International Journal of Water Resources and Environmental Engineering Vol. 2(7), pp. 164-173, November 2010
Available online at http://www.academicjournals.org/ijwree
ISSN-2141-6613 ©2010 Academic Journals

Full Length Research Paper

Environmental flows in Bhadra River, Karnataka, India

B. K. Harish Kumara, S. Srikantaswamy* and Shakuntala Bai

Department of Studies in Environmental Science, University of Mysore, Manasagangotri Mysore – 570 006, India.

Accepted 16 September, 2010

Environmental water requirements, also referred as 'environmental flows', are a compromise between water resources development and the maintenance of a river in ecologically acceptable or agreed condition. Managing environmental water flow is a complex task because the change of quantity of water occurs as the flow moves downstream. In this work, an attempt has been made to evaluate the existing conditions of the water flow in the Bhadra River at Lakkavalli, Shimoga District, Karnataka State, India and the significance of the ecosystem services through environmental flows. The possible impacts from the absence of environmental flows have also been recorded. The study involves an analysis of water flow status of Bhadra River for thirty years and also the field investigations which cover complete livelihood dependent fishermen communities and command area dependent agricultural communities. The upper catchment of the river is covered with good vegetation; the downstream of the river for 40 km has shrunken in its river bed due to the Bhadra dam, the river flow is completely irregular over a period of years. It has altered the natural flow, resulting in massive loss of riparian, aquatic habitat and water quality. Local communities are aware of the importance of environmental flows and have also realized the damages done by themselves through encroachments of flood plains and river bed for agricultural activities. More than 60% of the downstream dwellers have changed their livelihood occupations, and also migration level has increased in the fishermen communities. Communities have been impacted by irregular dry season water level fluctuations, which are characterized by extreme highs and lows, and rapid changes in water levels.

Key words: Environmental flows, ecosystem services, Bhadra River, water environment, livelihood support.

INTRODUCTION

Hydraulic civilizations have highly valued importance of water in human life and in the entire ecosystem. Degradation of ecosystem services has resulted in both social and economic costs. Affected people are largely from poorer sections. Recognizing the full value of the ecosystem services and investing in them accordingly can safeguard livelihoods in the future, which can help to achieve sustainable development goals. Failing to do so may cause serious damages to the ecosystems (Dyson et al., 2003; Millennium Ecosystem Assessment, 2005; Pearce et al., 2007). It is estimated that more than 60% of the world's rivers are fragmented by hydrological alterations. This has led to widespread degradation of aquatic ecosystems (Millennium Ecosystem Assessment, 2005; Dyson et al., 2003; Postel and Richter, 2003; Revenga et al., 2005; Poff et al., 1997). The Natural Flow Paradigm where the natural flow regime of a river is recognized as vital to sustaining ecosystems has now been widely accepted. This recognition of flow as a key driver of aquatic ecosystems has led to the development of the environmental flows concept (Dyson et al., 2003).

According to the World Bank's recently approved Water Resources Sector Strategy, "the environment is a special 'water-using sector' in that most environmental concerns are a central part of overall water resources management, and not just a part of a distinct water using sector'' (Richard and Hirji, 2003). Until recently, in Asian countries, the concept of environmental flows have related primarily to the flows required to flush the river systems and restore water quality. In these regions, the western concept of 'environmental flows' is nowadays

*Corresponding author. E-mail: srikantas@hotmail.com. Tel: +91-821-2410552 (O), +91-9448275348.

represented by the terms ‘ecological and environmental water requirements’ (EEWR), ‘ecological water demand’ and ‘eco-environmental water consumption’ (Song and Yang, 2003).

‘‘Environmental flows (EF)’’ refers to water considered sufficient for protecting the structure and function of an ecosystem and its dependent species. This flow requirement is defined by both long-term availability of water and its variability and is established through environmental, social, and economic assessment (King et al., 2003; Dyson et al., 2008; Christer et al., 2005). Environmental flows describe the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems (Brisbane declaration, 2007).

Undisturbed rivers are generally seen as healthy because their channels and species have evolved over long periods of time in harmony with their different environments, so that they process resources most efficiently. Their valued attributes include reliable, good-quality water supplies, floodplain fisheries, and stable banks. With increasing disturbance, rivers lose valued attributes and new attributes appear. Often, the new attributes are less welcome than the old; they can include, for instance, pest flies, unreliable water supply, and algal blooms. The trend is one of increasing degradation. The condition, in which aquatic ecosystems and their services are maintained, is essentially a socio-political decision. The objectives of this study is to carryout an evaluation of the present environmental flow rates in Bhadra River and assess the potential benefits, consequences and examine whether environmental flows have been maintained or not.

