Mamta Rawat · Sumit Dookia
Chandrakasan Sivaperuman *Editors*

Aquatic Ecosystem: Biodiversity, Ecology and Conservation

Springer

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ISBN 978-81-322-2177-7 ISBN 978-81-322-2178-4 (eBook)
DOI 10.1007/978-81-322-2178-4

Library of Congress Control Number: 2014957313

Springer New Delhi Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer (India) Pvt. Ltd. is part of Springer Science+Business Media (www.springer.com)

Preface

The total water resources of the earth equal to 326 million cubic mile; only 2–5 % of water is fresh water, 97.5 % is salt water. Almost 69 % of fresh water resources are tied in glaciers and ice caps, about 30 % is ground water and a mere 0.27 % is surface water. Water resources are important for the survival of the planet. Aquatic biodiversity is one of the most essential characteristic of the aquatic ecosystem for maintaining its stability and means of coping with any environmental changes.

India is one of the 17 "megadiverse" countries and is composed of a diversity of ecological habitats like forests, grasslands, wetlands, deserts, and coastal and marine ecosystems. From the biodiversity point of view, India is regarded as a mega diversity country. Out of the total estimated species of the world, about 8.4 million species are reported from India. India has a wealth of wetland ecosystems distributed in different geographical regions. Most of the wetlands in India are directly or indirectly linked with major river systems such as the Ganges, Cauvery, Krishna, Godavari and Tapti. India has total of 27,403 wetlands, of which 23,444 are inland wetlands and 3,959 are coastal wetlands. Wetland systems directly and indirectly support lakhs of people, providing goods and services to them. They help check floods, prevent coastal erosion and mitigate the effects of natural disasters like cyclones and tidal waves. They store water for long periods.

Biodiversity and conservation are the key concepts in ecology during the past decades and are considered important elements in elucidating the dynamics of ecosystems disturbed by human activities. Our aquatic ecosystem comprises a major regime due to its diversity, thus needs special attention and conservation approaches. The lakes, marshes, river systems and other wetlands in the country are under threat mainly due to domestic pollution from untreated sewage, industrial pollutant and toxic effluents. India is facing an alarming danger to the loss of aquatic biodiversity, and about 55 % of aquatic species are threatened.

This book is a result of detailed observation by reputed researchers working in the field of aquatic biodiversity in India. There are 19 chapters, and each effort has been made by an expert or professional in their respective

fields. The book offers novel information on aquatic biodiversity of India. We sincerely hope that this book will provide the much needed information in the field of aquatic biodiversity conservation.

Jodhpur, India — Mamta Rawat
New Delhi, India — Sumit Dookia
Port Blair, Andaman & Nicobar Islands, India — Chandrakasan Sivaperuman

Acknowledgements

We express our heartfelt gratitude to all those who helped in different ways to complete this work. We also thank all the authors who have contributed the various chapters for this book.

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About the Editors

Dr. Sumit Dookia M.Sc., Ph.D. is working as Assistant Professor at Guru Gobind Singh Indraprastha University, New Delhi. His doctoral research work is on the Ecology of Chinkara from Great Indian Desert. He worked as research fellow at Zoological Survey of India, Jodhpur, in the research project titled "Studies on faunal communities of Great Indian Desert". He also worked in Satpura-Maikal landscape, particularly in Kanha, Pench and Satpura Tiger Reserve in Madhya Pradesh with Project Tiger Directorate, New Delhi, and Wildlife Institute of India, Dehra Dun. He authored more than 40 research papers, in journals, chapters in books, symposium and conferences.

Dr. Mamta Rawat M.Sc. Ph.D., Scientist and Head, Water and Health Program, Ecology and Rural Development Society, Jodhpur, Rajasthan, is actively engaged in research activities on various health and environmental issues of the Great Indian Desert of Rajasthan since 1999. Apart from this she has keen interest in the area of groundwater contaminations, eco-toxicology, water pollution, ecological engineering and wastewater treatment. She has received Fast Track Young Scientist Fellowship in the year 2005 from the Department of Science and Technology, Government of India. Dr. Rawat is associated with various professional and scientific societies. Presently she is an editorial board member of the *Indian Journal of Environment and Fisheries*. She has published more than 35 research papers in peer-reviewed national and international journals, conferences, seminars and symposiums, and published two books.

Dr. C. Sivaperuman M.Sc., D.B.T., Ph.D. is working as Scientist-D in Zoological Survey of India, Port Blair. He received his Master Degree in Wildlife Biology from Bharathidasan University, Tamil Nadu. His doctorate degree is in Ecology of Wetland Birds in the Vembanad-Kole Ramsar site from (Kerala Forest Research Institute, Kerala) Forest Research Institute, Deemed University, Dehra Dun. He has worked in different parts of the country in various ecosystems, which include Kerala, Rajasthan and Andaman and Nicobar Islands. He has published more than 180 research papers in national and international journals and newsletters. He also authored/edited more than 20 books in his credit. He participated and presented research papers in 40 national and international seminars and symposiums. He is life member of different scientific societies in India and other countries.

Distribution of Aquatic Macrophytes in Balasore District, Odisha

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K.A. Sujana, R. Saravanan, and Amit Diwakar Pandey

Abstract

The qualitative survey was conducted from July 2013 to June 2014 in different aquatic environment in Balasore district of Odisha, eastern India. A total of 132 species including 129 flowering plants and 3 Pteridophyte taxa spread in 82 genera and 41 families were recorded. The most speciose families were Cyperaceae with 27 species followed by Poaceae (24). The other dominant families are Linderniaceae, Fabaceae, Onagraceae, Polygonaceae, Commelinaceae, and Scrophulariaceae. Reclamation of land and changes in land use pattern are the most serious problems observed from the study sites. Abundant growth of various macrophytes including grasses and sedges provides great value of ecological and economic importance.

Keywords

Aquatic macrophytes • Balasore • Distribution • Odisha

Introduction

Macrophytes colonize many different types of aquatic ecosystems, such as lakes, reservoirs, wetlands, streams, rivers, marine environments, and even rapids and falls. This variety of colonized environments results from a set of adaptive strategies achieved over evolutionary time. Primary production of macrophytes can surpass that of other aquatic primary producers (Wetzel 2001; Kalff 2002). Macrophytes generally colonize shallow ecosystems where they become important components, influencing ecological processes, and they support many life-forms including several vascular hydrophytes. The value of an aquatic environment is often ignored, and many of the world's aquatic environments have been drained and converted for other profitable uses (Gopal and Zutchi 1998; UNEP-DEWA 2004; Srivastava et al. 2008). Many of these ecosystem harbors several kinds of economically useful macrophytes. Their ecological value is yet to be estimated. Studies on aquatic

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M. Rawat et al. (eds.), *Aquatic Ecosystem: Biodiversity, Ecology and Conservation*,
DOI 10.1007/978-81-322-2178-4_1,

macrophytes in coastal Odisha are very sporadic and requires immediate attention. Rivers, soil moisture, and relatively shallow groundwater basins are the principal sources of water for human (Gleick 1996). One percent of the world's surface is covered by various freshwater habitats including the seasonally flooding rice paddies (Balian et al. 2008). They support life of 7 % of the estimated 1.8 million described species (Melzer 1999), including 25 % of the estimated vertebrates. Aquatic macrophytes can be used as a tool in the determination of pollution and nutrient level (Clayton and Edwards 2006), water quality and lake condition (Palmer and Bell 1992), trophic status of lakes (McCutcheon and Schnoor 2003), pollutant degradation (Nahlik and Mitsch 2006), and decontaminate wastewater (Cook 1996; Nichols 1991). Urbanization, industrialization, and bursting human population are the major threats to the freshwater ecosystem. Human interference is the main reason for the shrinkage of surface area and reduction of mean depth of the lakes of Balasore district of Odisha. For the first time, we present the aquatic macrophyte wealth of Balasore district of Odisha state, India.

