Hydrobiological Study of a Subtropical Shiwalik Lake, Jammu, J&K (India)

Deepika Slathia [1] and S.P.S. Dutta [2]

***Abstract*—** Lake Surinsar, an important subtropical lake in the Shiwalik hills of Jammu province along with another Lake Mansar has been recognized as Ramsar site owing to rich diversity of both producers and consumers. Besides being important breeding and resting ground for various migratory water fowls, the lake supports CITES and IUCN red listed species of a turtle *Lissemys punctata* and a coelenterate *Manseriella lacustris*. In the present investigation, an attempt has been made to study the influence of hydrological regime of this lake on the qualitative and quantitative distribution of zooplankton populations for a period of two years. Among various observed groups, *Protozoa, Rotifera* and *Crustacea (Cladocera, Copepoda* and *Ostracoda)* showed considerable seasonal variations in their abundance, diversity and number. Protozoan dominance, among various groups and presence of various pollution indicator species indicate eutropic conditions prevailing in the lake and has been attributed to increased anthropogenic activities in the catchment and excessive biotic interference in the littoral zone of the lake. Coefficient of correlation(r) of zooplankton with various water quality parameters has generally shown insignificant results.

***Keywords*—** Correlation coefficient, Ramsar site, Surinsar lake, water quality, zooplankton.

I. Introduction

INDIAN subcontinent is rich in inland water resources. Increased anthropogenic activities due to fast pace of development and quantum jump in population during the last century without corresponding expansion of civic facilities has resulted in lakes and reservoirs becoming sinks for contaminants [1]. Environmental degradation of these water bodies either directly from domestic and/or industrial discharges and encroachments or indirectly due to excessive deforestation, indiscriminate use of chemical fertilizers, insecticides and pesticides in the catchment etc. has gradient potential for introducing enduring changes in their ecological structure and functions. Pollution is a biological phenomenon because of impact on living organisms and abiotic monitoring of a water body alone is not enough. Zooplankton, also known as 'biomonitors', not only help in transforming energy from one trophic level to the next but can also be used for assessment of the changing trophic status of an aquatic system [2]. Although a large number of ecological studies on diversity and dynamics of zooplankton in various lentic water bodies have been carried out from both India and abroad [3-10], there is lack of knowledge on various aspects of lakes from this subtropical part of the country [11-16].

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II. Materials and Methods

Lake Surinsar (75^0 02' 30″ E and 32^0 46' 30″ N), the present area of study, is picturesque sweet water lake and holds importance due to its priceless historical, cultural and ecological possessions. Located about 25 Km north-east of Jammu city at an elevation of 605m above mean sea level, lake is oval in contour with a deep notch towards its north-west. Main source of water being rain is also aided by presence of natural springs within the lake. The lake presently is under tremendous biotic pressure due to increased human and cattle population in the catchment along with increase in tourist influx which has resulted in changes in its physical, chemical and biological characteristics.

For water quality analysis, monthly water samples were collected for two years in five litre plastic containers and analyzed in laboratory using standard methods [17].

For plankton study, monthly samples were collected by filtering 5 litres of water through a planktonic net (no. 25) in labeled plastic tubes. Samples were preserved in 5% neutralized formalin and lugol's iodine solution after collection. Preserved samples (1 ml) were used for species identification [18-24] and counted on a Sedgwick-Rafter cell in the laboratory. The results were expressed as number/ litre (n/l) and were correlated statistically.

III. Results and Discussion

Yearly variations in water quality and population dynamics of zooplankters for 2 years of investigations are presented in Table I and Table II.

A. Water Quality

Surface water temperature, closely followed the air temperature and was mainly influenced by solar illumination. Water level underwent major fluctuations due to natural factors such as rains/summer increased photoperiods or additional factors such as lifting of water for irrigation and drinking. Lake Surinsar is a monomictic lake which undergoes mixing during winters. Rise in parameters such as salinity, turbidity, electrical conductivity and TDS during this period has been attributed to dissolved solid enrichment caused due to lake overturn, release of salts during macrophytic decomposition and water agitation caused by migratory birds(migratory birds visit the area during this period).

