RIVER NARMADA

It's Environment and Fisheries

Central Inland Fisheries Research Institute

(Indian Council of Agricultural Research)

Barrackpore, Kolkata - 700120, West Bengal

RIVER NARMADA

It's Environment & Fisheries

Prepared by

Dr. S. N. Singh

Bull. No. 157 **2009**

Central Inland Fisheries Research Institute
(Indian Council of Agricultural Research)
Barrackpore, Kolkata – 700 120, West Bengal

River Narmada It's Environment & Fisheries

ISSN 0970-616 X

Published by: **The Director**, CIFRI, Barrackpore

Printed at : Eastern Printing Processor
93, Dakshindari Road
Kolkata - 700 048

Contents

FOREWORD

River Narmada is one of the most promising west-flowing rivers of the country. The Narmada Valley is presently undergoing a comprehensive resource development process, involving commissioning of a cascade of dams on the main stream and a series of impoundments on the tributaries. This sort of *"Compound Impounding"* will transform Narmada River Basin into small, medium and large sheets of water bodies which may involve serious environmental issues including biodiversity shifts and finally the sustainable development of the resource. As such, Narmada Valley development projects have become a subject of serious deliberations among planners, scientists and environmentalists besides media attention. Moreover, other forms of anthropogenic invasions, viz. water abstraction, release of untreated effluents and non-point source of pollution have adversely affected the pristine character of our valuable riverine resources having vast fisheries potential and considered sanctuaries for precious gene pool.

Considering the above eventualities, we had launched "Exploratory Survey" of important river systems of the country to delineate the prevailing status of their environment and fisheries. River Narmada, the "Life Line" of Central India was studied from its origin in Amarkantak, District Shahdol. M.P. till it's culmination into Arabian Sea through Gulf of Cambay, District Bharuch, Gujarat under the aegis of this survey program. This study has documented abiotic and biotic pools including present status of fisheries of river Narmada and dove-tailed with the fisheries scenario in retrospect. The study has revealed that over the years, the fisheries has declined manifold due to wanton killing of young and brooders by employing negative fishing measures, particularly mahseer catch, which has dwindled alarmingly. The study has also identified a score of "Hot Spots" discharging effluents but it is heartening that presently, the impact is confined to outfall region. The study also pronounces a word of caution with further anthropogenic interferences.

It is hoped that the information generated under this exploratory survey program , will prove a guiding tool for the planners, researchers and other stakeholders.

I feel obliged and convey sincere thanks to the State Government agencies of Madhya Pradesh, Maharashtra and Gujarat for extending desired help and cooperation.

CIFRI, Barrackpore, Kolkata

K. K. Vass
Director

PARTICIPANTS

Project Leader

Dr. S. N. Singh, Principal Scientist

Associates

Dr. Dibakar Nath, Principal Scientist
Dr. Vibhakar Pathak, Principal Scientist
Dr. Dhirendra Kumar, Principal Scientist
Shri N. P. Shrivastava, Principal Scientist
Dr. S. Samanta, Senior Scientist
Dr. A. K. Das, Senior Scientist
Dr. Krishna Chandra, Principal Scientist
Dr. R. K. Das, Senior Scientist
Dr. M. A. Khan, Principal Scientist
Dr. Vijay Kolekar, Senior Scientist
Shri R. K. Dwivedi, Senior Scientist
Shri P. N. Jaitley, Senior Scientist
Dr. P. K. Katiha, Senior Scientist

Technical Personnels

Shri Ramji Tiwari, T-4
Shri B. K. Biswas, T-4
Shri R. C. Mandi, T-6
Shri M. P. Singh, T-5
Ms A. Sengupta, T-4
Shri A. Roychoudhari, T-3

SUMMARY

River Narmada is ranked as one of the largest west-flowing rivers of the country and enjoys enormous potential as important fisheries resource. The river originates from an elevation of 1051 m above msl in Maikala highlands near Amarkantak, District Shahdol, M.P. and after traversing a distance of 1312 km in the states of Madhya Pradesh, Maharashtra and Gujarat, culminates into Arabian Sea, through Gulf of Cambay in District Bharuch, Gujarat.

Under a comprehensive resource development exercise envisaged by three riparian states, viz. Madhya Pradesh, Maharashtra and Gujarat, a series of dams on the mainstream of river Narmada and lateral chain of impoundments on its tributaries etc. are being commissioned. Such "Compound Impounding" of Narmada river basin shall transform whole of the valley into small, medium and large sheets of water bodies with possible far-reaching environmental implications involving issues relevant to biodiversity conservation and sustainable development of the resource. The apprehensions regarding above serious issues, have led to Narmada Basin Development Projects, being animatedly debated at different platforms. But there seems that no consensus regarding tackling of above important issues have been reached owing to dearth of relevant information. Moreover, with the aberrations in land-use pattern due to accelerated industrial growth and population explosion, river Narmada, like many other important rivers of the country has been exposed to composite effluents and non-point source of pollution, which have impacted their environ-ments.

Considering the above eventualities, Central Inland Fisheries Research Institute, Barrackpore launched "Exploratory Survey" of important river system of the country and river Narmada was explored with the objective of synthesizing scientific information on environment and fisheries status. Physico-chemical attributes of sediment and water, primary production, biotic communities and identification of "Hot Spots" and their impact on the environment have been studied from its origin till its culmination into Arabian Sea.

For executing the comprehensive technical program, whole of the 1312 km long Narmada river course was segmented into four stretches viz. **(a) Amarkantak to Gadarwada (b) Below Gadarwada to Harsud (c) Below Harsud to Surpan, and (d) Below Surpan to Gulf of Cambay.** Six to nine sites were identified on each stretch and samples from 28 sites have been collected. Three field campaigns were performed to cover summer, monsoon and winter seasons. Criss-cross sampling was employed and standard methodology was followed for analysis. The most salient features of the information generated under this program are portrayed as follows:

Sediment reaction was observed to be alkaline throughout the river course of Narmada from its origin till its culmination into Arabian Sea and the pH varied from 7.3 to 8.56. No particular trend of distribution of organic carbon was discerned, which vacillated from 0.094 to 1.59%. Total Nitrogen content (0.0086 to 0.1007%) and Free $CaCO_3$ (2.80 to 9.93%) fluctuated widely. The C:N ratio varied from 7.95 to 26.20, which denoted varied degree of mineralization and organic carbon availability in different stretches. The texture of sediment was pre-dominantly sandy (52.20 to 97.92%) and contribution of sand particles were least at the sites representing the submergence of Sardar Sarovar. Specific conductance and T.D.S was high at sites representing the lower estuarine expanse due to influx of marine environment. Available phosphorus content fluctuated from 0.2 to 1.57 mg $100g^{-1}$ and no particular trend of distribution of available phosphorus could be noticed. The stretch Amarkantak to Gadarwada contained high available nitrogen (20.05 to 36.93 mg $100g^{-1}$) due to high organic loading at Dindori, Kareli and Gadarwada sites of this stretch. However, no particular distribution pattern of

available nitrogen was evident which fluctuated widely (3.5 to 36.93 mg $100g^{-1}$) among the stretches.

Water temperature reflected seasonal relevance and this fluctuated from 15.0 to 34.0^{0}C in the whole course from its origin to its culmination in Gulf of Cambay. The transparency regime varied from stretch to stretch and freshwater expanse of stretch below Surpan to Gulf of Cambay recorded highest transparency (93.61 to 157.7 cm) while the water clarity was least at estuarine sites under this stretch (6.7 to 70.6 cm.) which is attributed to tidal oscillation. The D.O. content of the river (5.96 to 8.35 mg l^{-1}) was congenial and was by and large identically available. The role of macrophytes in maintaining prevailing regime of D.O seems to be quite important. Free CO_2 was recorded high at a few sites viz. Amarkantak, Sandia, Shahganj, Dongarwada and Handia where organic loading in the form of domestic sewage and other anthropogenic activities are prevalent. Chloride content particularly recorded in uppermost stretch, Amarkantak to Gadarwada indicated mild perturbation at a few sites. Water reaction (pH – 7.67 to 8.42) was alkaline through out the course of river except at Amarkantak site where it was marginally acidic. The total alkalinity regime (99.75 to 162.0 mg l^{-1}) prevailing in Narmada is indicative of productive nature, however, Amarkantak site (42.50 mg l^{-1}) representing the origin of this river experienced low total alkalinity. Total dissolved solids (102.40 to 16986.6 mg l^{-1}) and specific conductivity (193.4 to 19777.77 µmhos cm^{-1}) portrayed parallel trend and the prevailing regime of these two attributes corroborated the fertile nature . The highest levels of these attributes were recorded at Ambetha site representing the lowermost estuarine expanse. Ambetha site (2255.10 mg l^{-1}) also recorded significantly high total hardness which is contributed by influx of marine environment. Nutrient's status of the river evaluated on the basis of availability of major nutrients, phosphate (traces to 0.095 mg l^{-1}) and nitrate (0.023 to 0.383 mg l^{-1}) indicated poor to medium productive status. However, silicate (6.0 to 20.32 mg l^{-1}) was highly abundant.

Plankton population varied from stretch to stretch and average plankton abundance varied from 32 to 203 nos. l^{-1} in the stretch Amarkantak to Gadarwada, 258 to 515 nos. l^{-1} in stretch below Gadarwada to Harsud , 76 to 207 nos. l^{-1} in stretch below Harsud to Surpan and 63 to 1161 nos. l^{-1} in stretch below Surpan to Gulf of Cambay. Phytoplankton was the mainstay and diatoms and green algae were prominent. floral elements. Occurrence of Chlorophycean planktonic crop in sizable proportion indicated that river is not much interfered. Zooplankton community was by and large contributed by copepods and rotifers. Protozoans and cladocerans had also considerable contribution. Macrobenthic abundance experienced spatial aberrations quantitatively as well as qualitatively. The average macro-benthic crop vacillated from 259 to 641 nos.m^{-2} in stretch, Amarkantak to Gadarwada ; 608 to 1493 nos.m^{-2} in stretch, below Gadarwada to Harsud ; 47 to 512 nos.m^{-2} in stretch below Harsud to Surpan and 108 to 13739 nos.m^{-2} in last stretch denoted by below Surpan to Gulf of Cambay. Molluscans and dipterans excelled as major macro-faunal elements, annelids had also sizable contribution. Periphytic population varied from 201 to 930 nos. cm^{-2} in stretch Amarkantak to Gadarwada, 2380 to 11520 nos. cm^{-2} in stretch below Gadarwada to Harsud, 270 to 14400 nos. cm^{-2} in stretch below Harsud to Surpan and 340 to 1130 nos. cm^{-2} in stretch below Surpan to Gulf of Cambay. Bacillariophyceae and Chlorophyceae were most prominent groups contributing to the periphytic population of river Narmada, which vindicated earlier inference that the river environment is not much perturbed. Macrophytic infestation varied from stretch to stretch and the stretch below Gadarwada to Harsud (1304 to 39130 g m^{-2}) recorded maximum macrophytic density.

Carbon production rate fluctuated from stretch to stretch. Gross and net production rate were high in stretches below Gadarwada to Harsud and below Harsud to Surpan as compared to rest of the stretches. The assimilation efficiency varied from 54.44 to 69.43% in stretch Amarkantak to

Gadarwada; 52.18 to 68.82% in stretch below Gadarwada to Harsud ; 39.58 to 82.54% in stretch below Harsud to Surpan and 17.11. to 89.18% in the last stretch, below Surpan to Gulf of Cambay. A few sites namely Gadher in stretch below Harsuud to Surpan, and Shakkarpura and Ambetha in stretch below Surpan to Gulf of Cambay recorded quite low assimilation efficiency which indicated comparatively higher organic loading. The P/R ratio fluctuated from 1.10 to 1.63 in stretch Amarkantak to Gadarwada ; 0.81 to 1.23 in stretch below Gadarwada to Harsud ; 0.689 to 2.38 in stretch below Surpan to Gulf of Cambay. Based on P/R ratio, it may be concluded that autotrophic conditions prevailed in river Narmada barring a few sites namely Gadher, Shakkarpura and Ambetha, where heterotrophic environment existed.

Past fish and fisheries scenario has been projected which inferred that 40 fish species were recorded by Hora and Nair (1941), 77 fish species by Karamchandani et al. (1967), 46 fish species by Department of Fisheries, M.P. and 84 fish species by Rao et al. (1991). The present fish and fisheries scenario synthesized under this exploratory survey revealed 22 fish species from the stretch Amarkantak to Gadarwada, 55 (including prawns) from stretch below Gadarwada to Harsud, 38 from stretch below Harsud to Surpan and 63 fish taxa including prawns represented the stretch below Surpan to Gulf of Cambay. Catfishes (35.40%), Carps (32.94%) and miscellaneous fishes (31.66%) shared the fish landings in the stretch Amarkantak to Gadarwada. Major carps (39.44%) and Cat-fishes (32.23%) were mainstay of fish landed in the stretch below Gadarwada to Harsud. Mahseers accounted for 20.01%. Carps (39.52%), miscellaneous group (32.99%) and Cat-fishes (25.43%) shared bulk of the fish landings in the stretch below Harsud to Surpan. Major carps (27.76 to 48.23%) and Catfishes (12.0 to 19.60%) mostly shared the fish landings at Rajpipala market. *Tor tor* (2.53 to 7.40%) solely represented the mahseers. Katupura fish market (20.43 to 66.74%) and Dandia Bazar (32.88 to 69.74%) recorded significantly high landings of *Tenualosa ilisha*. The shell fishes at Dandia Bazar (9.53 to 21.07%) and Katupura Fish market (17.38 to 39.53%) representing the stretch below Surpan to Gulf of Cambay recorded significantly high contribution. Based on the secondary information, there has been considerable decline in fisheries, the most conspicuous decline has been recorded in mahseers fishery which has relegated to as low as 2.53 to 20.01% for the whole course of the river and its catch is overwhelmingly represented by *Tor tor*.

Negative fishing measures like use of dynamite and agricultural pesticides, viz. Democron, Thiodiaton and Rogor were observed to be employed in stretches, below Gadarwada to Harsud and below Harsud to Surpan. Juvenile fishing of mahseers and major carps were also prevalent and "Disco net", a fine meshed monofilament gear is used for such exploitation.

This exploratory survey has identified a score of "Hot Spots" bringing in domestic and industrial effluents. The environmental monitoring of Hoshangabad City sewage discharged at Nalaghat and SPM at Dongarwada revealed that the severity is felt at the outfall and the impact gets minimized about 300 m below the outfall in case of SPM discharge point. Two "Hot Spots" have also been identified at lower estuarine expanse of river Narmada. The combined GIDCs at Ankaleshwar and Zagadia release their composite effluents at Shakkarpura point; and domestic and industrial effluents from Bharuch City are discharged at Baijalpur point. The impact is presently felt at confluence but with the curtailment in fresh water availability coinciding with the second and third stages defined under NWDT award, the severity will further enhance.

Heavy metal status of river Narmada has been explored and it is inferred that accumulation of the heavy metals are within the permissible limits.

Assessment of impact of commissioning of Sardar Sarovar dam and other overlying projects

on its downstream environment including estuarine expanse revealed that the downstream shall have restrained allochthonous enrichment as SSP dam will retain 96% of the sediment. This would adversely affect the biological productivity of the downstream including Narmada estuary. The downstream shall also feel the fresh water crunch as per NWDT award provisions, particularly the second and third stage at 30th and 45th year after commencement of construction respectively shall be very critical and Narmada estuary may attain a new ecological equilibrium towards a hypersaline biotope.

Important socio-economic indicators have been computed which indicated that literacy is very poor (18.39%) in the stretch Amarkantak to Gadarwada and employment status is quite disturbing as 1.92 dependent per earner were estimated. The average annual income from fisheries and other sources was Rs.20468.57. In other stretch, below Harsud to Surpan, there are more literate (36.13%) as compared to preceding stretch and the ratio of earner to non-earner is 1: 0.61. Average annual income from fisheries and other sources is high (Rs. 63836.48).

1.0 Preamble

Since the dawn of civilization, the rivers have been associated with the endless crusade towards perpetuality of human colonization by catering to their multi-faceted demands on this biosphere. As a matter of fact, cradles of civilization viz. Nile, Tigris and Sindhu have flourished on the banks of the rivers. This crusade initially started with the fulfillment of day-to-day chores followed by, as a means of transport. At a later stage, the demand scenario changed and in consonance to this, these precious water resources have undergone the agony of damming, channelization etc. for hydel power generation and their regulated use in agricultural, domestic and industrial sectors. Such extensive resource development exercises have led to comprehensive aberrations in their pristine nature and the anthropogenic invasions have been manifested in the form of environmental degradation of our invaluable aquatic resources, being the repository of aquatic biodiversity, which are equally important from fisheries perspective.

The concern for the health status of the aquatic resources of the country is growing day by day owing to continued resource development exercise leading to aberrations in land and water-use pattern of the country. The consequent scenario has been compounded by interference in the catchment area. Deforestation can be considered as the eminent culprit, causing enhanced siltation and flash floods result, which meddle with the ecological cycle by constraining the benthic function. The food chain gets short-circuited and this adversely affects the sustainable development of the resource.

River Narmada, the "Life Line" of millions of people of Central India, has also experienced a score of environmental jolts over the years. Moreover, the three riparian states namely Madhya Pradesh, Maharashtra and Gujarat have embarked upon a very ambitious resource development plan under which the whole Narmada basin shall virtually transform into small, medium and large sheets of water bodies. This proposed "Compound Impounding" coupled with composite effluents received by the river during its sojourn to Gulf of Cambay, will have far reaching implications from environmental point of view.

In view of above, an exploratory survey was undertaken to assess the eco-status of important river systems of the country and Narmada river, since it plays a cardinal role in conserving the precious gene pools and contributes significantly towards the food basket of the country, was also studied under a mission project.

2.0 The Resource – The Narmada River System

River Narmada is one of the largest west-flowing rivers of the country and originates from an elevation of 1051 m above msl in Maikala highlands near Amarkantak, District Shahdol (M.P) at 22^0 40′ N latitude and 81^0 45′ E longitudes. The river traverses through country's real rift valley from east to west and since the rocks of the rift valley dates back to Precambrian and Paleozoic age, it is considered as one of the oldest river which flows through the mountains formed of the Gondwana Plate.

2.1 The Narmada Basin

The Narmada basin has an area of 98,769 km^2 and is located between longitude 72^0 32′ and 82^0 45 E and latitude 21^0 20′ and 23^0 45′ N. The northern extremity of Deccan plateau houses this drainage

area which falls in the states of Madhya Pradesh and Gujarat with a fraction coming under the State of Maharashtra. The basin is shielded by Vindhyas and Satpura ranges at the north and south side respectively. The Maikala range covers the Narmada basin from the eastern side while the Arabian Sea forms the western boundary.

2.2 Physiography of River Narmada

The river traverses a distance of 1312 km and culminates into Gulf of Cambay. The river negotiates a distance of 1077 km in Madhya Pradesh and flows through the districts of Shahdol, Mandla, Jabalpur, Narsinghpur, Hoshangabad, Khandawa and Khargone. Subsequently, this forms common boundary between States of M.P. and Maharashtra and Maharashtra and Gujarat for the following 35 and 39 km respectively. The river in its last leg of about 162 km exclusively flows through the districts of Vadodara, Narmada and Bharuch in State of Gujarat.

The basin is thus comprised of five conspicuous physiographic zones, as follows:

(a) upper hilly area under the districts of Shahdol, Mandla, Balaghat and Seoni,

(b) upper plains of Jabalpur, Narsinghpur, Sagar, Damoh, Hoshangabad, Betul, Raisen and Sehore,

(c) middle plains under the districts of East Nimar, part of West Nimar, Dewas, Indore and Dhar,

(d) lower hilly area comprising districts of West Nimar, Jhabua, Dhulia, and Vadodara

(e) lower plains under districts of Vadodara, Narmada and Bharuch.

There are 41 major tributaries; 22 of these join the river Narmada at the south bank (21 in M.P and 01 in Gujarat) and the rest meet at the north bank. Besides the tributaries, there are 50 rivulets and 17 waterfalls.

2.3 The Geology

River Narmada traverses through the rift valley constituted of rocks of Precambrian and Paleozoic age and flows through the ranges formed by Gondwana Plate. As such, Narmada is one of the oldest river in the world and geologically 125 to 150 million years older than Ganges which came into existence during Miocene to Pleistocene.

The geological formation of the Narmada valley varied from recent alluvium prevalent in the districts of Jabalpur, Hoshangabad, Narsinghpur and Bhopal to upper and lower Gondwanas (thick succession of sandstone and clay) while Pleistocene laterite occurs in Amarkantak plateau.

At the dam site of Sardar Sarovar Project (SSP), the main geological formation is of Bagh limestone, sand stone; the Deccan trap lava-flows and the alluvium Basaltic rocks prevail at the upstream of the SSP dam site but these are scattered at the downstream.

3.0 The Envisaged Narmada River Basin Development Plan

The Narmada river basin offers great prospects with regard to resource development owing to ideal altitudinal gradient. The entire Narmada basin shall be tapped under a comprehensive programme leading to multi-purpose resource development (Fig.1). The conceived "Master Plan" incises whole of the Narmada river basin area, as follows:

1. **Upper zone**
2. **Middle zone, and**
3. **Lower zone**

This plan encompasses commissioning of 30 major projects,188 medium irrigation and about 2637 minor schemes. The major projects entail 21 irrigational, 5 hydro-electric and 4 multi-purpose projects. Ten of the major projects are sited on the main river course while the rest have been proposed on the tributaries. The comprehensive details of the proposed projects and zone-wise break-up are portrayed in Table 1 which inferred that the highest submergence will be in the lower zone followed by middle and upper but numerically, the middle zone shall have the maximum concentration of dams. The relative positions of important projects have been offered (Fig.2)

The completion of the proposed water resource development plan will bring Madhya Pradesh state in the forefronts so far as the reservoir fishery resources (2,67,421 ha.) are concerned.

The Government of Gujarat have recently coined another ambitious project namely "Khambhat Gulf Development Project" (Kalpsar Project) and propose to erect a 34.0 km. long dam connecting the east and west banks of the Gulf of Cambay. This dam will be located between Ghogha on the Saurastra bank and Luhara, south of Dahej on the eastern bank and will be extended up to Aliabet island by crossing the Narmada estuary near Hansot. As such, the proposed developmental process will practically seal the mouth of Narmada estuary. The ecological repercussions of such exercise will be enormous.

4.0 Sampling Strategy

Exploratory survey of river Narmada was undertaken with the view to synthesize scientific information pertaining to its fishery status and prevailing environmental conditions from its origin in Amarkantak (M.P) to its culmination into Gulf of Cambay (Gujarat). Core physico-chemical parameters of sediments and water, organic production rate and associated biotic communities were considered for this survey. Identification of "Hot Spots" and their impact on the environment have also been included.

For executing the comprehensive technical programme, whole expanse of the river, measuring 1312 km from its origin to culmination was segmented into four stretches as below:

(a) Amarkantak to Gadarwada
(b) Below Gadarwada to Harsud,
(c) Below Harsud to Surpan, and
(d) Below Surpan to Gulf of Cambay

The upper most expanse of Narmada river denoted by *Amarkantak to Gadarwada* included marble rock area and was represented by six (06) sites namely Amarkantak, Mandla, Jabalpur, Narsinghpur, Kareli and Gadarwada ; the expanse following this stretch i.e. *Below Gadarwada to Harsud* encompassed seven (07) sites viz. Sandia, Shahganj, Hoshangabad, Dongarwada, Gondagaon, Handia and Mola and the expanse prior to the stretch representing the lower most expanse of Narmada river i.e. *Below Harsud to Surpan* was represented by six (06) sites namely Maheshwar, Khalghat, Hanfeshwar, Charbara, Gadher and Surpan. The last leg of Narmada River before its culmination into Gulf of Cambay, includes the estuarine extent and this stretch denoted by *Below Surpan to Gulf of Cambay* comprised nine (09) sites viz. Vedgam, Poicha, Sisodara, Velugam, Jhanor, Ankaleshwar, Shakkarpura, Bhadbhut and Ambetha.

Six to nine sites were identified on each stretch and samples were thus collected from 28 main sites (Fig.2). adopted for selection of sites were (i) important fishing centres, (ii) proximity to confluence of any tributary/rivulet and (iii) effluent discharge point. Three field campaigns were performed to cover summer (May/June), monsoon (September/October) and Winter (January/February) seasons. Criss-cross sampling was done and standard methodology was employed for analysis.

5.0 Abiotic Regime

5.1 Sediment Quality

The sediment quality attributes have been portrayed in Table 2 to 5. The salient information is presented below.

5.1.1 Physico-chemical Attributes

pH

Alkaline pH of the sediments prevailed through out the course of River Narmada from its origin to its culmination in Gulf of Cambay which by and large denoted prevalence of congenial environmental condition. Sediment's reaction was alkaline at the uppermost stretch representing Amarkantak (origin of river) to Gadarwada and the pH varied from 7.3 to 7.9 except at Amarkantak where slightly acidic conditions (pH 6.46) prevailed. The following expanse denoted by below Gadarwada to Harsud also experienced alkaline sediment's reaction with the pH variation of 7.85 to 8.25. The further downstream stretch expanding from below Harsud to Surpan, also recorded alkaline pH, vacillating from 7.92 to 8.09. The sediment's reaction was also observed to be alkaline (pH 7.68 to 8.56) at the expanse including the estuarine area of River Narmada denoted by below Surpan to Gulf of Cambay. Comparatively high alkaline pH (pH 8.37 to 8.56) was recorded at the sites representing estuarine extent of river Narmada. Higher alkaline pH (above 9.0) is not conducive since this may decline the availability of phosphorus.

Organic Carbon

The allochthonous and autochthonous are two main sources of organic carbon enrichment; the former source is from outside the system i.e the catchment area etc. while the later is from the system itself. Organic Carbon content of River Narmada varied from stretch to stretch and this fluctuated from 0.318 to 1.2% in the expanse denoted by Amarkantak to Gadarwada, 0.20 to 0.51% in the stretch represented by below Gadarwada to Harsud. The further downstream stretch denoted by below Harsud to Surpan contained higher content of organic carbon which vacillated from 1.34 to 1.59%. The high organic carbon content of this stretch may be attributed to the washings received from the surrounding forest cover. However, the lowermost stretch of the river, denoted by below Surpan to Gulf of Cambay, which also included the estuarine extent, was observed to contain lower carbon content (0.094 to 0.88%). As such, no particular trend of distribution of organic carbon could be discerned.

Total Nitrogen

Total Nitrogen was identically distributed and did not exhibit much variation (0.071 to 0.091%) in the stretch represented by Amarkantak to Gadarwada. The total nitrogen content was observed to decline (0.018 to 0.048%) in the stretch denoted by below Gadarwada to Harsud and this coincided with the least organic carbon availability in this stretch. The further downstream stretch of below Harsud to Surpan experienced by and large homogenous distribution of this attribute, which varied from 0.047 to 0.084% and the lowermost stretch represented by below Surpan to Gulf of Cambay recorded least total nitrogen (0.0086 to 0.1007%) content in the sediment.

Free $CaCO_3$

Free $CaCO_3$ portrayed wide distribution trend at sites representing the stretch Amarkantak to Gadarwada and this varied from 4.92 to 9.93%, whereas the stretch denoted by below Gadarwada to Harsud (4.0 to 6.4%) has comparatively lower availability of free $CaCO_3$. The stretch denoted by below Harsud to Surpan exhibited by and large similar trend of free $CaCO_3$ availability (4.58 to 7.50%). The lowermost stretch, viz. below Surpan to Gulf of Cambay, encompassing the estuarine extent portrayed wide distribution of this attribute and varied from 2.80 to 9.23%. It is worth placing

here that Narmada river flows through the marble rocks, insoluble $CaCO_3$ is available in plenty.

C : N Ratio

The C:N ratio, a coefficient to denote mineralization process varied from 10.75 to 15.5 for the stretch Amarkantak to Gadarwada, while the same fluctuated from 10.34 to 12.20 for the stretch below Gadarwada to Harsud. Higher C : N ratio was evident in the stretch below Harsud to Surpan (17.05 to 26.20) which also recorded highest organic carbon content; whereas the stretch denoted by below Surpan to Gulf of Cambay (7.95 to 12.41%) portrayed a lower C:N ratio. The variation in C : N ratio reflected varying degree of mineralization and organic carbon availability in different stretches.

Texture

The texture of the sediment did not vary significantly from stretch to stretch as the sand was invariably the most prominent constituent. The soil texture in the stretch Amarkantak to Gadarwada was predominantly sandy (66.70 to 94.60%) while the slit contribution varied from 3.4 to 18.10%. The sand (63.67 to 84.0%) was also observed to be most conspicuous component, followed by silt (9.33 to 26.33%) in the stretch below Gadarwada to Harsud while the stretch below Harsud to Surpan also recorded dominance of sand (65.16 to 89.5%) but clay (6.33 to 23.50%) contributed higher than silt (4.16 to 17.16%) in this stretch. The stretch denoted by below Surpan to Gulf of Cambay also recorded higher abundance of sand (55.22 to 97.92%) as compared to clay (1.50 to 31.11%) and silt (0.33 to 13.67%) in their sediment. Vedgam falling under submergence of Sardar Sarovar reservoir, recorded least sand (52.22%) due to setting in of lentic environment due to Sardar Sarovar dam coming up in proximity. The preceding two stretches are witnessing the impact of commissioning of dam, and as a result, the sediment texture is undergoing transformation as observed above.