Methods

Qualitative floristic survey was made in different aquatic environment including lentic (pools, ditches, lakes), lotic (streams, rivers), and wetlands seasonally through regular field visit during July 2013–June 2014 to record the aquatic macrophytic wealth of Balasore district. Angiosperm and Pteridophyte macrophytes were observed and collected including submerged, submerged anchored and floating-leaved anchored, emergent anchored, and free floating. The collected plant specimens were identified and confirmed with regional floras and regional checklist for hydrophytes. Binomial and author citation of all collected hydrophytes were checked with International Plant Names Index (http://www.ipni.org/ipni/plantnamesearchpage.do). Voucher specimens were deposited in Herbarium of Central Botanical Laboratory, Howrah.

Results and Discussion

Aquatic ecosystems perform many important environmental functions. They recycle nutrients, purify water, attenuate floods, recharge groundwater, and provide habitats for wildlife (Melzer 1999). Aquatic ecosystems are also used for human recreation and are very important to the tourism industry, especially in coastal regions. From this study, a total of 132 species including 129 flowering plants and 3 Pteridophyte species spread in 82 genera and 41 families were recorded (Table 1.1). The most speciose families were Cyperaceae with 27 species followed by Poaceae (24 taxa), Linderniaceae (7 taxa), and 5 species each for Fabaceae, Onagraceae, and Polygonaceae. Commelinaceae and Scrophulariaceae were represented by four species each. For 19 families like Alismataceae, Aizoaceae, Aponogetonaceae, Ceratophyllaceae, Sphenocleaceae, and Typhaceae, only one species each was recorded. Species richness and abundance appears to be influenced by seasonal variations. In rainy season (July–September), 112 species were collected, whereas in summer season (April–June), as many as 28 species were recorded. *Cyperus bulbosa*, *Cyperus rotundus*, *Ludwigia adscendens*, and *Ludwigia perennis* mostly grow during summer in low-depth areas near the embankment. Some species such as *Lemna gibba*, *Pistia stratiotes, Eicchorna crassipes*, and *Salvinia molesta* showed the seasonal appearance. Among 132 plant recorded, 117 taxa (89 %) are herbaceous plants. Eight shrubs (e.g., *Acanthus ilicifolius*, *Aeschynomene aspera*, *Sonneratia caseolaris*), four trees (e.g., *Barringtonia acutangula*, *Excoecaria agallocha*, *Taliparitti tiliaceum*), and three climbing plants (e.g., *Dalbergia candenatensis*, *Derris scandens*, *Derris trifoliata*) were also collected from the study sites which distributed to the banks of rivers, bunds of paddy fields, and mangrove forests. Most of the species are distributed widely, and none of the endemic species or narrowly distributing plants are collected.

Data on freshwater ecosystem, inhabiting lifeforms, and species distribution and richness and comprehensive taxonomical and ecological information are needed to assess the impacts of

Table 1.1 List of aquatic macrophytes distributed in Balasore district of Odisha

Sl. no.	Botanical name	Family	Habitat	Habit	Distribution	Locality
1.	*Acanthus ilicifolius* L.	Acanthaceae	Mangrove forests and marshy areas along backwaters	Shrub	Indo-Malesia and Australia	Chandipur
2.	*Aeschynomene aspera* L.	Fabaceae	Marshes, paddy fields, and banks of ponds	Shrub	Indo-Malesia	Balramgadi
3.	*Alloteropsis cimicina* (L.) Stapf	Poaceae	Margins of wetlands and forests, moist and dry deciduous forests, roadsides, and wastelands	Herb	Paleotropics	Mirzapur
4.	*Alternanthera philoxeroides* (Mart.) Grisb.	Amaranthaceae	Shallow water pools, ditches, and marshes and mangroves	Herb	Native of South America, now established in Indo-Malesia and Australia	Chandipur
5.	*Alternanthera sessilis* (L.) R. Br. ex. DC.	Amaranthaceae	Along sides of water courses and marshy areas	Herb	Pantropical	Nilgiri
6.	*Apluda mutica* L.	Poaceae	Moist and waste places	Herb	Tropical Asia and Australia	Nilgiri
7.	*Aponogeton natans* (L.) Engl. Krause	Aponogetonaceae	Ponds and paddy fields	Herb	Indo-Malesia to Australia	Naupalgadi
8.	*Arundo donax* L.	Poaceae	Along banks of streams and backwaters	Herb	Mediterranean region eastwards to North Africa, India-Pakistan, introduced into many parts of world	Chandipur
9.	*Axonopus compressus* (Sw.) P. Beauv.	Poaceae	Dry and moist deciduous forests, wastelands, and paddy fields	Herb	Tropics and subtropics	Balramgadi
10.	*Azolla pinnata* R. Br.	Salviniaceae	Ponds and paddy fields	Herb	Pantropical	Naupalgadi
11.	*Bacopa monnieri* (L.) Pennell	Scrophulariaceae	Ponds and paddy fields	Herb	Paleotropics	Naupalgadi
12.	*Barringtonia acutangula* (L.) Gaertn.	Lecythidaceae	Along riverbanks and water courses	Herb	Indo-Malesia to Australia	Nilgiri
13.	*Brachiaria mutica* (Forssk.) Stapf	Poaceae	Shallow water, banks of stream, backwaters and rivers	Herb	Native of America, widespread in all tropical regions	Chandipur
14.	*Bulbostylis barbata* (Rottb.) Kunth ex Clarke	Cyperaceae	Near banks of streams, sandy, and wastelands	Herb	Paleotropics and southern USA	Barnuguna chauk
15.	*Canscora diffusa* (Vahl) R. Br. Ex Roem & Schult	Gentianaceae	Along streamsides	Herb	Tropical Africa, Asia, and Australia	Jodachua
16.	*Centella asiatica* (L.) Urban	Apiaceae	Wet places in the plains	Herb	Tropical Asia and Africa	Balramgadi

(continued)

Table 1.1 (continued)