The water of the lake was generally alkaline. However, due to the presence/absence of free CO_2 and CO_3^{2-}, pH showed a wide annual mean variation between 7.92 to 9.82/7.8 to 9.1. An inverse relationship of pH with free CO_2 and direct with CO_3^{2-} is already on record [25-26]. DO in the present lake showed an inverse relationship with free CO_2 and observed winter low values. Winter decline in DO is contrary to the earlier observations of Hutchinson[26], Cole [27] and Reid and Wood[28] who reported rise in DO at low temperature. During this period mass mortality of *Puntius* was also seen in this lake which was attributed to increased CO_2 concentration.

Winter lake upwelling also results in conversion of marls produced by macrophytes such as *Chara* and *Potamogeton* into soluble form {$CO_2 + H_2O \leftrightarrow H_2CO_3$
$CaCO_3 + H_2CO_3 \leftrightarrow Ca(HCO_3)_2$}. High solubility of these ions at low temperature and low metabolic activities of aquatic flora utilizing these nutrients [29] has its relation with rise in bicarbonate, calcium, magnesium and total hardness ions.

Present high range of chloride between 7.41mg/l (May) to 19.60mg/l (December) is higher than earlier observations of Sehgal [12] from this lake (2.53-8.97 mg/l). This has been ascribed to increased human interference (bathing, washing etc.) and cattle population. High amount of chloride as indicative of pollution load of animal origin is already on record [30-31].

COD followed seasonal pattern of BOD and recorded summer and monsoon peaks. Sodium and potassium in lake water generally recorded irregular seasonal fluctuations.

Phosphate, nitrate, sulphate and silicate showed well marked seasonal fluctuations. Present observations of phosphate, nitrate and sulphate are higher as compared to the earlier observation of Sehgal[12] from the same lake. Rise in iron coincided with increased free CO_2 concentration during winter. Formation of soluble Fe^{2+} as $Fe(HCO_3)_{2,}$ in the presence of excess CO_2 is already on the record [29],[32]. Other trace metals like zinc and copper were below the detectable limits as there is no source of industrial pollution in the vicinity. Comparative study of various physico-chemical parameters with observations made by Sehgal [12] clearly indicates an increase in the annual range of most of these parameters.

B. Zooplankton

Fig. I (a) & I (b) shows annual mean variations in different groups of zooplankton observed in lake Surinsar. Three different groups viz. Protozoa, Rotifera and Crustracea (Cladocera, Copepoda and Ostracoda) comprising of one hundred and twenty-three species represented the zooplankton community in this lake. The order of dominance has been recorded as Protozoa (51 species)> Rotifera(40 species)> Crustracea(29 species with eighteen species of order Cladocera, five species of order Copepoda and six species of order Ostracoda). In addition, two species of Oligochaeta and one species of Aschelminthes were also noticed. The total zooplankton density in Surinsar lake ranged from 1297n/l to 2812n/l during the first year and 2257n/l to 4634n/l during the subsequent year (Table II).

Predominance of protozoans, with sub-dominance of rotifers, as observed during the present investigations has been accorded to their adaptability and tolerance to varying habitats including their multiplication in eutrophic waters [27], presence of large amount of detritus, richness of dissolved organic matter and dense bacterial population on which protozoans are known to feed [22],[33]. Contrary to the present observation Sehgal[12] observed dominance of rotifers in Surinsar lake which further supports eutrophic nature of this lake. Qualitative dominance of Class Sarcodina over Ciliata and Mastigophora, also confirms nutrient enrichment in lake as class Mastigophora, among protozoans is considered to be rich in oligotrophic waters. Qualitative richness of various rhizopod species such as *Difflugia, Centropyxis* and *Arcella* in Surinsar lake water, may be due to their high tolerance to organic enrichment and is in agreement with the findings of Wetzel [29].

Rotifera was the second dominant group in lake Surinsar. Appearance of various pollution indicator species like *Rotaria sp.* and *Philodina sp*. not reported earlier further supports eutrophic conditions prevalent in lake water.