Specific Conductance

Specific conductance varied from 182.7 to 326.0 mhos cm^{-1} for the stretch Amarkantak to Gadarwada while this, by and large exhibited similar trend (146.0 to 382.33 mhos cm^{-1}) in the following stretch denoted by below Gadarwada to Harsud and below Harsud to Surpan (199.33 to 312.33 mhos cm^{-1}). However, sites under lower estuarine extent of stretch below Surpan to Gulf of Cambay recorded high specific conductance (466.3 to 4210.0 mhos cm^{-1}) because of ingress of marine environment.

5.1.2 Nutrient's Status

Available Phosphorus

Available Phosphorus (0.2 to 1.57 mg $100g^{-1}$) did not evince any distributional trend in upper most stretch represented by Amarkantak to Gadarwada while this was comparatively high in the stretch denoted by below Gadarwada to Harsud (1.05 to 2.35 mg $100g^{-1}$). However, this declined in the stretch represented by below Harsud to Surpan (0.258 to 0.421 mg $100g^{-1}$) whereas the lowermost river stretch including its estuarine expenses recorded relatively higher available phosphorus (0.577 to 1.611 mg $100g^{-1}$). As such, there has been evident considerable variation in available phosphorous content of the sediment and no particular trend of distribution could be discerned. Based on the available phosphorus levels, Narmada river may be categorized under poor to medium productive system. Of course, the macrophytes abundant in the river play important role since these act as nutrient sink and upon their decay, nutrients are released leading to autochthonous enrichment.

Available Nitrogen

The uppermost stretch denoted by Amarkantak to Gadarwada experienced quite high content of available nitrogen and this varied from 20.05 to 36.93 mg $100g^{-1}$ which is attributed to high organic

loading at Dindori, Kareli and Gadarwada sites under this stretch. The stretch denoted by below Gadarwada to Harsud contained lower available nitrogen (3.5 to 10.4 mg $100g^{-1}$). The available nitrogen content of the stretch below Surpan to Gulf of Cambay recorded comparatively higher content of this attribute (4.2 to 20.58 mg $100g^{-1}$) as compared to its preceding stretch and no particular trend of distribution could be noticed. Stretch to stretch variation in available nitrogen content may be attributed to varied availability of organic matter and the pace of mineralization process. Further, the extent of utilization by macrophytes is also one of the important decisive factors.

5.2 Water Quality

The physico-chemical regime of water has been presented in Table 6 to 9 and the important features of the same are described below:

5.2.1 Physico-chemical Attributes

Water Temperature

Water temperature reflected seasonal relevance and the temperature varied from 15.0 to 30.3^0c at the stretch Amarkantak to Gadarwada which encompass the origin point of this river. A bit higher temperature regime (18.0 to 34.0^0c) was evident at the downstream expanse denoted by below Gadarwada to Harsud while further higher temperature regime was recorded at stretch, below Harsud to Surpan (23.0 to 32.0 ^{0}c). The river stretch including its estuarine extent denoted by below Surpan to Gulf of Cambay recorded by and large similar temperature regime (22.7 to 31.8^0c) like its preceding stretch. The prevailing temperature regime indicated that higher temperature was associated with low altitude and vice versa.

Transparency

The water clarity portrayed seasonal pertinence and the average Secchi disc depth fluctuated from 22.3 to 79.0 cm in stretch Amarkantak to Gadarwada. Dindori site experienced least transparency while Gadarwada site recorded the maximum water clarity. The further downstream stretch denoted by below Gadarwada to Harsud recorded improved transparency regime (66.33 to 95.33 cm) as compared to preceding stretch and Mola site recorded minimum transparency whereas maximum water clarity was evident at Handia. The stretch, below Harsud to Surpan experienced lower transparency which vacillated from 24.66 to 77.33 cm. Hanfeshwar site was observed to be least transparent while Surpan site, falling under the submergence of SSP dam, recorded highest water clarity. The lowermost stretch of the river including its estuarine expanse denoted by below Surpan to Gulf of Cambay exhibited horizontal demarcation since the freshwater sites of this stretch had high transparency regime (93.61 to 157.7 cm) in comparison to estuarine sites (6.7 to 70.6 cm) and the transparency declined as one moved towards estuarine sites. The transparency regime of this stretch fluctuated from 6.7 to 157.7 cm, being least at Ambetha site, representing the lowermost estuarine expanse and highest at Velugam,the site representing upper fresh water expanse. The least transparency recorded at sites representing estuarine expanse of River Narmada is attributed to effective tidal oscillation.

Dissolved Oxygen

The dissolved oxygen (D.O.) content of river was observed to be quite favorable for bio-production and this varied from 6.05 to 8.35 mg l^{-1} in the stretch, Amarkantak to Gadarwada. Kareli site recorded the maximum D.O content while Dindori experienced least content of D.O. Further downstream stretch, viz. below Gadarwada to Harsud recorded D.O. regime varying from 6.27 to 7.0 mg l^{-1} and D.O. content was by and large identically distributed at all the sites of this stretch. The stretch denoted by below Harsud to Surpan portrayed similar regime of D.O. content as recorded in the preceding stretch which fluctuated from 6.57 to 7.03 mg l^{-1}. The river stretch before its

culmination into Arabian Sea through Gulf of Cambay experienced more or less identical D.O. regime being 5.96 to 7.76 mg l^{-1}. By and large, there has been observed homogenous distribution of D.O., indicative of congenial environment. The role of macrophytes contributing to the D.O. regime of Narmada River system, through photosynthesis process is equally important in maintaining the prevailing conducive levels of D.O.

Free CO_2

Free CO_2 was detected at certain sites and this reflected comparative enhanced organic inputs at these sites. The stretch denoted by Amarkantak to Gadarwada recorded free CO_2 varying from 0.7 to 3.7 mg l^{-1}. Free CO_2 content was recorded highest (2.0 – 6.1 mg l^{-1}) at Amarkantak site under this stretch due to receipt of domestic sewage from Amarkantak township. The downstream site designated as below Gadarwada to Harsud experienced considerably high free CO_2 (4.13 to 10.33 mg l^{-1}) which is attributed to a score of outfalls of domestic sewage and other anthropogenic activities particularly at Sandia, Shahganj, Dangarwada and Handia where high free CO_2 have been recorded. Free CO_2 could only be detected occasionally at Charbara and Gadher sites under the stretch below Harsud to Surpan. The lowermost stretch denoted by below Surpan to Gulf of Cambay was observed not so much affected by organic loading as compared to preceding stretches and free CO_2 could only be detected at Shakkarpura site (1.55 mg l^{-1}).

pH

Water reaction was alkaline through out the whole course of river Narmada and this indicated prevalence of congenial environmental conditions. The pH of the river water varied from 7.97 to 8.17 in the stretch Amarkantak to Gadarwada except at Amarkantak, the site representing the origin of the river, where it was observed to be slightly acidic (pH-6.8). The water of stretch denoted by below Gadarwada to Harsud had also alkaline reaction (pH- 7.67 to 8.12) while the stretch following this stretch, denoted by below Harsud to Surpan recorded high alkaline reaction (pH - 8.07 to 8.36). Below Surpan to Gulf of Cambay stretch (pH- 8.08 to 8.42) also portrayed similar status of alkaline reaction of the water as projected by its preceding stretch. Alkaline pH above 9.0 is not conducive since this may decline the availability of phosphate.

Total Alkalinity

Total alkalinity, an indicator of productivity status of any aquatic resource vacillated from 99.75 to 138.60 mg l^{-1} in the stretch Amarkantak to Gadarwada and projected the productive nature of the stretch. Amarkantak site under this stretch, however recorded lower total alkalinity (42.5 mg l^{-1}). Total alkalinity regime prevailing in the stretch below Gadarwada to Harsud (139.33 to 162.0 mg l^{-1}) is indicative of its productive nature while the stretch denoted by below Harsud to Surpan (139.6 to 151.2 mg l^{-1}) corroborated the fertile nature of the resource. The stretch, below Surpan to Gulf of Cambay also recorded total alkalinity regime varying from 131.33 to 143.72 mg l^{-1} and reflected the high productive status of River Narmada.

Total Dissolved Solids and Specific Conductivity

Total dissolved solids (T.D.S.) and specific conductivity reflected parallel trend and prevailing regime of these two attributes corroborated the fertile nature of the river. T.D.S. and specific conductivity varied from 102.4 to 138.3 mg l^{-1} and 193.4 to 249.46 µmhos cm^{-1} respectively in the stretch Amarkantak to Gadarwada. Amarkantak site representing the origin of the river recorded lower conductivity (97.6 µmhos cm^{-1}) and T.D.S. (51.9 mg l^{-1}). The stretch denoted by below Gadarwada to Harsud recorded higher specific conductivity (230.0 to 296.66 µmhos cm^{-1}) while the following stretch, below Harsud to Surpan, by and large maintained the similar conductivity regime (242.8 to 250.8 µmhos cm^{-1}) as observed for the preceding stretch. The T.D.S. content of this

stretch varied narrowly from 142.3 to 147.5 mg l^{-1}. Based on T.D.S and specific conductivity regime, the stretch below Surpan to Gulf of Cambay portrayed zonal demarcation since the freshwater expanse recorded T.D.S and specific conductivity. varying from 177.6 to 216.66 mg l^{-1} and 285.1 to 304.11 µmhos cm^{-1} respectively while the estuarine extent experienced significantly high T.D.S. and specific conductivity, varying from 394.33 to 16986.6 mg l^{-1} and 613.43 to 19777.77 µmhos cm^{-1} respectively which is attributed to influx of marine water.

Alkaline Earth Metals

The alkaline earth metals, Calcium and Magnesium are important from eco-functions perspective. Calcium varied from 15.9 to 28.4 mg l^{-1} in the stretch Amarkantak to Gadarwada while this was significantly high at the stretch below Gadarwada to Harsud (44.06 to 51.06 mg l^{-1}). The following stretch denoted by below Harsud to Surpan recorded comparatively declined Calcium content (20.04 to 44.93 mg l^{-1}) while the last stretch including the estuarine extent represented by below Surpan to Gulf of Cambay had Calcium levels varying from 24.07 to 27.28 mg l^{-1} with lowermost estuarine site Ambetha having very high Calcium content (542.88 mg l^{-1}). Based on the Calcium levels, the river may be classified under moderate to high productive. The other alkaline earth metal, Magnesium which is constituent of chlorophyll in producers, varied from 9.04 to 17.0 mg l^{-1} in the stretch Amarkantak to Gadarwada while comparatively high levels of the same were recorded in the stretch below Gadarwada to Harsud (13.8 to 18.26 mg l^{-1}). The stretch denoted by below Harsud to Surpan, however experienced marginally low Magnesium content (11.02 to 18.23 mg l^{-1}) as compared to the preceding stretch. By and large, identical regime of Magnesium (10.93 to 16.84 mg l^{-1}) was evident in the last stretch denoted by below Surpan to Gulf of Cambay. However, significantly high content of Magnesium was recorded at Ambetha (218.42 mg l^{-1}), the site representing the lowermost estuarine expanse of this stretch, which is attributed to effective tidal oscillation bringing in marine environment.

Total Hardness

Total hardness portrayed parallel trend as observed for total alkalinity and this vacillated from 102.56 to 134.56 mg l^{-1} in the stretch Amarkantak to Gadarwada except Amarkantak site (54.16 mg l^{-1}) which experienced relatively declined total hardness. Below Gadarwada to Harsud, the stretch following above stretch, recorded higher total hardness (173.46 to 202.73 mg l^{-1}) which however declined at the stretch below Harsud to Surpan (113.5 to 124.2 mg l^{-1}). The stretch designated as below Surpan to Gulf of Cambay (111.2 to 131.38 mg l^{-1}) recorded by and large similar regime of total hardness as its preceding stretch. However, Ambetha, the site in proximity of mouth of Narmada estuary, was observed to have significantly high total hardness (2255.1 mg l^{-1}) which is contributed by influx of marine environment.

Dissolved Organic Matter

There has been observed horizontal demarcation in River Narmada based on dissolved organic matter content. The stretch, Amarkantak to Gadarwada experienced low content of dissolved organic matter (0.74 to 1.57 mg l^{-1}) while the same was recorded significantly high in the stretch, below Surpan to Gulf of Cambay (16.9 to 43.8 mg l^{-1}). However, the observations on other two stretches could not be made.

Chloride

Chloride content which denotes the freshness of water varied from 24.40 to 32.01 mg l^{-1} in the uppermost stretch Amarkantak to Gadarwada; 7.13 to 10.13 mg l^{-1} in stretch below Gadarwada to Harsud and 4.72 to 6.87 mg l^{-1} in the penultimate stretch denoted by below Harsud to Surpan. Based on the chloride levels recorded for the uppermost stretch, Amarkantak to Gadarwada, it may be

inferred that the stretch is mildly impacted from the City sewage at Dindoori, and at Jabalpur by Jabalpur City sewage. Such adverse impact was also felt at Kareli site which during Magh Mela received large number of pilgrims for taking bath and at Gadarwada site, where river Sakkar confluences with Namada river and discharges its sewage. The other two downstream stretches are by and large totally fresh. The last stretch , below Surpan to Gulf of Cambay exhibited zonal demarcation with regard to chloride content since the upper sites of this stretch had lower chloride content (7.01 to 10.39 mg l^{-1}) while the sites representing estuarine expanse recorded high chloride content and Ambetha site representing the lowermost estuarine extent, experienced highest chloride content(2495.79 mg l^{-1}). The high chloride content is attributed to tidal ingress and proximity to estuarine mouth.

5.2.2 Nutrient's Status

Nutrient's status of the river was evaluated in terms of availability of major nutrients namely Phosphate, Nitrate and Silicate. Based on the availability of phosphate, the river may be considered fairly productive while silicate was abundantly available and coincidentally, diatoms have been the major planktonic community.

Phosphate, Nitrate and Silicate

The phosphate content of the river varied from 0.002 to 0.03 mg l^{-1} in the upper stretch denoted by Amarkantak to Gadarwada while the nitrate fluctuated from 0.15 to 0.18 mg l^{-1} . Silicate was significantly abundant in this stretch and its content varied from 6.0 to 13.26 mg l^{-1} . The following stretch denoted by below Gadarwada to Harsud contained higher phosphate and nitrate content as compared to preceding stretch and these varied from 0.052 to 0.095 mg l^{-1} and 0.135 to 0.203 mg l^{-1} respectively. Silicate content was higher in this stretch as compared to preceding stretch and vacillated from 15.36 to 17.36 mg l^{-1} . The stretch below Harsud to Surpan recorded phosphate and nitrate content varying from 0.017 to 0.033 mg l^{-1} and 0.06 to 0.126 mg l^{-1} respectively. Silicate like preceding stretches was highly available (12.6 to 13.83 mg l^{-1}). The stretch below Surpan to Gulf of Cambay which includes the estuarine extent, recorded low phosphate content (traces to 0.0186 mg l^{-1}) while nitrate content ranged from 0.023 to 0.383 mg l^{-1}. However, silicate content (14.10 to 20.32 mg l^{-1}) was highest in this stretch. Based on the availability of phosphate and nitrate, Narmada River may be classified under medium productive system, however, silicate was highly abundant in the system.

6.0 Biotic Regime

Biotic communities play an important role in dissemination of energy from higher to lower levels and sustainable development of the resource depends upon the efficiency of different components of biotic pool. Salient information on important biotic communities has been generated and the same are offered as follows:

6.1 Plankton

Plankton abundance exhibited horizontal variations and varied from stretch to stretch. The salient information of the plankton dynamics are offered as follows:

Total plankton abundance of the stretch Amarkantak to Gadarwada (Table 10) varied from 32 to 203 Nos.l^{-1} with least plankton abundance at Dindori site and maximum abundance at Amarkantak, the site representing the origin of this river. Regarding the qualitative texture of this abundance, phytoplankton (68.35 to 97.44%) excelled as the main stay while zooplankton (2.56 to 32.65%) had also considerably high contribution.

Pertaining to the qualitative spectrum of phytoplankton, diatoms (57.23 to 90.62%) were by

and large the most prominent planktonic community, however green algal assemblage was conspicuous at Amarkantak (44.82%) and Mandla (40.51%) sites. *Fragilaria sp., Synedra ulna, Cymbella sp., Diatoma sp., Gomphonema sp., Navicula radiosa, N. cuspidata , Melosira sp., Asterionella sp., Tabellaria sp., Surirella sp., Meridion sp. , Gyrosigma sp., and Pinnularia sp.* mostly represented the diatom flora and *Pediastrum sp., Protococcus sp., Ulothrix sp. and Spirogyra sp.* contributed to the green-algal assemblage of this stretch.

Zooplankton community was contributed by Copepoda (1.28 to 30.38%) and Rotifera (1.27 to 9.38%). *Diaptomus sp.* and *Cyclops sp.* were important copepod taxa while *Keratella sp, Lecane sp., Brachionus sp.* and *Polyarthra sp.* represented the rotifer community of this stretch.

The river stretch downstream of above stretch viz. below Gadarwada to Harsud (Table 11) experienced average total plankton population varying from 258 to 515 nos. l^{-1} with minimum plankton abundance at Dongarwada site while highest was recorded at Gondagaon site. Like the preceding stretch, the phytoplankton population (58.82 to 64.85%) emerged as the major component while zooplankton (35.15 to 41.18%) also contributed significantly. Phytoplankton assemblage of this stretch was shared by Chlorophyceae (23.20 to 34.88%), Bacillariophyceae (10.81 to 26.47%) and Myxophyceae (8.82 to 23.08%). A meager contribution of Dinophyceae (0.33%) was witnessed only at Sandia site. *Spirogyra sp., Protococcus sp., Hormidium sp., Volvox sp., Pediastrum sp., Microspora sp., Mougetia sp.,* and *Botryococcus sp.* were important green algal taxa . The diatom flora of this stretch mainly comprised *Fragilaria sp., Navicula sp., Synedra sp., Surirella sp., Tabellaria sp., Nitzschia sp., Gyrosigma sp., Rhopaloidia sp., Cymbella sp.* and *Asterionella* sp. while the blue-green algal assemblage was contributed by *Spirulina sp., Anabaena sp., Oscillatoria sp., Nostoc sp., Phormidium sp., Coelosphaerium sp., and Merismopedia sp.*

Zooplankton population of this stretch comprised Copepoda (8.13 to 17.03%), Cladocera (4.66 to 16.01%), Protozoa (8.17 to 11.77) and Rotifera (5.05 to 8.14%). A scanty population of ostracods (1.92%) was also recorded at Hoshangabad. *Diaptomus sp., Cyclops sp.,* and their nauplii represented the copepod population while *Moina sp., Chydorus sp., Alonella sp., Daphnia sp., Diaphnosoma sp.* and *Bosmina* sp. were important cladoceran taxa. *Centropyxis sp., Difflugia sp., Euglena sp., Arcella sp.* and *Oxytricha sp.* constituted the protozoan population of this stretch. The rotifers were represented by *Brachionus sp., Filinia sp., Polyarthra sp., Trichocerca sp., Lecane sp., Gastropus sp., Epiphanes sp.* and *Asplanchna sp.* in this stretch.

The expanse further downstream of above stretch namely below Harsud to Surpan (Table 12) contained average total plankton abundance vacillating from 76 to 207 nos. l^{-1} being maximum at Maheshwar and minimum at Hanfeshwar site. This stretch exhibited regional relevance with regard to the most conspicuous phytoplanktonic component since green algal assemblage (47.78 to 74.11) excelled as major component at river expanse extending from Maheshwar to Charbara while diatoms (54.39 to 57.95%) emerged as most prominent floral element at Gadher and Surpan sites of this stretch. *Ankistrodesmus sp., Oedogonium sp., Eudorina sp.,Pediastrum simplex, Coelastrum sp.* and *Microspora sp.* represented the green algal assemblage while *Tabellaria sp., Asterionella sp.,Melosira granulata, Fragilaria sp.,Surirella sp.* and *Synedra ulna* were important diatom taxa. The blue-green algal assemblage (0.51 to 9.94%) seemed to emerge slowly which is attributed to impoundment impact of Sardar Sarovar dam being commissioned in proximity of Surpan site of this stretch. *Microcystis aeruginosa, Spirulina sp.,* and *Oscillatoria sp.* mostly contributed to the blue-green assemblage of this stretch.

The zooplankton (4.83 to 15.79%) had lower contribution as compared to the preceding stretch and copepods (1.79 to 10.53%) and rotifers

(0.49 to 8.92%) were important faunal elements contributing to the zooplankton community of this stretch. Cladoceran population (nil to 2.63%) was also fairly represented. *Diaptomus sp., Cyclops sp.* and the nauplial larval forms mostly constituted the copepod population while *Polyarthra sp., Asplanchna sp., Keratella sp., Brachionus sp.* and *Monostyla sp* were important rotifer taxa. *Diaphnosoma sp., Moina sp.* and *Bosmina longirostris* represented the cladoceran assemblage of this stretch.

The stretch, below Surpan to Gulf of Cambay (Table 13) which also included the estuarine expanse of river Narmada experienced average total plankton population varying from 63 to 1161 nos. l^{-1}. The highest plankton population was witnessed at Jhanor site while the least was recorded at Shakkarpura. Phytoplankton (70.42 to 98.70%) like upstream stretches was the dominant component of this plankton abundance. The zooplankton (1.30 to 29.58%) had also fair contribution.

Pertaining to the qualitative texture of phytoplankton assemblage of this stretch, diatoms (34.92 to 79.01%) excelled as major floral component except at Sisodara and Jhanor sites where blue-greens (54.67%) and Chlorophyceae (88.20%) respectively were dominant floral components. The other group of secondary importance was Chlorophyceae at rest of the sites of this stretch. *Coscinodiscus* grani., *C. subtilis, Chaetoceros decipiens, Biddulphia sinensis, Amphora ovalis, Rhizosolenia sp., Surirella elegans, Anomoeoneis sphaerophora, Synedra ulna, Nitzschia sp., Gyrosigma sp., Asterionella sp.* and *Pleurosigma angulatum* were important diatom taxa and the green algal assemblage was mainly represented by *Pediatrum simplex, Spirogyra sp., Dictyosphaerium sp., Westella sp., Ankistrodesmus sp.* and *Eudorina sp.*

The zooplankton assemblage of this stretch was mostly shared by Protozoa (0.52 to 14.61%), Copepoda (0.26 to 12.68%) and Rotifera (0.43 to 5.63%).*Candeina sp., Pulvinulina sp.* and *Difflugia sp.* were important taxa representing protozoan population of this stretch.

6.2 Macro-benthos

There has been observed spatial aberrations in macro-benthic abundance, quantitatively as well as qualitatively across the stretches. Salient features of macro-benthic population of the river from its origin till its culmination into Gulf of Cambay are presented below.

The stretch Amarkantak to Gadarwada (Table 14) harboured average total macro-benthos abundance vacillating from 259 to 641 nos. m^{-2} which was recorded least at Mandla and maximum at Jabalpur site. Regarding the qualitative spectrum of prevailing macro-benthic assemblage, molluscans and dipterans have been observed to be the conspicuous faunal elements. Mollusca (62.01 to 93.32%) excelled as major faunal component at Narsinghpur, Kareli and Gadarwada sites while Diptera (40.56 to 69.44%) recorded their prominence at Dindori, Mandla and Jabalpur sites. Annelids (nil to 51.25%) were other important faunal element contributing to the benthic communities of this stretch. *Thiara scabra, Thiara tuberculata, Bellamaya bengalensis, Gyraulus sp. ,Lymnaea acuminata , Corbicula striatella, Lamellidens marginalis* and *Sphaerium sp.* were important molluscan taxa while chironomid larval forms mainly represented the dipteran community of this stretch. *Tubifex sp* contributed solely to the annelid population.

There has been rich macro-benthic population at the stretch downstream of above stretch i.e. below Gadarwada to Harsud and this contained average total macro-benthic population varying from 608 to 1493 nos. m^{-2} (Table 15). Dongarwada and Shahganj sites recorded minimum and highest macro-benthic crop respectively.

An insight into the qualitative texture of macro-benthic community of this stretch revealed that the molluscans (52.35 to 66.20%) were invariably the

most prominent macro-faunal element except at Mola site where Diptera (39.58%) and Mollusca (37.64%) shared the bulk of macro-benthic crop. Dipterans (28.59 to 42.04%) were the faunal element of secondary importance. This stretch was also observed to have fair contribution of Trichoptera (nil to 7.55%) and Odonata (nil to 15.23%) in their benthic abundance. *Thiara sp. Viviparus sp., Lymnaea sp., Gyraulus sp., Corbicula sp., Parreysia sp., Pisidium sp., and Lamellidens sp.* represented the molluscan population whereas *Chaoborus sp., Culicoides sp. and Chironomus sp.* were important dipteran taxa.

The macro-benthic abundance was observed to decline at the penultimate stretch, designated as below Harsud to Surpan (Table 16) and the total average macro-benthic population fluctuated from 47 to 512 nos. m^{-2}. Gadher site falling under the submergence of Sardar Sarovar reservoir contained the least benthic crop while the maximum macro benthic population was recorded at Khalghat site under this stretch.

Pertaining to the qualitative spectrum of this abundance, dipterans (6.45 to 85.51%), molluscs (nil to 88.87%) and annelids (3.71 to 60.65%) mainly shared the macro-benthic population of this stretch. *Thiara tuberculata, Corbicula striatella, Lamellidens marginalis* mainly contributed to the molluscan community of this stretch while chironomid developmental stages constituted the dipteran population. *Nais sp* .and *Tubifex* sp. were important annelid taxa.

The stretch of river before its culmination into Gulf of Cambay designated as below Surpan to Gulf of Cambay (Table 17) harboured total average macro-benthos abundance, varying from 108 to 13739 nos. m^{-2}. This stretch experienced diverse benthic population since this was contributed by eight taxonomic groups. Pertaining to qualitative texture of this abundance, annelids (65.84 to 93.81%) emerged as most conspicuous faunal element at Ambetha, Bhadbhut, Ankleshwar and Jhanor sites. Dipterans (47.36 to 86.46%) replaced annelids as most prominent macro-faunal element at Sisodara and Poicha sites while molluscs (57.06 to 95.15%) constituted the prime benthic community at Shakkarpura, Velugam and Vedgam sites of this stretch. *Tubifex tubifex, Nais sp.* and *Neanthes sp.* represented the annelid population while *Chironomus sp.,Pentaneura sp.,Palpomyia sp., Chaoborus sp., Culicoides sp., Tipula sp.,* and *Psychoda sp.* were important dipteran taxa. The molluscan fauna of this stretch was represented by *Thiara tuberculata, T. scabra ,Stenothyra sp. Bellamaya bengalensis, Lymnaea acuminata, Corbicula sp., Digoniostoma sp., Gyraulus convexiculus, Perreysia sp.* and, *Sphaerium sp.*

6.3 Periphyton

The periphytic population of the stretch Amarkantak to Gadarwada varied from 201 to 930 nos. cm^{-2} which was maximum at Jabalpur site and least at Narshinghpur. High periphytic abundance at Jabalpur and Gadarwada sites may be attributed to gelatin factory discharges at former and confluence of river Shakkar bringing in domestic sewage at later site. Regarding the qualitative texture, diatoms (57.4 to 98.3%) invariably constituted the bulk of periphytic crop and these were followed by blue-greens (nil to 41.8%) and Chlorophyceae (0.2 to 17.2%).

Bacillariophyceae was the most diversified group, represented by *Synedra ulna, Navicula sp., Cymbella sp., Diatoma sp., Gyrosigma sp., Gomphonema sp. and Fragilaria sp.*while the blue-greens comprised *Phormidium sp., Oscillatoria sp., and Merismopedia sp.* The green algal assemblage was contributed by *Ankistrodesmus sp. Scenedesmus sp., Cladophora sp., Closteriopsis sp., and Spirogyra sp.*

The periphytic assemblage of the stretch below Gadarwada to Harsud was quite dense and this varied from 2380 to 11520 nos. cm^{-2} which was observed to be densest at Gondagaon site while least at Mola site.

Regarding the qualitative texture of the periphytic biocoenoses, Chlorophyceae emerged as conspicuous component at Shahganj (43.20%), Handia (60.50%) and Mola (52.90%) sites while diatoms replaced them at Sandia (46.20%), Dongarwada (52.80%) and Gondagaon (42.20%) sites. as the most prominent group of periphytic assemblage. Blue-greens (5.90 to 16.20%) were the group of further importance, constituting the periphytic population of this stretch.

Blue-greens were represented by *Spirulina sp., Anabaena sp.,* and *Oscillatoria sp.* while green algal assemblage was contributed by *Spirogyra sp., Microspora sp., Tribonema sp., Pediastrum sp.,Actinastrum sp., Ulothrix sp.* and *Spirotaenia sp.* The diatoms were represented by *Fragilaria sp., Asterionella sp., Nitzschia sp., Diatoma sp., Synedra sp., Surirella sp., Navicula sp., Gomphonema sp., Gyrosigma sp., Tabellaria sp., Cocconeis sp.,* and *Diploneis sp.*

The periphytic population of the stretch below Harsud to Surpan was observed to vary from 270 to 14400 nos. cm^{-2} and diatoms (66.67 to 100.0%) excelled as dominant component. *Navicula sp., Tabellaria sp. , Amphora sp.* were important diatom taxa.