Sl. no.	Botanical name	Family	Habitat	Habit	Distribution	Locality
17.	*Centipeda minima* (L.) A. Braun & Asch.	Asteraceae	Paddy fields and along river banks	Herb	Indo-Malesia	Barnuguna chauk
18.	*Ceratophyllum demersum* L.	Ceratophyllaceae	Small ditches and ponds at lowlands, sometimes in brackish water	Herb	Cosmopolitan	Barnuguna chauk
19.	*Chloris barbata* Sw.	Poaceae	Degraded forests, wastelands, and riversides	Herb	Native of tropical Africa, spread to other tropical countries	Patrapoda
20.	*Clerodendrum inerme* (L.) Gaertn.	Verbenaceae	Scrub jungles and mangroves	Shrub	Coastal India, Sri Lanka, now naturalized on the shores of Myanmar, Australia, and China	Chandipur
21.	*Colocasia esculenta* (L.) Schott in Schott & Endl.	Araceae	Waterlogged ditches and streamside	Herb	Pantropical	Kuldiha
22.	*Commelina benghalensis* L.	Commelinaceae	Wastelands, also in deciduous forests	Herb	Africa, India, China, Japan, and Malesia	Nilgiri
23.	*Commelina clavata* C.B. Clarke	Commelinaceae	Wastelands, also in deciduous forests	Herb	Africa, India, China, Japan, and Malesia	Nilgiri, Patrapoda
24.	*Cyanotis axillaris* (L.) D. Don ex Sweet	Commelinaceae	Waterlogged ditches and streamside	Herb		Chandipur
25.	*Cynodon dactylon* (L.) Pers.	Poaceae	Along banks of backwaters, bunds of paddy fields, and wastelands	Herb	Tropical and warm temperate regions of the world	Jampara
26.	*Cyperus articulatus* L.	Cyperaceae	Marshy areas	Herb	Pantropics	Barnuguna chauk
27.	*Cyperus bulbosus* Vahl	Cyperaceae	Sandy beaches, riversides, and marshy fields	Herb	Tropical Africa, Southern Asia, Malesia, and Northern Australia	Chandipur
28.	*Cyperus cephalotes* Vahl	Cyperaceae	Permanent pools and streams	Herb	Indo-Malesia and China to Australia	Barnuguna chauk
29.	*Cyperus compressus* L.	Cyperaceae	Along banks of streams and watercourses and wastelands	Herb	Pantropical	Barnuguna chauk
30.	*Cyperus corymbosus* Rottb.	Cyperaceae	Along banks of streams	Herb	Pantropical	Barnuguna chauk
31.	*Cyperus difformis* L.	Cyperaceae	Marshy areas and paddy fields	Herb	Tropical, Subtropical, and temperate regions of the world	Karanjja

32.	*Cyperus digitatus* Roxb.	Cyperaceae	Marshy fields	Herb	Pantropical	Barnuguna chauk
33.	*Cyperus distans* L. f.	Cyperaceae	Along banks of streams, also in wastelands and roadsides	Herb	Pantropical	Chandipur
34.	*Cyperus imbricatus* Retz.	Cyperaceae	Wetlands	Herb	Pantropical	Kuldiha
35.	*Cyperus iria* L.	Cyperaceae	Degraded deciduous forests, marshy areas, and paddy fields	Herb	Tropical Asia and East Africa, introduced in the USA and West Indies	Kuldiha
36.	*Cyperus javanicus* Houtt.	Cyperaceae	Marshy areas in degraded forests and mangrove forests, also in the plains	Herb	Pantropical	Barnuguna chauk
37.	*Cyperus malaccensis* Lam.	Cyperaceae	Banks of backwaters and ponds and mangrove forests	Herb	Paleotropics	Barnuguna chauk
38.	*Cyperus pangorei* Rottb.	Cyperaceae	Grasslands, river banks and pools	Herb	India, Sri Lanka, Nepal and Myanmar	Barnuguna chauk
39.	*Cyperus tenuispica* Steud.	Cyperaceae	Along streams, paddy fields, and marshy areas	Herb	Tropical and subtropical Africa and Asia	Haldipada
40.	*Dactyloctenium aegyptium* (L.) P. Beauv.	Poaceae	Marshy lands and open areas	Herb	Native of South America, naturalized in Paleotropics	Nilgiri
41.	*Dalbergia candenatensis* (Dennst.) Prain	Fabaceae	Mangrove swamps	Climber	Indo-Malesia, China, and Australia	Balramgadi
42.	*Derris scandens* (Roxb.) Benth.	Fabaceae	Deciduous forests, also in mangrove forests and sacred groves	Climber	Indo-Malesia	Kuldiha
43.	*Derris trifoliata* Lour.	Fabaceae	Along banks of backwaters and mangrove forests	Climber	Paleotropics	Bhitarkanika
44.	*Echinochloa colona* (L.) Link.	Poaceae	Marshes and bunds of paddy fields	Herb	Tropical Asia and Africa	Naupalgadi
45.	*Echinochloa crus-galli* (L.) P. Beauv.	Poaceae	Marshy fields	Herb	India, Southeast Asia, and Africa	Balramgadi
46.	*Echinochloa stagnina* (Retz.) P. Beauv.	Poaceae	Marshy areas	Herb	Tropical Asia and Africa	Barnuguna chauk
47.	*Eclipta prostrata* (L.) L., Mant.	Asteraceae	Paddy fields and moist localities	Herb	Pantropical	Naupalgadi
48.	*Eichhornia crassipes* (Mart.) Solms. in A. & C. DC.	Pontederiaceae	Ponds and wet lowlands	Herb	South America, now naturalized in the Paleotropics	Balramgadi

(continued)

Table 1.1 (continued)

Sl. no.	Botanical name	Family	Habitat	Habit	Distribution	Locality
49.	*Eleocharis acutangula* (Roxb.) Schult.	Cyperaceae	Marshy areas in grasslands	Herb	Pantropical	Balramgadi
50.	*Eleocharis dulcis* (Burm. f.) Trimen ex Hensch.	Cyperaceae	Marshy areas and mangroves	Herb	Paleotropics	Balramgadi
51.	*Eleocharis spiralis* (Rottb.) Roem. & Schult.	Cyperaceae	Wet areas in grasslands and mangroves	Herb	Paleotropics	Naupalgadi
52.	*Eragrostis unioloides* (Retz.) Nees ex Steud.	Poaceae	Streams, banks of backwaters, and waste places	Herb	Southeast Asia, India, and Africa	Naupalgadi
53.	*Excoecaria agallocha* L.	Euphorbiaceae	Banks of backwaters and mangrove forests	Tree	Indo-Malesia to Australia and Pacific islands	Balramgadi
54.	*Fimbristylis argentea* (Rottb.) Vahl	Cyperaceae	Wet or moist sandy grounds, grasslands and in rice fields	Herb	South and Southeast Asia	Balramgadi
55.	*Floscopa scandens* Lour.	Commelinaceae	Marshy areas	Herb	Indo-Malesia	Kuldiha
56.	*Fuirena ciliaris* (L.) Roxb.	Cyperaceae	Marshy areas in grasslands and paddy fields	Herb	Pantropical	Balramgadi
57.	*Glinus oppositifolius* (L.) A. DC.	Molluginaceae	Open areas, lakeshores, and stream banks	Herb	Pantropical	Balramgadi
58.	*Heliotropium indicum* L.	Boraginaceae	Along lakeshores and paddy fields during summer	Herb	Pantropical	Balramgadi
59.	*Hydrilla verticillata* (L.f.) Royle	Hydrocharitaceae	Stagnant ponds	Herb	Asia, Europe, and Africa	Balramgadi
60.	*Hydrolea zeylanica* (L.) Vahl	Hydrophyllaceae	Wet sandy areas near water bodies	Herb	Pantropical	Karanja
61.	*Hygrophila schulli* (Buch.-Ham.) M. R. & S. M. Almeida	Acanthaceae	Paddy fields and other moist localities	Herb	India, Myanmar, and Indo-China	Balramgadi
62.	*Ipomoea aquatica* Forssk.	Convolvulaceae	Ponds and lakes	Herb	Pantropics	Balramgadi
63.	*Ipomoea carnea* Jack. ssp. *fistulosa* (Mart. ex Choisy) Austin	Convolvulaceae	In marshy areas along the banks of streams and paddy fields, also grown as hedge plant	Shrub	Native of America, now Pantropical	Panchalingeswar
64.	*Isachne globosa* (Thunb.) O. Ktze.	Poaceae	Wetlands	Herb	Tropical Asia	Balramgadi
65.	*Isachne miliacea* Roth	Poaceae	Marshy fields, wetlands, along the streams, and paddy fields	Herb	India, China and Southeast Asia	
66.	*Ischaemum indicum* (Houtt.) Merr.	Poaceae	Moist areas	Herb	America, Australia, and Southeast Asia	Balramgadi
67.	*Kandelia candel* (L.) Druce	Rhizophoraceae	Mangrove swamps	Tree	Indo-Melasia and China	
68.	*Kyllinga bulbosa* P. Beauv.	Cyperaceae	Marshy areas	Herb	Paleotropics	Balramgadi