MATERIALS AND METHODS

Many early applications of environmental flow assessments (EFA) were focused on single species. As a result, environmental flows were set to maintain critical levels of habitat for these species. However, managing flows without consideration for other ecosystem components may fail to capture the system processes and biological community interactions that are essential for creating and sustaining the habitat and well-being of that target species. Recent advances in EFAs reflect this knowledge and EFA methodologies increasingly take a holistic approach (King and Brown, 2006; in stream Flow Council, 2002). The overview of EF assessment methods were shown in Table 1. The analytical methods have undergone considerable change over the years due to the contribution from various research groups. Dyson and his co workers (2003) have worked extensively on look up tables, desktop analysis, functional analysis and habitat modeling. In the most recent review of international environmental flows assessments, Tharme et al. (2003), recorded 207 different methods within 44 countries, wherein a series of experiments were conducted and finally the holistic approach was found to be the most suitable method which could be applied in such studies.

The present study has been carried out using both desktop analysis and field investigations covering two modules for the assessment of the environmental flows (EF) in study area, viz: (a) Biophysical assessment; (b) Socio-economic assessment.

Biophysical assessment

In the present study thirty year data of inflow and outflow of Bhadra Reservoir Project (BRP) were analyzed and also compared was the flow status with the benchmarking of available methods. The existing flow status was compared with French fisheries law method and Montanna method of environmental flow assessment. It has given the physical status of the river flow over a period of time.

Socio-economic assessment

Socio-economic studies have been carried out on the river course by analyzing common-property users for subsistence, and the river-related health profiles of these people and their livestock. Questionnaires, both closed and open-ended and focus group discussions were used to collect household-wise information on water utilization and its conservation. A survey was conducted in the downstream of Bhadra Reservoir Project, which covered 5 villages along the bank of the river. All these studies have been linked to the flow, with the objective of predicting how the people have been affected by specified river changes.

Study area

Bhadra River is a tributary of the River Tungabhadra (Figure 1). Bhadra rises near Samse in the Aroli hill range of Kudremukh latitude 13° 15' 70" N and longitude 75° 09' 42" E, Karnataka State, India. Bhadra river initially flows east, changing course to north and joins Tunga at Kudli latitude 75°40'32.61"E and longitude13°59'43.75"N in Shimoga District. Tungabhadra River flows up to 298 km and is formed by the confluence of Tunga and Bhadra rivers at Kudli of Shimoga District, then flows through Karnataka and some part of Andhra Pradesh and joins River Krishna. The catchment and command area comprises of seven districts and 27 taluks and covers an area of 48,000 km^2. This study has been conducted in the downstream of Bhadra River, which flows 186 km from the origin and meets with Tunga River. Bhadra catchment covers Chikamagalur, N. R. Pura taluks and the command area covers Tarikere, Bhadravati, Channagiri, Honnali, Davanagere, Harihar taluks. Catchment and command area of Bhadra river covers three districts, Chikamagalur, Shimoga and Davanagere.

The survey covered five villages on both right and left banks of the river, namely: Gondi, Thallikatte, Kagekodamagge, Baballi and Balehonnur. It is commonly seen throughout the world that land use pattern changes rapidly, which is similar in the case of the study area. The wasteland and fallow land show a decreasing trend and net sown areas show an increasing trend, reasons being increasing population over time and also increase in the extraction of groundwater for cultivation. Two important sanctuaries in the reach of Bhadra River are Kudremukh National Park with a geographical area of 563.28 km^2 and Bhadra Tiger reserve with 492.46 km^2 of geographical areas as shown in Table 2. Kudremukh National Park has a significant biodiversity cover, with different kinds of vegetation cover. Bhadra wildlife Sanctuary is well known because of its Tiger Conservation project. The immediate vicinity of Bhadra Dam is covered by rich forest cover. However, this forest cover goes on diminishing as we move away from the dam.

Situational analysis

The main source of drinking water for the Bhadra River catchment and command area is both surface as well as groundwater. One major reservoir has been built across the river Lakkavalli, latitude 75° 38' 9" E and longitude 13° 42' 35" N a small village in

Table 1. Overview of environmental flow assessment methods.

Organization	Categorization of methods	Sub-category	Example
IUCN (Dyson et al., 2003)	Methods	Look-up tables	Hydrological (e.g. Q95 index) ecological (e.g. tennant method)
		Desk-top analyses	Hydrological (e.g. Richter method) hydraulic (e.g. wetted perimeter method)
		Functional analyses	BBM, expert panel assessment method, benchmarking methodology
		Habitat modeling	PHABSIM
	Approaches		Expert team approach, stakeholder approach (expert and non-expert)
	Frameworks		IFIM, DRIFT
World Bank (King and Brown, 2003)	Prescriptive approaches	hydrological index methods	Tennant method
		Hydraulic rating methods	Wetted perimeter method
		Expert panels	
		Holistic approaches	BBM
	Interactive approaches		IFIM DRIFT
IWMI (Tarme, 2003)	Hydrological index methods		Tennant method
	Hydraulic rating methods		Wetted perimeter method
	Habitat simulation methodologies		IFIM
	Holistic methodologies		