Phylum Arthropoda is represented by three orders viz. Cladocera, Copepoda and Ostracoda belonging to Class Crustacea. Qualitative dominance of *Chydorus* (7 species), among various genera of cladocerans may be ascribed to its epiphytic nature and is in conformity with the findings of Ghadouani[34].

There was a distinct seasonal fluctuations and composition of the zooplankton in the Surinsar lake with productive (March to June), retardation (July to September) and recovery (October to February) periods (Fig. II). Present two year analysis has shown seasonal presence of various zooplanktonic species in Surinsar lake. Earlier, Jhingran[35] also documented seasonal planktonic association in tropical and sub-tropical climates and attributed temporary disappearances of planktons to the fact that the species concerned either become too scarce or occur as spores or resting eggs etc. which are not easily detectable. Upon the return of the favourable conditions these plankters multiply and thus, increase in number. Seasonally, total zooplankton recorded bimodal peaks during summer and post-monsoon with trough during monsoon. This bimodal pattern of total zooplanktonic fluctuations is well supported by the findings of Mukherjee *et al.*[7]. Summer high record of total zooplankton may be attributed to favourable water conditions and satisfactory supply of food in the form of phytoplankton upon which zooplankton are known to feed. Sudden dip during winter (December and January) in total zooplankton may be attributed to high free CO_2, low temperature and low DO[36]. Also, mixing caused due to lake overturn may also contribute to this decrease in total zooplankton population. Monsoon decline in total zooplankton population may be ascribed to the dilution caused by rain water and low availability of food[37].

Ecological studies on total zooplankton have been carried out by various workers. Sinha and Sinha[37] reported positive correlation of total zooplankton with temperature, DO, chloride and phosphate. However, an inverse relationship of total zooplankton with temperature, positive correlation with free CO_2 and DO and negative with total hardness, phosphate and nitrate has been reported by Salaskar and Yeragi[38]. Srivastava[39] reported inverse relationship between zooplankton and turbidity. Jhingran[35] recorded positive correlation of total zooplankton with potassium, total hardness and iron.

An overall zooplanktonic study of the present lake has revealed mostly insignificant results of coefficient of correlation (r) of total zooplankton with various physico-chemical characteristics of lake water(Table III). This indicates that no single factor is strong determinant for zooplanktonic abundance in lake and a sum total of a number of factors are responsible for their diversity and density.

Acknowledgment

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C. Tables

Table I. Water quality variations in Surinsar lake during the study period.