The stretch below Surpan to Gulf of Cambay experienced periphytic population vacillating from 340 to 1130 nos.cm^{-2} and Poicha site experienced the highest periphytic crop and Ankaleshwar recorded the least. Bacillariophyceae (63.85 to 87.51%) excelled as the most prominent component of periphytic population of this stretch. *Navicula sp, Surirella sp Fragilaria sp., Asterionella sp., Nitzschia sp., Diatoma sp., Synedra sp. Gomphonema sp., Gyrosigma sp., Tabellaria sp* and, *Cymatopleura sp* were important diatom taxa.

6.4 Macrophytes

The stretch Amarkantak to Gadarwada was by and large devoid of macrophytes except during summer months in the marginal areas of Mandla, Jabalpur and Narshinghpur sites. The macrophytic biomass vacillated from 0.60 to 1.25 kg m^{-2} which was least at Jabalpur site while highest at Narshingpur. *Potamogeton sp. Najas sp.* and *Vallisneria sp.* were important macro-phytic flora.

The stretch below Gadarwada to Harsud experienced high macrophytic infestation varying from 1304 to 26087 kg m^{-2} which was recorded maximum at Gondagaon site with least abundance at Sandia site under this stretch. *Potamogeton sp., Vallisneria sp., Ceratophyllum sp., Chara sp., Najas sp.* and *Hydrilla sp.* constituted the macrophytic assemblage of this stretch. Macrophytes showed luxuriant growth during summer and their density vacillated from 6.522 (Sandia) to 39.130 kg m^{-2} (Hoshangabad). Considerably high macrophytic infestation was recorded at Gondagaon also. Enhanced per capita availability of nutrients due to low level of water and stagnancy may be attributed to such intense growth of macrophytes. Macrophytes were not recorded during monsoon season due to frequent water vacillation.

The stretch below Harsud to Surpan was practically devoid of macrophytes during monsoon season which may be attributed to water fluctuations.

Isolated patches of macrophytes were evident in the stretch below Surpan to Gulf of Cambay. This stretch contained fair abundance of macrophytes, vacillating from 1.875 to 4.825 kg m^{-2}, which was more dense at Sisodara and least at Ankaleshwar site. The lower estuarine sites were practically devoid of macrophytes. The macrophytic infestation was observed to be more intense in marginal areas and coves having more or less stagnant conditions. *Hydrilla verticillata, Potamogeton crespus, Vallisneria spiralis, Chara sp.* and *Ceratophyllum demersum* mainly contributed to the macrophytic population of this stretch.

7.0 Primary Production

Carbon production rate is an important criterion to reach to the health status of any aquatic resource. Narmada river system has also been studied to delineate the same and the salient account pertaining to different stretches is described below.

Average gross production rate in the uppermost stretch denoted by Amarkantak to Gadarwada (Table 18) vacillated from 67.06 to 91.31 mg C m^{-3} hr^{-1} which was recorded least at Dindori site and highest at Jabalpur site. Net production rate which reflects the energy spared by the producers exhibited similar trend as observed for gross production and the same fluctuated from 38.33 to 61.52 mg C m^{-3} hr^{-1}. The respiration rate (24.46 to 38.60 mg C m^{-3} hr^{-1}) of this stretch experienced narrow variation.

The assimilation efficiency which is an important consideration from production point of view at following trophic levels has been found to vary from 54.44 to 69.43% which indicated availability of fair amount of energy at secondary level (Fig. 3) The P/R ratio varied from 1.10 to 1.63 which indicated prevalence of autotrophic conditions in the stretch and corroborated the above inference (Fig. 4).

The average gross production rate relevant to the stretch below Gadarwada to Harsud (Table 19) was observed to be high as compared to preceding stretch and this fluctuated from 52.93 to 135.36 mg C m^{-3} hr^{-1}. Dongarwada site experienced the lowest rate while it was maximum at Gondagaon site. Net production rate portrayed similar trend and varied from 29.50 to 88.50 mg C m^{-3} hr^{-1} for the stretch as whole. This stretch recorded a quite varied (28.13 to 73.70 mg C m^{-3} hr^{-1}) respiration rate and Shahganj (73.70 mg C m^{-3} hr^{-1}), Gondagaon (57.76 mg C m^{-3} hr^{-1}) and Handia (46.83 mg C m^{-3} hr^{-1}) sites recorded considerably high respiration rate, indicating comparatively high inputs of organic matter at these sites.

The assimilation efficiency of this stretch (Fig. 5) was by and large of same magnitude (52.18 to 68.82%) as that of the preceding stretch but P/R ratio (0.81 to 1.23) projected a mixed scenario since heterotrophic conditions prevailed at Shahganj, Dongarwada and Handia sites while autotrophic conditions could only be observed at rest of the sites (Fig. 6). Heterotrophic condition denoted impaired environmental condition due to anthropogenic invasions at above sites.

The penultimate stretch designated as below Harsud to Surpan recorded average gross production rate varying from 72.91 to 127.77 mg C m^{-3} hr^{-1} (Table 20) which was least at Khalghat and highest at Charbara site. The net production rate (39.23 to 77.77 mg C m^{-3} hr^{-1}) by and large followed similar trend as recorded for gross production. The respiration rate of this stretch, like the preceding stretch, recorded wide fluctuation (15.37 to 72.49 mg C m^{-3} hr^{-1}).

The assimilation efficiency (53.81 to 82.54%) of the stretch was by and large favourable (Fig. 7) except at Gadher (39.58%) site. Similar inference could be drawn based on P/R ratio (0.90 to 2.38%) that by and large autotrophic conditions (Fig. 8) prevailed through out the stretch except Gadher site (0.689) where high heterotrophic condition existed.

The stretch confluencing into Arabian Sea, denoted by below Surpan to Gulf of Cambay (Table 21) recorded comparatively lower rate of gross (36.34 to 89.39 mg C m^{-3} hr^{-1}) and net (6.24 to 60.47 mg C m^{-3} hr^{-1}) production, being least at Shakkarpura/Ambetha and highest at Ankaleshwar site. The respiration rate (7.5 to 36.25 mg C m^{-3} hr^{-1}) portrayed wide variation between the sites and indicated that Shakkarpura and Ambetha sites seem to be stressed.

Assimilation efficiency (67.64 to 89.18 %) reflected congenial conditions for secondary production (Fig. 9) except at certain sites under this stretch, viz. Shakkarpura (20.06 %) and Ambetha (17.11 %) which portrayed stressed environmental conditions. The above inference was corroborated by P/R ratio values reflecting high heterotrophic conditions at Shakkarpura (0.52) and Ambetha (0.50) sites (Fig.10) while the rest of the sites under this stretch experienced congenial autotrophic condition (PIR-1.38 to 3.85).

8.0 Fish and Fisheries in Retrospect and Prevailing Scenario

8.1 Past Fish and Fisheries Scenario

Hora and Nair (1941) were the pioneer to provide the initial information on the ichthyo-faunal assemblage of river Narmada and recorded 40 species from the hill streams joining the Narmada River in Satpura range under Hoshangabad district. Karamchandani et al. (1967) have recorded 77 species inclusive of 11 recorded by Hora and Nair (op. cit.) by confining their survey to Hoshangabad area during the pre- and post - monsoon period of 1959-64. The Department of Fisheries, M.P. executed an extensive survey of River Narmada at Hoshangabad, Jabalpur, Maheshwar, Khalghat and Omkareshwar during the period 1967 to 1971 and 46 fish taxa were recorded. Rao et al.(1991) have undertaken pre-impoundment survey at Punasa, Omkareswar, Mandleswar, Maheswar and Barwani pertaining to the western zone of the river and have enlisted 84 fish species (Table 22).

The aberrations in fish production trend and the fishery spectrum of river Narmada in space and time have been reached by comparing the available fish catch statistics from 1959 to 1990. A comparative statement relevant to fish catch statistics of above referred periods is portrayed in Table 23. A perusal of data pertaining to the periods 1959-64, 1971 and 1990 did not reflect any significant change in the catch composition and the carp fishery varied from 58.20 to 65.40% while the contribution of cat fishes fluctuated from 21.80 to 35.92%. The carp fishery was invariably dominated by *Tor tor* (25.30 to 30.10%) and was followed by *Labeo fimbriatus* (18.54 to 24.40%). The mahseer fishery earlier represented by three species, is now mostly contributed by *T. tor* only ; and *T. khudree* and *T. putitora* have become quite rare. There has been recorded decline in mahseer fishery as compared to the periods, 1971 to 1990. The estimated inland fish production offered by the Commissionerate of Fisheries, Gujarat also indicated that the mahseer fishery have declined from 330 t in 1992-93 to meager 53 t in 1996-97 (Table 24). A perusal of the data pertaining to the collection of fry and fingerlings undertaken during the period 1987-88 to 1995-96 by the Department of Fisheries, M.P. concluded a drastic decline (77.60%) in the mahseer fry availability which possibly has been caused by the disruption of breeding and nursery grounds of mahseers, as evident from the fact that Tawa, a major tributary of river Narmada which used to offer congenial breeding and nursery grounds is now dammed resulting into negative habitat modification . The secondary information regarding the state of fish production of River Narmada, as compared to yesteryears, revealed that there has been significant decline in fish production over the years.

8.2 Prevailing Fish and Fisheries Scenario

Fish Fauna of Different Stretches

Stretch Amarkantak to Gadarwada – Following fish taxa have been recorded :

Family	Species
NOTOPTERIDAE	*Notopterus notopterus* ((Pallas)
CYPRINIDAE	*Catla catla* (Hamilton -Buchanan)
	Labeo rohita (Hamilton-Buchanan)
	Labeo calbasu (Hamilton-Buchanan)
	Labeo gonius (Hamilton-Buchanan)
	Labeo bata (Hamilton-Buchanan)
	Labeo fimbriatus (Bloch)
	Cirrhinus mrigala (Hamilton-Buchanan)
	Cirrhinus reba (Hamilton -Buchanan)
	Tor tor (Hamilton -Buchanan)
	Puntius sophore (Hamilton – Buchanan)
	Salmostoma bacaila (Hamilton – Buchanan)
	Aspidoporia morar (Hamilton – Buchanan)
BAGRIDAE	*Aorichthys aor* (Hamilton -Buchanan)
	Aorichthys seenghala (Sykes)
	Rita pavimentata (Valenciennes)
CLARIIDAE	*Clarias batrachus* (Scolopi)
HETEROPNEUSTIDAE	*Heteropneusteus fossilis* (Bloch)
SILURIDAE	*Wallago attu* (Schneider)
SCHILBEIDAE	*Clupisoma garua* (Hamilton – Buchanan)
CHANNIDAE	*Channa punctatus* (Hamilton -Buchanan)
MASTACEMBELIDAE	*Mastacembelus armatus* (Lacepedae)

Stretch – Below Gadarwada to Harsud :- Following fish taxa represented this stretch:

Family	Species
NOTOPTERIDAE	*Notopterus notopterus* (Pallas)
CYPRINIDAE	*Catla catla* (Hamilton -Buchanan) *Cirrhinus mrigala* (Hamilton -Buchanan) *Cirrhinus reba* (Hamilton -Buchanan) *Labeo bata* (Hamilton -Buchanan) *Labeo boggut* (Sykes) *Labeo calbasu* (Hamilton -Buchanan) *Labeo dyocheilus* (McClelland) *Labeo filmbriatus* (Bloch) *Labeo gonius* (Hamilton -Buchanan) *Labeo pangusia* (Hamilton -Buchanan) *Labeo rohita* (Hamilton -Buchanan) *Osteobrama cotio cotio* (Hamilton-Buchanan) *Osteobrama vigorsii* (Sykes) *Puntius sarana sarana* (Hamilton-Buchanan) *Puntius sophore* (Hamilton -Buchanan) *Puntius ticto*(Hamilton -Buchanan) *Tor tor* (Hamilton -Buchanan) *Tor putitora* (Hamilton -Buchanan) *Chela laubuca* (Hamilton -Buchanan) *Salmostoma bacaila* (Hamilton -Buchanan) *Barilius barila* (Hamilton -Buchanan) *Barilius bendelisis* (Hamilton -Buchanan) *Parluciosoma daniconius* (Hamilton-Buchanan) *Garra gotyla gotyla* (Gray) *Nemacheilus beavani* (Gunther) *Nemacheilus botia* (Hamilton -Buchanan) *Esomus danricus* (Hamilton -Buchanan)
BAGRIDAE	*Aorichthys aor* (Hamilton -Buchanan) *Aorichthys seenghala* (Hamilton – Buchanan) *Mystus bleekeri* (Day) *Mystus cavasius* (Hamilton -Buchanan) *Mystus vittatus* (Bloch) *Rita pavimentata* (Valenciennes)

Family	Species
SILURIDAE	*Ompok pabda* (Hamilton -Buchanan) *Ompok bimaculatus* (Bloch) *Wallago attu* (Schneider)
SCHILBEIDAE	*Clupisoma garua* (Hamilton -Buchanan) *Eutropiichthys vacha* (Hamilton -Buchanan) *Silonia silondia* (Hamilton -Buchanan)
SISORIDAE	*Bagarius bagarius* (Hamilton – Buchanan)
BELONIDAE	*Xenentodon cancila* (Hamilton -Buchanan)
AMBASSIDAE	*Chanda nama* (Hamilton -Buchanan) *Pseudambassis ranga* (Hamilton -Buchanan)
NANDIDAE	*Nandus nandus* (Hamilton -Buchanan)
GOBIIDAE	*Glossogobius giuris* (Hamilton -Buchanan)
CHANNIDAE	*Channa marulius* (Hamilton -Buchanan) *Channa punctatus* (Hamilton -Buchanan) *Channa striatus* (Bloch) *Ophiocephalus gachua* (Hamilton -Buchanan)
COBITIDAE	*Lepidocephalus guntea* (Hamilton – Buchanan)
MASTACEMBELIDAE	*Macrognathus pancalus* (Hamilton -Buchanan) *Mastacembelus armatus* (Lacepedae)
PRAWNS	*Macrobrachium rosenbergii* *Macrobrachium lamarrei*

Stretch - Below Harsud to Surpan : – Following fish taxa was encountered:

Family	Species
NOTOPTERIDAE	*Notopterus chitala* (Hamilton-Buchanan)
	Notopterus notopterus (Pallas)
CYPRINIDAE	*Catla catla* (Hamilton -Buchanan)
	Cirrhinus mrigala (Hamilton -Buchanan)
	Cirrhinus reba (Hamilton -Buchanan)
	Labeo rohita (Hamilton-Buchanan)
	Labeo bata (Hamilton -Buchanan)
	Labeo calbasu (Hamilton -Buchanan)
	Labeo filmbriatus (Bloch)
	Labeo gonius (Hamilton -Buchanan)
	Tor tor (Hamilton-Buchanan)
	Osteobrama cotio (Hamilton-Buchanan)
	Aspidoporia morar (Hamilton – Buchanan)
	Puntius sarana (Hamilton -Buchanan)
	Puntius sophore (Hamilton -Buchanan)
	Salmostoma bacaila (Hamilton -Buchanan)
	Cyprinus carpio (Linnaeus)
BELONIDAE	*Xenentodon cancila* (Hamilton -Buchanan)
SCHILBEIDAE	*Ailia coila* (Hamilton – Buchanan)
	Clupisoma garua (Hamilton -Buchanan)
	Eutropiichthys vacha (Hamilton -Buchanan)
	Silonia silondia (Hamilton -Buchanan)
MASTACEMBELIDAE	*Macrognathus pancalus* (Hamilton-Buchanan)
	Mastacembelus armatus (Lacepedae)
BAGRIDAE	*Aorichthys aor* (Hamilton -Buchanan)
	Aorichthys seenghala (Hamilton – Buchanan)
	Mystus cavasius (Hamilton -Buchanan)
	Rita rita (Hamilton – Buchanan)
	Rita pavimentata (Valenciennes)

Family	Species
PANGASIIDAE	*Pangasius pangasius* (Hamilton – Buchanan)
AMBASSIDAE	*Chanda nama* (Hamilton -Buchanan) *Pseudambassis ranga* (Hamilton -Buchanan)
GOBIIDAE	*Glossogobius giuris* (Hamilton -Buchanan)
SILURIDAE	*Ompok bimaculatus* (Bloch) *Wallago attu* (Schneider)
CHANNIDAE	*Channa punctatus* (Hamilton -Buchanan) *Channa striatus* (Bloch)
PRAWNS	*Macrobrachium rosenbergii*

Stretch - Below Surpan to Gulf of Cambay:- Following fish taxa represented this stretch:

Family	Species
CLUPEIDAE	*Tenualosa ilisha* (Whitehead) *Setipinna phasa* (Hamilton – Buchanan)
NOTOPTERIDAE	*Notopterus notopterus* (Pallas)
CYPRINIDAE	*Catla catla* (Hamilton -Buchanan) *Cirrhinus mrigala* (Hamilton – Buchanan) *Cirrhinus reba* (Hamilton – Buchanan) *Labeo rohita* (Hamilton – Buchanan) *Labeo bata* (Hamilton -Buchanan) *Labeo calbasu* (Hamilton -Buchanan) *Labeo fimbriatus* (Bloch) *Labeo gonius* (Hamilton -Buchanan) *Labeo boggut* (Sykes) *Labeo pangusia* (Hamilton – Buchanan) *Tor tor* (Hamilton – Buchanan) *Puntius sophore* (Hamilton – Buchanan)

Family	Species
	Puntius sarana (Hamilton – Buchanan)
	Osteobrama vigorsii (Sykes)
	Osteobrama cotio(Hamilton – Buchanan)
	Salmostoma bacaila (Hamilton – Buchanan)
	Salmostoma phulo (Hamilton – Buchanan)
	Rasbora daniconius (Hamilton – Buchanan)
	Chela laubuca (Hamilton -Buchanan)
	Garra gotyla gotyla (Gray)
	Amblypharyngodon mola (Hamilton – Buchanan)
BAGRIDAE	*Rita rita(Hamilton – Buchanan)*
	Rita pavimentata (Valenciennes)
	Aorichthys vittatus (Bloch)
	Aorichthys bleekerii(Day)
	Aorichthys aor (Hamilton – Buchanan)
	Aorichthys seenghala (Hamilton – Buchanan)
	Mystus cavasius (Hamilton – Buchanan)
SILURIDAE	*Wallago attu* (Schneider)
	Ompok bimaculatus (Bloch)
CHANNIDAE	*Channa marulius* (Hamilton -Buchanan)
	Channa punctatus (Hamilton -Buchanan)
	Channa striatus (Bloch)
SCHILBEIDAE	*Clupesoma garua* (Hamilton-Buchanan)
	Eutropiichthys. vacha (Hamilton-Buchanan)
	Ailia coila (Hamilton-Buchanan)
MASTACEMBELIDAE	*Mastacembelus armatus* (Lacepedae)
CENTROPOMIDAE	*Chanda ranga* (Hamilton – Buchanan)
	Chanda nama (Hamilton – Buchanan)
	**Lates calcarifer* (Bloch)

Family	Species
GOBIIDAE	*Glossogobius giuris* (Hamilton – Buchanan) **Periophthalmodon schlosseri* (Pallas) **Periophthalus variabilis* (Eggert)
BELONIDAE	*Xenentodon cancila* (Hamilton – Buchanan)
MUGILIDAE	*Rhinomugil corsula* (Hamilton – Buchanan) **Mugil cephalus* (Linn*aeus)* **Liza macrolepis* (Smith) **Liza parsia* (Hamilton – Buchanan)
HARPODONTIDAE	**Harpodon nehereus* (Hamilton – Buchanan)
CICHLIDAE	**Etroplus suratensis* (Bloch) **Etroplus maculatus* Bloch)
LUTIANIDAAE	**Lutianus argentimaculatus* (Forsskal)
CHANIDAE	**Chanos chanos* (Forsskal)
CYNOGLOSSIDAE	**Cyanoglossus elongatus* (Hamilton – Buchanan)
POLYNEMOIDAE	**Polynemus indicus* (Shaw) **Polynemus tetradactylus* (Shaw)
ARIIDAE	**Arius arius* (Hamilton – Buchanan)
SCIAENIDAE	**Scianoides biauritus* (Blyth)
PRAWNS	**Penaeus indicus* * *Macrobrachium rosenbergii*

* *Estuarine Fish Taxa*

Fisheries Spectrum of Different Stretches

Amarkantak to Gadarwada

Observations on fish landings and their qualitative composition were undertaken for two days at each core centre under the stretch Amarkantak to Gadarwada. A total of 1499.46 kg of fish landed in this stretch and Mandala was the most important fish landing centre with contribution of 45.98 % followed by Kareli (16.04 %) and Gadarwada(15.66 %) . Cat fishes (35.40 %), carps (32.94 %) and miscellaneous fishes (31.66 %) shared the fish landings. Considerable quantity of smoked fishes (715.0 kg) was also recorded form this stretch which varied from 40.0 to 405.0 kg being least at Jabalpur and maximum at Mandla site. The smoked fishes comprised *Labeo bata, L. gonius, Puntius sp., Chela sp., Aspidoparia morar, Clarias batrachus, Heteropneustes fossilis* and murrels.

Below Gadarwada to Harsud

Nine (09) reputed fish markets were accessed to record the fish arrivals in the stretch below Gadarwada to Harsud. Per day fish arrivals varied from 10.0 to 200.0 kg being least in Dongarwada and highest at Hoshangabad. An insight into the qualitative texture, major carps (39.44%) and Cat fishes (32.23%) contributed bulk of the fishery of this stretch. Mahseers accounted for (20.01%). Mahseers were predominantly represented by *T. tor* in size range of 450.0 to 780.0 mm and weight range of 1.0 to 6.0 kg and *T. putitora* with size range of 500.0 to 520.0 mm and weight range of 1.0 to 1.4 kg were recorded in very less number. *Catla catla* (500.0 to 630.0 mm, 1.7 to 3.5 kg), *Labeo rohita* (500.0 to 770.0 mm, 1.8 to 3.5 kg), *Cirrhinus mrigal a*(500.0 to 600.0 mm, 1.6 to 3.2 kg) and *L. calbasu* (350.0 to 520.0 mm, 0.5 to 1.6 kg) were important fish taxa representing the major carps.

Cat fishes were represented by *Rita pavimentata* (230.0 to 250.0 mm, 0.15 to 0.2 kg), *Wallago attu*(700.0 to 950.0 mm, 3.5 to 4.5 kg) and *Aorichthys seenghala* (340.0 to 780.0 mm, 0.1 to 2.5 kg). Minnows(12.51%) were comprised of *Puntius sarana, P. sophore., Osteobrama cotio, Salmostoma bacaila and Glossogobius giuris.*

Juveniles of mahseer and major carps weighing 10.0 to 200.0 g and 200.0 to 300.0 g respectively were also found exploited, which otherwise would have added to overall fishery enhancement. The collection of fry and fingerlings of mahseers by M.P. Fisheries Department till 1995-96 revealed that there has been drastic decline in the their availability as compared to earlier years which may be attributed to drastic decline in mahseer fishery of river Narmada. Tawa, an important tributary of river Narmada used to offer ideal breeding grounds for mahseers, is now dammed and this negative habitat modification has led to non-accessibility of breeding grounds.

Dynamite fishing is prevalent in this stretch, particularly at Mola and Gondagaon sites. The catch of dynamite fishing comprised *T. tor* (360.0 mm, 350g), *L. fimbriatus* (290.0 mm, 200g), *L. gonius* (190.0 mm, 50g) and other miscellaneous fish species. The small meshed mono-filament gill-net locally called "Disco Net" is mainly employed to catch juveniles of major carps, mahseers and other commercial fishes. The use of agricultural pesticides, viz. Rogor, Thiodioton and Demicron for exploiting fishes was also recorded .

Below Harsud to Surpan

The fishing activities are not pronounced in winter in the stretch below Harsud to Surpan and fish landings were observed on single day basis. The fish landings varied from 6.50 to 24.75 kg. Carps (39.52 %) followed by miscellaneous group (32.99 %) and Cat-fishes (25.43 %) shared the bulk of fish landings of this stretch. This stretch also witnessed small contribution from *Macrobrachium rosenbergii* (2.06%). The fish landings during monsoon vacillated from 15.0 to 50.0 kg per day.

The fish catch composition revealed that the Catfishes (50.0%) constituted the most conspicuous fishery of the stretch and was followed by miscellaneous group (30.0%). Estimated fish landings of the stretch varied from 18.0 to 38.0 kg per day during summer. Carps (54.0 to 60.0%) were the major group.

This stretch also witnessed "Negative Fishing" measures like dynamiting at Maheshwar and Khalghat and use of agricultural pesticides viz. Thiodiaton, Demicron at Maheshwar, Khalghat and Hanfeshwar sites. Such negative exploitation methods shall make the stretch more vulnerable to environmental degradation.

Below Surpan to Gulf of Cambay

Three important fish markets, viz. Rajpipala, Katupura and Dandia Bazar were scanned for synthesizing information on the fisheries of this stretch.

Rajpipala market catch representing the upper hilly expanse of this stretch was mainly comprised of major carps(27.76 to 48.23 %) and minor carps (15.84 to 27.15 %). The major carp fishery was conspicuously contributed by *Labeo rohita, L. calbasu, Catla catla* and *Cirrhinus mrigala* while *Labeo bata , Puntius sarana and Cirrhinus reba* were important fish taxa representing the minor carps. Mahseer fishery was mainly represented by *Tor tor* (2.53 to 7.40%). The Cat fishery had also significant contribution (12.0 to 19.60%) which was represented by *Rita rita, R. pavimentata, Aorichthys aor, A. seenghala, A. vittatus, Ompok bimaculatus and Wallago attu.* Murrels(3.68 to 6.19%) also formed sizable fishery and were represented by *Channa punctatus* and *C. striatus*. The Indian shad, *Tenualosa ilisha* (nil to 3.54%) was insignificantly represented.

Katupura market which received the fish catch mainly from estuarine expanse, was observed to record significantly high catch of *T. ilisha* (20.43 to 66.74%). The shell fishes (17.38 to 39.53%) which included the catches of *Macrobrachium rosenbergii* and penaeid prawns, had also significant representation. A sizable contribution by mullets (2.81 to 13.74%) represented by *Mugil cephalus* and *M. parsia* was also evident. Cat fishes (2.31 to 5.63%) had comparatively higher contribution than the carps, major(1.61 to 4.43%) and minor(0.26 to 1.18%).

Dandia Bazar recorded the highest catch of *T. ilisha* (32.88 to 69.45%). The shell fishes (9.53 to 21.07%) had significant representation while the catfishes(1.64 to 8.91%) formed sizable fishery of this stretch.

9.0 Environmental Degradation

River Narmada, during its sojourn till its culmination into Arabian Sea through Gulf of Cambay, receives domestic as well as industrial effluents besides non-point source inputs. Influx of such anthropogenic refuses impact its environment. This exploratory survey of river Narmada has identified a score of "Hot Spots" bringing in domestic and industrial effluents and environmental monitoring of these sensitive spots was undertaken.

Under the stretch, below Gadarwada to Harsud, Hoshangabad city sewage is discharged at Nalaghat and Security Paper Mill (SPM), Hoshangabad discharges its effluents near Dongarwada. As such two "Hot Spots" have been identified under this stretch. With the view to monitor the impact of the discharges at these points, relevant attributes of water were studied for environmental monitoring. The salient information is offered as follows:

Characteristic features of Hoshangabad City Sewage at Nalaghat

(a) D.O – 3.3 mg l^{-1}

(b) pH – 8.5

(c) High Total alkalinity – 770.0 mg l^{-1}

(d) Very high Chloride – 208.0 mg l^{-1}
(e) High Free CO_2 – 60.0 mg l^{-1}
(f) High BOD – 25.0 mg l^{-1}
(g) Very high specific conductivity – 2020.0 µmhos cm^{-1}
(h) Very high phosphate – 2.932 mg l^{-1}

Based on the above attributes of the city sewage, it may be inferred that the water of Narmada is getting negatively impacted at the outfall, particularly Satanighat which is important public bathing ghat. With the curtailment in fresh water availability, the severity of the impact shall further enhance. Plans to shift the sewage outfall to further downstream may improve the conditions at Satanighat.

Characteristic features of S.P.M. effluents

(a) D.O – 5.0 mg l^{-1}
(b) pH – 7.07
(c) Free CO_2 – 32.8 mg l^{-1}
(d) High Sp. Conductivity – 580.0 µmhos cm^{-1}
(e) Chloride – 16.0 mg l^{-1}
(f) Free NH_3 – 0.6 mg l^{-1}
(g) BOD – 35.0 mg l^{-1}
(h) Total alkalinity – 204.0 mg l^{-1}

Characteristic features of Narmada water at outfall (near Dongarwada)

(a) D.O – 5.6 mg l^{-1}
(b) pH – 7.2
(c) Free CO_2 – 25.0 mg l^{-1}
(d) High Sp. Conductivity – 510.0 µmhos cm^{-1}
(e) Chloride – 14.5 mg l^{-1}
(f) Free NH_3 – 0.33 mg l^{-1}
(g) BOD – 10.0 mg l^{-1}
(h) Total alkalinity – 199.0 mg l^{-1}

Characteristic features of Narmada water at Below Outfall(300 m)

(a) D.O – 6.5 mg l^{-1}
(b) pH – 7.7
(c) Free CO_2 – 8.0 mg l^{-1}
(d) Sp. Conductivity – 420.0 µmhos cm^{-1}
(e) Chloride – 13.0 mg l^{-1}
(f) Total alkalinity – 196.0 mg l^{-1}

The environmental monitoring undertaken at outfall and below outfall of SPM effluents revealed that the effluents are contaminating Narmada river water at outfall region during summer but the impact seems to get minimized after 300 m below outfall. Serious impact may be felt with further curtailment in fresh water availability owing to priority utilization.