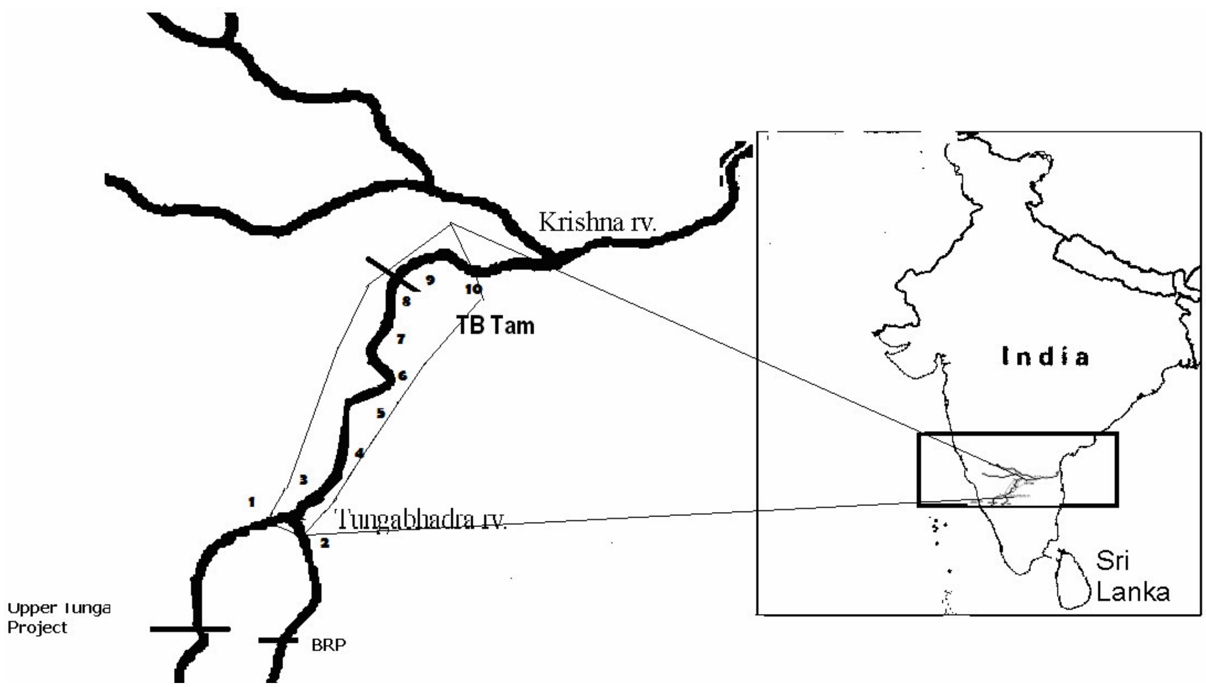

Figure 1. Map of study area, Tungabhadra River.

Table 2. List of wildlife sanctuaries in the Basin.

Circle	Division	Name of the wildlife wing	Geographical area (km^2)
Mangalore circle	Kudremukh wildlife division	Kudremukh national park	563.28
Chikamagalur circle	Wildlife division, Chikamagalur	Bhadra wildlife sanctuary	492.46

Source: Annual report 2004-2005, Karnataka Forest Department.

Table 3a. Designed and actual area for surface water irrigation in Ha.

Source	Designed irrigable area in ha	Actual area irrigated in ha (2004 -2005)
Reservoirs	629,013.00	437,876
Minor irrigation tanks	37,006.36	
ZP and TDP tanks	26,137.00	44,015
Total area irrigated by the tanks	63,143.36	
Total area irrigated from surface water sources	692,156.36	481,891

Table 3b. Number of tanks, storage and designed command area.

Tanks	Number	Designed storage capacity in TMC ft	Total designed command area in ha
Minor Irrigation	401	8.40	37,006
Total ZP and TDP tanks	4,037	5.98	26,137
Total number of tanks (MI + ZP + TDP)	4,438	14.38	63,143

Chikamagalur district. The designed capacity for the storage of water allocated for Bhadra Reservoir Project (BRP) is 67 thousand million cubic feet (TMC/ft). Tanks are another source of surface water. Details of the surface water sources and their usage across various sectors have been shown in Tables 3a and b. The available total water in the designed area for surface water irrigation is 692,156.36 ha, out of which the irrigation from reservoirs is 629,013 ha and from Tanks is 63,143.36 ha. This clearly indicates that about 1/3rd of the area are not being irrigated.