Parameters	Mean±SD (Min-Max) (2002-03)	Mean±SD (Min-Max) (2003-04)
AT(^{0}C)	28.0±7.5 (15.2-36.0)	28.1±7.3 (16.7-39.4)
WT(^{0}C)	23.7±6.6 (13.0-32.4)	24.3±6.4 (15.0-32.1)
Depth(cm)	53.4±9.1 (42.0-69.1)	55.0±32.2 (25.0-121.9)
Turbidity(NTU)	21.5±13.6 (3.9-46.3)	15.9±18.3 (3.7-69.4)
Salinity(ppt)	0.2±0.1 (0.1-0.3)	0.2±0.1 (0.1-0.4)
EC(mS/cm)	0.1±0.0 (0.101-0.172)	0.2±0.1 (0.1-0.3)
TDS(ppm)	74.1±20.4 (49.6-111.8)	81.5±35.7 (57.6-177.0)
pH	8.8±0.6 (7.92-9.82)	8.4±0.4 (7.8-9.1)
FCO_2(mg/l)	3.0±6.1 (0.00-19.22)	4.6±5.4 (0.0-15.3)
DO(mg/l)	8.5±0.9 (6.82-9.90)	7.9±1.6 (4.7-9.4)
CO_3^{2-}(mg/l)	9.8±6.5 (0.00-18.38)	7.6±6.9 (0.0-20.6)
HCO_3^-(mg/l)	102.9±38.3 (60.99-170.7)	127.0±36.5 (77.6-168.7)
Cl^-(mg/l)	10.1±1.6 (7.41-12.35)	12.6±2.8 (9.6-19.6)
Ca^{2+}(mg/l)	17.2±10.5 (6.85-38.50)	36.1±34.4 (11.8-140.5)
Mg^{2+}(mg/l)	6.3±0.8 (4.62-7.22)	9.9±9.8 (3.9-39.1)
TH(mg/l)	69.1±27.8 (40.29-125.5)	130.3±123.6 (56.6-511.1)
BOD(mg/l)	4.1±0.9 (3.12-5.79)	6.1±4.0 (1.3-16.2)
COD(mg/l)	45.7±20.5 (17.74-75.42)	46.7±15.2 (26.6-73.0)
Na^+(mg/l)	17.7±2.5 (14.2-22.5)	19.7±5.4 (12.2-30.9)
K^+(mg/l)	3.1±0.7 (1.8-4.2)	4.2±1.1 (2.3-6.2)
PO_4^{3-}(mg/l)	0.1±0.1 (0.048-0.233)	0.1±0.2 (0.0-0.6)
NO_3^-(mg/l)	0.6±0.3 (0.13-1.30)	0.7±1.1 (0.1-4.1)
SO_4^{2-}(mg/l)	7.1±5.0 (1.60-19.19)	5.3±3.8 (1.4-15.7)
SiO_2(mg/l)	1.9±1.1 (0.14-4.23)	1.8±1.8 (0.3-7.0)
Fe(mg/l)	0.1±0.2 (0.00-0.65)	0.2±0.2 (0.0-0.4)
Zn(mg/l	*	*
Cu(mg/l)	*	*

Below detection limit SD-Standard Deviation

Table II. Zooplanktonic diversity and density(n/l) in Surinsar lake during the study period.

Name of Species	Mean±SD (2002-03)	Mean±SD (2003-04)
PROTOZOA		
Class Mastigophora		
Euglena sp.	8±10	14±11
Chlamydomonas sp.	8±12	9±19
Phacus sp.	11±18	6±10
Class Sarcodina		
Arcella discoides	27±37	51±29
A.vulgaris	24±28	44±26
A.polypora	7±22	8±25
A.megastoma	10±17	18±25
A.dentata	15±38	45±63
Arcella sp.	5±12	5±12
Difflugia urceolata	29±20	38±13
D.acuminata	30±25	46±27
D.oblonga	26±22	42±34
D.corona	8±13	18±17
D.lebes	6±11	17±13
D.rubescens	2±4	9±22
D.tuberculata	5±13	6±13
Difflugia sp.	1±2	4±7
Centropyxis aculeate	40±40	75±25
C.hemisphaerica	25±28	45±20
C.ecornis	24±17	54±25
C.constricta	26±19	64±65
C.stellata	5±8	15±31
Centopyxis sp.	3±5	16±20
Lesquereusia spiralis	6±11	9±13
L.modesta	6±14	15±13
Lesquereusia sp.	3±7	3±7