Under the stretch below Surpan to Gulf of Cambay, two "Hot Spots" at lower estuarine expanse have been identified. The combined GIDCs at Ankaleswar and Zagadia release their composite effluents at Shakkarpura point and domestic sewage and industrial effluents are discharged from Bharuch City at Baijalpur point. Eminent hydro-biological features of these points are offered as follows:

Baijalpur Outfall

(a) Incidence of bacterium *Zoogloea ramigera*, an established bio-indicator of water contaminated with sewage and industrial waste was recorded at outfall

(b) Planktonic community dominated by blue-greens,

(c) High abundance of tubificid worms coupled with developmental forms of *Tipula sp.* and *Psychoda* sp. indicated organic enrichment at confluence

(d) Occasional critically low D.O (1.7 mg l^{-1}), high free CO_2(46.0 mg l^{-1}), high total alkalinity(400.0 mg l^{-1}), T.D.S (1605.0 mg l^{-1}), and specific conductivity (3210.0 µmhos cm^{-1})

(e) High BOD (up to 44.0 mg l^{-1})

(f) High respiration rate(up to 330.0 mg c m^{-3} hr^{-1})

Shakkarpura outfall

(a) Low macro-benthic abundance, dominated by molluscans, dead molluscan shells prevalent,

(b) Occasionally critically low D.O (0.6 mg l^{-1}), high free CO_2 (55.0 mg l^{-1}), high total alkalinity (600.0 mg l^{-1}), T.D.S (1475.0 mg l^{-1}), and specific conductivity (2950.0 µmhos cm^{-1}), D.O.M (430.0 mg l^{-1})

(c) High BOD (up to 312.0 mg l^{-1})

(d) High respiration rate (up to 207.5 mg cm^{-3} hr^{-1})

The impact of effluents is presently felt at confluence. With the curtailment in freshwater availability coinciding with the second and third stage defined under NWDT award, the diluting, flushing and transporting of waste function in the Narmada estuary will get imperiled. This will have comprehensive impact on the estuarine environment leading to stressed conditions resulting into sub-dued biological production function.

The river is also used for religious fervor and the devotees release enormous amount of offerings at Handia site. Free Ammonia nil to 0.08 mg l^{-1} detected at Handia site is although not toxic to aquatic life but with further increase in this sort of loading, the riverine environment is bound to degrade. The discharges from M/s Shaw Wallace Gelatin Factory confluencing the river at Bhedaghat, District Jabalpur (M.P) have also made the river environment susceptible to environmental degradation. The impact of effluents on water quality has been observed in terms of free CO_2 increasing up to 12.2 mg l^{-1}, TDS – 1118.0 mg l^{-1}, specific conductance – 1966.0 µmhos cm^{-1}, Chloride – 43.7 mg l^{-1} at outfall, and at this juncture, the impact is confined to outfall.

10.0 Heavy Metals Status

Heavy metals/Trace elements, viz. Zn, Mn, Fe, Na and K were estimated with the view to delineate their status in river Narmada. Stretch-wise salient information is presented below.

Amarkantak to Gadarwada

The accumulation of heavy metals in water and sediment phases at different sites of the stretch Amarkantak to Gadarwada is offered in Table 25. The concentration of Copper in sediment varied from 54.4 to 132.2 µg g^{-1} being highest at Dindori site and least at Amarkantak. The accumulation of other metal Chromium fluctuated from 19.8 to 47.6 µg g^{-1} which was recorded maximum at Amarkantak and least at Gadarwada. Cadmium was by and large identically distributed at all the sites and its concentration vacillated from 2.59 to 2.77 µg g^{-1}. Lead accumulation varied from 24.7 to 42.5 µg g^{-1} which recorded its highest accumulation at Amarkantak. Zink concentration in sediment fluctuated from 111.27 to 307.42 µg g^{-1}, the highest concentration of which was experienced at Kareli. Mercury accumulation in this stretch varied from 0.001 to 0.008 and Amarkantak site experienced the maximum accumulation of Mercury.

In water phase, the accumulation of Copper fluctuated widely from 7.9 to 35.95 µg g^{-1}, having its highest accumulation at Dindori site while the concentration of Chromium varied from 10.87 to 31.65 µg g^{-1} being maximum at Dindori site. Cadmium, like in sediment was, by and large equally distributed at all the sites and vacillated from 5.5 to 6.77 µg g^{-1}. Lead accumulation varied

from 13.63 to 20.92 µg g^{-1} which was recorded maximum at Gadarwada site. Zink accumulation fluctuated from 49.76 to 126.6 µg g^{-1} and Amarkantak site recorded the highest accumulation. The accumulation of heavy metals in water phase has been within permissible limit.

Below Gadarwada to Harsud

The heavy metal contamination in water phase of the stretch below Gadarwada to Harsud has been studied and the relevant data is portrayed in Table 26. Zn metal accumulation varied from below detection level to 0.383 mg l^{-1} and this recorded its maximum concentration at Gondagaon site under this stretch. Manganese content fluctuated from below detection level to 0.17 mg l^{-1} and like Zn, Gondagaon contained the highest concentration of this metal too. Iron and Sodium metal accumulation varied from below detection level to 1.16 mg l^{-1} and 7.0 to 22.4 mg l^{-1} respectively. The maximum concentration of Iron and Sodium was recorded in Hoshangabad and Handia site respectively. The accumulation of Potassium recorded narrow variation of 1.08 to 2.53 mg l^{-1} and Dongarwada site recorded the highest content of this metal. The levels of heavy metal accumulation in this stretch have also been found within permissible limit.

Below Harsud to Surpan

Relevant data pertaining to heavy metal accumulation have been portrayed in Table 27. This stretch was by and large observed to accumulate less metal as compared to the preceding stretch. The Zn metal content in this stretch varied from 0.01 to 0.056 mg l^{-1} which was recorded maximum at Maheshwar site. Mn content which vacillated from below detection level to 0.02 mg l^{-1} was meager. Iron metal content varied from traces to 0.33 mg l^{-1} and highest content of this metal was recorded at Hanfeshwar site. The accumulation of Sodium was recorded less as compared to earlier stretch and this fluctuated from 5.9 to 15.93 mg l^{-1} and maximum content of this metal was experienced at Khalghat site. Like earlier stretches, this stretch also did not contain heavy metal accumulation beyond tolerance limit.

Below Surpan to Gulf of Cambay

Table 28 portrays the data pertaining to heavy metal accumulation in this stretch. Zn content varied from 0.007 to 0.075 mg l^{-1} and the maximum content of this metal was recorded at Poicha site. The accumulation of Manganese (Mn) fluctuated from below detection level to 1.665 mg l^{-1} and Ambetha, the lowermost estuarine site experienced the highest content of this metal. Iron (Fe) accumulation, like Manganese was maximum at Ambetha site and its concentration vacillated from 0.05 to 11.19 mg l^{-1}. Sodium (Na) and Potassium (K) were also recorded maximum at lower estuarine sites and their content varied from 14.0 to 2576.8 mg l^{-1} and 0.86 to 471.84 respectively for the stretch as a whole. The higher Na and K accumulation may be attributed to influx of marine environment.

The heavy metal accumulation in river Narmada is presently within permissible limits but continued monitoring is required in view of fast changing land-use pattern, involving commissioning of industrial complexes.

11.0 Assessment of Impact of SSP dam on the Downstream

Sardar Sarovar Project (SSP) involves commissioning of a dam (FRL – 138.68 m) at 5.6 km upstream of Village Navagam under Taluka Nandod, District Narmada, Gujarat. The accomplishment of SSP and other overlying projects, will have serious repercussions since the natural flow of any river is moderated by commissioning of a dam and regulation of flow due to varied uses of water results in the containment of freshwater availability at the

downstream environment including the estuary. This leads to negative impact on the estuarine environment. Downstream environment of SSP dam including Narmada estuary shall also feel the fresh water crunch and may attain new ecological equilibrium.

Narmada estuarine system is the largest fishery resource of Gujarat state since it contributes 14250 ha (67.12%), out of the total estuarine extent of Gujarat State being 21230 ha. *Tenualosa ilisha* and *Macrobrachium rosenbergii* constitute the prime fishery of this resource.

The impact of impoundment may be categorized as follows :

Sedimentation

Studies on sedimentation rate (Anon, 1983) based on 20 years data led to the conclusion that SSP dam will retain 96% of the sediment and will allow only 4% of the sediment transported through the out-flowing water. The role of dams as check dams is well recognised and this will be manifested by reduction in allochthonous addition of nutrients at the downstream .With the completion of upstream projects, the downstream including the estuarine expanse will experience further reduction in nutrients availability leading to considerable decline in biological productivity at the down-stream of the SSP dam including Narmada estuary.

Freshwater Crunch

The fresh water availability at the downstream of the SSP dam has been precisely documented in the Narmada Water Dispute Tribunal (NWDT) award which prescribes the freshwater availability to the tune of 15.90 MAF at 10th year, 4.34 MAF at 30th year while at 45th year from the commencement of construction the fresh water release from SSP dam will cease (Fig.11) . As such, the downstream will experience chronological increasing stressed conditions in consonance with the freshwater availability.

The prevailing average total annual flow based on 10 years data(1981-1990) is 23.68 MAF. The average flow during the 4 months period of monsoon is computed to 21.25 MAF whereas the same for the rest of 8 non-monsoon months is 2.43 MAF. In other terms monthly average for the monsoon months is 5.31 MAF while the same for the non-monsoon months is 0.30 MAF.

Keeping in view the three scenario defined by NWDT award, the stage to be attained at 10th year from the commencement of construction , when total annual flow will be to the tune of 15.90 MAF, is safe and no major impact is apprehended. Of course, the efficiency of silt-deficient water in containing the tidal ingress will get sub-dued and this would also affect the allochthonous enrichment at the downstream due to SSP dam acting as "Check Dam". Stage to be attained at 30 years from the commencement of construction will experience drastic reduction (72.71%) in fresh water availability at the downstream. This will involve non-attainment of annual event of dilution during the monsoon months when 89.74% of total annual flow is received. This monsoon event is associated with the anadromous migration of *Tenualosa ilisha* , as such, the *Tenualosa* fishery shall experience severe impact leading to significant decline in estuarine total fish catch. With the enhancement in salinity regime, the prestigious fishery contributed by *M. rosenbergii* will also get impacted. Stage to be attained at 45th year from the commencement of the construction will be very critical as this shall be associated with steep hike in salinity regime with further tidal ingress towards inland side. The fishery not tuned to such enhanced salinity will succumb to such pressure. The major fishery contributed by *T.ilisha* and *M. rosenbergii* will have repercussions. Mangroves will also be affected and the rich fishery supported by them will undergo drastic change. This will also have an impact on the marine fish production since many marine fishes use them as nursery grounds. Severity of pollution shall further enhance chronologically as per provisions of NWDT award discussed above. Narmada estuary may attain an

aberrated ecological equilibrium and may transform into a hyper-saline biotope.

12.0 Socio-economic conditions

Stretch Amarkantak to Gadarwada

The information on socio-economic parameters has been gathered from fisher-families at five centres namely Mandla, Jabalpur, Narsinghpur, Kareli and Gadarwada. It included the nature of family, demographic structure, family size, literacy and employment status, fishery assets, fishing effort and income.

The estimates of demographic structure are contained in Table 29. The nature of family revealed above 65% of families as single and remaining as joint. At all the centres percentage of single families was higher than joint except Narsinghpur, where it was 40%. The maximum single families were at Gadarwada (87.50%). The sex-wise family structure favoured males (about 53%) as compared to females (above 47%). The maximum percentage of males was at Mandla (56.25), while for females it was at Jabalpur (50.62). Age-wise these fisher-families comprised of 52% adult and 48% minors. The maximum percentage difference between adults and minors was at Narsinghpur (23.68), with 61.84% adults and 38.16% minors. Maximum minors were at Gadarwada (54.95%). The overall sex ratio for the stretch was estimated at 0.89 females per male, while number of minors per adult was 0.92. The highest and lowest sex ratio was for Jabalpur (1.03 females per male) and Mandla (0.78 females per male). The maximum minors per adult were for Gadarwada (1.22) and the minimum for Narsingpur (0.62). The average size of family was 5.71 consisting of 3.02 male and 2.69 female members per family. The age-wise average composition revealed 2.97 adults and 2.74 minors. The family size ranged from 4.80 at Mandla to 7.60 at Narsinghpur. Correspondingly, the number of male and female members was highest at Narsinghpur (4.20 and 3.40) and lowest at Mandla (2.70 and 2.10). Regarding age structure average number of adults were minimum at Kareli (2.50) and maximum at Narsinghpur (4.70), while for minors 2.10 at Mandla and 2.90 at Narsingpur. The fishermen community, which was traditionally living under joint umbrella, seemed to shift towards nuclear or single families. They appeared to be aware of family welfare programmes as depicted by moderate average family size.

The level of literacy and employment is presented in Table 30. It indicated that majority of family members were illiterate (81.61%) followed by educated upto primary (15.52%) and middle (2.87%) standards. The literacy percentage was highest at Mandla (35.42) and minimum at Narsinghpur (1.32). The employment status of fisher-families revealed that one third of the family members were employed and two third were dependent on them. The percentage of employed family members was highest at Mandla (41.67) and lowest at Gadarwada (25.27). For the stretch 1.92 dependent per earner were estimated. It was maximum at Gadarwada (2.96) and minimum at Mandla (1.40).

The fishery requisites with fishermen, their fishing effort, catch and income form subject matter of Table 31 . Most of the fishermen owned boats (75.41%) followed by others (21.31%) and hired labour (3.28%). At Gadarwada all the fishermen had own boat, while at Kareli only 40% were the boat owners. Regarding gears, gill net was most prevalent (80.33%) followed by hook and drag nets. The average annual fishing effort per fishermen was 325.75 days varying from 277.27 to 365 days at Jabalpur and Kareli, respectively. The annual fish catch per fishermen was 619.75 kg with highest at Mandla (772.05 kg) and lowest at Jabalpur (480.20 kg). The limited area of fishing due to religious reasons and construction of Bergi dam in the upper stretch may be accounted for minimum fishing effort and catch at Jabalpur, while maximum fish catch at Mandla may be attributed to very high fish catch during rainy

season. The average income from fisheries and other sources was Rs.14833.07 and Rs.5585.50 to aggregate at Rs.24468.57. The fishing income varied between Rs.10747.90 and Rs.21198.90, while income from other sources ranged from Rs.4875 to Rs.9220. The maximum aggregate income was at Narsingpur (Rs.28160.80) and the minimum at Jabalpur (Rs.16566.37). The quantum of catch and the price fetched influenced fish business income while the earnings from other resources varied according to potential for the employment in other enterprises in the respective area.

Stretch below Harsud to Surpan

About 17% of the population belongs to fishermen community in the stretch below Harsud to Surpan. The analysis of family structure revealed that 60% families are joint and rest being nuclear or single. Sex-wise demographic composition indicated that male and female are equally distributed (Table 32). The age-wise family structure favoured adults (70.59%) as compared to minors(29.41%). The average family size varied from 4 at Malitha to 7.33 at Khalghat with average of 5.95 and there has been dominance of non-fishing population at all sites. The more joint families, higher number of adults than minors and average family size below six indicated towards adoption of family welfare measures. Regarding the literacy(Table 33), illiterate were found to be 63.87% while primary and middle class passed were 22.69% and 13.44% respectively. 62.18% were employed and rest were dependent, The ratio of earner to non-earner was computed to be 1:0.61.

Regarding the fishery requisites (Table 34) with fishermen, their annual fish catch and aggregate income, most of the fishers owned boat except one hired labour at maheshwar. Gill net (16) was the most prevalent net followed by cast(14) and drag net(14). Hook and line was rarely operated. The average annual catch per fisher-family was above 2 tonnes and this varied from 547.5 kg at Malitha to 4051.56 kg at Rangan. Fisheries was the main source of income for most of the families. The gross income was estimated at Rs. 48503.98 for the stretch. The average annual gross income from other enterprises was Rs. 15332.50 which makes average aggregate gross income to Rs. 63836.48.

13.0 The Verdict

The resource development exercise envisaged for the Narmada River basin is likely to exert immense pressure on the environmental status of Narmada Valley. The proposed compound impounding of the basin will ruin its' fluviatile nature and this will be characterized by water spreads of different shapes and dimensions. From fisheries perspective, there are certain bright areas in the form of increased hectarage under reservoir fisheries development but there are gloomy areas as well, the prime being the threats for sustainable development of the resource including biodiversity conservation. The efficient development of reservoir fisheries in emerging reservoirs in Narmada basin on scientific lines, will be helpful in enhancing food basket of the country and would also be helpful in rehabilitating the fishers population to some extent. This would also open employment avenues through ancillary industries. Eco-tourism shall further enhance the economic gains from the above eventuality.

Our concern for sustainable development including biodiversity conservation gets defeated owing to lack of interaction among the stake holders with isolated management approach. In context of present Narmada river, there has been significant overall decline in its fisheries as compared to yesteryears particularly the mahseer fishery, which has declined drastically. There is exigent need to revive fisheries in River Narmada particularly the mahseer fishery. The reservoirs emerging in narmada river basin may also be stocked towards conservation of mahseers. It is heartening to note that mahseer fishery is already established in a number of lacustrine environments (Sampna ,Harsi, Tigra and Sukta reservoirs in Narmada basin, Walwhan and Shivajisagar on

Koyana river) although with varied abundance. This may open new vistas in the annals of mahseer conservation by resorting to artificial propagation of mahseers under a well conceived scientific management programme .

Following measures are suggested:

(a) Fish Stock enhancement (River ranching), with special efforts for mahseer fishery so that the emerging reservoirs have sufficient fish population

(b) Strict ban on exploitation of juveniles as well as brood fishes

(c) Observation of closed season

(d) Free fishing concept need to be discouraged, there is need to regulate fishing by issuing licenses and prepare a data base

(e) Need for awareness drives so that negative fishing measures like dynamiting and use of agricultural pesticides may be checked.

Pertaining to the downstream environment of SSP dam, the fresh water crunch shall be experienced in consonance to the developments taking place as per the provisions of NWDT award. This eventuality will lead to constrained allochthonous enrichment at the downstream and as such would affect its biological productivity. Due to fresh water crunch, the salinity regime of the downstream shall also enhance and will exert immense pressure on the biotic communities including fish fauna. It is expected that eury-haline flora and fauna may be able to survive. The anadromous migration of *T. ilisha*, the prime commercial fishery shall be affected and due to enhanced salinity, the other commercially important fishery contributed by *M. rosenbergii*, will also get a jolt. With the increased development of power and irrigation infra-structure, there shall be more industrialization and more and more use of agricultural inputs, viz. fertilizer, insecticides, pesticides etc. and this would further compound the scenario by adding non-point pollution inputs. The ultimate result will be highly stressed downstream environment. *There is a need to pursue a holistic and integrated approach which is the key to the sustainable development.*

This exploratory survey has identified a score of" Hot Spots" pouring in composite effluents. There is a need to define the impact of these sensitive areas consequent to execution of resource development exercise. Moreover, with the view to assess the magnitude of impact in consonance to changes in land use pattern, chronological evidences need to be gathered so as to identify the negative processes and for this, scientific monitoring in time and space is essentially required. This will also help in scanning the biodiversity shift in response to the operating anthropogenic interferences and may be used as an effective alarm system to switch over to restorational practices in the form of "River Health Restoration Programme". This programme needs to be conceived on "River Continuum Concept" so that impact on any river continuum component is addressed well in time so as to protect from possible future maladies.

From socio-economics perspective, there is a need to urgently assess the crises areas since the degraded aquatic environment snatches away the breads of its dependents and exert negative impact on the society by inflicting various negative ramifications. These "Refugees" as a result of environmental degradation migrate to the urban area and exert pressure in the form of slums resulting into a score of vagaries of life including social disturbances .There is urgent need to change the mindset of the people to make them environmentally conscious so that they utilize the precious aquatic resources judiciously and participate effectively in ensuring the environmental protection of our natural wealth.

Table : 1. Proposed Major Reservoir projects in Narmada River basin

Name of Project	Location of dam (Km)	River bed level at dam site (m)	Proposed			Capacity of Reservoir		Submergence (Ha)
			Max. Reservoir level (m)	Full Reservoir level (m)	Dead storage level (m)	Gross ($M m^3$)	Live ($M m^3$)	
1	2	3	4	5	6	7	8	9
ON MAIN RIVER								
Upper Narmada	77	701.00	732.13	731.52	720.85	0.249	0.203	3043.23
Raghavpur (H)	135	597.41	649.04	648.04	631.35	0.319	0.252	2370.00
Rosra (H)	206	499.87	552.69	551.08	529.74	0.559	0.497	3200.00
Basania (H)	252	435.56	482.41	481.80	460.25	1.911	1.799	14201.00
MIDDLE ZONE								
Bargi (M)	378	366.98	424.13	422.76	403.55	3.921	3.181	27296.00
Chinki	489	316.99	348.84	348.08	342.59	1.012	0.475	11107.00
LOWER ZONE								
Narmada Sagar (M)	845	176.78	263.35	262.13	243.23	12.220	9.750	91348.00
Omkareshwar (M)	899	159.83	198.12	196.60	193.54	1.141	0.299	9393.00
Maheshwar (H)	947	138.99	171.25	162.76	162.20	0.483	0.028	4856.00
Sardar Sarovar (M)	1163	22.86	140.21	138.68	110.64	9.462	5.823	37030.00
ON TRIBUTATIES								
UPPER ZONE								
Upper Burhner	111	580.64	617.68	616.61	609.5	0.660	0.304	6153.84
Halon	109	595.58	623.62	623.01	612.95	0.173	0.134	2070.00
Dhobatoria	55	452.63	480.36	479.17	472.44	0.134	0.085	18000.90

Table 1. Continued

Name of Project	Location of dam (Km)	River bed level at dam site (m)	Proposed			Capacity of Reservoir		Submergence (Ha)
			Max. Reservoir level (m)	Full Reservoir level (m)	Dead storage level (m)	Gross ($M m^3$)	Live ($M m^3$)	
1	2	3	4	5	6	7	8	9
MIDDLE ZONE								
Ataria	48	386.18	409.69	409.04	398.98	0.111	0.103	2161.10
Sher	53	381.00	413.31	412.70	400.20	0.227	0.185	2256.00
Marchrawa	55	387.10	421.54	420.93	404.73	0.054	0.482	505.87
Shakkar	74	366.67	445.92	445.31	405.08	0.387	0.359	2121.00
Sitarwa (H)	80	657.76	691.29	690.67	680.62	0.104	0.074	947.00
Dudhi	71	356.01	388.72	388.10	372.30	0.260	0.244	3849.00
Barna	29	313.94	351.43	348.55	338.10	0.524	0.447	7705.00
Tawa	32	309.67	356.69	355.39	334.24	2.311	2.048	20055.00
Kolar	76	420.50	463.30	462.20	432.93	0.270	0.263	2380.00
Morand	63	319.43	363.38	362.71	345.64	0.026	0.185	1940.00
Ganjal	61	338.00	374.26	373.68	357.84	0.187	0.097	1092.00
Chotta Tawa	45	274.08	299.99	299.00	291.38	0.178	0.137	2914.00
Sukta	80	382.20	414.22	410.70	401.42	0.121	0.075	1350.00
LOWER ZONE								
Beda Upper	72	287.73	310.70	310.28	299.62	0.092	0.080	1300.00
Man	37	255.87	297.65	297.63	273.00	0.145	0.136	1077.00
Lower Goi	53	260.30	296.26	295.81	281.94	0.102	0.084	1020.00
Jobat	58	229.28	260.77	260.17	249.50	0.078	0.070	970.37

M — Multipurpose.
H — Hydel only and rest are irrigation reservoirs
Source — Narmada Planning Agency

Table 2. Physico-chemical characteristics of Sediment at identified sites of river Narmada pertaining to Amarkantak to Gadarwada (average in parentheses)

Parameter	Amarkantak	Dindori	Mandla	Jabalpur	Narsinghpur	Kareli	Gadarwada
pH	6.26- 6.58 (6.46)	7.19- 7.64 (7.49)	7.05- 7.58 (7.3)	7.4 -7.79 (7.54)	7.41-7.75 (7.58)	7.62- 8.12 (7.9)	7.25 -7.62 (7.42)
Organic Carbon (%)	0.685 -2.045 (1.2)	0.391-1.08 (0.67)	0.132 -1.24 (0.71)	0.171 -1.08 (0.48)	0.239 - 0.517 (0.378)	0.36 - 1.03 (0.71)	0.171-1.02 (0.318)
Total Nitrogen (%)*	0.08 (0.08)	0.091 (0.091)	0.08 (0.08)	0.083 (0.083)	—	0.071 (0.071)	0.08 (0.08)
Available Phosphorus (mg $100g^{-1}$)	Tr – 0.3 (0.2)	Tr – 1.33 (0.846)	Tr – 0.43 (0.23)	Tr – 1.88 (1.57)	0.26-1.09 (0.806)	Tr – 1.32 (0.85)	Tr – 0.58 (0.353)
Available Nitrogen (mg $100g^{-1}$)	6.15-33.6 (20.05)	4.56-36.8 (25.36)	11.5-37.90 (22.36)	33.6-38.6 (35.76)	22.75-29.95 (26.35)	5.6-50.59 (30.23)	22.76-50.91 (36.93)
Free $CaCO_3$ (%)	(7.13) 2.75-10.7	(7.08) 4.74-11.25	(6.12) 0.24-13.25	(6.43) 1.92-13.5	(4.92) 4.72-5.12	(9.0) 5.0-17.0	(9.93) 6.54-16.5
C : N*	10.75 (10.75)	11.8 (11.8)	15.5 (15.5)	13.1 (13.1)	—	14.2 (14.2)	12.7 (12.7)
Sand (%)	62.0-69.6 (66.7)	72.0-83.0 (78.0)	68.0-94.4 (80.3)	85.0-99.5 (93.6)	81.25-92.35 (86.8)	93.0-96.8 (94.6)	77.0-91.4 (85.2)
Slit (%)	10.5-24.5 (18.1)	9.6-14.5 (12.7)	5.5-16.2 (11.9)	0.4 -7.0 (3.4)	5.25-13.75 (9.5)	1.7-6.0 (3.9)	5.9-11.0 (8.4)
Clay (%)	11.1-21.0 (15.3)	6.5-14.0 (9.3)	0.1-18.0 (7.76)	0.1-8.0 (3.2)	2.40-5.0 (3.7)	1.0-2.0 (1.5)	2.7-12.0 (6.4)
Sp. Conductance (µmhos cm^{-1})	136.0-241.0 (188.5)	298.0-354.0 (326.0)	234.1-252.5 (243.3)	153.5-313.9 (233.7)	244.0-256.0 (250.0)	158.0-247.0 (202.5)	182.4-183.0 (182.7)

* Single observation

Table 3. Physico-chemical characteristics of Sediment at identified sites of river Narmada pertaining to stretch below Gadarwada to Harsud (average in parentheses)

Parameter	Sandia	Shahganj	Hoshangabad	Dongarwada	Gondagaon	Handia	Mola
pH	7.92-8.15 (8.06)	7.95-8.1 (8.04)	7.9-8.21 (8.08)	7.91-8.5 (8.25)	7.95-8.15 (8.04)	7.55-8.14 (7.85)	7.75-8.04 (7.92)
Organic Carbon (%)	0.18-0.29 (0.25)	0.18-0.56 (0.32)	0.12-0.26 (0.20)	0.12-0.42 (0.25)	0.21-0.62 (0.44)	0.38-0.60 (0.51)	0.18-0.63 (0.40)
Total Nitrogen (%)	0.014-0.025 (0.018)	0.017-0.05 (0.029)	0.011-0.023 (0.0180)	0.013-0.034 (0.021)	0.017-0.05 (0.036)	0.034-0.06 (0.048)	0.019-0.056 (0.038)
Available Phosphorus (mg $100g^{-1}$)	1.0-4.04 (2.35)	0.45-2.2 (1.05)	0.4-2.6 (1.16)	0.45-2.8 (1.52)	0.5-2.56 (1.22)	0.6-2.76 (1.55)	0.4-2.48 (1.13)
*Available Nitrogen (mg $100g^{-1}$)	3.5	4.0	5.10	7.1	10.4	7.2	8.2
Free $CaCO_3$ (%)	3.0-7.0 (5.16)	6.0-7.2 (6.4)	2.5-5.5 (4.0)	2.4-5.5 (4.3)	2.5-6.5 (4.5)	2.0-7.0 (5.17)	2.5-8.0 (4.83)
C : N	10.58-14.3 (12.16)	10.58-11.6 (11.12)	10.71-11.3 (11.0)	9.23-12.94 (11.52)	11.90-12.40 (12.20)	9.0-12.0 (10.73)	9.47-11.25 (10.34)
Sand (%)	73.0-94.0 (84.0)	70.0-94.0 (78.0)	70.0-92.0 (80.0)	62.0-95.0 (75.66)	60.0-93.0 (72.67)	58.0-70.0 (63.67)	58.0-96.0 (71.0)
Silt (%)	3.0-23.0 (9.33)	3.0-28.0 (17.0)	2.0-20.0 (12.33)	2.0-21.0 (14.33)	1.0-30.0 (19.67)	18.0-32.0 (26.33)	1.0-33.0 (19.67)
Clay (%)	3.0-13.0 (6.67)	2.0-10.0 (5.0)	6.0-10.0 (7.67)	3.0-18.0 (10.0)	6.0-10.0 (7,67)	8.0-12.0 (10.0)	3.0-16.0 (9.33)
Sp. Conductivity (µmhos cm^{-1})	118.0-180.0 (146.0)	125.0-220.0 (185.0)	127.0-240.0 (182.33)	95.0-190.0 (155.0)	130.0-410.0 (243.33)	200.0-610.0 (382.33)	103.0-270.0 (187.66)