The major types of industries in the study area are Iron and Steel, Paper and Pulp, Chemical and Sugar. Across the river Bhadra, the major industries are Kudremukh Iron Ore Company Ltd (presently closed), Mysore Paper Mills and Vishweshvarayya Iron and Steel Industries. In addition, there were 59,500 small-scale industries as on 2006-2007 with an investment of 117,494 lakhs (Department of Industries and commerce). Water allocated for agriculture, drinking and industrial uses is shown in Table 4. Water consumption patterns across the sections clearly shows that a major portion of water is utilized for agricultural purposes. It is also to be noted that water consumption is comparatively higher in the industrial sector than in the domestic sector.

RESULTS

The population growth detail shows that urban population is increasing, putting more pressures on infrastructure. Particularly between 1991 and 2001, there was 36% increase while the rural population showed a decreasing trend (Table 5). The forests in upper reaches of the river are of wet deciduous type. The inner slopes are covered by grassy downs with wet deciduous semi-evergreen shoals. On the outer edges of Lakkavalli area, the forests tend to intergrades into dry deciduous type. On the whole, Muthodi area is wetter and more and more verdant than Lakkavalli, particularly during the dry seasons.

Agriculture is the main occupation in the Bhadra river catchment and command areas. Cultivation of water demanding crops like sugarcane and paddy and spread of bore wells are causative factors. Both surface and subsurface water meet the drinking water requirements for various human settlements across the basin. The water usage liter per capita per day ranges from 70 to 135 lpcd across the towns. None of the urban settlements on the river bank has sewage treatment plants. The sewage from the Urban Local Bodies (ULBs) is directly discharged into the River system or into the agricultural fields of the villages located along the river basin.

The average flow status from the Bhadra reservoir of 33 years is shown in Table 6 and Figure 2. It is compared with the existing standard methods, French fisheries law and Montana method. It clearly indicates that the flow

Table 4. Total water consumption across sectors.

Sectors	Bhadra in TMC
Agriculture	62.00
Drinking water	1.46
Industries	1.54
Total	3.00

Table 5. Population growth of the River Basin.

Year	Population	
	Urban	Rural
1961	3,184,585	2,444,369
1971	3,851,098	3,005,054
1981	5,456,334	3,905,472
1991	6,162,941	4,727,507
2001	9,669,701	5,402,166

Source: Census of India, 1961 – 2001.

varies over the years (Figure 3). During the monsoon season the flow is moderate. Utilization from the reservoir is high. It is interesting to note that in some years, during non-monsoon periods, while the inflow is nil, outflow from the reservoir is high. From the field observation it is found that, this is mainly due to the commitments with the downstream users, industries and some cultural festivals. From earlier agricultural pattern of semi arid crops entire basin has shifted to water intensive crops wherever possible.

DISCUSSION

Ecology of the River

Based on the ecology of the River, the entire river stretch can be divided into two distinct regions, as thus explained.

Region 1: Region of surplus

This area comprises from point of origin to Badhra Reservoir Project near Lakkavalli. Somavahini River, draining the area inside the crater, passes through a narrow gap in the mountain wall and joins Bhadra River at Hebbe. Bhadra is dammed up at BR project area forming a vast (about 100 km^2) reservoir whose backwaters extend nearly 13 km backwards. In addition to these major water sources, there are numerous streams and tanks scattered all over the area, some of them being perennial in nature.

Region 2: Controlled flow region

This area comprises from BRP till Kudli where it confluences with River Tunga. During the monsoon period, this region has natural flows while in lean periods, flows governed by agreement with Tungabhadra (TB) board is available. The region is remarkable with intensive cultivation and also the domestic and industrial waste water discharge to the main River. In this region, some of the places are severely under the controlled flow from Bhadravathi first urban settlement after Bhadra reservoir to Kudli, due to major industrial waste discharge and urban wastes.

Ecosystem services in the River Basin

Environmental flows mean enough water left in the rivers, which manages to ensure downstream environmental, social and economic benefits. Aquatic ecosystems, such as rivers, provide a great variety of benefits to the people. These include ‘goods’ such as clean drinking water, fish and fibre, and ‘services’ such as water purification, flood mitigation and recreational opportunities. Healthy rivers and associated ecosystems also have an intrinsic value to the people which may be expressed in terms of cultural significance, particularly to indigenous cultures. This intrinsic value is often overlooked as it is difficult to identify and quantify. A distinction may be made here between the amount of water needed to maintain an ecosystem in close-to-pristine condition, and that which might eventually be allocated to it, following a process of environmental, social and economic assessments. The latter is referred to as the ‘environmental flow’, and it will be a flow that maintains the ecosystem in a less than pristine condition. Intuitively, it might be seem that all of the natural flow, in its natural pattern of high and low flows, would be needed to maintain a near-pristine ecosystem, however, that some small portion of flow could be removed without measurable degradation of the ecosystem. How much could be removed in this way is more difficult to assess. A summary of the present ecosystem services by Bhadra River have been summarized in the Table 7. From the available data it is evident that most of the ecosystem services in regions I and II are of significance. Local communities are completely dependent on the provisional services, like livelihood support, fishing, livestock, fuel wood collection, fodder collection. Supporting services like groundwater recharge, seed dispersal, meeting water demands are also significant. Any alterations in these services would remarkably affect the life and sustenance of local communities.