69.	*Kyllinga brevifolia* Rottb. var. *stellulata* (Sur.) Hooper in Saldanha & Nicolson	Cyperaceae	Forest margins	Herb	Indo-Malesia and Australia	Naupalgadi
70.	*Kyllinga bulbosa* P. Beauv	Cyperaceae	Marshy areas, wastelands, and roadsides	Herb	Paleotropics	Naupalgadi
71.	*Kyllinga nemoralis* (J. R & G. Forst.) Dandy ex Hutch. & Dalz.	Cyperaceae	Waste places, degraded forest areas, and grasslands	Herb	Pantropical	Balramgadi
72.	*Kyllinga odorata* Vahl ssp. *cylindrica* (Nees ex Wight) Koyama	Cyperaceae	Marshy areas in degraded deciduous forests, also in the plains	Herb	Paleotropics	Naupalgadi
73.	*Lemna gibba* L.	Lemnaceae	Stagnant waters	Herb	Cosmopolitan	Naupalgadi
74.	*Limnophila aquatica* (Roxb.) Alston	Scrophulariaceae	Flooded paddy fields, ponds, etc	Herb	Indo-Malesia and East and South China	Naupalgadi
75.	*Limnophila chinensis* (Osbeck) Merr.	Scrophulariaceae	Water logged areas	Herb	Paleotropics	Naupalgadi
76.	*Limnophila indica* (L.) Druce	Scrophulariaceae	Along banks of streams and marshy areas	Herb	Pantropical	Naupalgadi
77.	*Limnophyton obtusifolium* (L.) Miq.	Alismataceae	Marshy areas	Herb	Pantropical	Naupalgadi
78.	*Lindernia anagallis* (Burm. f.) Pennell	Linderniaceae	Banks of streams and marshy areas	Herb	Indo-Malesia	Balramgadi
79.	*Lindernia antipoda* (L.) Alston in Trimen	Linderniaceae	Sides of streams, reservoirs and marshy areas	Herb	Tropical and subtropical Asia and Australia	Balramgadi
80.	*Lindernia crustacea* (L.) F.v. Muell.	Linderniaceae	Moist deciduous forests and wastelands	Herb	Africa, America, and tropical and subtropical Asia	Balramgadi
81.	*Lindernia hyssopioides* (L.) Haines	Linderniaceae	Marshy areas	Herb	Southeast Asia, Malesia, and China	Naupalgadi
82.	*Lindernia ruellioides* (Colsm.) Pennell	Linderniaceae	Wet areas in semievergreen forests, also in the plains	Herb	Tropical and subtropical Asia	Balramgadi
83.	*Lindernia tenuifolia* (Colsm.) Alston in Trimen	Linderniaceae	Along banks of backwaters and mangroves	Herb	Indo-China and Indo-Malesia	Balramgadi
84.	*Lindernia viscosa* (Hornem.) Merr.	Linderniaceae	Wet areas in moist deciduous forests	Herb	Indo-Malesia and China	Kuldiha
85.	*Lobelia alsinoides* Lam.	Campanulaceae	Wet areas in moist deciduous forests	Herb	Indo-Malesia	Pancharjuna Nalla
86.	*Lobelia heyneana* Schult.	Campanulaceae	Wet areas in moist deciduous forests	Herb	Indo-Malesia, China, and Africa	Kuldiha

(continued)

Table 1.1 (continued)

Sl. no.	Botanical name	Family	Habitat	Habit	Distribution	Locality
87.	*Ludwigia adscendens* (L.) H. Hara	Onagraceae	Ponds and ditches	Herb	Continental Asia, Malesia, and Australia	Kuldiha
88.	*Ludwigia hyssopifolia* (G. Don) Exell	Onagraceae	Marshy places	Herb	Pantropical	Kuldiha
89.	*Ludwigia octovalvis* (Jacq.) P.H. Raven	Onagraceae	Marshy places	Herb	Pantropical	Kuldiha
90.	*Ludwigia perennis* L.	Onagraceae	Waterlogged areas in grasslands	Herb	Tropical Africa, Asia, and Australia	Chandipur
91.	*Ludwigia peruviana* (L.) H. Hara	Onagraceae	Marshy areas	Shrub	Originally from America, now naturalized throughout the Old World	Panchalingeswar
92.	*Marsilea polycarpa* Hook. & Grev.	Marsileaceae	Pools and streams	Herb	Pantropical	Chandipur
93.	*Monochoria vaginalis* (Burm. f.) Presl	Pontederiaceae	Paddy fields and wet lowlands	Herb	India to China, Malesia, and Japan	Chandipur
94.	*Najas graminea* Del.	Najadaceae	Pools and streams	Herb	Pantropical	Chandipur
95.	*Najas indica* (Willd.) Cham.	Najadaceae	Streams, ditches, and ponds	Herb	Tropical Asia and Africa	Chandipur
96.	*Nelumbo nucifera* Gaertn.	Nelumbonaceae	Freshwater ponds and lakes, also grown as an ornamental plant	Herb	South and East Asia to far eastern Russia and to Australia	Balramgadi
97.	*Nymphaea nouchali* Burm. f.	Nymphaeaceae	Ponds and pools in plains	Herb	Indo-Malesia and tropical Africa	Balramgadi
98.	*Nymphaea pubescens* Willd.	Nymphaeaceae	Freshwater pools, lakes, and flooded paddy fields	Herb	Indo-Malesia	Naupalgadi
99.	*Nymphaea rubra* Roxb. ex Salisb.	Nymphaeaceae	Ponds	Herb	Native of Europe	Naupalgadi
100.	*Nymphoides hydrophylla* (Lour.) O. Ktze	Menyanthaceae	Ditches and ponds	Herb	Indo-Malesia and South China	Jaleswar
101.	*Oryza rufipogon* Griff.	Poaceae	Marshy grasslands	Herb	India, Sri Lanka, and tropical Australia	Balramgadi
102.	*Oryza sativa* L.	Poaceae	Cultivated	Herb	Widely cultivated	Balramgadi
103.	*Ottelia alismoides* (L.) Pers.	Hydrocharitaceae	Ponds and streams	Herb	Indo-Malesia to Pacific Islands and East Asia	Naupalgadi
104.	*Pandanus fascicularis* Lam.	Pandanaceae	Mangrove forests and sea coasts	Shrub	Tropical and subtropical Asia	Naupalgadi
105.	*Panicum repens* L.	Poaceae	Wetlands, marshy areas of grasslands, and wastelands	Herb	Tropics and subtropics of both hemispheres	Balramgadi