* Analysed during 03rd Campaign

Table 4. Physico-chemical characteristics of Sediment at identified sites of river Narmada pertaining to stretch below Harsud to Surpan (average in parentheses)

Parameter	Maheshwar	Khalghat	Hanfeshwar	Charbara	Gadher	Surpan
pH	7.96-8.0 (7.98)	7.87-8.0 (7.92)	7.96-8.28 (8.09)	7.78-8.07 (7.93)	7.78-8.01 (7.92)	7.91-8.29 (8.05)
Organic Carbon (%)	0.345-3.75 (1.59)	0.36-3.51 (1.44)	0.315-3.11 (1.41)	0.675-2.91 (1.47)	0.750-2.39 (1.34)	0.525-2.87 (1.41)
Total Nitrogen (%)	0.058-0.08 (0.067)	0.04-0.06 (0.047)	0.048-0.09 (0.067)	0.075-0.097 (0.084)	0.075-0.095 (0.082)	0.066-0.08 (0.072)
Available Phosphorus (mg $100g^{-1}$)	0.2-0.70 (0.421)	0.075-0.50 (0.258)	0.025-0.78 (0.401)	0.2-0.70 (0.396)	0.25-0.50 (0.35)	0.188-0.50 (0.296)
Free CaCO3 (%)	5.0-7.25 (6.33)	3.25-7.0 (4.58)	4.0-7.25 (6.08)	7.0-7.75 (7.50)	4.5-8.0 (6.58)	5.25-5.75 (5.5)
C : N	5.94-46.87 (21.30)	8.37-58.5 (26.20)	6.56-34.5 (17.78)	6.95-36.37 (18.21)	7.89-31.86 (17.05)	7.95-35.87 (18.44)
Sand (%)	72.0-83.5 (79.5)	82.0-97.5 (89.5)	62.0-83.5 (70.16)	64.0-67.5 (65.5)	61.5-70.0 (65.16)	62.5-74.0 (68.33)
Silt (%)	5.0-12.0 (8.66)	1.5-7.0 (4.16)	4.0-14.0 (7.83)	10.5-26.5 (17.16)	9.5-19.5 (13.16)	4.5-11.0 (8.16)
Clay (%)	7.5-16.0 (11.83)	1.0-11.0 (6.33)	12.5-32.5 (22.0)	6.0-25.5 (17.33)	10.5-29.0 (21.66)	17.0-33.0 (23.5)
Sp. Conductance (µmhos cm^{-1})	199.0-345.0 (248.0)	186.0-280.0 (218.66)	160.0-255.0 (199.33)	136.0-548.0 (288.0)	136.0-581.0 (312.33)	140.0-405.0 (231.0)

Table 5. Physico-chemical characteristics of Sediment at identified sites of river Narmada pertaining to the stretch below Surpan to Gulf of Combay (average in parentheses)

Parameter	Vedgam	Poicha	Sisodara	Velugam	Jhanor	Ankaleshwar	Shakkarpura	Bhadbhut	Ambetha
pH	7.58-7.84 (7.68)	7.74-8.40 (8.15)	7.79-8.35 (8.13)	7.78-8.35 (8.13)	7.88-8.61 (8.21)	7.94-8.65 (8.37)	8.07-8.87 (8.49)	8.09-8.97 (8.52)	8.07-9.12 (8.56)
Organic Carbon (%)	0.87-0.91 (0.886)	0.010-0.24 (0.094)	0.05-0.25 (0.155)	0.045-0.23 (0.123)	0.025-0.47 (0.266)	0.03-0.29 (0.185)	0.0116-0.25 (0.0973)	0.075-0.44 (0.216)	0.035-0.44 (0.217)
Total Nitrogen (%)	0.076-0.116 (0.1007)	0.005-0.02 (0.012)	0.010-0.026 (0.0187)	0.007-0.019 (0.0136)	0.009-0.046 (0.028)	0.007-0.027 (0.186)	0.0075-0.01 (0.0086)	0.011-0.02 (0.0156)	0.009-0.023 (0.0167)
Available Phosphorus (mg $100g^{-1}$)	0.02-2.67 (0.942)	0.359-1.428 (0.795)	0.5-1.001 (0.815)	0.20-0.964 (0.577)	0.20-1.445 (0.802)	0.30-2.615 (1.283)	0.20-1.70 (0.843)	0.20-2.484 (1.482)	0.30-3.417 (1.611)
*Available Nitrogen (mg $100g^{-1}$)	20.58	7.28	8.96	8.12	13.16	9.52	4.2	7.56	9.52
Free CaCO3 (%)	4.73-6.31 (5.70)	1.65-3.5 (2.80)	3.23-4.56 (4.09)	2.48-3.75 (3.176)	2.98-6.25 (4.82)	2.70-8.75 (6.54)	2.28-4.75 (3.33)	3.71-7.50 (5.65)	6.86-12.08 (9.23)
C : N	7.84-11.57 (9.09)	2.94-20.0 (11.64)	5.0-12.5 (7.956)	4.82-16.42 (9.21)	2.77-15.66 (8.346)	4.28-13.18 (8.72)	1.54-25.0 (10.05)	6.8-22.0 (12.41)	3.89-19.13 (10.89)
Sand (%)	43.0-63.16 (55.22)	95.5-99.0 (97.66)	90.5-98.0 (94.0)	94.5-99.0 (96.67)	86.5-98.0 (91.33)	84.5-98.0 (91.50)	96.5-98.76 (97.92)	86.0-95.75 (91.41)	86.5-98.4 (92.13)
Slit (%)	10.0-20.0 (13.67)	Nil – 1.0 (0.33)	Nil – 4.0 (2.0)	Nil – 2.00 (1.33)	0.5-6.0 (3.33)	0.5-9.0 (4.33)	0.24-1.0 (0.58)	2.0-10.3 (4.93)	Nil – 11.5 (6.5)
Clay (%)	26.84-37.0 (31.11)	1.0-3.5 (2.00)	1.7-5.5 (3.9)	1.0-3.5 (2.0)	1.5-7.5 (5.34)	1.5-6.5 (4.17)	1.0-2.5 (1.50)	2.25-5.0 (3.65)	1.5-2.0 (1.7)
Sp. Conductance (µmhos cm^{-1})	230.0-443.0 (359.0)	57.2-230.0 (118.73)	105.0-210.0 (150.33)	79.1-210.0 (150.7)	89.0-290.0 (194.33)	87.5-380.0 (221.16)	106.63-310.0 (194.04)	182.0-759.0 (460.33)	1260.0-7950.0 (4210.0)

* Analysed only during 1st camapaign

Table 6. Physico-chemical characteristics of water at identified sites of river Narmada pertaining to the stretch Amarkantak to Gadarwada (average in parentheses)

Parameter	Amarkantak	Dindori	Mandla	Jabalpur	Narsinghpur	Kareli	Gadarwada
Water Temperature (°C)	15.0 – 30.0 (24.0)	18.5 – 28.0 (23.5)	20.3 – 30.3 (26.7)	21.1 – 28.6 (25.9)	21.1 – 26.1 (24.4)	20.1 – 28.8 (25.35)	18.6 – 27.5 (24.4)
Transparency (cm)	65.0-98.0 (76.0)	7.0 – 47.9 (22.3)	19.3 –115.9 (53.6)	20.3-68.3 (41.5)	22.6 – 108.0 (69.0)	23.6 – 100.6 (53.28)	21.6 – 136.3 (79.0)
D.O (mg l^{-1})	4.4-9.28 (6.43)	5.0-7.36 (6.05)	6.29-7.06 (6.58)	7.52-7.84 (7.72)	5.86-8.1 (7.24)	7.95-9.1 (8.35)	8.08-8.2 (8.15)
Free CO_2 (mg l^{-1})	2.0-6.1 (3.7)	Nil – 2.0 (0.7)	Nil – 4.3 (1.44)	Nil – 2.7 (1.27)	Nil – 4.33 (1.85)	Nil – 5.0 (2.12)	Nil – 1.7 (0.87)
pH	6.62-6.98 (6.8)	7.6-8.4 (8.0)	7.57-8.15 (7.84)	7.66-8.0 (7.82)	7.98-8.08 (8.02)	7.8-8.11 (7.97)	8.0-8.35 (8.17)
Total Alkalinity (mg l^{-1})	30.0-63.5 (42.5)	70.0-162.6 (115.54)	90.0-174.3 (123.12)	67.6-141.6 (99.75)	104.0-144.6 (127.21)	110.3-165.2 (132.61)	110.3-162.2 (138.6)
T.D.S. (mg l^{-1})	35.8-80.9 (51.9)	45.0-164.9 (102.4)	92.8-166.3 (118.6)	65.5-135.7 (104.3)	90.9-144.6 (124.0)	92.1-155.8 (132.3)	98.0-163.9 (138.3)
Sp. Conductivity (µmhos cm^{-1})	60.0-161.7 (97.6)	150.0-329.9 (224.8)	149.6-332.8 (224.8)	130.9-277.0 (193.4)	181.9-258.0 (221.5)	184.3-299.8 (236.71)	196.5-316.2 (249.46)
Ca^{2+} (mg l^{-1})	4.76-32.0 (15.9)	20.94-24.04 (22.70)	19.96-25.64 (23.66)	14.5-27.3 (22.33)	22.21-29.92 (26.91)	21.76-36.60 (28.4)	21.76-32.06 (26.0)
Mg^{2+} (mg l^{-1})	7.34-12.0 (9.04)	12.31-20.39 (16.34)	13.32-14.6 (14.0)	13.73-14.6 (14.07)	14.91-15.7 (15.37)	15.57-16.86 (16.3)	15.6-18.4 (17.0)
Total Hardness (mg l^{-1})	42.5-60.0 (54.16)	96.0-134.48 (118.76)	87.3-137.2 (114.5)	94.0-117.68 (102.56)	120.0-133.3 (127.5)	124.6-136.6 (130.8)	124.6-140.0 (134.56)
Chloride (mg l^{-1})	7.0-42.0 (24.4)	13.0-44.0 (28.43)	12.3-46.0 (28.8)	8.67-49.0 (31.6)	7.8-53.0 (30.6)	7.83-55.0 (31.13)	9.17-56.0 (32.01)
Dissolved Organic Matter (mg l^{-1})	1.5-1.64 (1.57)	1.06-1.2 (1.13)	0.85-1.45 (1.15)	0.63-1.25 (0.94)	0.68-0.8 (0.74)	0.74-0.92 (0.83)	0.84-0.92 (0.88)
Phosphate (mg l^{-1})	0.002-0.086 (0.03)	0.003-0.036 (0.018)	0.004-0.036 (0.02)	Tr – 0.012 (0.0046)	0.001-0.003 (0.002)	Tr – 0.005 (0.003)	0.0009-0.003 (0.0023)
Nitrate (mg l^{-1})	0.07-0.24 (0.18)	0.15-0.18 (0.165)	0.151-0.177 (0.164)	0.152-0.189 (0.174)	0.136-0.164 (0.15)	0.067-0.202 (0.15)	0.16-0.185 (0.176)
Silicate (mg l^{-1})	3.4-8.2 (6.0)	5.0-18.98 (13.26)	6.0-13.9 (11.2)	4.6-13.6 (10.5)	5.0-13.2 (9.42)	5.0-12.6 (10.0)	5.0-13.96 (10.82)

Table 7. **Physico-chemical characteristics of water at identified sites of river Narmada pertaining to stretch below Gadarwada to Harsud (average in parentheses)**

Parameter	Sandia	Shahganj	Hoshangabad	Dongarwada	Gondagaon	Handia	Mola
Water Temperature (°C)	18.5 - 28.5 (24.36)	20.0 -31.6 (25.46)	21.7 - 31.5 (26.56)	20.9 - 33.0 (25.76)	18.0 - 34.0 (27.03)	18.7 - 31.8 (25.5)	20.2 - 29.5 (26.23)
Transparency (cm)	20.0 -109.0 (71.33)	20.0 -100.0 (66.67)	20.0 -125.0 (85.0)	23.0 -115.0 (81.0)	24.0 -140.0 (89.33)	21.0 -165.0 (95.33)	17.0 -100.0 (66.33)
D.O (mg l^{-1})	5.3 -7.0 (6.27)	6.0 -7.8 (6.93)	5.9 -7.0 (6.5)	6.8 -7.0 (6.93)	6.2 - 8.0 (7.0)	5.6 -7.8 (6.66)	6.4 -7.0 (6.7)
Free CO_2 (mg l^{-1})	7.0 - 16.0 (10.33)	5.6 - 9.0 (7.53)	4.0 - 6.0 (5.0)	4.5 -10.0 (7.1)	1.0 - 6.0 (4.13)	4.5 -12.0 (8.17)	2.2 - 10.0 (4.73)
pH	7.4 -7.93 (7.67)	7.7-7.9 (7.78)	7.8-8.0 (7.86)	7.87 - 8.07 (8.0)	7.9 - 8.26 (8.12)	7.7 - 8.1 (7.86)	7.6 - 8.2 (7.87)
Total Alkalinity (mg l^{-1})	140.0 - 168.0 (155.33)	124.0 -160.0 (144.67)	98.0 -208.0 (153.67)	120.0 -194.0 (162.0)	120.0 -184.0 (151.33)	134.0-160.0 (148.0)	136.0-144.0 (139.33)
T.D.S. (mg l^{-1})	N	O	T	D	O	N	E
Sp. Conductivity (umhos cm^{-1})	201.0 -290.0 (250.33)	180.0 - 280.0 (230.0)	200.0 - 405.0 (273.0)	190.0 -390.0 (276.66)	200.0 -380.0 (290.0)	240.0 -350.0 (296.66)	210.0 -290.0 (258.33)
Ca^{2+} (mg l^{-1})	32.0 -73.3 (45.8)	24.0 - 83.1 (46.36)	22.4 - 97.8 (51.06)	24.8 - 92.9 (50.56)	26.4 -75.8 (44.06)	30.5 -73.3 (45.26)	30.0 -70.9 (46.46)
Mg^{2+} (mg l^{-1})	10.56 -19.2 (14.72)	9.6 -19.8 (13.8)	10.4 -28.0 (17.9)	9.6 -25.6 (18.26)	9.8 - 25.4 (16.83)	9.6 - 21.6 (16.8)	9.8 - 26.6 (16.26)
Total Hardness (mg l^{-1})	124.0 -263.5 (175.83)	110.0 -290.4 (173.46)	120.0 -361.1 (202.36)	125.0 -339.2 (202.73)	116.0 -295.2 (180.4)	120.0 -273.3 (183.1)	116.0 -287.9 (183.96)
Chloride (mg l^{-1})	7.0 - 9.0 (7.66)	6.0 - 8.4 (7.13)	2.0 -13.0 (8.33)	8.0 -11.0 (9.66)	8.0 -10.0 (9.33)	8.0 -14.0 (10.13)	8.0 -10.0 (8.66)
Phosphate (mg l^{-1})	0.006 - 0.204 (0.079)	0.004 - 0.25 (0.095)	0.019 - 0.13 (0.067)	0.006 - 0.134 (0.060)	0.014 - 0.128 (0.062)	0.014 - 0.15 (0.072)	0.01- 0.112 (0.052)
Nitrate (mg l^{-1})	0.11- 0.21 (0.168)	0.09 - 0.20 (0.154)	0.12 - 0.30 (0.197)	0.059 - 0.296 (0.203)	0.082 - 0.22 (0.15)	0.09 - 0.20 (0.163)	0.08 - 0.176 (0.135)
Silicate (mg l^{-1})	14.7 -19.4 (16.3)	14.3 -16.2 (15.36)	15.1 -19.3 (16.93)	15.4 -17.0 (16.16)	13.8 -16.2 (15.36)	15.5 -19.1 (17.36)	15.5 - 16.4 (15.9)
Free NH_3 (mg l^{-1})	Nil – Tr (Tr)	Nil – Tr (Tr)	Nil (Nil)	Nil – 0.04 (0.013)	Nil (Nil)	Nil – 0.08 (0.0267)	Nil (Nil)
BOD5 (mg l^{-1})	0.4-0.84 (0.64)	0.3-0.7 (0.46)	0.46-0.60 (0.52)	0.6-0.85 (0.725)	0.40-0.80 (0.60)	0.2-0.90 (0.78)	0.2-0.70 (0.446)

Table 8. Physico-chemical characteristics of water at identified sites of river Narmada pertaining to stretch below Harsud to Surpan (average in parentheses)

Parameter	Maheshwar	Khalghat	Hanfeshwar	Charbara	Gadher	Surpan
Water Temperature (°C)	23.0-30.0 (27.7)	24.0-29.0 (27.1)	28.0-32.0 (29.6)	29.0-32.0 (30.1)	28.0-30.5 (29.6)	27.0-31.8 (29.7)
Transparency (cm)	28.0-120.0 (66.66)	25.0-78.3 (59.1)	15.0-39.0 (24.66)	32.3-73.0 (49.1)	51.0-90.0 (67.5)	70.0-83.0 (77.33)
D.O (mg l^{-1})	5.3.3-7.3 (6.61)	6.24-7.4 (6.78)	5.32-7.6 (6.57)	4.8-10.2 (7.03)	5.6-7.8 (6.66)	5.81-8.2 (6.93)
Free CO_2 (mg l^{-1})	Nil-Nil	Nil	Nil	Nil-5.86	Nil-2.8	Nil
pH	7.75-8.74 (8.23)	7.81-8.75 (8.28)	7.77-8.87 (8.36)	7.6-8.9 (8.07)	7.75-8.88 (8.14)	7.78-8.92 (8.2)
Total Alkalinity (mg l^{-1})	137.0-161.0 (147.3)	134.7-168.0 (151.2)	133.06-162.0 (147.02)	136.0-158.0 (146.4)	131.0-147.0 (139.6)	125.0-150.0 (141.4)
T.D.S. (mg l^{-1})	139.0-146.0 (142.5)	138.3-150.0 (144.1)	139.6-145.0 (142.3)	143.0-152.0 (147.5)	146.0-148.0 (147.0)	144.0-149.6 (146.8)
Sp. Conductivity (µmhos cm^{-1})	214.0-292.0 (248.6)	212.6-300.0 (250.8)	215.0-289.0 (244.6)	220.6-305.0 (248.5)	220.0-293.0 (247.0)	210.0-288.0 (242.8)
Ca^{2+} (mg l^{-1})	23.78-26.18 (44.93)	11.22-25.38 (20.04)	18.44-25.06 (22.25)	16.83-25.06 (21.98)	25.65-28.80 (26.7)	24.05-30.2 (27.25)
Mg^{2+} (mg l^{-1})	10.05-14.17 (12.94)	11.35-23.80 (18.23)	12.32-17.96 (15.75)	11.8-19.42 (15.58)	10.17-13.58 (12.44)	9.0-12.44 (11.02)
Total Hardness (mg l^{-1})	106.6-120.0 (115.5)	108.7-140.0 (124.2)	113.3-128.0 (120.4)	111.3-122.0 (118.4)	114.0-120.0 (118.0)	108.0-120.0 (113.5)
Chloride (mg l^{-1})	4.0-7.57 (5.75)	4.0-5.9 (4.72)	4.0-10.91 (6.87)	4.0-8.5 (6.2)	2.0-7.1 (5.0)	2.0-8.0 (5.2)
Dissolved organic matter. (mg l^{-1})	N	O	T	D	ON	E
Phosphate (mg l^{-1})	Tr-0.09 (0.03)	Tr – 0.07 (0.023)	Tr – 0.09 (0.03)	Tr – 0.09 (0.033)	Tr – 0.05 (0.017)	Tr – 0.07 (0.025)
Nitrate (mg l^{-1})	Tr-0.13 (0.06)	0.12-0.13 (0.126)	0.05-0.18 (0.103)	Tr – 0.14 (0.093)	0.07-0.12 (0.096)	0.05-0.13 (0.076)
Silicate (mg l^{-1})	11.4-14.5 (13.4)	12.2-14.6 (13.63)	9.1-14.5 (12.66)	12.9-14.7 (13.83)	11.0-14.7 (12.6)	11.4-15.0 (13.6)
Free NH_3 (mg l^{-1})	Nil	Nil	Nil	Nil	Nil	Nil

* Analysed once

Table 9. Physico-chemical characteristics of water at identified sites of river Narmada pertaining to the stretch below Surpan to Gulf of Cambay (average in parentheses)

Parameter	Vedgam	Poicha	Sisodara	Velugam	Jhanor	Ankaleshwar	Shakkarpura	Bhadbhut	Ambetha
Water Temp (°C)	24.6 - 31.8 (29.26)	24.6 - 30.6 (28.3)	24.6 - 30.1 (28.23)	24.0 - 30.2 (27.9)	23.5 - 30.8 (28.06)	22.9 - 3 0.3 (27.4)	22.7 - 30.8 (28.0)	23.3 - 30.7 (27.8)	24.1 - 30.5 (28.06)
Transparency (cm)	57.0 - 124.0 (93.61)	29.6 - 152.0 (108.5)	24.0 - 178.0 (121.53)	35.5 - 219.6 (157.7)	60.5 - 196.6 (139.7)	58.0 - 88.3 (70.6)	11.0 - 52.0 (25.0)	9.3 - 31.2 (22.6)	5.3 - 8.8 (6.7)
D.O (mg l^{-1})	6.1 - 7.08 (6.69)	7.1 - 8.64 (7.71)	6.8 - 7.04 (7.28)	7.2 - 8.04 (7.54)	7.3 - 8.58 (7.76)	7.1 - 8.34 (7.61)	5.3 - 6.3 (5.96)	6.2 - 7.2 (6.76)	6.4 - 7.14 (6.68)
Free CO_2 (mg l^{-1})	Nil Nil	Nil Nil	Nil Nil	Nil Nil	Nil Nil	Nil Nil	0.7 - 2.4 (1.55)	Nil Nil	Nil Nil
pH	8.1- 8.74 (8.37)	8.17 - 8.56 (8.32)	8.04 - 8.54 (8.29)	8.18 - 8.42 (8.32)	8.22 - 8.54 (8.40)	8.26 - 8.52 (8.42)	7.8 - 8.29 (8.08)	7.95 - 8.61 (8.23)	7.83-8.38 (8.1)
Total Alkalinity (mg l^{-1})	116.8-142.0 (132.93)	112.0-141.0 (131.33)	120.0-144.0 (133.33)	119.0-144.0 (132.53)	120.9-149.0 (134.63)	125.0-152.0 (139.66)	127.8-153.0 (140.7)	122.0-161.0 (141.0)	134.66-155.0 (143.72)
*T.D.S. (mg l^{-1})	214.5 (214.5)	208.0 (208.0)	216.66 (216.66)	201.5 (201.5)	177.6 (177.6)	195.0 (195.0)	554.6 (554.6)	394.33 (394.33)	16986.6 (16986.6)
Sp. Conductivity (µmhos cm^{-1})	274.0-330.0 (293.66)	283.0-320.0 (297.33)	287.0-331.33 (304.11)	283.0-310.0 (295.0)	273.3-298.0 (285.1)	299.0-305.0 (301.33)	401.0-853.3 (613.43)	295.0-1465.0 (788.88)	5700.0-27500.0 (19777.77)
Ca^{2+} (mg l^{-1})	25.60-25.90 (25.71)	25.65-28.6 (26.99)	25.25-28.59 (27.28)	24.05-28.6 (26.51)	24.05-29.39 (27.08)	24.85-28.0 (26.03)	19.77-30.0 (24.07)	22.58-29.4 (25.34)	62.5-989.99 (542.88)
Mg^{2+} (mg l^{-1})	8.75-13.74 (11.83)	8.38-12.64 (11.20)	9.23-13.12 (11.59)	9.36-12.64 (10.93)	9.23-12.64 (11.16)	9.36-14.22 (12.19)	10.20-23.79 (16.84)	9.72-24.70 (16.53)	104.57-439.22 (218.42)
Total Hardness. (mg l^{-1})	100.0-121.33 (112.94)	106.0-118.6 (113.53)	108.0-122.66 (115.88)	110.0-112.0 (111.2)	107.5-121.3 (113.6)	108.5-120.6 (115.2)	117.0-147.3 (129.43)	113.5-158.0 (131.38)	615.0-3245.0 (2255.1)
Chloride (mg l^{-1})	3.15-15.43 (7.76)	3.55-14.95 (7.9)	4.35-13.72 (8.09)	4.30-11.83 (7.01)	4.05-19.88 (9.87)	5.10-19.88 (10.39)	19.53-160.93 (73.32)	5.7-109.5 (58.28)	937.0-4925.0 (2495.79)
*Dissolved organic matter (mg l^{-1})	30.83 (30.83)	33.63 (33.63)	43.8 (43.8)	19.1 (19.1)	32.73 (32.73)	33.76 (33.76)	25.8 (25.8)	16.9 (16.9)	22.36 (22.36)
Phosphate (mg l^{-1})	Tr (Tr)	Tr – 0.01 (0.003)	Tr – 0.009 (0.003)	Tr – 0.012 (0.007)	Tr – 0.027 (0.009)	Tr – 0.024 (0.008)	Tr – 0.055 (0.018)	Tr – 0.046 (0.015)	Tr – 0.046 (0.0186)
Nitrate (mg l^{-1})	0.05-0.837 (0.312)	Tr – 0.421 (0.157)	0.023-0.334 (0.155)	0.006-0.29 (0.115)	Tr – 1.091 (0.383)	Tr – 1.062 (0.354)	0.06-0.585 (0.248)	0.09-0.659 (0.303)	Tr – 0.07 (0.023)
Silicate (mg l^{-1})	13.06-22.87 (18.21)	12.8-24.10 (19.23)	13.1-23.74 (19.68)	11.86-24.16 (19.34)	12.06-24.26 (20.14)	12.73-24.1 (20.26)	12.63-24.30 (20.32)	11.2-23.90 (19.46)	4.8-20.42 (14.10)
Free NH_3 (mg l^{-1})	Nil Nil	Nil Nil	Nil Nil	Nil Nil	Nil Nil	Nil – 0.02 (0.007)	Nil Nil	Nil Nil	Nil Nil

* Analysed once

Table 10. Plankton abundance at identified sites of river Narmada pertaining to stretch, Amarkantak to Gadarwada (average in parentheses)

Planktonic Group	Amarkantak nos l^{-1} %	Dindori nos l^{-1} %	Mandla nos l^{-1} %	Jabalpur nos l^{-1} %	Narsinghpur nos l^{-1} %	Kareli nos l^{-1} %	Gadarwada nos l^{-1} %
Myxophyceae	Nil – 10 (7) 3.45	- - -	Nil – 9 (4) 5.06	8 – 18 (14) 9.21	Nil – 3 (1) 0.99	Nil – 2 (1) 1.28	Nil – 32 (11) 8.40
Bacillariophyceae	69 – 77 (72) 35.47	Nil – 58 (29) 90.62	5 – 27 (18) 22.78	15 – 179 (87) 57.23	10 – 34 (70) 69.31	18 – 101 (61) 78.21	24 – 132 (80) 61.07
Cholorophyceae	12 – 205 (91) 44.82	- - -	2 – 91 (32) 40.51	Nil – 92 (33) 21.71	Nil – 76 (26) 25.74	10 – 22 (14) 17.95	6 – 54 (27) 20.61
Dinophyceae	Nil – 8 (4) 1.97	- - -	- - -	Nil -6 (2) 1.32	- - -	- - -	- - -
PHYTOPLANKTON	98 – 292 (174) 85.71	Nil – 58 (29) 90.62	7 – 121 (54) 68.35	29 – 289 (136) 89.47	10 – 145 (97) 96.04	28 – 124 (76) 97.44	30 – 185 (118) 90.08
Protozoa	Nil – 5 (3) 1.48	- - -	- - -	- - -	- -	- - -	- -
Rotifera	5 – 40 (17) 8.37	1 – 4 (3) 9.38	Nil – 4 (1) 1.27	Nil – 16 (6) 3.95	Nil – 6 (2) 1.98	Nil – 2 (1) 1.28	Nil – 24 (9) 6.87
Cladocera	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Ostracoda	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Copepoda	Nil – 12 (9) 4.44	- - -	Nil – 69 (24) 30.38	Nil – 28 (10) 6.58	Nil – 5 (2) 1.98	Nil – 2 (1) 1.28	Nil – 11 (4) 3.05
ZOOPLANKTON	10 – 56 (29) 14.29	1 – 4 (3) 9.38	1 – 72 (25) 32.65	4 -28 (16) 10.53	Nil – 6 (4) 3.96	1 – 2 (2) 2.56	1 – 35 (13) 9.92
Un-identified organisms	- - -	- - -	- - -	- - -	- - -	- - -	- - -
TOTAL PLANKTON	108-348 (203) 100.0	4 -59 (32) 100.0	8-193 (79) 100.0	33-317 (152) 100.0	16-146 (101) 100.0	30-125 (78) 100.0	33-186 (131) 100.0