Humankind usually benefits from resources and processes that are supplied by the natural ecosystems. Collectively, these benefits are known as ecosystem services which are directly dependent on environmental flows and include products like clean drinking water and

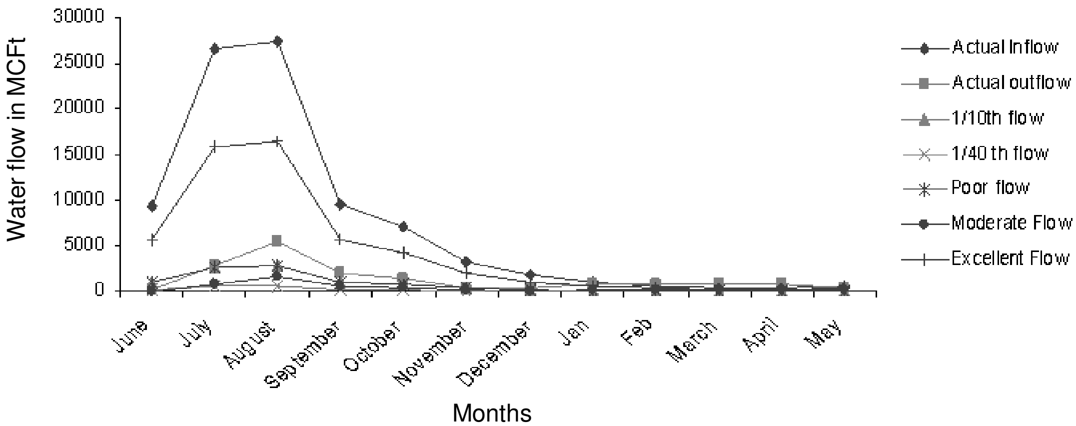

Figure 2. Average flow from the Bhadra reservoir.

Table 6. Quantum of environmental flows is required from Bhadra Reservoir in MCFt.

Month	Average inflow	Actual outflow	French fisheries law		Montana method		
			1/10th flow	1/40th flow	Poor flow	Moderate flow	Excellent flow
June	9,363	261	936.272	234.068	936.272	2,808.818	5,617.636
July	26,481	2,784	2,648.073	662.018	2,648.073	7,944.218	15,888.440
August	27,449	5,569	2,744.912	686.228	2,744.912	8,234.736	16,469.470
September	9,469	2,017	946.860	236.715	946.860	2,840.582	5,681.164
October	7,107	1,319	710.697	177.674	710.697	2,132.091	4,264.182
November	3,331	391	333.060	83.265	333.060	999.181	1,998.364
December	1,764	311	176.397	44.099	176.397	529.190	1,058.382
Jan	1,011	820	101.100	25.275	101.100	303.300	606.600
Feb	550	836	55.012	13.753	55.012	165.036	330.072
March	437	884	43.727	10.931	43.727	131.181	262.363
April	489	770	48.854	12.213	48.854	146.563	293.127
May	704	421	70.415	17.603	70.415	211.246	422.493

Source: Bhadra Reservoir Project circle, Ministry of Water Resources, Government of Karnataka.