106.	*Paspalum scrobiculatum* L.	Poaceae	Marshes, ponds, wetlands, and other waterlogged areas	Herb	India and Pakistan	Mirzapur
107.	*Persicaria barbata* (L.) H. Hara	Polygonaceae	Along streamsides	Herb	Paleotropics	Balramgadi
108.	*Persicaria hydropiper* (L.) Delarbre	Polygonaceae	Moist localities in semievergreen forests	herb	Pantropical	Kuldiha
109.	*Persicaria pulchra* (Blume) Soják	Polygonaceae	Marshy areas	Herb	Indo-Malesia and Africa	Balramgadi
110.	*Phragmites karka* (Retz.) Trin. ex Steud.	Poaceae	Mangrove swamps and marshy areas	Herb	Paleotropics	Naupalgadi
111.	*Phyla nodiflora* (L.) Greene	Verbenaceae	Coastal sandy areas, paddy fields, and streamsides	Herb	Tropics and subtropics	Naupalgadi
112.	*Pistia stratiotes* L.	Araceae	Ponds and tanks	Herb	Tropics and subtropics	Karanja
113.	*Polygala arvensis* Willd.	Polygalaceae	Moist deciduous forests, also in the plains	Herb	Indo-Malesia to Australia	Kuldiha
114.	*Polygala chinensis* L.	Polygalaceae	Moist deciduous forests, also in the plains	Herb	Indo-Malesia and China	Balramgadi
115.	*Polygonum barbatum* L.	Polygonaceae	Along streamsides	Herb	Paleotropics	Balramgadi
116.	*Polygonum pubescens* Blume	Polygonaceae	Marshy areas	Herb	Indo-Malesia and East Asia	Jodachua
117.	*Pycreus polystachyos* (Rottb.) P. Beauv.	Cyperaceae	Marshy areas in grasslands	Herb	Widely distributed in the tropical and subtropical regions	Naupalgadi
118.	*Sacciolepis interrupta* (Willd.) Stapf	Poaceae	Wetlands	Herb	Tropics of Southeast Asia and Africa	Balramgadi
119.	*Salvinia molesta* D. S. Mitchell	Salviniaceae	Ponds and streams	Herb	Pantropical	Naupalgadi
120.	*Schoenoplectiella articulata* (L.) Lye	Cyperaceae	Marshy areas in grasslands and wet fallow fields	Herb	Indo-Malesia	Naupalgadi
121.	*Sesbania javanica* Miq.	Fabaceae	Bunds of paddy fields	Shrub	India	Balramgadi
122.	*Sesuvium portulacastrum* (L.) L.	Aizoaceae	Near mangrove swamps along sea coasts	Herb	Pantropical	Naupalgadi
123.	*Sonneratia caseolaris* (L.) Engl.	Rhizophoraceae	Along backwaters and mangrove forests	Tree	Indo-Malesia and Australia	Naupalgadi
124.	*Sphenoclea zeylanica* Gaertn.	Sphenocleaceae	Along water courses and mangrove forests	Herb	Pantropical	Balramgadi
125.	*Sporobolus indicus* (L.) R.Br.	Poaceae	Moist and dry deciduous forests	Herb	Pantropical	Kuldiha
126.	*Taliparitiliaceum* (L.) Fryxell	Malvaceae	Along streamside and banks of tidal streams and mangrove forests, also grown as live fence	Tree	Pantropics	Balramgadi
127.	*Typha angustata* Bory & Chaub.	Typhaceae	Marshy fields	Herb	Cosmopolitan	Balramgadi

(continued)

Table 1.1 (continued)

Sl. no.	Botanical name	Family	Habitat	Habit	Distribution	Locality
128.	*Utricularia caerulea* L.	Lentibulariaceae	Grasslands and marshy areas	Herb	Paleotropics	Balramgadi
129.	*Utricularia polygaloides* Edgew.	Lentibulariaceae	Wet or waterlogged sandy areas near seashores	Herb	India and Sri Lanka	Naupalgadi
130.	*Vallisneria natans* (Lour.) Hara	Hydrocharitaceae	Pools and ponds	Herb	Pantropical	Naupalgadi
131.	*Myriostachya wightiana* (Nees ex Steud.) Hook.f.	Poaceae	Wetlands	Shrub	Indo-Malesia	Naupalgadi
132.	*Sacciolepis mysuroides* (R. Br.) A. camus	Poaceae	Ditches and marshes	Herb	Tropical Asia and Australia	Balramgadi

developmental activities on freshwater ecosystem. Increasing sedimentation in the aquatic environments due to both natural and man-made causes affect water quality and clarity (Cook 1996). Addition of silt during rainy season, run-off of garbage from human settlement, and draining of wastewater into the lake from industries have resulted shrinkage of this habitat (Nichols 1991). For rural people, this environment is to a certain extent functions as a bio-resource in a sustainable way. *Aponogeton natans*, *Alternanthera sessilis*, *Ipomoea aquatica*, *Marsilea polycarpa*, *Persicaria barbata*, and *Sesbania javanica*, common leafy greens, are available throughout the year, and they are harvested from the wetlands and marshy areas for human consumption. *Ipomoea carnea*, an aggressive alien-invasive weed, is collected from the bunds of the ponds and ditches for fencing of agriculture lands. Flowers of sacred plants *Nymphaea nouchali* and *Nelumbo nucifera* are sold in the market; matured seeds are eaten raw or roasted and made into flour to make nutritious meal. The presence of *Ipomoea carnea*, *Pistia stratiotes*, *Eichhornia crassipes*, and *Salvinia molesta* is a clear indication of invasion of alien species in this perennial ecosystem. *Centella asiatica*, *Bacopa monnieri*, and *Eclipta prostrata* were used in different medicinal formulations. *Arundo donax*, *Cyperus corymbosus*, *Cyperus digitatus*, *Cyperus pangorei*, *Pandanus fascicularis*, and *Typha angustata* were used for basketries and mat-making purposes. However, a detailed study about the suitability of these plants for human consumption as supplemental food or as feed for the cattle has to be carried out as these are growing in water that is dangerously polluted both industrially and biologically.