Euglypha sp.	21±19	48±33
Pareuglypha reticulate	4±10	1±5
Bullinula indica	3±6	8±9
Plagiopyxis labiate	5±12	12±15
Pyxidicula operculata	8±12	14±15
Nebela flabellulum	14±16	8±10
Astrameoba radiosa	3±6	6±8
Ameoba discoides	2±6	7±8
Actinophrys sp.	1±3	4±7
Class Ciliata		
Paramecium caudatum	12±15	58±52
P.bursaria	9±15	11±22
P.aurelia	2±4	7±14
P.multimicronucleatum	13±19	49±20
Uronema sp.	3±7	20±45
Urocentrum sp.	6±10	45±30
Coleps sp.	11±17	48±62
Lionotus sp.	1±3	13±28
Chilodonella sp.	0±0	7±12
Homalozoon sp.	3±6	13±25
Euplotes sp.	29±32	55±55
Stylonchia sp.	13±14	29±23
Condylostoma sp.	9±17	13±25
Halteria sp.	4±8	24±39
Vorticella sp.	14±16	47±39
Carchesium sp.	7±10	23±26
TOTAL PROTOZOA	557±417	1220±600
	(0-1540)	(414-2538)
ROTIFERA		
Class Monogonata		
Lecane(Monostyla)bulla	27±30	49±26
L.(M)quadridentata	8±12	25±26
L.(M) decipeans	15±27	14±29
L.closterocerca	16±32	28±35
L.lunaris	19±23	15±14
L.minuta	3±11	5±12
L.luna	15±18	17±20
L.arculata	7±16	29±27
Lecane sp.	2±5	15±21
Colurella adriacta	12±15	11±21
C.bicuspidata	12±13	15±27
C.obtusa	17±17	42±19
Colurella sp.	11±15	10±14
Keratella tropica	88±60	107±75
Euchlanis dilatata	17±28	48±46
Squatinella mutica	11±20	21±18
Anuraeopsis sp.	14±11	16±18
Mytilina ventralis	16±30	27±26
Brachionus calicyflorus	60±58	88±47
B. falcatus	10±14	10±20
B. patulus	22±26	37±45
B.quadridentatus	38±41	39±34
B.bidentata	50±44	94±53
Brachionus sp.	14±19	45±38
Lepadella cristata	6±8	8±22
L.ovalis	18±12	11±26
Lepadella patella	4±6	5±10
Polyartha sp.	35±35	49±41
Asplanchna sp.	32±33	48±53
Trichocerca sp.	14±17	18±17
Cephalodella gibba	7±8	14±15
Cephalodella sp.	17±18	20±23
Hexarthra sp.	15±19	6±10
Filinia sp.	28±28	18±22
Testudinella sp.	14±13	29±20
Platyias quadricornis	26±23	28±24
Proales decipiens	4±8	10±13
Class Bdelloidae		
Philodina sp.	7±14	35±22
Rotaria neptunia	0±0	17±16
R.rotaria	6±14	23±19
TOTAL ROTIFERA	(292-1475)	1145±338
	734±348	(555-1833)
ARTHROPODA		
Class Crustacea		
Order Cladocera		
Daphnia sp.	20±39	29±35
Simocephalus sp.	8±11	25±19
Scapholebris kingi	6±10	12±16
Ceriodaphnia sp.	32±31	44±36
Moinodaphnia sp.	10±10	24±23
Moina sp.	27±36	42±41
Macrothrix rosea	34±40	39±46
Macrothrix sp.	18±20	40±56
Graptoleberis sp.	30±40	50±56
Alonella sp	16±30	25±42
Alona sp.	34±40	43±54
Pleuroxus sp.	20±35	24±40
Chydorus faviformis	26±42	24±46
C.ovalis	27±45	24±43
C.sphaericus	40±41	50±46
C. piger	9±20	10±23
C.gibbus	26±33	32±48
Chydorus sp.	19±26	41±34
Order Copepoda		
Cyclops sp.	23±16	71±32
Mesocyclops sp.	25±14	50±32
Eucyclops sp.	2±5	8±9
Paracyclops sp.	1±2	5±9
Tropocyclops sp.	7±7	17±16
Nauplius & metanauplius larvae	35±19	48±18
Order Ostracoda		
Cypris sp.	21±21	32±21
Stenocypris fontinalis	21±25	29±24
Stenocypris malcolmsoni	15±20	10±13
Cypricercus sp.	21±21	36±22
Eucypris sp.	14±16	10±16
Candona sp.	24±23	33±20
TOTAL CRUSTACEA	(261-1381)	926±416
	610±321	(438-1762)
Miscellaneous		
Oligocheata		
Cheatogaster sp.	8±16	8±12
Aelosoma sp.	22±29	23±22
Aschelminthes		
Cheatonotus sp.	28±31	39±32
TOTAL ZOOPLANKTON	(1297-282)	3362±739
	1959±429	(2257-4634)

SD-Standard Deviation

Table III. Coefficient of correlation (r) of zooplankton with various physico-chemical parameters of Surinsar lake.