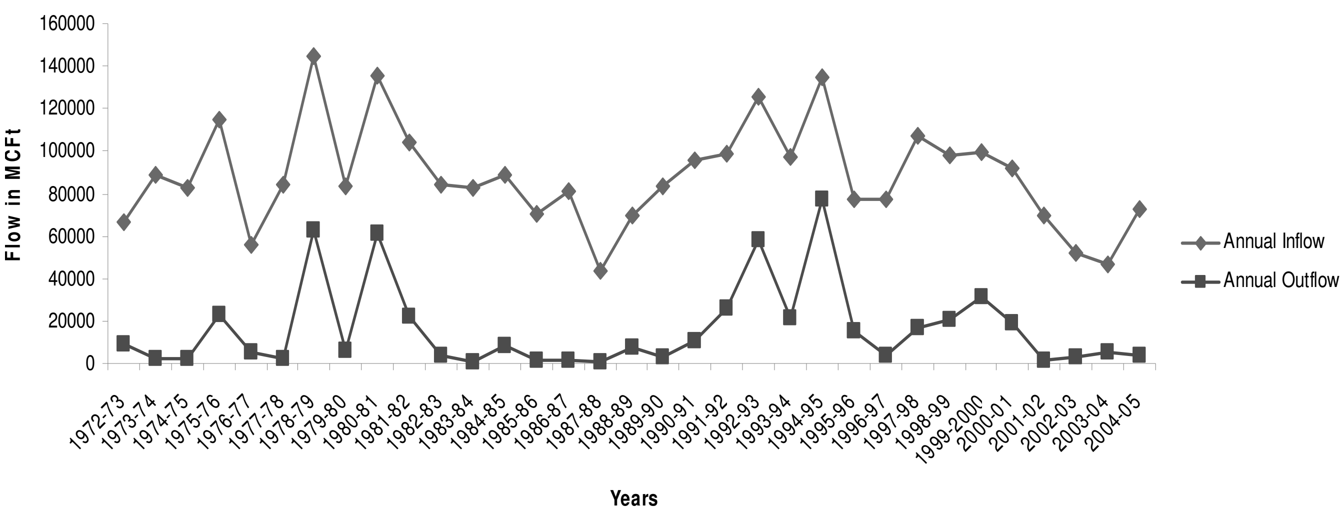

Figure 3. Annual flow status in Bhadra River.

Table 7. Status of ecosystem services of Bhadra River.

	Services	Region I	Region II
Provisional services	Food – fish catch	S	S
	Livestock	S	S
	Fuel wood	NS	NS
	Genetic resources	S	NS
Supporting services	Regular flows – recharge of groundwater	S	S
	Flood plains – recharge of soil	NS	NS
	Periodic high flows – seed dispersal	S	Ns
	Well timed flows – water demands	S	S
Regulating services	Flood and Irrigation	S	S
1. Spiritual	Religious	S	S
2. Cultural	Kalasa – (tourism, reduced pressure on the natural ecosystem)	S	S

S: Significant; NS: Non-significant.

processes like the decomposition of wastes. Ecosystems provide a wide range of services to the people (Costanza, 2003; Emerton and Bos, 2005; Millennium Ecosystem Assessment, 2005; Pearce et al., 2006). The services provided by environmental flows may either be provided directly by flow (e.g. flushing of sediments, salinity control) or indirectly via ecosystem functions. The extent to which ecosystems functions and create the ecosystem services depend on the cultural, socio-economic and technical settings. In the present study area, the same observations were also found. It is strongly believed that the secured amount of water throughout the year or absence of irregular flows in the river surely makes big difference in the livelihood of local community and downstream dwellers.

Possible impacts due to the absence of natural flow

As per the field survey, it is observed that there was decrease in wetlands along the downstream of river. The source of irrigation was primarily canals, tanks and wells. Bore wells were introduced in recent decades. It is clear that with water impoundment, natural flow of water regime is disturbed. Tanks which are basically dependent on the natural flow of water are drastically decreased. While the overall area irrigated under wells has shown a marginal increase, indicating the recharge of groundwater table in some areas. In the river basin, 3,878 villages are located for which the main source of water for drinking purpose is groundwater. This has increased the burden on groundwater in addition to agriculture. Over-exploitation of groundwater has lead to groundwater quality degradation in the study area. Possible impacts from the environmental flows have been shown in Table 8. It is clearly understood that the flow status in the river fluctuates frequently, leading to disturbances in the natural flows and further potential benefits like pollution dilution, fishing, livelihood supports, being affected seriously. The negative impacts from the less flow or nil flow can cause both direct and indirect impacts. Direct impacts like water quality declining in the river is observed by Central Pollution Control Board (CPCB) studies. Indirect impacts like massive decline of riparian vegetation have been found during field visits. Riparian loss is not the direct impacts of the nil flow, but the nil flow promotes the local community for encroachments and unauthorized agricultural activities. It is happening in a large scale on the bank of the Bhadra River.

Invasion of dry river channels and former wetlands by vegetation

In the river basin, some region of the river bank is converted into the agricultural land during summer season. In some places, like in Holehonnur, it is observed that local communities are using the river bed as agricultural land during the lean months. As a result, river bed has decreased from its original width and the local community has made it as agricultural land. Community is using pesticides and fertilizers to grow vegetables and they are released directly to the river, which leads to water pollution. It is interesting to listen to the local communities, which have done enormous damage to the river and riparian are through encroachments and unauthorized agricultural activities. Fortunately, the community is well aware of the value of riverine ecosystem and ecosystem services. They have also realized about the damages done by them. The justification about the encroachment is mainly due to nil flow in the river. Even though community is much aware

Table 8. Possible impacts from environmental flows.