Table 11. Plankton abundance at identified sites of river Narmada pertaining to stretch below Gadarwada to Harsud (average in parentheses)

Planktonic Group	Sandia nos l^{-1}	%	Shahganj nos l^{-1}	%	Hoshangabad nos l^{-1}	%	Dongarwada nos l^{-1}	%	Gondagaon nos l^{-1}	%	Handia nos l^{-1}	%	Mola nos l^{-1}	%
Myxophyceae	Nil – 72 (27)	8.82	Nil – 96 (33)	11.46	Nil – 276 (96)	23.08	Nil – 60 (24)	9.31	Nil – 312 (109)	21.17	Nil – 180 (60)	16.26	Nil – 144 (48)	14.82
Bacillariophyceae	8 – 222 (81)	26.47	8 – 1926 – 120 (70)	24.30	4 – 108 (45)	10.81	12 – 205 (41)	15.89	8 – 156 (77)	14.95	6 – 132 (58)	15.72	(49)	15.17
Chlorophyceae	8 – 180 (71)	23.20	18 – 132 (69)	23.96	18 – 288 (109)	26.20	14 – 240 (90)	34.88	26 – 384 (148)	28.73	18 – 276 (116)	31.44	20 – 252 (97)	30.03
Dinophyceae	Nil – 2 (1)	0.33	-	-	-		-	-	-	-	-	-	-	-
PHYTOPLANKTON	24 – 480 (180)	58.82	30 – 420 (172)	59.72	28 – 684 (250)	60.09	18 – 408 (155)	60.08	50 – 901 (334)	64.85	26 – 612 (234)	63.42	26 – 528 (194)	60.06
Protozoa	Nil – 72 (25)	8.17	Nil – 84 (28)	9.72	Nil – 121 (42)	10.10	Nil – 84 (30)	11.63	4 – 144 (51)	9.90	2 – 107 (38)	10.30	Nil – 108 (38)	11.77
Rotifera	Nil – 36 (19)	6.21	Nil – 36 (19)	6.60	4 – 60 (31)	7.45	Nil – 36 (21)	8.14	6 – 37 (26)	5.05	6 – 36 (21)	5.68	2 – 36 (19)	5.88
Cladocera	Nil – 144 (49)	16.01	4 – 108 (40)	13.89	Nil – 96 (33)	7.94	Nil – 60 (23)	8.91	4 – 59 (24)	4.66	2 – 132 (46)	12.47	Nil – 48 (17)	5.26
Ostracoda	-	-	-	-	Nil – 23 (8)	1.92	-	-	-	-	-	-	-	-
Copepoda	4 – 84 (33)	10.79	4 – 72 (29)	10.07	4 – 132 2 – 72 52	12.50	4 – 215 (29)	11.24	6 – 73 (80)	15.54	4 – 144 (30)	8.13	(55)	17.03
ZOOPLANKTON	4 – 336 (126)	41.18	8 – 300 (116)	40.28	8 – 432 (166)	39.91	2 – 252 (103)	39.92	18 – 455 (181)	35.15	16 – 348 (135)	36.58	6 – 336 (129)	39.94
Un-identified organisms	-	-	-		-		-	-	-	-	-	-	-	-
TOTAL PLANKTON	40 – 816 (306)	100.0	70 – 720 (288)	100.0	36 – 1116 (416)	100.0	20 – 660 (258)	100.0	68 – 1356 (515)	100.0	80 – 960 (369)	100.0	32 – 864 (323)	100.0

Table 12. Plankton abundance at identified sites of river Narmada pertaining to stretch below Harsud to Surpan (average in parentheses)

Planktonic Group	Maheshwar		Khalghat		Hanfeshwar		Charbara		Gadher		Surpan	
	nos l^{-1}	%	nos l^{-1}	%	nos l^{-1}	%	nos l^{-1}	%	nos l^{-1}	%	nos l^{-1}	%
Myxophyceae	Nil – 6 (2)	0.96	Nil – 10 (4)	2.22	Nil – 6 (2)	2.63	Nil – 16 (9)	8.03	Nil – 3 (1)	0.51	Nil – 50 (17)	9.94
Bacillariophyceae	6-100 (44)	21.26	17-200 (79)	43.89	4-50 (21)	27.63	Nil – 13 (6)	5.36	13-300 (113)	57.95	8-250 (113)	57.95
Cholorophyceae	3-425 (151)	72.95	5-525 (86)	47.78	6-75 (40)	52.63	14-151 (83)	74.11	37-100 (69)	35.38	20-71 (47)	27.48
Dinophyceae	- -	-	- -	-	Nil – 4 (1)	1.32	- -	-	- -		- -	-
PHYTOPLANKTON	15-525 (197)	95.17	22-425 (169)	93.89	10 – 25 (64)	84.21	29-167 (98)	87.50	65-400 (183)	93.84	28-350 (157)	91.81
Protozoa	Nil – 7 (2)	0.96	- -	-	- -	-	- -	-	- -	-	- -	-
Rotifera	Nil – 5 (1)	0.49	Nil – 5 (2)	1.11	Nil – 6 (2)	2.63	4 - 16 (10)	8.92	Nil – 7 (4)	2.05	Nil – 10 (6)	3.51
Cladocera	Nil – 5 (1)	0.49	Nil – 2 (1)	0.56	Nil – 5 (2)	2.63	Nil – 3 (2)	1.79	- -	-	- -	-
Ostracoda	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-
Copepoda	Nil – 12 (6)	2.89	Nil –21 (8)	4.44	Nil – 18 (8)	10.53	Nil – 4 (2)	1.79	Nil – 16 (8)	4.11	Nil – 21 (8)	4.68
ZOOPLANKTON	Nil – 29 (10)	4.83	Nil – 28 (11)	6.11	Nil – 29 (12)	15.79	11-16 (14)	12.50	Nil - 23 (12)	6.16	Nil – 30 (14)	8.19
Un-identified organisms	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-
TOTAL PLANKTON	19-525 (207)	100.0	27-425 (180)	100.0	17-125 (76)	100.0	40-183 (112)	100.0	78-400 (195)	100.0	42-350 (171)	100.0

Table 13. Plankton abundanc and its qualitative composition (%) at identified sites of river Narmada pertaining to the stretch below Surpan to Gulf of Cambay (average in parentheses)

Planktonic Group	Vedgam nos l^{-1} %	Poicha nos l^{-1} %	Sisodara nos l^{-1} %	Velugam nos l^{-1} %	Jhanor nos l^{-1} %	Ankaleshwar nos l^{-1} %	Shakkarpura nos l^{-1} %	Bhadbhut nos l^{-1} %	Ambetha nos l^{-1} %
Myxophyceae	Nil – 2 (1) 0.93	2-18 (7) 5.51	11-823 (287) 54.67	3-15 (8) 4.94	7-159 (66) 5.68	Nil - 45 (15) 18.75	Nil - 40 (14) 22.22	Nil - 23 (11) 8.46	Nil - 9 (5) 7.04
Bacillariophyceae	6-201 (83) 76.85	1-257 (90) 70.87	3-480 (163) 31.05	2-373 (128) 79.01	5-124 (56) 4.82	4-68 (33) 41.25	12-33 (22) 34.92	15-116 (57) 43.85	15-75 (37) 52.11
Chlorophyceae	Nil – 34 (14) 12.96	Nil – 34 (19) 14.96	1-80 (44) 8.38	2-41 (16) 9.88	2-3003 (1024) 88.20	2-46 (22) 27.50	2-59 (21) 33.33	Nil - 70 (26) 20.0	Nil - 21 (8) 11.27
PHYTOPLANKTON	40-211 (98) 90.74	14-282 (116) 91.34	64-830 (494) 94.10	19-380 (152) 93.83	200 -3015 (1146) 98.70	50-86 (70) 87.50	16-80 (57) 90.47	38-125 (94) 72.31	25-80 (50) 70.42
Protozoa	Nil – 7 (3) 2.78	1-9 (4) 3.15	Nil – 12 (5) 0.95	Nil - 2 (1) 0.62	1-14 (6) 0.52	Nil - 4 (2) 2.50	1-2 (2) 3.18	3-50 (19) 14.61	3-10 (6) 8.45
Rotifera	2-9 (5) 4.62	2-5 (4) 3.15	2-13 (9) 1.71	1-6 (3) 1.85	2-8 (5) 0.43	2-4 (3) 3.75	Nil - 2 (1) 1.59	Nil - 8 (3) 2.31	3-5 (4) 5.63
Cladocera	- - -	- - -	Nil - 4 (1) 0.91	- - -	Nil - 3 (1) 0.09	- - -	- - -	- - -	Nil - 3 (1) 1.41
Ostracoda	- - -	Nil – 5 (2) 1.57	Nil - 12 (4) 0.76	- - -	- - -	- - -	- - -	Nil - 10 (3) 2.31	Nil - 3 (1) 1.41
Copepoda	Nil – 1 (1) 0.93	Nil – 2 (1) 0.79	Nil - 28 (12) 2.29	1-14 (6) 3.70	1-5 (3) 0.26	1-2 (2) 2.50	Nil - 7 (3) 4.76	1-30 (11) 8.46	Nil - 25 (9) 12.68
ZOOPLANKTON	2-17 (9) 8.33	6-20 (11) 8.66	3-68 (31) 5.90	4-15 (10) 6.17	4-28 (15) 1.30	6-8 (7) 8.75	2-11 (6) 9.53	5-90 (36) 27.69	15-35 (21) 29.58
Un-identified organisms	Nil -1 (1) 0.93	- - -	- - -	- - -	- - -	Nil - 4 (3) 3.75	- - -	- - -	- - -
TOTAL PLANKTON	47-228 (108) 100.0	20-302 (127) 100.0	86-833 (525) 100.0	23-395 (162) 100.0	204-3027 (1161) 100.0	58-98 (80) 100.0	20-91 (63) 100.0	43-210 (130) 100.0	40-115 (71) 100.0

Table 14. Macro-benthos abundance at identified sites of Narnada River pertaining to stretch Amarkantak to Gadarwada (average in parentheses)

Benthic Group	Amarkanta		Dindori*		Mandla		Jabalpur		Narsinghpur		Kareli		Gadarwada	
	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%
Annelida	65 – 408		88	30.56	Nil – 42		13 – 323		-		-		Nil – 7	
	(184)	51.25			(19)	7.34	(133)	20.75	-	-	-	-	(2)	0.53
Ephemeroptera	-		-	-	Nil – 14		Nil – 43		-		-		Nil – 7	
	-	-	-	-	(4)	1.54	(15)	2.34	-	-	-	-	(2)	0.53
Odonata	-		-	-	-		-		-		-		-	
	-	-			-	-	-	-	-	-	-	-	-	-
Coleoptera	-		-	-	-		-		-		-		-	
	-	-			-	-	-	-	-	-	-	-	-	-
Ostracoda	-		-	-	-		-		-		-		Nil – 43	
	-	-			-	-	-	-	-	-	-	-	(14)	3.69
Diptera	Nil – 274		200	69.44	7 – 337		Nil – 425		Nil – 55		Nil – 64		7 – 221	
	(170)	47.35			(129)	49.81	(260)	40.56	(22)	5.45	(36)	8.49	(121)	31.93
Mollusca	Nil – 11		-	-	14 – 284		160 – 370		223 – 544		122 – 820		Nil – 490	
	(5)	1.40			(107)	41.31	(233)	36.35	(377)	93.32	(384)	90.57	(235)	62.01
Nematoda	-		-	-	-		-		-		-		-	
	-	-			-	-	-	-	-	-	-	-	-	-
Malacostraca	-		-	-	-		-		Nil – 15		Nil – 14		Nil – 15	
	-	-			-	-	-	-	(5)	1.23	(4)	0.94	(5)	1.31
TOTAL ORGANISMS	312 – 408		288	100.0	72 – 373		496 – 789				165 – 884		244 – 632	
	(359)	100.0			(259)	100.0	(641)	100.0	404	100.0	(424)	100.0	(379)	100.0

* Single observation

Table 15 **Macro-benthos abundance at identified sites of river Narmada pertaining to the stretch below Gadarwada to Harsud (average in parentheses)**

Benthic Group	Sandia		Shahganj		Hoshangabad		Dongarwada		Gondagaon		Handia		Mola	
	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%
Annelida	Nil – 86		-	-	-	-	Nil – 87		-	-	-	-	-	-
	29	3.18					29	4.77						
Ephemeroptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Odonata	Nil – 87		Nil – 43		-	-	-	-	Nil – 44		Nil – 43		87-175	
	58	6.35	14	0.94					15	1.23	14	1.64	117	15.23
Trichoptera	Nil – 131		Nil – 174		-	-	Nil – 87		Nil – 262		Nil – 87		Nil – 130	
	44	4.82	58	3.88			29	4.77	87	7.15	29	3.39	58	7.55
Ostracoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera	130 – 522		261 – 783		44 – 1477		87 – 391		130 – 652		130 – 348		87 – 522	
	304	33.30	450	30.14	579	42.04	217	35.69	348	28.59	246	28.77	304	39.58
Mollusca	391 – 609		652 – 1521		478 – 1436		304 – 319		522 – 1086		478 – 652		Nil – 477	
	478	52.35	971	65.04	798	57.96	333	54.77	767	63.03	566	66.20	289	37.64
Nematoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malacostraca	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL ORGANISMS	652 – 1348		913 – 2478		522 – 2913		478 – 870		783 – 2000		696 – 956		435 – 1304	
	913	100.0	1493	100.0	1377	100.0	608	100.0	1217	100.0	855	100.0	768	100.0

Table 16. Macro-benthos abundance at identified sites of river Narmada pertaining to stretch below Harsud to Surpan (average in parenthesis)

Benthic Group	Maheshwar		Khalghat		Hanfeshwar		Charbara		Gadher		*Surpan	
	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%	nos. m^{-2}	%
Annelida	Nil – 180 (83)	38.96	6-31 (19)	3.71	Nil – 25 (10)	14.49	120-215 (168)	60.65	Nil – 12 (6)	12.76	12	19.35
Ephemeroptera	-		-		-		-		-		-	-
Odonata	Nil – 70 (23)	10.80	-		-		-		-		-	-
Coleoptera	-		-		-		-		-		-	
Ostracoda	-		-		-		-		-		-	-
Diptera	12-60 (43)	20.19	Nil – 76 (38)	7.42	Nil – 177 (59)	85.51	20-157 (88)	31.77	2-60 (31)	65.96	4	6.45
Mollusca	45-95 (64)	30.05	417-494 (455)	88.87	-		Nil-42 (21)	7.58	Nil-20 (10)	21.28	46	74.20
Nematoda	-		-		-		-		-		-	
Malacostraca	-		-		-		-		-		-	
TOTAL ORGANISMS	180-237 (213)	100.0	448-576 (512)	100.0	Nil-202 (69)	100.0	140-414 (277)	100.0	34-60 (47)	100.0	62	100.0

* Sampled only during Summer Campaign

Table 17. Macro – benthos abundance and its qualitative composition (%) at identified sites of River Narmada pertaining to Stretch below Surpan to Gulf of Cambay (Average in parentheses)

Benthic Group	Ambetha nos. m^{-2} %	Bhadbhut nos. m^{-2} %	Shakkarpura nos. m^{-2} %	Ankaleshwar nos. m^{-2} %	Jhanor nos. m^{-2} %	Velugam nos. m^{-2} %	Sisodara nos. m^{-2} %	Poicha nos. m^{-2} %	Vedgam nos. m^{-2} %
Annelida	Nil – 1014 (507) 65.84	28-390 (227) 77.21	Nil - 55 (18) 16.67	292-37069 (12889) 93.81	Nil – 2125 (1242) 83.81	143-1125 (589) 13.03	Nil – 83 (32) 0.64	Nil – 28 (14) 0.19	Nil – 28 (9) 0.82
Conchostraca	-	-	-	-	-	-	Nil – 28 (9) 0.18	-	-
Ephemeroptera	-	-	-	-	-	Nil – 325 (111) 2.46	Nil – 278 (93) 1.85	Nil – 83 (28) 0.39	-
Odonata	-	-	-	-	-	Nil – 108 (36) 0.80	Nil – 55 (18) 0.36	Nil – 14 (5) 0.07	-
Coleoptera	-	-	-	-	-	-	-	-	-
Trichoptera	-	-	-	-	-	Nil – 43 (15) 0.33	Nil – 41 (14) 0.28	-	-
Ostracoda	-	Nil – 27 (9) 3.06	-	-	Nil – 28 (9) 0.61	Nil – 173 (57) 1.26	Nil – 1180 (398) 7.92	Nil – 277 (92) 1.27	Nil – 97 (32) 2.93
Diptera	-	Nil – 14 (5) 1.70	-	Nil – 1180 (393) 2.86	Nil – 111 (37) 2.49	Nil – 3398 (1133) 25.06	Nil – 5416 (2379) 47.36	Nil – 18666 (6247) 86.46	Nil – 28 (12) 1.10
Mollusca	19-500 (259) 33.64	14-83 (48) 16.33	28-153 (76) 70.37	28-828 (457) 3.33	14-486 (185) 12.48	56– 7533 (2580) 57.06	Nil – 6086 (2080) 41.41	56 – 1793 (839) 11.62	Nil – 3124 (1041) 95.15
Un-identified organism	-	Nil – 14 (5) 1.70	-	-	-	-	-	-	-
Malacostraca	Nil – 9 (4) 0.52	-	Nil – 42 (14) 12.96	-	Nil – 27 (9) 0.61	-	-	-	-
TOTAL ORGANISMS	28-1514 (770) 100.0	125-438 (294) 100.0	48-153 (108) 100.0	320-38763 (13739) 100.0	84-2217 (1482) 100.0	1181 – 4696 (4521) 100.0	1750-6086 (5023) 100.0	70 – 19748 (7225) 100.0	Nil – 3161 (1094) 100.0

Table 18. **Primary production rate (mg C m^{-3} hr^{-1}) at identified sites of river Narmada pertaining to the stretch Amarkantak to Gadarwada (average in parentheses)**

Primary Production	Amarkantak	Dindori	Mandla	Jabalpur	Narsinghpur	Kareli	Gadarwada
Gross	62.5-112.6 (87.5)	37.5-122.0 (67.06)	43.75-125.0 (73.69)	46.87-188.5 (91.31)	18.75-172.2 (81.01)	25.0-187.5 (84.73)	37.5-142.5 (78.61)
Net	41.7-75.0 (56.25)	25.0-65.5 (38.33)	31.25-62.5 (45.31)	24.9-125.0 (61.52)	12.5-125.0 (56.25)	18.75-78.0 (46.13)	25.0-95.0 (45.11)
Respiration	30.0-37.5 (31.25)	15.0-56.0 (28.73)	15.0-37.5 (28.38)	13.5-62.5 (29.79)	7.5-47.0 (24.46)	7.5-53.5 (38.6)	15.0-42.5 (33.5)
Assimilation efficiency (%)	64.28	57.16	61.48	67.37	69.43	54.44	57.38
P/R	1.4	1.16	1.30	1.53	1.63	1.10	1.17

Table 19. **Primary production rate (mg C m^{-3} hr^{-1}) at identified sites of river Narmada pertaining to stretch below Gadarwada to Harsud (average in parentheses)**

Primary Production	Sandia	Shahganj	Hoshangabad	Dongarwada	Gondagaon	Handia	Mola
Gross	31.2-112.6 (64.6)	20.8-270.8 (124.96)	31.2-104.2 (65.96)	23.4-104.2 (52.93)	93.8-208.3 (135.36)	31.2-166.7 (76.46)	43.7-125 (77.06)
Net	20.8-75.1 (44.46)	10.4-125.0 (69.43)	23.4-62.5 (39.03)	15.6-52.1 (29.5)	65.5-125.0 (88.5)	15.6-83.3 (39.9)	25.0-83.3 (51.73)
Respiration	15.5-37.5 (30.16)	12.5-175.0 (73.7)	9.4-50.0 (28.13)	9.4-62.5 (30.6)	23.3-100.0 (57.76)	18.7-100.0 (46.83)	18.75-50.0 (31.31)
Assimilation efficiency (%)	68.82	55.56	59.17	55.73	65.30	52.18	67.13
P/R	1.07	0.85	1.17	0.86	1.17	0.81	1.23

Table 20. Primary Production rate (mg C m^{-3} hr^{-1}) at identified sites of river Narmada pertaining to the stretch below Harsud to Surpan (average in parentheses)

Primary Production	Maheshwar	Khalghat	Hanfeshwar	Charbara	Gadher	Surpan
Gross	50.0 -125.0 (84.37)	41.66 - 93.75 (72.91)	78.13 - 175.0 (126.04)	75.0 - 225.0 (127.77)	75.0 -125.0 (100.0)	46.88 - 100.0 (73.44)
Net	37.5 - 83.33 (55.90)	20.83 - 50.0 (39.23)	62.5 - 87.5 (77.77)	50.0 -100.0 (70.83)	37.5 - 41.67 (39.58)	31.25 - 90.0 (60.62)
Respiration	12.5 - 49.99 (33.33)	24.99 - 56.25 (40.41)	18.75 - 105.0 (57.91)	24.99 - 150.0 (68.33)	45.0 - 99.99 (72.49)	12.0 -18.75 (15.37)
Assimilation Efficiency (%)	66.25	53.81	61.70	55.43	39.58	82.54
P/R	1.26	0.90	1.08	0.93	0.689	2.38

Table 21. Primary production rate (mg C m^{-3} hr^{-1}) at identified sites of river Narmada pertaining to stretch below Surpan to Gulf of Cambay (average in parentheses)

Primary Production	Vedgam	Poicha	Sisodara	Velugam	Jhanor	Ankaleshwar	Shakkarpura	Bhadbhut	Ambetha
Gross	23.21-90.63 (58.78)	23.44-75.0 (50.86)	29.16-62.50 (44.09)	22.12-67.19 (46.43)	41.17-90.63 (60.60)	50.0-145.83 (89.39)	27.70-43.75 (36.34)	Tr – 78.13 (57.81)	3.12-100.0 (36.45)
Net	17.85-87.50 (47.61)	18.75-50.0 (36.80)	25.0-37.50 (33.33)	12.5-65.63 (32.52)	35.29-89.06 (53.95)	25.0-90.63 (60.47)	Tr – 12.50 (7.29)	25.0 – 78.13 (51.56)	-9.38-25.0 (6.24)
Respiration	3.75-30.0 (13.39)	5.63-30.0 (16.87)	3.75-30.0 (12.91)	1.88-45.0 (16.73)	1.88-15.0 (7.97)	7.89-30.0 (22.63)	30.0-41.25 (34.86)	Tr – 15.0 (7.5)	Tr – 90.0 (36.25)
Assimilation Efficiency (%)	80.99	72.35	75.59	70.04	89.02	67.64	20.06	89.18	17.11
P/R	2.19	1.50	1.70	1.38	3.80	1.97	0.52	3.85	0.50

Table 22. Enlisted Fish Taxa of River Narmada since year 1941

		1	2	3
1.	*Hilsa ilisha (Hamilton)*	E	-	E
2.	*Gonialosa manmina (Hamilton)*	E	-	E
3.	*Notopterus notopterus (Pallas)*	E	E	E
4.	*N. chitala (Hamilton)*	-	-	E
5.	*Chela laubuca (Hamilton)*	E	-	E
6.	*Oxygaster clupeoides (Bloch)*	E	-	E
7.	*Barilius barila (Hamilton)*	E	E	E
8.	*B. bendelisis var chedra (Hamilton)*	E	E	E
9.	*B. evezardi (Day)*	E	-	E
10.	*B. radiolatus (Gunther)*	E	-	E
11.	*B. vagra (Hamilton)*	-	E	-
12.	*Danio (Danio) aequipinnatus (McClelland)*	E	-	E
13.	*D. (Danio) devario (Hamilton)*	E	-	E
14.	*D. (Brachydanio) rerio (Hamilton)*	E	-	E
15.	*Esomus danricus (Hamilton)*	E	-	E
16.	*Rasbora daniconius (Hamilton)*	E	E	E
17.	*Amblypharyngodon mola (Hamilton)*	E	-	E
*18.	*Tor khudree (Sykes)*	E	-	E
19.	*T. tor (Hamilton)*	E	E	E
20.	*T. putitora (Hamilton)*	E	-	E
21.	*Puntius ambassis (Day)*	E	-	E
22.	*P. amphibia (Cuvier & Valenciennes)*	E	-	E
*23.	*Puntius chrysopoma (Cuvier)*	E	-	E
24.	*P. conchonius (Hamilton)*	E	-	E
25.	*P. dorsalis (Jerdon)*	E	-	E
*26.	*P. guganio (Hamilton)*	E	-	E
*27.	*P. pinnauratus (Day)*	E	-	E
28.	*P. Sarana (Hamilton)*	E	E	E
29.	*P. sophore (Hamilton)*	E	E	E
30.	*P. ticto ticto (Hamilton)*	E	E	E

Table 22. Continued

*31.	*P. titius (Hamilton)*	E	-	E
32.	*Oreichthys consuatis (Hamilton)*	E	-	E
33.	*Catla catla (Pallas)*	E	E	E
34.	*Cirrhinus mrigala (Hamilton)*	E	E	E
35.	*C. reba (Hamilton)*	E	E	E
*36.	*Garra gotyla (Gray)*	E	-	E
37.	*G. lamta (Hamilton)*	E	-	E
*38.	*G. mullya (Sykes)*	E	E	E
39.	*Labeo bata (Hamilton)*	E	E	E
40.	*L. boggut (Sykes)*	E	-	E
41.	*L. calbasu (Hamilton)*	E	E	E
42.	*L. dyocheilus (Bloch)*	E	-	E
43.	*L. fimbriatus (Bloch)*	E	E	E
44.	*L. gonius (Hamilton)*	E	E	E
45.	*L. rohita (Hamilton)*	E	-	E
46.	*L. pangusia (Hamilton)*	-	E	-
47.	*Osteobrama cotio cotio (Hamilton)*	E	E	E
48.	*Crossocheilus latius latius (Hamilton)*	E	E	E
*49.	*Parapsilorhynchus tentaculatus (Annandale)*	E	-	E
50.	*Noemacheilus botia (Hamilton)*	E	E	E
51.	*N. beavani (Gunther)*	-	E	-
52.	*N. dayi (Hora)*	E	-	E
*53.	*N. evezardi (Day)*	E	-	E
54.	*Lepidocephalichthys guntea (Hamilton)*	E	-	E
55.	*Ompok bimaculatus (Bloch)*	E	E	E
56.	*Wallago attu (Bloch & Schneider)*	E	E	E
57.	*Mystus (Mystus) bleekeri (Day)*	E	E	E
58.	*M. (Mystus) cavasius (Hamilton)*	E	E	E
59.	*M. (Mystus vitatus (Bloch)*	E	E	E
60.	*M. (Osteobagrus) aor (Hamilton)*	E	E	E
61.	*M. (Osteobagrus) seenghala (Sykes)*	E	E	E
62.	*Rita pavimentata (Gunther)*	E	E	E
63.	*R. rita (Hamilton)*	-	-	E

Table 22. Continued

*64.	*Amblyceps mangois (Hamilton)*	E	-	E
65.	*Gagata itchkeen (Sykes)*	E	-	E
66.	*Glyptothorax lonah (Sykes)*	E	-	E
*67.	*Laguvia ribeiroi (Hora)*	E	-	E
68.	*Clupisoma garua (Hamilton)*	E	E	E
69.	*Heteropneustes fossilis (Bloch)*	E	E	E
70.	*Clarias batrachus (Linnaeus)*	E	-	E
71.	*Anguilla bengalensis (Gray)*	E	E	-
72.	*Xenentodon cancila (Hamilton)*	E	E	E
73.	*Channa gachua (Hamilton)*	E	E	E
74.	*C. marulius (Hamilton)*	E	E	E
75.	*C. punctatus (Bloch)*	E	E.	E
76.	*C. striatus (Bloch)*	-	E	-
77.	*Chanda nama (Hamilton)*	E	E	E
78.	*C. ranga (Hamilton)*	E	E	E
79.	*Badis badis (Hamilton)*	E	-	E
80.	*Nandus nandus (Hamilton)*	E	E	E
81.	*Glossogobius giuris giuris (Hamilton)*	E	E	E
82.	*Mastacembelus armatus armatus (Lacepede)*	E	E	E
83.	*M. pancalus (Hamilton)*	E	E	E
84.	*Silonia silondia (Hamilton)*	-	E	-
85.	*Anabas testudineus (Bloch)*	-	-	E
86.	*Lebistes reticulatus (Menon)*	-	-	E
87.	*Oxygaster bacaila (Hamilton)*	-	E	E
88.	*Eutropiichthys vacha (Hamilton)*	-	-	E
89.	*Rhinomugil corsula (Hamilton)*	-	-	E
90.	*Colisa fasciatus (Bloch & Schneider)*	-	-	E

1. = Karamchandani et al. (1967)
2. = Department of Fisheries Govt of M.P. Survey Report, 1971
3. = Rao et al. (1991)
*** = Recorded by Hora & Nair (1941)**
E = Encountered

Table 23. Qualitative Spectrum of fish landings of River Narmada

Fish species	Karamchandani et al.(1967)	Anon (1971)			Rao et al. (1991)
	Central Zone	Eastern Zone	Central Zone	Western Zone	
Tor tor	28.00	25.30	30.10	28.10	25.87
Labeo fimbriatus	19.70	21.50	24.40	22.10	18.54
L. gonius	0.30	1.10	–	–	0.48
L. calbasu	4.10	3.50	–	5.00	5.42
L.rohita	–	–	–	–	0.36
L. dyocheilus	1.60	–	–	1.20	1.31
L. bata	1.70	1.40	2.90	1.30	1.40
Cirrhinus mrigala	2.50	1.20	1.80	2.70	2.71
C. reba	0.50	–	–	–	0.48
Catla catla	0.60	0.60	–	0.40	0.81
Puntius spp.	–	–	–	–	2.15
P. Sarana	1.40	3.60	3.50	4.60	–
Total Carps	**60.40**	**58.20**	**62.70**	**65.40**	**59.53**
Rita spp	–	–	–	–	12.60
R. pavimentata	10.20	6.40	3.00	4.70	8.18
Mystus seenghala	9.00	8.20	10.30	5.60	4.84
M. aor	4.70	6.50	9.10	6.80	7.70
M. cavasius	0.30	–	–	–	0.68
M. tengara	–	–	–	–	0.36
Wallago attu	7.70	10.50	4.40	3.90	–
Clupisoma garua	1.80	–	0.80	–	–
Ompok bimaculatus	0.40	–	–	0.80	1.56
Total Cat Fishes	**34.10**	**31.60**	**27.60**	**21.80**	**35.92**
Channa spp.	3.70	4.20	2.00	2.60	1.88
Mastacembelus spp.	1.30	1.90	–	3.10	1.64
Notopterus notopterus	0.50	–	–	–	0.70
Other small fishes	–	4.10	7.70	7.10	0.33
Total Miscellaneous	**5.50**	**10.20**	**9.70**	**12.80**	**4.55**

Table 24. Species-wise estimated inland fish production (in tones)

Name of fish	YEARS				
	1992-93	1993-94	1994-95	1995-96	1996-97
Catla	3686	4888	8132	6753	7653
Rohu	4304	6580	8462	7870	9351
Mrigal	2868	3919	5102	5094	5883
Calbasu	72	52	763	91	133
Minor Carps	118	186	65	116	147
Wallago attu	1460	968	1040	1657	2167
Scorpion fish	77	65	77	194	165
Murrels	826	952	813	1383	1646
Cat fishes	4722	5743	2807	3590	5162
Bombay Duck	466	475	1380	480	582
Hilsa/Clupids	11086	15319	5995	9346	8849
Mullets	2605	1715	1685	2260	2626
Eels	126	255	55	850	445
Prawn (Shrimp)	4971	6196	12152	6984	6373
Prawn (Medium)	6102	8425	11960	1143	2391
Prawn (Jumbo)	0	0	0	600	475
Crab	48	31	33	26	32
Mahseer	**330**	**152**	**103**	**133**	**53**
Bokti	618	237	316	333	203
Levta	356	213	212	649	603
Misc.	6313	8648	8948	10606	10339

Courtesy – Commissionerate of Fisheries, Gandhinagar, Gujarat

Table 25. Heavy metal accumulation(µg l^{-1}) in sediment and water-phase (in parentheses) at identified sites of stretch, Amarkantak to Gadarwada of River Narmada.