Parameter	Zooplankton	
	(2002-03)	(2003-04)
Water temperature	-0.24	-0.56*
Depth	-0.49	-0.05
Turbidity	0.46	-0.19
Salinity	0.28	0.36
Electrical conductivity	0.36	0.20
TDS	0.49	0.29
pH	0.24	-0.52*
FCO_2	0.21	-0.19
DO	-0.19	0.39
CO_3^{2-}	-0.09	0.51*
HCO_3^-	-0.20	0.30
Cl^-	0.01	0.12
Ca^{2+}	0.01	0.05
Mg^{2+}	-0.11	-0.13
Total hardness	0.23	0.46
BOD	-0.40	0.24
COD	0.46	-0.47
Na^+	-0.05	0.48
K^+	-0.43	-0.48
PO_4^{3-}	-0.30	0.19
NO_3^-	0.37	-0.30
SO_4^{2-}	-0.15	-0.30
SiO_2	-0.30	-0.53*
Fe	-0.32	0.47

Marked correlations were significant (p<0.05)

A. Figures

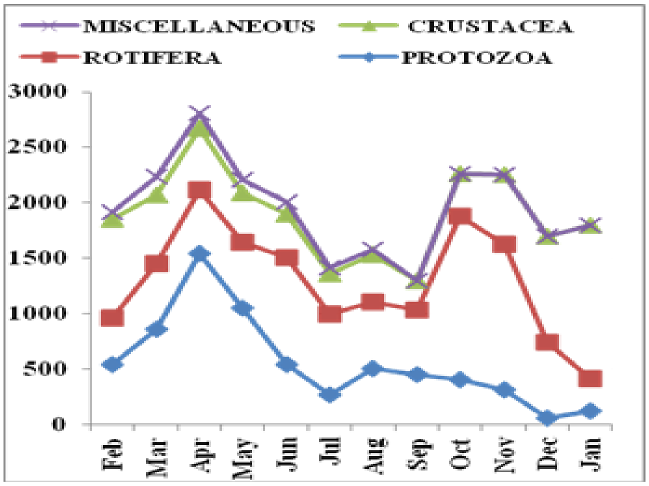

Fig. I(a) Seasonal dynamics of various groups of zooplankton(n/l) in Surinsar lake, Jammu during the year 2002-03.

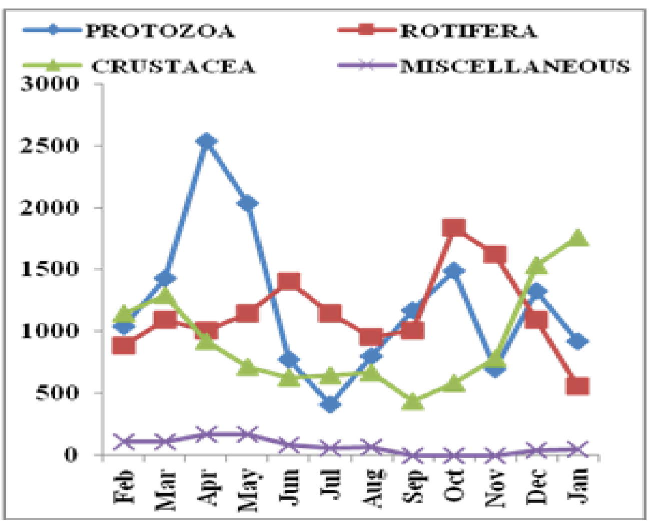

Fig. I(b) Seasonal dynamics of various groups of zooplankton(n/l) in Surinsar lake, Jammu during the year 2003-04.