Conclusions

Studies on aquatic plants are crucial in this ever-changing environment; in India, to assess life-forms and the aquatic environment. In-depth knowledge on macrophyte biology will pave the way for formulation of new management techniques and enhance the efficacy of the present management practices of the aquatic ecosystem. Inhabitants around the aquatic environments are unaware of the importance and role of flora and fauna. Anthropogenic activities such as building construction, accumulation of garbage, encroachment, industrialization, and mining of clay or soil are escalating around the wetlands. Further studies on the impacts of pollutants, nutrient load, microphyte wealth, seed germination strategies, and water quality and ecological quantitative studies are needed to efficiently conserve these important ecosystems and its invaluable biota. Assessment of biota and continuous monitoring and preservation of natural resources are important activities to safeguard the biological wealth of freshwater ecosystems.

Acknowledgements The authors are thankful to the Director of Botanical Survey of India for providing all the facilities and to the Forest Department (WL) of Odisha for the permission, help, and support.

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Aquatic Resources: A Case Study of Udaipur 'City of Lakes', Rajasthan

2

Hemant Mangal and Sandhya Pathania

Abstract

Aquatic resources refer to water and its multiple roles as a natural resource and in supporting all human, animal and plant life. It has a meaning that is broader than that of water resources alone, in that it encompasses all the possible roles for water, including human survival needs, supporting aquatic ecosystems and as an essential component of economic development. It considers both the quantity of available water and its quality for its intended uses. Aquatic resources also encompass the linkage between fresh water systems and the downstream coastal areas into which it drains, where it sustains biologically rich and commercially important coast as ecosystems. This chapter highlights the aquatic resources of Udaipur City, and the study is based on secondary data collected from various government and nongovernment organizations.

Keywords

Aquatic • Biodiversity • Lakes • Rajasthan

Introduction

The total water resources of the earth equal to 326 million cubic mile; only 2–5 % of water is fresh water; 97.5 % is salt water. Almost 69 % of fresh water resources are tied in glaciers and ice caps, about 30 % is ground water and a mere 0.27 % is surface water (www.drinkingwater.com). Water resources are important for the survival of a planet. As water is a prime resource, a basic need, it is essential to realise its full potential. It has always played a very important role in human life since its existence. All human activities are affiliated to water. Water is a supreme economic wealth besides its biological importance. It serves as an ideal medium for biochemical reactions so necessary for life. Thus water sustains life and regulates all important economic activities because of which it has been termed as the richest of all economic resources. Nearly 70 % of the

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M. Rawat et al. (eds.), *Aquatic Ecosystem: Biodiversity, Ecology and Conservation*,
DOI 10.1007/978-81-322-2178-4_2, © Springer India 2015

world's population that is concentrated in the river valleys and deltas, around lakes and in the coastal areas speaks volumes of utility of aquatic resources for man. It seems that water is abundant, but usable water is very limited and creates a serious conservation problem in many places where it is needed. While plants and animals living in oceans are called marine resources, those living in flowing water like rivers as well as inland standing water like reservoirs and ponds are called aquatic resources (fresh water resources). This chapter highlights the present scenario of aquatic resources in Udaipur City, Udaipur being the Kashmir of Rajasthan, Lake City or Venus of India.

Methods

This chapter has been prepared with the help of secondary data collected from various government and nongovernment organizations and various websites. Maps are prepared on Corel Draw.

Study Area

Site Udaipur City is located in the southern part of Rajasthan. It is actually lying in the centre of a bowl-shaped basin surrounded by the Aravalli hills and is drained by the Ayad river.

Location Its latitudinal location is from 23° 9′ to 25° 28′ N and longitudinal extension is from 73° 1′ to 75° 49′ E. Its geographical region is 12,499 km^2 and is about 577 m above sea level. Udaipur evolved as a result of a decline in political power. The decision to site the new capital was favoured by a number of factors including having the temple of Eklingji close by, its isolated position caused by a hilly and forest-covered terrain, availability of water in abundance and the area having a quality of defence, to name a few. The increase in the municipal area of the town was primarily in response to the increase in population. Except for the two consecutive decades, 1891–1901 and 1901–1911, when the population recorded decline due to natural calamities, it has otherwise registered a steady and continuous growth, except that of 1941–1951 when it had the highest growth due to various reasons of which the post partition being the most significant. Besides this the growth rate in Udaipur City had been in accordance with Udaipur's economic and cultural growth. Udaipur being an important tourist centre has a floating population of considerable size (Fig. 2.1).

Though demographically it is a class I city, functionally it is only a medium-sized regional city without having any major or metropolitan function (Bhattacharya 2000). Till 2011 Udaipur continues to develop and expand its commercial, administrative, educational, cultural, recreational and tourist interests. Thus, this throws light on the fact that with the rapid increase in population, the area of city is also increasing.

Aquatic Resources of Udaipur City

Rain water remains reserved in nature in various forms called water reservoirs. They can be broadly classified into surface sources and underground sources.

Surface Water Sources

Udaipur, famous as 'City of Lakes', includes rivers, lakes and ponds that are surface water sources, namely, Fateh Sagar, Pichhola Lake, Swaroop Sagar, Nandeshwar Talab, Badi, Madar, Choti Madar, Ayad river, etc. Figure 2.2 gives a clear picture of all the surface water sources of Udaipur City (Babel and Gupta 1994). Besides these, there were 121 baovries of which 83 have dried up.

Ayad

Berach the main tributary of river Banas rises originates from the Girwa ranges of Aravalli situated to the north of Udaipur City. It is called Ayad river from its fountainhead through Bedla up to Udai Sagar Lake, in which it falls. It is the principal river of the Udaipur basin. Beyond Udai Sagar up to Dabok village, the river passes through a distance of about 75.5 km and is named