Heavy Metal	Amarkantak	Dindori	Mandala	Jabalpur	Narsinghpur	Kareli	Gadarwada	Range	Average
Copper	54.4 (9.98)	132.2 (35.95)	122.9 (10.85)	79.9 (8.84)	62.06 (7.9)	131.6 (8.37)	88.42 (11.20)	54.4 -132.2 (7.9 -35.95)	95.93 (13.29)
Chromium	47.6 (10.87)	42.56 (31.65)	28.86 (13.17)	20.0 (13.05)	25.94 (21.73)	21.83 (12.26)	19.8 (19.40)	19.8-47.6 (10.87 -31.65)	29.51 (17.44)
Cadmium	2.61 (6.11)	2.59 (6.77)	2.77 (5.95)	2.73 (5.5)	2.76 (6.28)	2.67 (5.9)	2.70 (5.99)	2.59-2.77 (5.5-6.77)	2.69 (6.07)
Lead	42.5 (13.63)	26.42 (16.63)	41.98 (14.18)	24.7 (14.19)	26.46 (18.87)	38.9 (13.9)	30.78 (20.92)	24.7-42.5 (13.63-20.92)	33.01 (16.05)
Zink	276.6 (126.6)	224.3 (90.63)	111.27 (91.73)	167.74 (91.58)	210.5 (49.76)	307.42 (65.34)	193.35 (64.48)	111.27-307.4 (49.76-126.6)	2213.03 (82.87)
Mercury	0.008	0.002	0.003	0.0016	0.002	0.002	0.001	0.001-0.008	0.0028

Table 26. Heavy metal accumulation (mg l^{-1}) in water-phase at identified sites of stretch, below Gadarwada to Harsud of River Narmada (average in parentheses)

Metal	Sandia	Shahganj	Hoshangabad	Dongarwada	Gondagaon	Handia	Mola
Zn	0.01-0.056 (0.028)	BDL-0.066 (0.029)	0.01-0.099 (0.044)	0.02-0.101 (0.053)	0.026-0.383 (0.149)	0.023-0.107 (0.053)	0.021-0.109 (0.053)
Mn	BDL-0.014 (0.008)	BDL-0.028 (0.013)	BDL-0.054 (0.021)	BDL-0.029 (0.016)	BDL-0.17 (0.063)	BDL-0.02 (0.006)	BDL-0.01 (0.006)
Fe	BDL-0.340 (0.14)	BDL-0.43 (0.18)	BDL-1.16 (0.416)	BDL-0.50 (0.19)	BDL-0.73 (0.27)	BDL-0.36 (0.15)	BDL-0.43 (0.17)
Na	7.0-15.7 (11.67)	10.6-13.6 (12.37)	14.4-21.3 (16.93)	16.5-21.3 (18.3)	13.1-19.0 (15.76)	15.3-22.4 (17.7)	14.4-18.2 (16.17)
K	1.08-2.20 (1.64)	1.63-2.27 (1.95)	1.83-2.40 (2.11)	1.84-2.53 (2.18)	1.66-2.27 (1.96)	1.78-2.37 (2.07)	1.52-2.51 (2.01)

Table 27. Heavy metal accumulation (mg l^{-1}) in water-phase at identified sites of stretch, Below Harsud to Surpan of River Narmada.

Heavy Metal	Maheshwar	Khalghat	Hanfeshwar	Charbara	Gadher	Surpan
Na	5.9 -15.1 (10.5)	12.1-15.93 (14.01)	11.6 -15.77 (13.68)	14.0 -14.3 (14.15)	11.3 -13.57 (12.43)	14.1-15.3 (14.7)
*K	2.21	2.41	2.49	2.04	2.28	2.21
Mn	Tr - 0.01 (0.003)	Tr - 0.009 (0.003)	Tr – 0.02 (0.007)	BDL – Tr (Tr)	Tr – 0.01 (0.003)	Tr - 0.01 (0.003)
Zn	0.011 - 0.056 (0.032)	0.01 - 0.020 (0.013)	0.016 - 0.05 (0.030)	0.014 - 0.053 (0.029)	0.017 - 0.04 (0.026)	0.017 - 0.025 (0.020)
Fe	0.027 - 0.15 (0.101)	0.012 - 0.15 (0.080)	0.022 - 0.33 (0.184)	Tr – 0.107 (0.069)	Tr – 0.20 (0.10)	Tr – 0.14 (0.082)

Table 28. Heavy metal accumulation (mg l^{-1}) in water-phase at identified sites of stretch, below Surpan to Gulf of Cambay of River Narmada (average in parentheses)

Metal	Vedgam	Poicha	Sisodara	Velugam	Jhanor	Ankleshwar	Sakkarpura	Bhadbhut	Ambetha
Na	14.0 -17.5 (16.17)	14.1-18.10 (16.73)	15.1-20.5 (18.22)	16.47 -18.6 (17.82)	15.0 -20.0 (16.77)	15.8-22.8 (19.7)	36.3-96.83 (66.47)	22.9-146.8 (70.07)	231.37-2576.8 (1234.72)
Zn	0.03-0.057 (0.040)	0.02-0.075 (0.045)	0.02-0.032 (0.026)	0.02-0.042 (0.029)	0.03-0.040 (0.033)	0.007-0.034 (0.022)	BDL-0.051 (0.027)	0.006-0.040 (0.021)	0.03-0.132 (0.067)
Mn	0.002-0.02 (0.013)	BDL-0.017 (0.009)	BDL-0.028 (0.012)	BDL-0.031 (0.020)	BDL-0.023 (0.014)	BDL-0.03 (0.016)	BDL-0323 (0.111)	BDL-0.027 (0.016)	BDL-1.665 (0.575)
Fe	0.07-0.238 (0.139)	0.07-0.422 (0.197)	0.05-0.404 (0.194)	0.14 -0.447 (0.252)	0.21-0.288 (0.246)	0.17-0.80 (0.394)	0.11-0.283 (0.198)	0.08-0.513 (0.234)	0.20-11.19 (3.87)
K	1.57-2.73 (2.15)	0.86-2.73 (1.79)	0.99-2.64 (1.81)	1.06-2.63 (1.84)	0.86-2.23 (1.54)	2.32-2.39 (2.35)	8.58-13.19 (10.88)	7.09-14.25 (10.67)	307.84-471.84 (389.84)

Table 29. The demographic structure of fisher-families at sampling sites of stretch Amarkantak to Gadarwada of River Narmada

Unit			Mandla	Jabalpur	Narsingpur	Kareli	Gadarwada	Total
A.	**Fishermen families surveyed**							
i)	Single	Number	6 (60.00)	10 (66.67)	4 (40.00)	6 (60.00)	14 (87.50)	40 (65.67)
ii)	Joint	Number	4 (40.00)	5 (33.33)	6 (60.00)	4 (40.00)	2 (12.50)	21 (34.43)
iii)	Total	Number	10 (100.00)	15 (100.00)	10 (100.00)	10 (100.00)	16 (100.00)	61 (100.00)
B.	**Demographic structure**							
i)	Male	Adult Number	14	20	25	12	20	91
		Minor Number	13	20	17	15	28	93
		Total Number	27 (56.25)	40 (49.38)	42 (55.26)	27 (51.92)	48 (52.75)	184 (52.87)
ii)	Female	Adult Number	13	21	22	13	21	90
		Minor Number	8	20	12	12	22	74
		Total Number	21 (43.75)	41 (50.62)	34 (44.74)	25 (48.08)	43 (47.25)	164 (47.13)
iii)	Total	Adult Number	27 (56.25)	41 (50.62)	47 (61.84)	25 (48.08)	41 (45.05)	181 (52.01)
		Minor Number	21 (43.75)	40 (49.38)	29 (38.16)	27 (51.92)	50 (54.95)	167 (47.99)
		Total Number	48 (100.00)	81 (100.00)	76 (100.00)	52 (100.00)	91 (100.00)	348 (100.00)
C.	**Sex ratio (Male: Female)**		1.00:0.78	1.00:1.03	1.00:0.81	1.00:0.93	1.00:0.90	1.00:0.89
D.	**Adult minor ratio**		1.00:0.78	1.00:0.98	1.00:0.62	1.00:1.08	1.00:1.22	1.00:0.92
E.	**Average family size**							
		Male Number	2.07	2.67	4.20	2.70	3.00	3.02
		Female Number	2.10	2.73	3.40	2.50	2.69	2.69
		Adult Number	2.70	2.73	4.70	2.50	2.56	2.97
		Minor Number	2.10	2.67	2.90	2.70	3.13	2.74
		Total Number	4.80	5.40	7.60	5.20	5.69	5.71

Figures in the parentheses represented percent of total

Table 30. The literacy and employment level of fishermen at sampling sites of stretch Amarkantak to Gadarwada of River Narmada

Particular	Mandla	Jabalpur	Narsingpur	Kareli	Gadarwada	Total
A. Literacy						
i) Illiterate	31 (64.58)	56 (69.14)	75 (98.68)	37 (71.15)	85 (93.41)	284 (81.61)
ii) Primary	15 (31.25)	20 (24.69)	1 (1.32)	13 (25.00)	5 (5.49)	54 (15.52)
iii) Middle	2 (4.17)	5 (6.17)	—	2 (3.85)	1 (1.10)	10 (2.87)
B. Employment						
i) Employed	20 (41.67)	32 (39.51)	26 (34.21)	18 (34.62)	23 (25.27)	119 (34.20)
ii) Dependent	28 (58.33)	49 (60.49)	50 (65.79)	34 65.38)	68 (74.73)	229 (65.80)
C. Earner: Non-earner ratio	1:1.40	1:1.53	1:1.92	1:1.89	1:2.96	1:1.92

Figures in the parentheses represented percent of total

Table 31. The status of fishery requisites and income of fishermen at sampling sites of stretch Amarkantak to Gadarwada of River Narmada

Particular	Mandla	Jabalpur	Narsingpur	Kareli	Gadarwada	Total
A. Fisheries requisites						
1. Craft						
i) Owned	6 (60.00)	12 (66.67)	8 (40.00)	4 (60.00)	16 (87.50)	46 (65.67)
ii) Hired labour	1 (10.00)	1 (6.67)	—	—	—	2 (3.28)
iii) Other	3 (30.00)	2 (13.33)	2 (20.00)	6 (60.00)	—	13 (21.31)
2. Gear						
i) Gill	3 (30.00)	14 (93.33)	6 (60.00)	10 (100.00)	16 (100.00)	49 (80.33)
ii) Drag	3 (30.00)	4 (26.67)	2 (20.00)	—	1 (6.25)	10 (16.39)
iii) Cast	3 (30.00)	—	2 (20.00)	2 (20.00)	5 (31.25)	12 (19.67)
iv) Scoop	2 (30.00)	—	—	—	11 (68.75)	13 (21.31)
v) Hook and line	1 (10.00)	1 (6.67)	5 (50.00)	2 (20.00)	14 (87.50)	23 (37.70)
B. Average annual effort (days)	286.50	277.27	348.70	365.00	353.50	325.75
C. Average annual catch (kg)	772.05	480.20	628.55	679.25	611.55	619.45
D. Average annual income (Rs)						
i) Fisheries	10747.90	11241.37	18940.80	21198.90	14398.19	14883.07
ii) Alternative	6990.00	5325.00	9220.00	3220.00	4875.00	5585.50
Total	17737.90	16566.37	28160.80	24318.90	19273.19	20468.57

Figures in the parentheses represented percent of total

Table 32 The population and family structure at sampling sites of stretch below Harsud to Surpan of River Narmada

Unit		Maheswar	Khalghat	Rangan	Malitha	Kothiya	Total
A. Population							
i) Total	Number	3000	15000	5000	Not recorded	4000	27000
ii) Fishermen	Number	950	750	2000	Not recorded	850	4550
		(31.67)	(5.00)	(40.00)	—	(21.25)	(16.85)
B. Fishermen families surveyed							
i) Single	Number	2	0	4	0	2	8
ii) Joint	Number	4	3	3	1	1	12
iii) Total	Number	6	3	7	1	3	20
C. Demographic structure							
i) Male	Adult Number	16	6	13	2	6	43
	Minor Number	2	6	7	0	2	17
	Total Number	18	12	20	2	8	60
		(48.65)	(54.55)	(48.78)	(50.00)	(53.33)	(50.42)
ii) Female	Adult Number	14	7	12	2	6	41
	Minor Number	5	3	9	0	1	18
	Total Number	19	10	21	2	7	59
		(51.35)	(45.45)	(51.22)	(50.00)	(46.67)	(49.58)
iii) Total	Adult Number	30	13	25	4	12	84
		(81.08)	(59.09)	(60.98)	(100.00)	(80.00)	(70.59)
	Minor Number	7	9	16	0	3	35
		(18.92)	(40.91)	(39.02)	(0.00)	(20.00)	(29.41)
	Total Number	37	22	41	4	15	119
		(100.00)	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)
D. Sex ratio	(Male : Female)	0.95:1.00	1.20:1.00	0.95:1.00	1.00:1.00	1.14:1.00	1.02:1.00
E. Adult minor ratio		1.00:0.23	1.00:0.69	1.00:0.64	—	1.00:0.25	1.00:0.42
F. Average family size							
	Male Number	3.00	4.00	2.86	2.00	2.67	3.00
	Female Number	3.17	3.33	3.00	2.00	2.33	2.95
	Adult Number	5.00	4.33	3.57	4.00	4.00	4.20
	Minor Number	1.17	3.00	2.29	0.00	1.00	1.75
	Total Number	6.17	7.33	5.86	4.00	5.00	5.95

Figure in the parentheses represent percent of total

Table 33. The literacy and employment level of fishermen at sampling sites of stretch below Harsud to Surpan of River Narmada

Particular	Maheswar	Khalghat	Rangan	Malitha	Kothiya	Total
A. Literacy						
i) Illiterate	23 (62.16)	8 (36.36)	29 (70.73)	3 (75.00)	13 (86.67)	76 (63.87)
ii) Primary	11 (29.73)	8 (36.36)	5 (12.20)	1 (25.00)	2 (13.33)	27 (22.69)
iii) Middle	3 (8.11)	6 (27.28)	7 (17.07)	- (13.44)	-	16
B. Employment						
i) Employed	23 (62.16)	8 (36.36)	29 (70.73)	4 (100.00)	10 (66.67)	74 (62.18)
ii) Dependent	14 (37.84)	14 (63.64)	12 (29.27)	-	5 (33.33)	45 (37.82)
C. Earner : Non-earner	1 : 0.61	1 : 1.75	1 : 0.41	1 : 0.0	1 : 0.50	1 : 0.61

Figure in the parentheses represent per cent of total

Table 34. The status of fishery requisites and income of fishermen at sampling sites of Stretch below Harsud to Surpan of River Narmada

	Maheswar	Khalghat	Rangan	Malitha	Kothiya	Total
A. Fisheries requisites						
1. Craft						
i) Owned	5	3	7	1	3	19
ii) Hired labour	1	0	0	0	0	1
2. Gear						
i) Gill	5	2	5	1	3	16
ii) Drag	2	2	5	-	2	11
iii) Cast	4	2	5	1	2	14
iv) Hook and line	2	1	0	0	0	3
v) Other	2	0	1	0	0	3
B. Average annual catch (Kg)	1368.75	1064.58	4051.56	547.50	1277.50	2002.43
Average annual income (Rs)						
i) Fisheries	41746.92	38020.92	62519.32	19462.50	49579.17	48503.98
ii) Alternative	21350.00	15700.00	14514.29	16200.00	4550.00	15332.50
Total	**63096.92**	**53720.92**	**77033.61**	**35662.50**	**54129.17**	**63836.48**

Fig. 1: Scoop net (Pelna) fishing at Gadarwada site

Fig. 2: Catfish caught by a gull

Fig. 3: A gillnet (Phasla) getting prepared for fishing

Fig. 4: A *Macrobrachium rosenbergii* haul

Fig. 5: A fish market in Hoshangabad

Fig. 6: *Tor tor,* a prized fish of river Narmada

Fig. 7: Fish catch haul from Dongarwada site

Fig. 8: Rajpipla Fish market Dist. Narmada (Gujarat)

Fig. 9: Participation of women in fish marketing at Kutupura, District Bharuch

Fig. 10: Drag netting operation in middle stretch

Fig. 11: Drag net in operation in middle stretch

Fig. 12: Traditional cast net (Bohar jal)

Fig. 13: Cast net (Bohar Jal) in operation at Hoshangabad

Fig. 14: Hoshangabad city sewage at Nalaghat

Fig. 15: Hoshangabad city sewage before confluence at Nalaghat

Fig. 16: Birds getting attracted after dynamite fishing

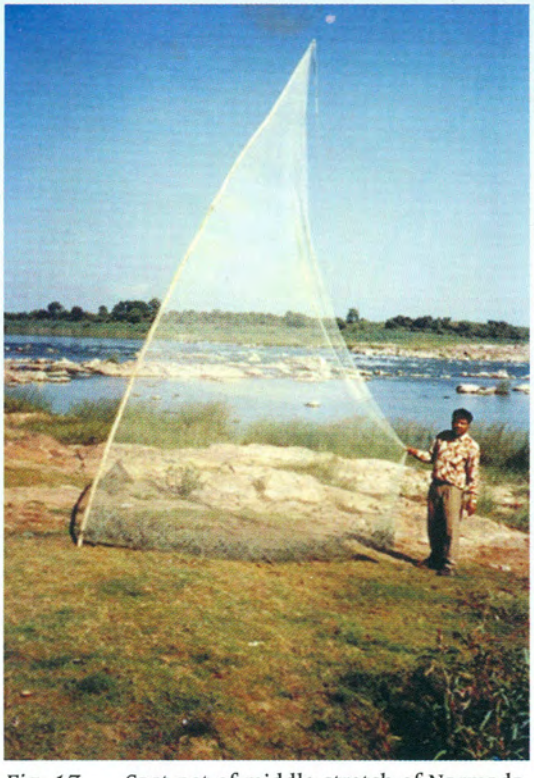

Fig. 17: Cast net of middle stretch of Narmada

Fig. 18: Narmada Sagar dam site

Fig. 19: River flowing through rocky terrain

Fig. 20: Traditional craft (Donga)

Fig. 21: Macrophytic infestation during summer at Shahganj site

Fig. 22: *Tenualosa ilisha* haul at Bhadbhut site

Fig. 23: Smoking of fishes in lower estuary at Shakkarpura

Fig. 24: Mudskipper fishing at Ambetha site in lower Narmada estuary

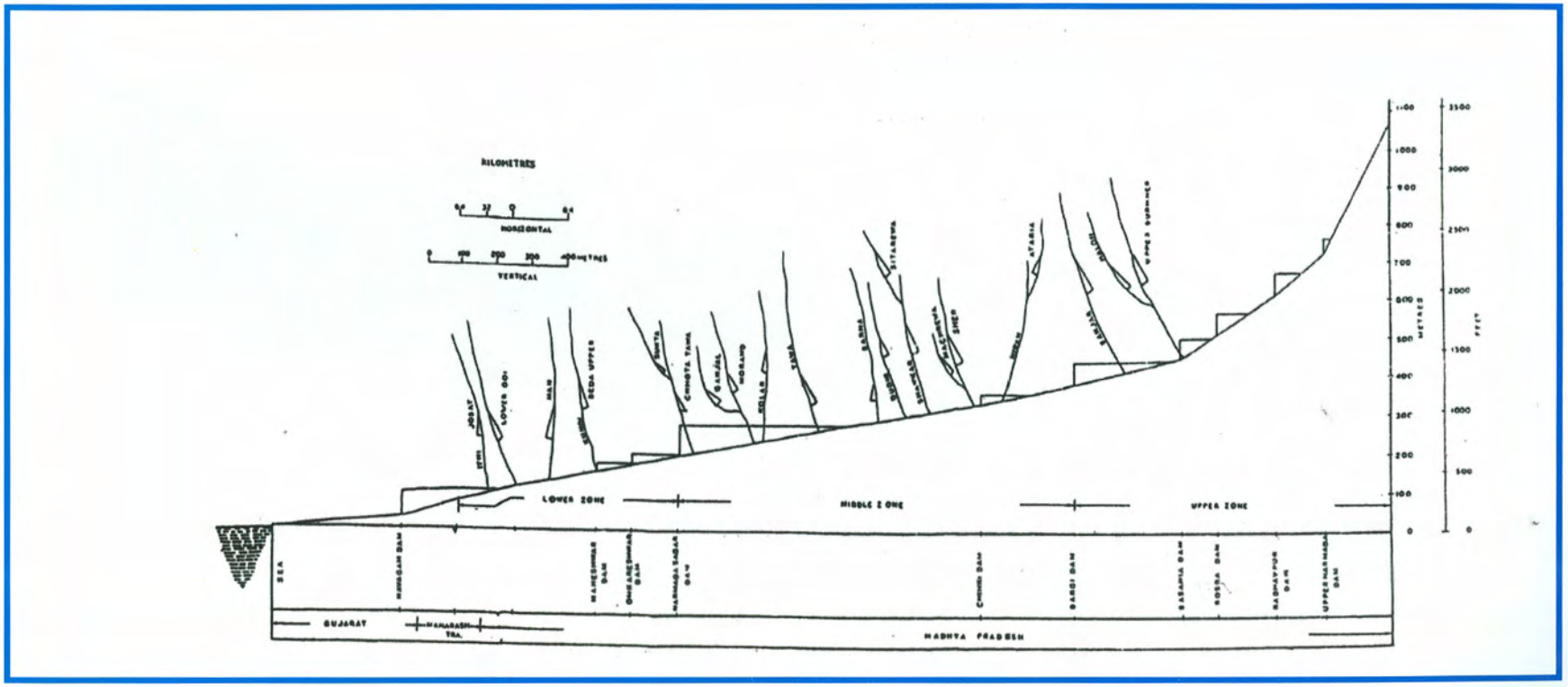

Fig. 1. Longitudinal section of Narmada River showing major proposed projects

- **Sampling Site**

1. Amarkantak
2. Mandla
3. Jabalpur
4. Narsinghpur
5. Kareli
6. Gadarwada
7. Sandia
8. Shahganj
9. Hoshangabad
10. Dongarwada
11. Gondagaon
12. Handia
13. Mola
14. Maheshwar
15. Khalghat
16. Hanfeshwar
17. Charbara
18. Gadher
19. Surpan
20. Vedgam
21. Poicha
22. Sisodara
23. Velugam
24. Jhanor
25. Ankaleshwar
26. Shakkarpura
27. Bhadbhut
28. Ambetha