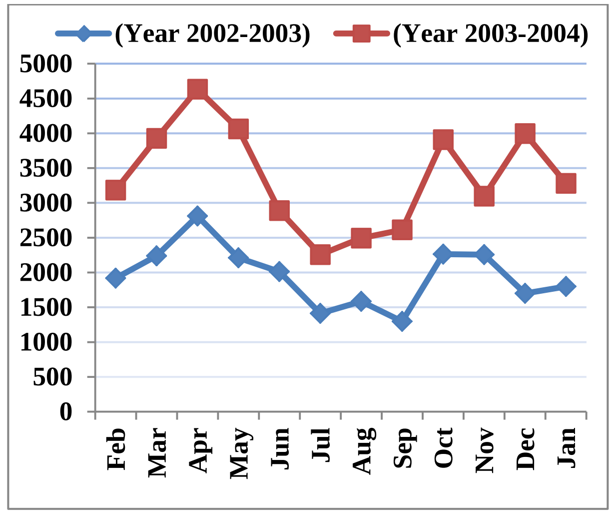

Fig. II. Annual variations in total zooplankton(n/l) of Surinsar lake, Jammu during the study period.

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Correlation between RMR and SMR Based on Field Data: A Case Study in Limestone Mining Area in Citatah, West Java, Indonesia

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Abstract**—** This paper presents a correlation between **RMR** and **SMR** based on the field data. **SMR** classification is a development of the Bieniawski 'Rock Mass Rating' **(RMR)** system which has become known worldwide, and applied by many technicians as a systematic tool to describe rock mass conditions. The **RMR** concept has been proven to be particularly useful in assessing the need for support in tunnel studies. Application of the **RMR** system to slopes has not been possible to date. The **SMR** system provides adjustment factors, field guidelines and recommendations on support methods which allow a systematic use of geomechanical classification for slopes.

Keywords**—**adjustment factors, correlation, field data, RMR, SMR

I. INTRODUCTION

A. Concept of Rock Mass Classification (RMR):

BIENIAWSKI (1976) published the details of a rock mass classification called the Geomechanics Classification or the Rock Mass Rating (*RMR*) system. Over the years, this system has been successively refined as more case records have been examined and the reader should be aware that Bieniawski has made significant changes in the ratings assigned to different parameters. The discussion which follows is based upon the 1989 version of the classification (Bieniawski, 1989). Both this version and the 1976 version deal with estimating the strength of rock masses. The following six parameters are used to classify a rock mass using the *RMR* system:

1. Uniaxial compressive strength of rock material.
2. Rock Quality Designation (*RQD*).
3. Spacing of discontinuities.
4. Condition of discontinuities.
5. Groundwater conditions.
6. Orientation of discontinuities.

Each of the six parameters is assigned a value corresponding to the characteristics of the rock. These values are derived from field-surveys. The sum of the six parameters is the "RMR value", which lies between 0 and 100.

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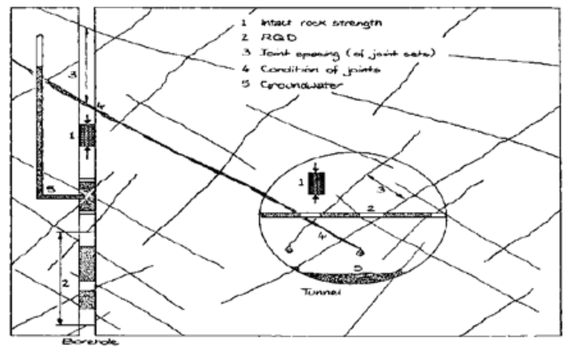

Fig. 1 Showing Parameters of RMR System

TABLE I
CLASSIFICATION TABLE FOR THE RMR SYSTEM

Rating	Class	Description
81-100	**I**	**Very Good Rock**
61-80	**II**	**Good Rock**
41-60	**III**	**Fair Rock**
12-40	**IV**	**Poor Rock**
Less than 20	**V**	**Very Poor Rock**

Rock Quality Designation' (RQD):

Rock Quality Designation (RQD) was defined by Deere as the total length of all the pieces of sound core over 10 cm long, expressed as a percentage of the length drilled. If the core is broken by handling or by the drilling process (giving a fresh fracture) the broken pieces must be fitted together and counted as one piece. The length of individual core pieces must be measured along the axis of the core, trying to avoid a joint parallel to the drill hole that penalizes the RQD values too much. RQD must be estimated for variable length, logging