among the people to hold such logic for an ecosystem so live and vibrant that it

attracts the attention of nature's jewels the bird like flamingos.

On exploration, it was surprisingly found that lake is not simply a salt producing source but allows many hydro-biological, socio-cultural and bio-environmental activities. The benefit driven out of such saline wetlands are immense if systematically worked out and sustainably exploited (Kumar, 1998). Here, it is important to mention that sustainability is like having an investment, which produces interest. If we live off the interest not the capital than the future can be secured but if we live off the capital, it will disappear in toto in course of time. Sustainability also necessitates a balanced relation between human investment and natural exploitation.

The simple and foremost benefits accounted so far from Sambhar Lake are: salt extraction, algal blooms harvested as organic manure for agriculture, home for variety of wetland birds, a place to culture brine shrimp as food for aquaculture, a land depression to control floods in the region and not the least its pristine environment with placid water enough to give solace to man kind.

But it has become vividly clear from the burgeoning account of threats faced by Sambhar Lake that it needs the utmost attention of scientists, planners and local Government to take measures and conserve this unique saline wetland.

In the wake of being declared as Ramsar site, Sambhar Lake needs protective coverage under the Wildlife (Protection) Act, 1972 or some other legal framework to restrict the agencies degrading this wetland. Declaring a wetland as Ramsar site is something like designating an ordinary man a VVIP without any protective cover and security. It will then result in man becoming more vulnerable and object of every body's attention to be easily exploited due to unprotected shine, which it reflects being labeled as VVIP. The same has happened with Sambhar Lake. The wetland is widely known as Ramsar site, a place of significance. The people around it have become more conscious to drive maximum possible benefits out of the ecosystem without caring for the consequences especially when no legal protective cover exists on the lake. This has resulted in exploiting the lake elements in whatever possible terms they can before any measure is taken by the local administration, of which the local population is very much aware. Each of the threats discussed above are the result of no attention or negligence of authorities and local administration to estimate the far-reaching consequences of these activities of modern development (Kumar, 1996a & b and 1998; Kumar and Bhargava, 1996 and Rahamani and Gayatri, 2002).

SUMMARY

The following conservation measures are suggested :

1. Restriction on removal of top-soil from the lake bed by private salt industries.
2. Restriction on trespass by vehicular traffic.

3. Restriction and removal of private salt industries from the periphery of the lake in Gudha-Nawa stretch in the Nagaur district.
4. Restriction on small dam construction in the catchment area.
5. Minimization of biotic interference including human activities through bio-fencing the area.
6. Afforestation of the border areas of the lake by salt tolerant tree species to create a buffer for protection of avifauna.
7. Declaration of Sambhar Lake as a Wetland Reserve.

Since Sambhar Lake do not fall under any category of Wildlife Sanctuary, National Park or a Reserve or for that matter any conservation strategy under the Wildlife (Protection) Act 1972, therefore keeping the spirit of Ramsar Convention, the lake is required to be declared as First Wetland Reserve in India.

ACKNOWLEDGEMENTS

I am grateful to Dr. J.R.B. Alfred, Director Zoological Survey of India, Calcutta and Dr. Q.H. Baqri, Additional Director, Desert Regional Station, Zoological Survey of India, Jodhpur for providing facilities and encouragement to carry out such a mega investigation on this Ramsar site. I am also thankful to Dr. N.S. Rathore for his encouragement and lucid suggestions throughout the period of investigation.

REFERENCES

- Chatrath, K.J.S. 1992. Wetlands of India. *Publ. By Ashish Publ. House*. New Delhi. pp. xiv + 1-200.
- Glunder, G. 1983. Actinobacillus-like bacteria associated with joint disease in a flamingo. *Tagung der fachgruppe Geflugelkrankheiten*, 3 & 4 : 178-183.
- Kumar, Sanjeev. 1996a. New Flamingo Breeding ground at Sambhar Lake. *Hornbill*, No. (1) : 26-27.
- Kumar, Sanjeev. 1996b. Conservation of New Breeding grounds of Flamingoes at Sambhar Lake, India. In : *Salim Ali Centenary Seminar on Conservation of Avifauna of Wetlands and Grasslands*, BNHS, Bombay, February 12-15, 1996. Abstract : 45-46.
- Kumar, Sanjeev. 1998. Biodiversity of Sambhar Lake, A Ramsar site and its sustainable development. In : *International Conference on Asian Wetlands*, New Delhi/Bharatpur. January 29-31, 1998. Abstract : 7.

- Kumar, Sanjeev and Bhargava, R.N. 1996. Sambhar Lake – A new Breeding ground of flamingoes in India. *Sanctuary Asia*, **XVI** (2) : 59.
- Misra, V. and Bakre, P.P. 1994. Organochlorine contaminants and avifauna of Mahala water reservoir, Jaipur, India. *Sci. Total Environ.*, **144** : 1-3.
- Williams, W.D. 1996. The largest, highest and lowest lakes of the world: Saline lakes. Peter Kilham Memorial Lecture, Sao Paulo, 1995, *Verh. Internat. Verein. Limnol.*, **26** : 61-79.
- Rahmani A.R. and Gayatri, U. (Eds.) 2002. Recommendations: 8. In : *Birds of Wetlands and Grasslands*. Proceedings of the Sálím Ali Centenary Seminar on the Conservation of Avifauna of Wetlands and Grasslands (February 12-15, 1996) Mumbai, India. pp. 226.
- Tewari, D.N. 1994. Mangroves and Wetlands for Conserving Environment. In : *Forest and Environment*. International Book Distributors, Dehradun. pp. 78-99.