Water requirement	Methodology	Existing water flows	Potential Benefits	Implications
Water Requirement	Desktop analysis French fisheries Law 1/10th flow- 1/40th flow- Montana method Poor – 1/10th flow Moderate flow- 1/30th flow Excellent flow- 1/60th flow	Poor flow according to all the methods	Pollution dilution Groundwater recharge Improvements of fish population	Upper Bhadra project has planned to divert water from Tunga, in the region. Coffee plantations have increased resulting in high water demand leading to cuts in potential benefits and bringin about severe environmental damages. Downstream from Lakkavalli to Holehonnur 38 kms has been facing industrial water pollution
Upstream ecosystem	Interaction with all the stakeholders in the following locations; Malleswara Kalasa Magundi	Origin of the river (Gangamula) to Bhadra Reservoir Project (BRP) Surplus	Has rich biodiversity with, one National Park and one Tiger Reserve, water flow changes is not significant in the catchment area	This region has rich biodiversity Human dependency on water is less compared to downstream and mid stream.
Downstream Ecosystem	Desktop analysis and interaction with farmers, fishermen communities of Bhadravathi, Kagakodamagge and Holehonnur	BRP to Kudli (place of confluence) Controlled flow region	Semi arid region, agricultural and Industrial activities are high and it is essential for dilution and also for drinking water. Dependency of fishermen communities is high	This region is largely depending on fresh water. Fishing activities are high and industrial and human settlements are increasing on the bank of the river
Dependent	Interaction with fishermen communities	Changes in livelihood options	Riverine fishing activities are reduced, Industries have increased	Dependency on water is increasing by all the sectors, agriculture, domestic usage, and industrial sector

of the ethical and ecological value of the river, they are still continuing due to the absence of regular water flow in the river and the availability in the command area.

Decline in population and species diversity declines of invertebrates, fish and water birds

Until 1999 in Karnataka, 201 freshwater fish species belonging to 9 orders, 27 families and 84 genera have been recorded, of which 40 fish species are under 'threat' and urgent conservation measures need to be implemented to ensure their survival (Jayaram, 1999). The systematic of freshwater fish species recorded from the inland waters of the state is based on the work carried out by Jayaram (1999). There are 81 fish species from 8 orders with 14 families which are endemic to the Bhadra river. Annual fish production in the state from the freshwater sector is about 1.2 lakh metric tonnes as against an estimated potential of 2.6 lakh metric tonnes. In order to boost inland fish production to meet the ever growing demand, the State Department of Fisheries has laid more emphasis on the culture of fast-growing Indian major carps like *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*, and also exotic fish - *Cyprinus carpio, Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*. These introduced fish species have adopted well in the various types of freshwater bodies. Introduction of exotic fish species, in a way, has resulted in the decline in native fish population comprising of *Labeo, Cirrhinus, Puntius, Catfish, Murrels*, etc. The culture of African catfish - *Clarias gariepinus* undertaken by private entrepreneurs is going to damage the entire picture of indigenous fish fauna in particular if corrective measures are not undertaken at the earliest.

Water quality reduction in the study area

The chemical quality of groundwater is expressed in terms of pH, salinity and/or other potential constituents, including nutrients and contaminants. Across the river Bhadra, only a few industries are found. Kudremukh Iron Ore Company Ltd, during its working period affected the river Bhadra due to its mining activity. There are another two major industries along the bank of the river Bhadra at Bhadravathi, the Mysore Paper Mills and Vishweshvarayya Iron and Steel Industries. In addition, mining and quarrying activities have resulted in decreased depth and increased siltation. A study by Karntaka State Pollution Control Board (KSPCB) has highlighted pollution as result of dumping of agricultural residues/pesticides at Balehonnur in 2005 where ginger is the major crop grown which uses huge amounts of pesticides. Pollution due to industrial activities is mainly observed in downstream of BRP, from Bhadravati to Kudli. It is estimated that around 15 villages in the area have been affected by industrial pollution (Manjappa, 2002).

Conclusions

The immediate impact of flow regime change was observed in the vicinity of the river in the study area, where farmers observed that their consumption of inorganic fertilizers has increased and their fields were getting enriched by the silt. The groundwater table has declined along the river course and quality of river water has decreased which indicate reduction in the diversity factor. Agricultural and industrial water demand has increase the stress on the water resources of the river basin. Several incidents had occurred in the basin due to less flow. Local community had failed to link the effects due to the less flow of runoff. In the river basin from the origin of the river to the confluence with the Tunga River at Kudli, it had been observed that there is massive loss of riparian forest cover. In many places on the river bank, forest cover has clearly vanished. Agricultural activities on the river bed during lean months are commonly seen in the study area. It clearly indicates that the flow varied over the years. During the monsoon season, it flow at a moderate level. The utilization from the reservoir was high. It is interesting to note that during non-monsoon periods, while inflows were nil, outflows from the reservoir were high.

Local communities have observed negative impacts from the Bhadra dam, when large amounts of water were released from the reservoir, causing massive down-stream flooding at Bhadravathi. Rainy season flooding, believed to have been caused by water releases from the dam, damaged agricultural crops and flooded villages along the Bhadra River every year, although floods in the upper part of the basin had being much less severe than those in lower parts.