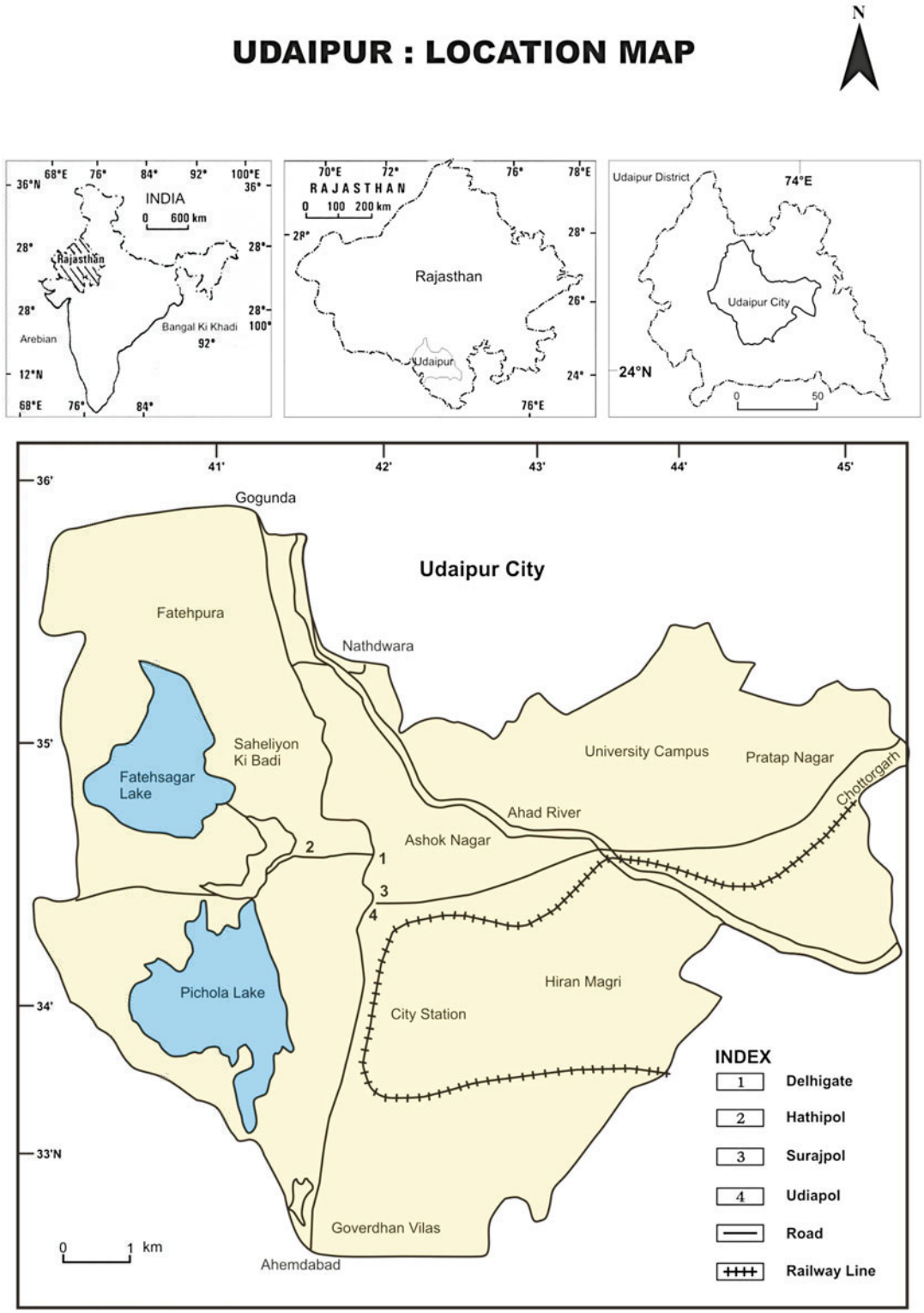

Fig. 2.1 Map of Udaipur City with major water bodies

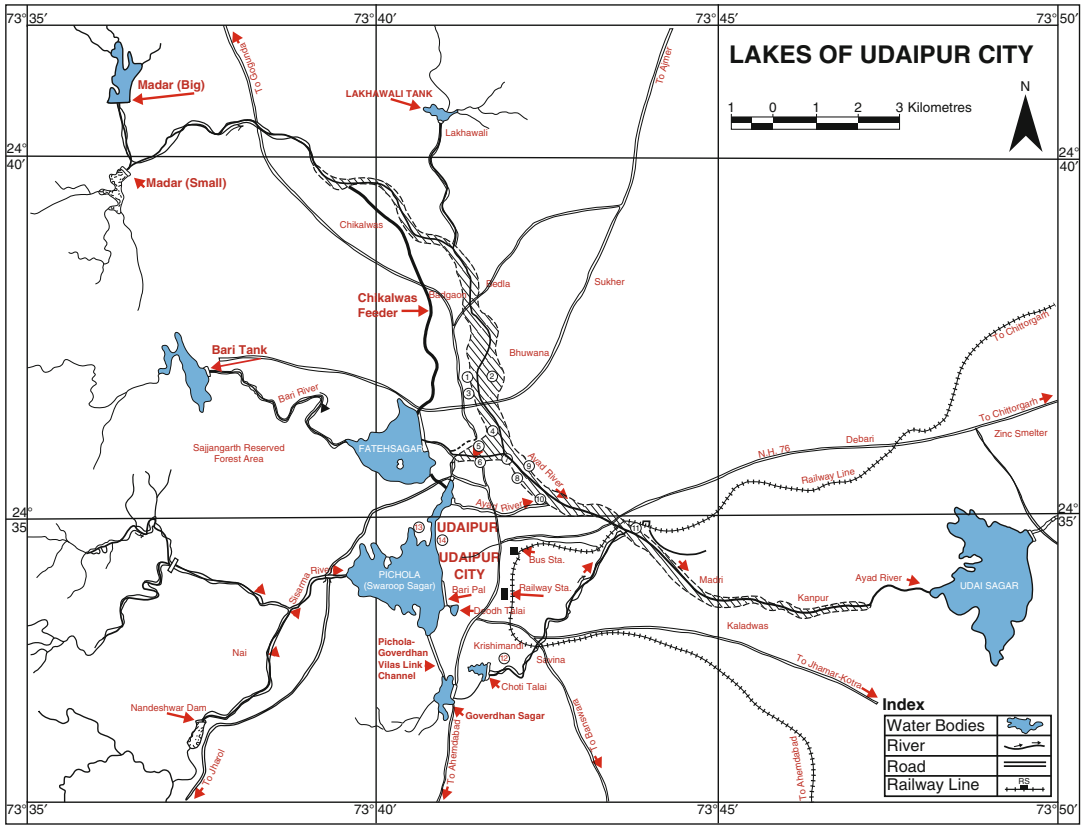

Fig. 2.2 River of Udaipur City

as Udai Sagar ka nala. Afterwards known as Berach it runs for another 70 km towards the northeast and finally merges into river Banas, near Bigod in the Bhilwara district, which is a tributary of Chambal river; Chambal again is a tributary of river Yamuna, and Yamuna is the principal tributary of the holy river Ganga. Near the town of Chittorgarh, it receives the water of Gambhiri river, then it turns northeast, and after flowing for about 190 km, it joins river Banas at the place acclaimed as Triveni Sangam near the village Bigod (Gupta 1991).

Lakes of Udaipur City

Pichhola Lake

Pichhola Lake is in Udaipur, was originally constructed by some Banjara, in the fourteenth century A.D., and later on was extended to Rang Sagar and Swaroop Sagar and finally was connected to Fateh Sagar by the successive rulers of the princely state of Mewar. Pichhola lies to the west of the majestic 'City Palace' providing them with unique and water frontage which enchants every tourist's heart and soul. It is roughly triangular in shape with its base along the palace ridge. It was renovated and enlarged in 1559 A.D. along with the establishment of Udaipur itself; it enjoys a water spread of 10.8 km^2 and a maximum depth of 9.15 m. The gross, live and dead capacities of the lake is 13.67 mcm, 9.00 mcm and 4.67 mcm, respectively, while the gauge height above and below sill level is 3.35 and 5.2 m. The lake has a net catchment area of 142 km^2, and it has an average yield of 493.5 mcft water. Presently 13.50 mld of water is drawn from this lake by the PHED to serve the thickly

populated areas of the old city lying around this lake. The lake is extended towards the north and south forming smaller lakes, viz. Doodh Talai and Swaroop Sagar, as shown in map 2 which gives a detailed picture of the lakes of Udaipur (Sujas 2010).