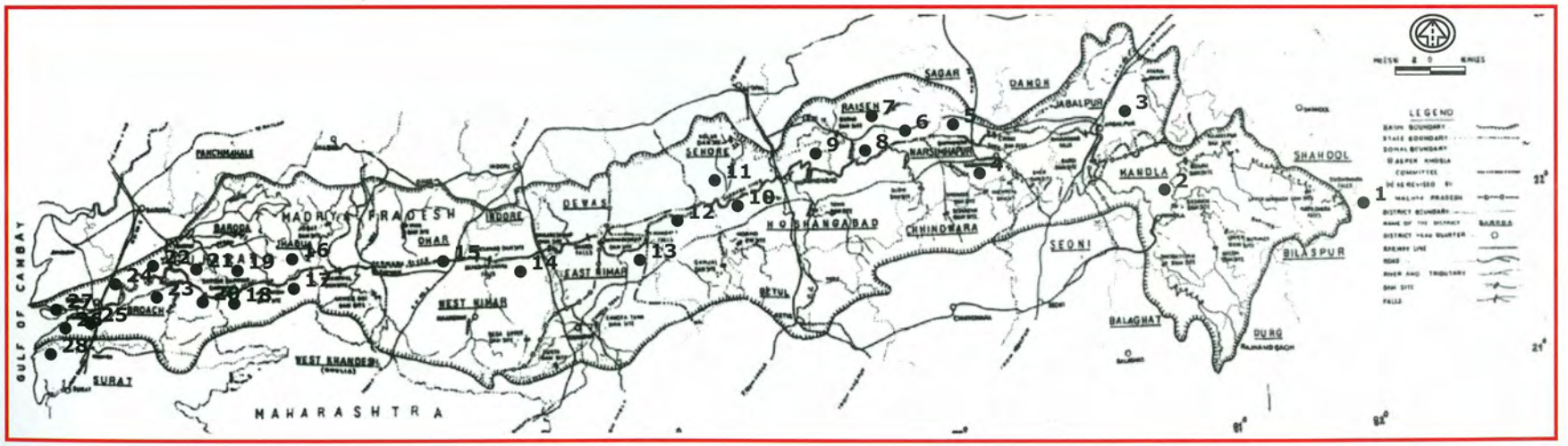

Fig. 2. Narmada River Basin showing impoundments and the sampling sites

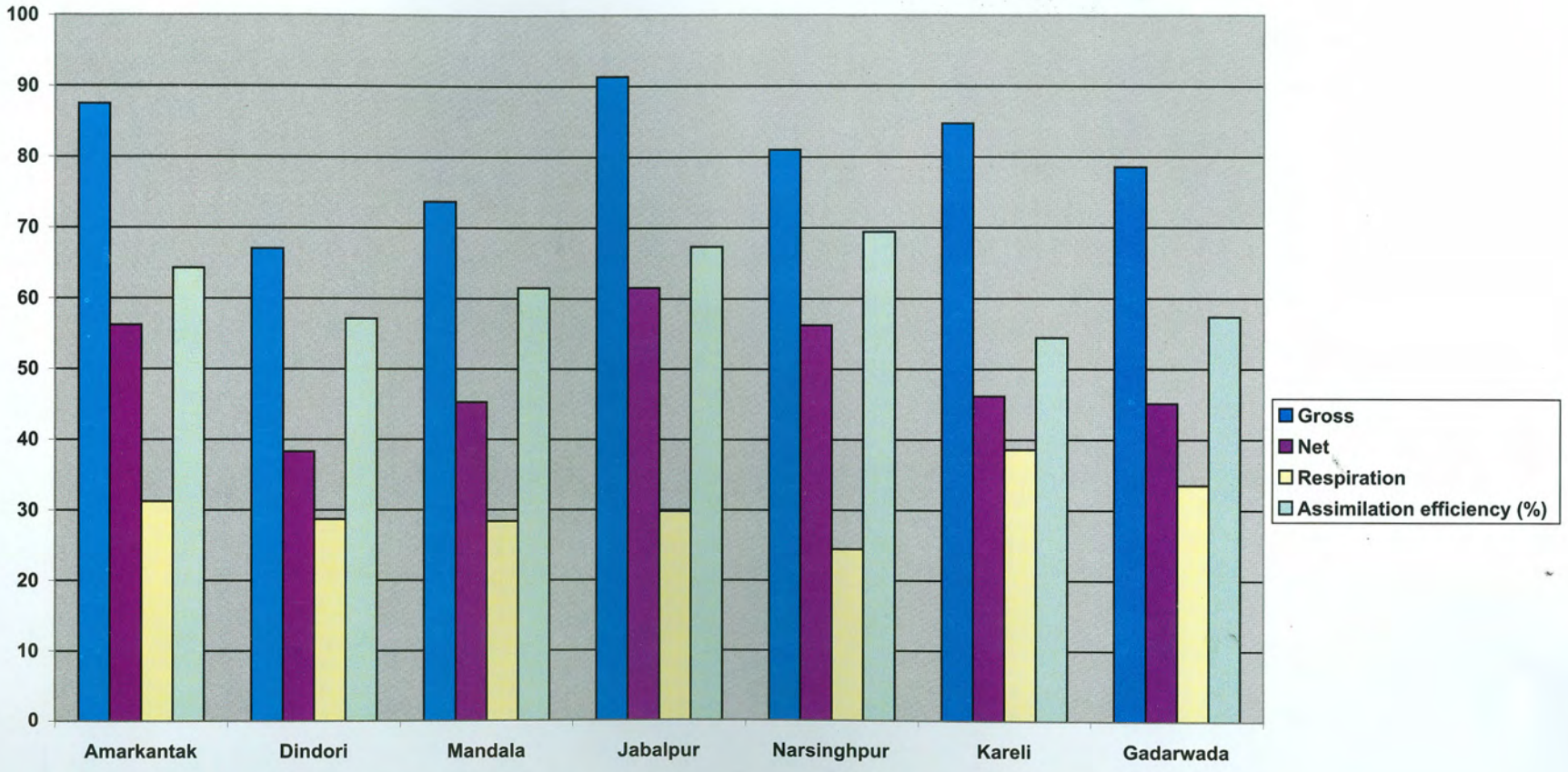

Fig. 3 Primary Production Rate(mg C m^{-3} hr^{-1}) and Assimilation Efficiency(%) at identified sites of stretch Amarkantak to Gadarwada of River Narmada

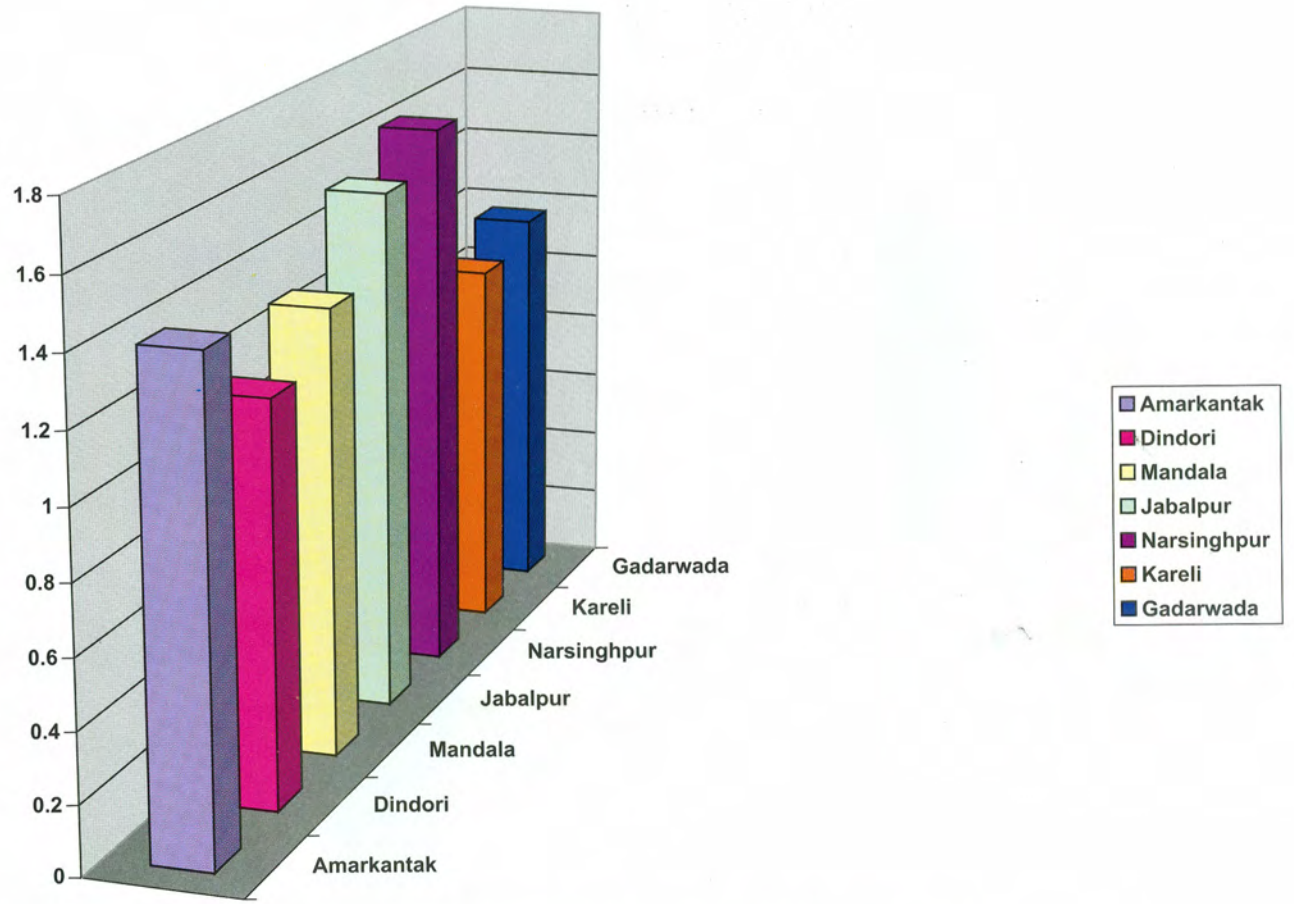

Fig. 4. P/R Ratio at identified sites of stretch Amarkantak to Gadarwada of River Narmada

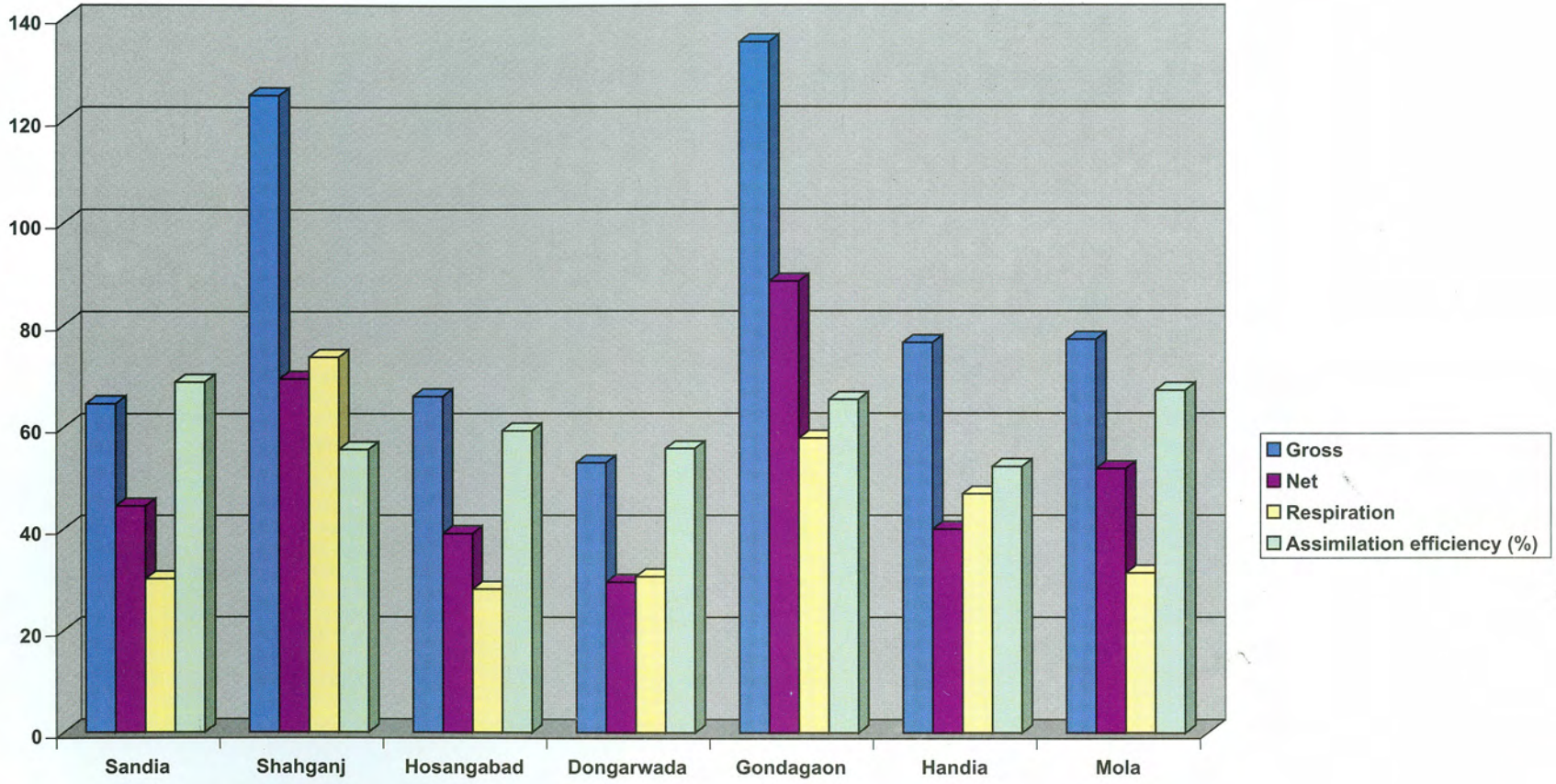

Fig. 5 Primary Production Rate (mg C m^{-3} hr^{-1}) and Assimilation efficiency(%) at identified sites of stretch below Gadarwada to Harsud of River narmada

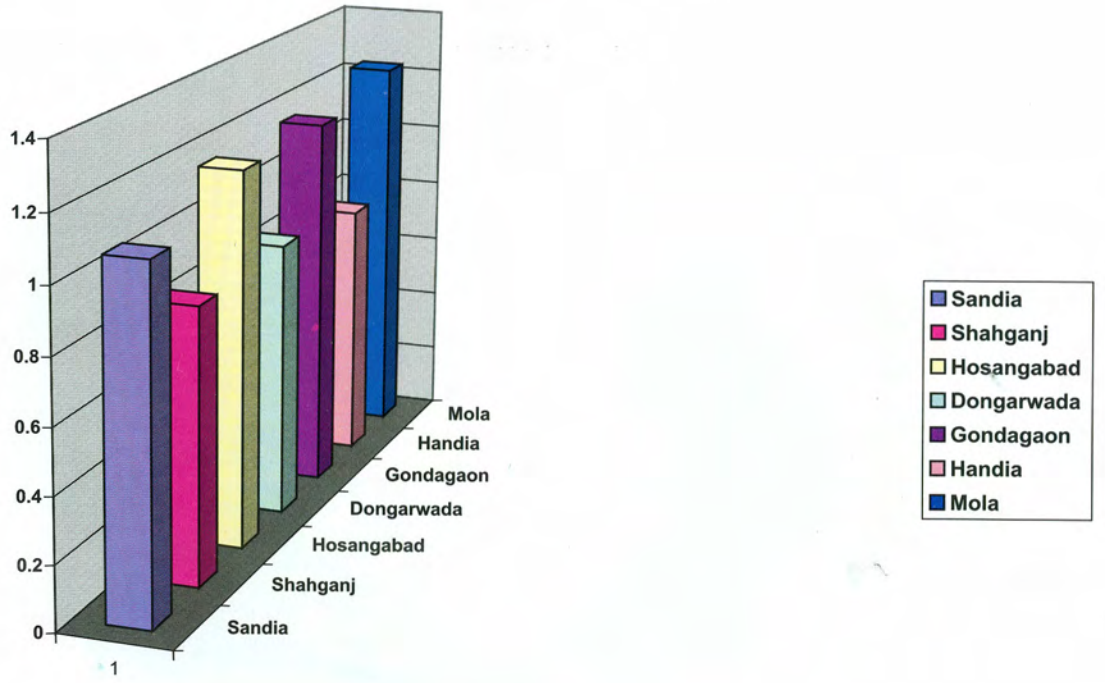

Fig. 6 P/R ratio at identified sites of stretch below Gadarwada to Harsud of River Narmada

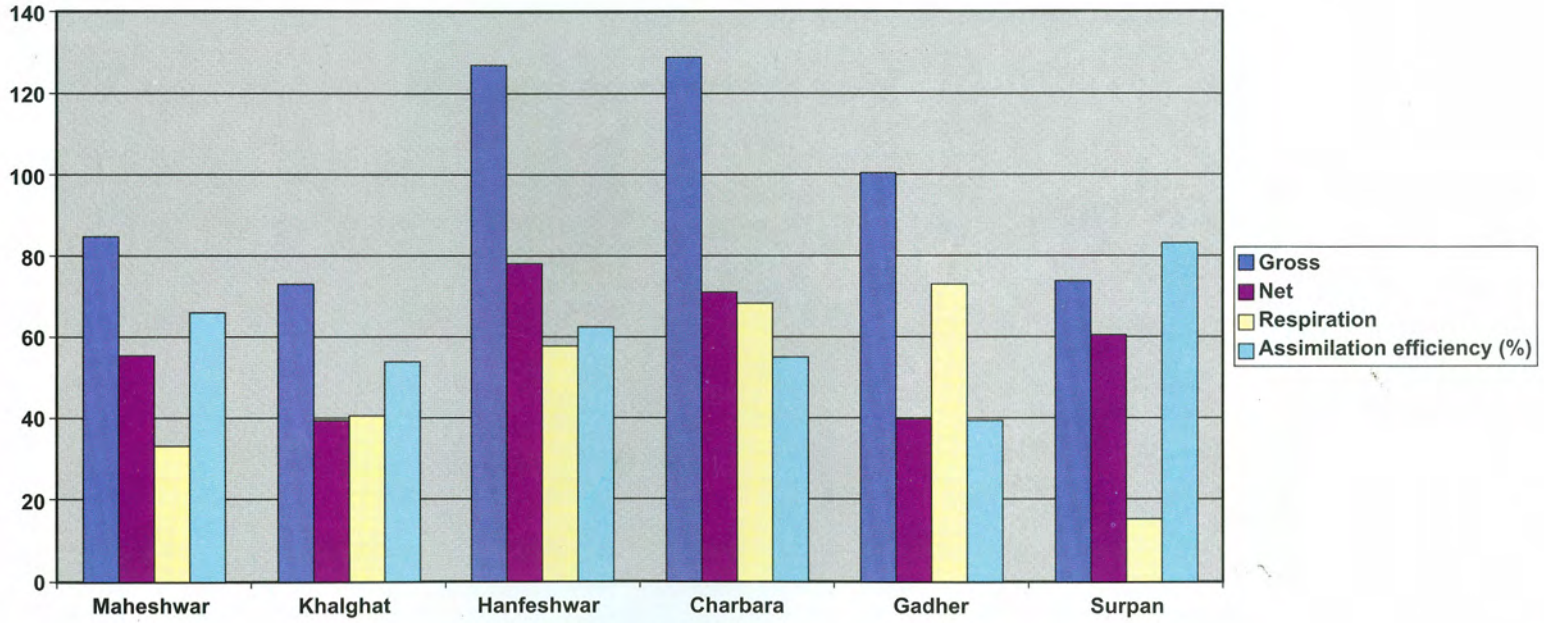

Fig. 7 Primary Production Rate (mg Cm^{-3} hr^{-1}) and Assimilation Efficiency (%) at identified sites of stretch below Harsud to Surpan of River Narmada

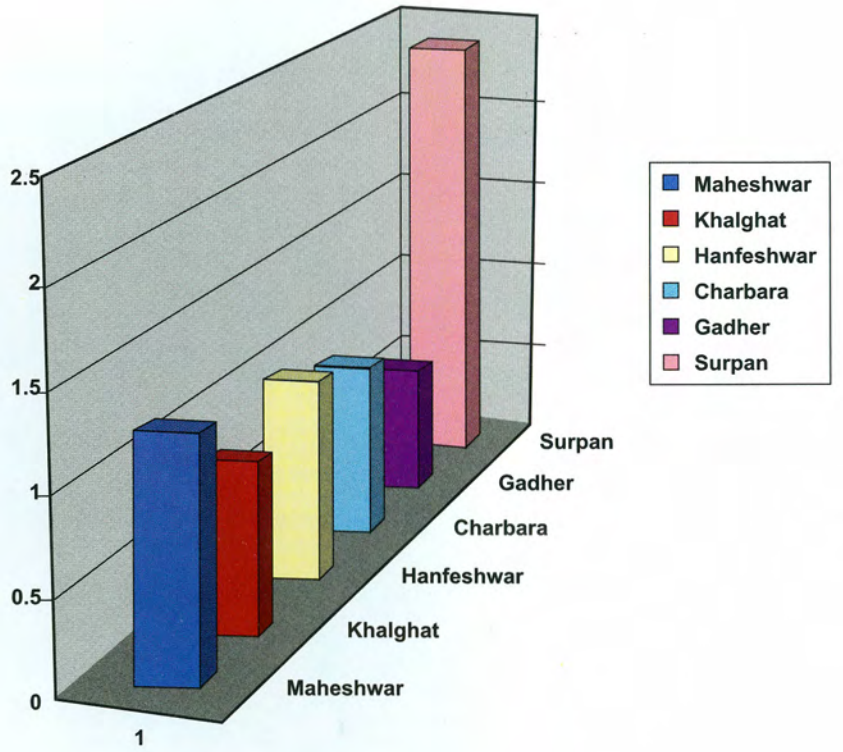

Fig.8 P/R ratio at identified sites of stretch below Harsud to Surpan of River Narmada

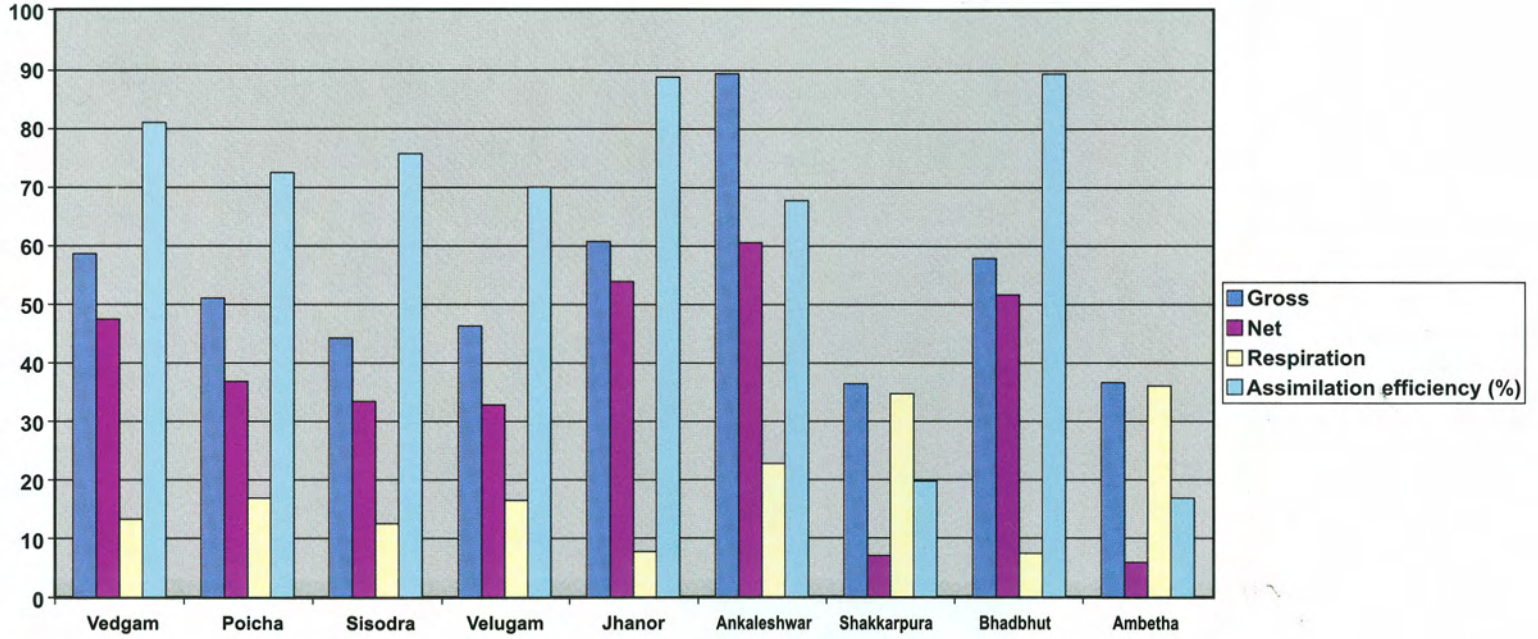

Fig9 Primary Production Rate (mg Cm^{-3} hr^{-1}) and Assimilation Efficiency (%) at identified sites of stretch below Surpan to Gulf of Cambay

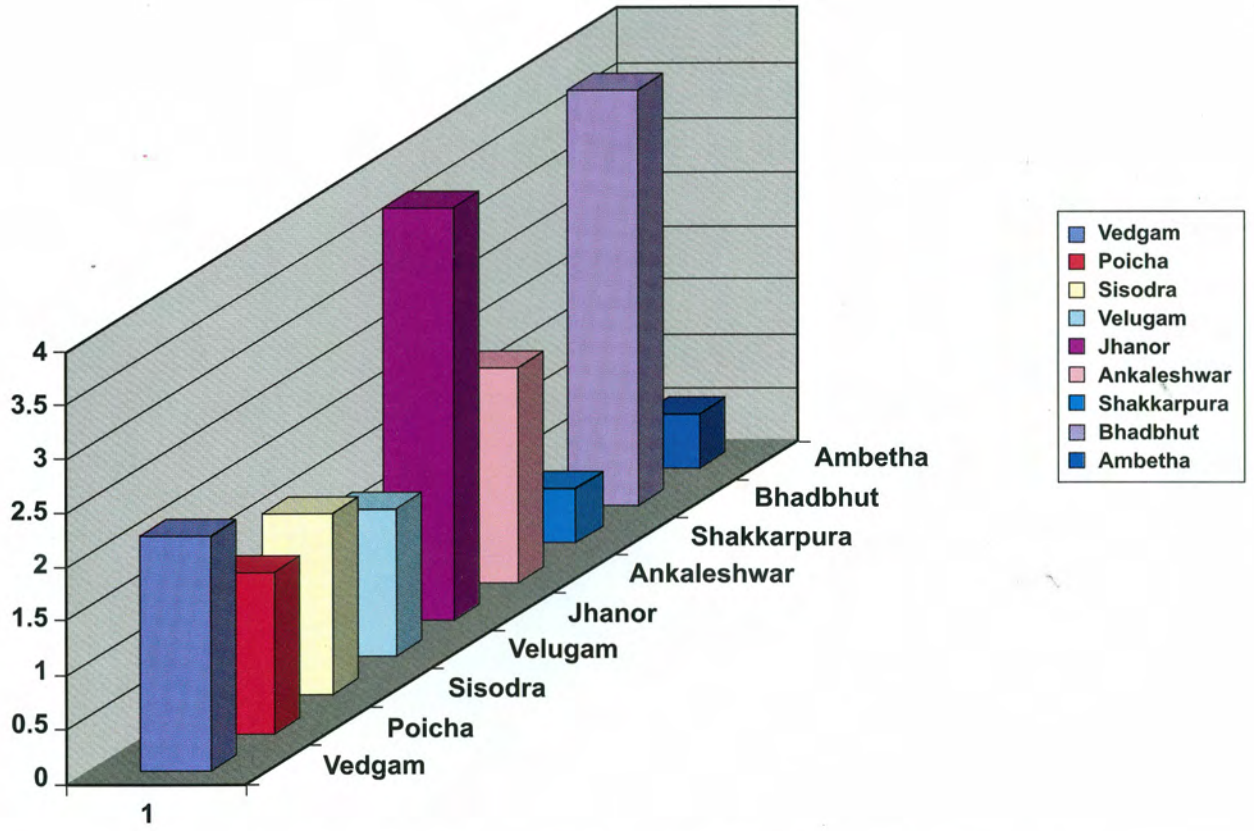

Fig.10 P/R ratio at identified sites of stretch below surpan to Gulf of Cambay of River Narmada

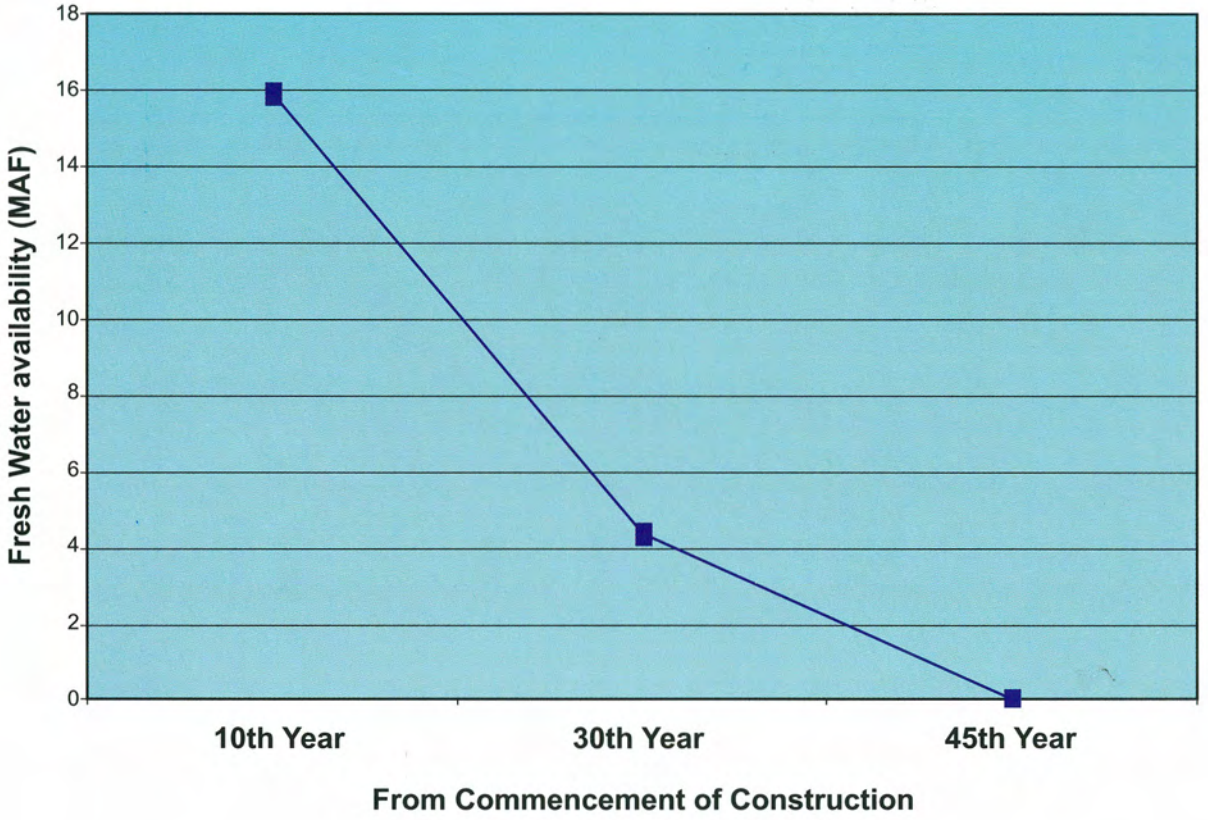

Fig.11. Fresh Water availability as per Narmada Water Dispute Tribunal Award