Communities have been impacted by irregular dry season water level fluctuations, which are characterized by extreme highs and lows, and rapid changes in water levels. Massive surges of water over 2 m high have caused serious damage downstream, including large amounts of riverbank erosion. Dry season gardens have been flooded, and a number of other dry season activities such as fishing etc., have been severely disrupted. The water quality in the Bhadra River has seriously deteriorated. However, Local communities opined that the water quality problems originated with the Bhadra reservoir, which have been contaminated with toxic elements. The river has become turbid and smells bad. Irregular fluctuations in the Bhadra River have seriously affected riverine vegetation, birds, reptiles and various aquatic life forms whose lifecycles are dependent on the natural rhythm of the Bhadra River.

Native fish, fish habitat and riverine fisheries have been severely impacted by changes in the hydrological regime and water quality. Fish catches have declined drastically, which badly affected the villagers, who are highly dependent on fishing for food and income. Although all fish species have apparently been impacted, large fish have apparently more affected. Fish diseases have also increased. The rapidly rising waters, which occur without warning, have washed away large numbers of fishing boats. It is impossible to imagine a river in the virgin condition, but it is necessary to maintain river in pristine condition by allocating minimum water release regularly to the downstream of the river.

REFERENCES

Brisbane Declaration (2007). The Brisbane Declaration. Environmental Flows are Essential for Freshwater Ecosystem Health and Human Well-Being. Declaration of the 10th International River symposium and International Environmental Flows Conference, Brisbane, Australia, 3-6 September, 2007.

Christer N, Catherine AR, Dynesius M, Revenga C (2005). Fragmentation and Flow Regulation of the World's Large River Systems, Science 15 April , 308(5720): 405-408.

Costanza R (2003). Social Goals and the Valuation of Natural Capital. Environ. Monit. Assess., 86: 19-28.

Dyson M, Bergkamp G, Scanlon J (2008). Flow – The essentials of environmental flows, 2nd Edition. Gland, Switzerland: IUCN. Reprint, Gland, Switzerland: IUCN, 2008.

Dyson M, Bergkamp M, Scanlon J (2003). Flow: The Essentials of Environmental Flows. IUCN, Gland, Switzerland and Cambridge, U.K.

Dyson M, Bergkamp M, Scanlon J (2007). Water and Nature Initiative - Gland: IUCN. Switzerland and Cambridge, U.K.

Emerton L, Bos E (2005). Value. Counting Ecosystems as an Economic Part of Water Infrastructure". IUCN, Gland, Switzerland and Cambridge, UK.
Flessa KW (2004). Ecosystem services and the value of water in the Colorado River delta and Estuary, USA and Mexico: Guidelines for mitigation and restoration.
Jayaram KC (1999). The Freshwater fishes of the Indian region. Narendra publishing house, New Delhi, p. 551.
King J, Brown C (2006). Environmental flows: striking the balance between development and resource protection. Ecol. Soc., 11(2): 26.
King J, Brown C, Sabet H (2003). A scenario-based holistic approach to environmental flow assessments for rivers. River Res. Appl., 19: 619-639.
Manjappa S (2002). Studies on the heavy metal pollution in river Bhadra near Bhadravathi town, Karnataka. Ph.D Thesis, Kuvempu University, Shimoga, Karnataka.
Megan D, Bergkamp G, Scanlon J (2003). Flow: The Essentials of Environmental Flows. IUCN, Gland, Switzerland and Cambridge, UK, p. 118.
Millennium Ecosystem Assessment (2005). Millennium Ecosystem Assessment Synthesis Report. Island Press, Washington DC.
Pearce F (2007). When the Rivers Run Dry: What Happens When our Water Runs Out? Transworld Publishers, London.
Pearce D, Atkinson G, Mourato S (2006). "Cost-Benefit Analysis and the Environment. Recent Developments". OECD Publishing.
Poff NL, Allan JD, Bain MB, Karr JR, Prestegaard KL, Richter BD, Sparks RE, Stromberg JE (1997). The natural flow regime: a paradigm for river conservation and restoration. BioScience, 47:769-784
Postel S, Richter B. (2003). Rivers for Life: Managing Water for People and Nature. Island Press, Washington, DC.
Revenga C, Campbell I, Abell R, De Villiers P, Bryer M (2005). Prospects for monitoring freshwater ecosystems towards the 2010 targets. Philosophical transactions of the Royal Society of London. Series B, Biol. Sci., 360: 397-413.
Richard D, Hirji R (2003). Water Resources And Environment Technical Note C.2, Environmental Flows: Case Studies, The World Bank, Washington, DC.
Song BY, Yang J (2003). Discussion on ecological use of water research. J. Nat. Resour., 18: 617-625.
Tharme RE (2003). A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Res. Appl., 19: 397-441.