Swaroop Sagar

It was constructed during 1845–1850 A.D. Its intermediate position has sluice gates and canal to feed water to Fateh Sagar Lake which is towards the north and linked with Pichhola through Rang Sagar Lake in the south.

Rang Sagar

It has an average depth of 7 m, but its width is about 245 m, whereas its westward extension is known as Kalaliya tank.

Fateh Sagar

It is situated in the northwestern part of the city and almost in the central west of the basin covering an area of 12.88 km^2. It has a pear-like shape, covering about 4 km^2 areas and gross, live and dead capacity of 12.0 mcm, 7.00 mcm, and 5.09 mcm, respectively. Nearly 20.71 km^2 of its catchment area yields annually 71.87 mcft of water, evidently lower than that of Pichhola. The daily drawl of water for domestic purposes has been recorded as 30 lakh litres in 2004 which was 0.00 in 2008, that is, no water was taken from Fateh Sagar for supply for domestic purpose which serves about 40 % of the population residing in the northern and western part of Udaipur City.

Bari

Bari ka talab or Lake Bari is lying 10 km away towards the west from Udaipur City. This lake was constructed by Maharaja Raj Singh in 1643 A.D. for recreation purpose. The lake is formed by damming the river Ubheswar coming from the west. The total length of the canal is measured as 3,300 m which is constructed for supplying water to the nearby areas, namely, Bari, Liyo ka Guda, Hawala Khurd and Dewali villages. The full gauge of the lake is 9.76 m. Almost no supply of water is rendered from this lake.

Lakhawali

It is located at a distance of 10 km from the centre of the basin in the north direction. It ranks fifth from the point of view of capacity, yield water level, catchment area and command area of the six lakes of the region. Its nearby terrain provides no scope for bed cultivation area. The lake is comprised of a good canal system spread over a length of 7.5 km of irrigation about 1,012.50 km^2 of land per year. The water of this lake is also used for domestic purposes.

Goverdhan Vilas

It is the smallest water reservoir of all the major lakes of the basin lying in the south. The length of the canals of this lake is also meagre extending over an area of only 3,750 m.

Udai Sagar

It is one of the largest lakes of the Udaipur basin constructed by Maharana Udai Singh in 1559 A.D. and named after him; this lake is situated in the far south-east of this basin. The lake was formed after damming river Ahar, particularly for the strategic and water source point of view.

Vallabh Nagar

Vallabh nagar is in Udaipur, on river Berach. The total catchment area is 1,188 km^2. Its gross, dead and live capacity is 31.14 mcm, 3.54 mcm and 27.60 mcm, respectively. Its full tank level is 492.71 mcm. Its water is used for irrigation as well as for drinking purpose (Sujas 2010).

Badgaon

Badgaon is in Udaipur, on river Berach. Its catchment area is 1,698.3 km^2. Its gross capacity is 31.50 mcm, with its dead and live capacity of 1.34 mcm and 30.16 mcm, respectively. Its water is used for irrigation as well as for drinking purpose.

Jaisamand

Also known as Dhebar, Jaisamand is located 51.48 km south-east of Udaipur. It was made by Maharaja Raj Singh in 4 years from 1687 to 1691. It is more than 14.48 km long, and its breadth is more than 9.65 km. The dam on this

lake is made of marble and is in between two mountains. It is 1,000 ft long at a height of 95 ft. Behind this another water reservoir at the same height was constructed which according to Dr. O.J. Ojha remained empty for about 184 years. In the year 1875, being afraid of heavy rainfall, Maharana Sajjan Singh spent Rs. 2 lakh to fill the two third gap in between the two dams; the remaining work was completed afterwards (Raju et al. 2004). Jaisamand is the world-famous artificial lake. Its catchment area is 1,813 km^2 and gross capacity is 414.60 mcm followed by dead and live capacity of 118.46 mcm and 296.14 mcm, respectively. Its water is used for supplying drinking water to Udaipur and also for irrigation. All these water bodies stand endangered today because of their misuse.

Baovries of Udaipur City

There are 121 baovries in Udaipur out of which 83 have dried up (Goswami and Mathur 2000). Most of these baovries are situated in the Sajjan Niwas Garden area. Maximum load was recorded on Sarvaritu vilas Baovri and lowest was on the Chowk Wali Baovri. The other baovries of Udaipur are Sagasji Ki Baovri, Tarkari Wali Baovri, Garden Wali Baovri, Nalaka, Chhatriwali, Jalijiwali, Maji, Ayurvedic Hospital, Satyanarayan, Toranwali and Om Prakashji Ki Baovri, Customwali, Ramdas Colony, Dore Nagar, Goverdhan Vilas, Phoolji, Jethji, Maliwali, Bhanbagh, Kalanwali, Khilonawali, Delhi Gate and Maszidiji Baovri.

Underground Water Sources of Udaipur City

The Udaipur City average water level pre-monsoon was 11.44 mbgl and post-monsoon was 6.87 mbgl. All the years show a rise in post-monsoon water table which was less in 2007 in comparison to other years as shown in Fig. 2.3.

It becomes clear how rainfall affects the underground water availability. In the years when rainfall in two consecutive years had been above mean average, the underground water level pre-monsoon and post-monsoon observed a lesser gap which has been minimized in the year 2011. Although the post-monsoon water level has fallen down in comparison to 2010, water demand has been increasing every year, thus resulting in Udaipur City lying in an over-exploited zone because of overharvesting of underground water (Swati 2003).

Water Quality

The water quality of the lakes has a high sodium and bicarbonate content, which is attributed to

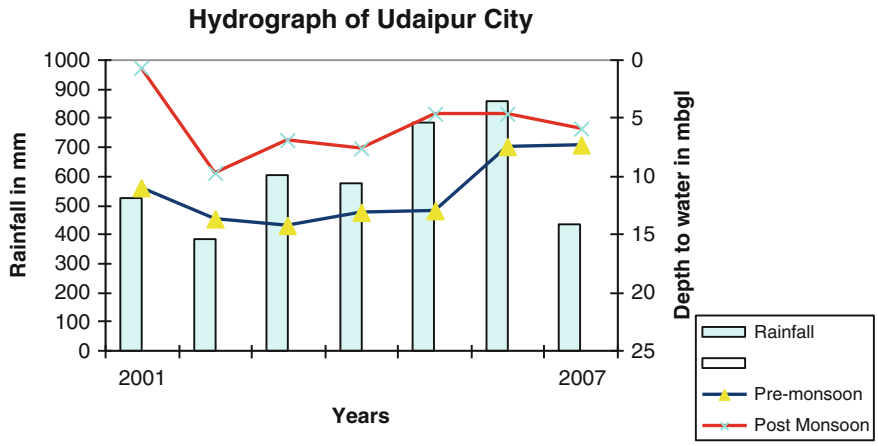

Fig. 2.3 Underground water sources of Udaipur City