

## Mapping the Socio – Economical and Environmental Impact of Weir Constructed on Tapti River and Industrial zone developed at Hazira of Surat : A study focused on Fisherman community (*Machhi Samaj*) of city

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**Abstract:** This research study examines the socio-economic and environmental impact in the downstream area of weir constructed on the river and industries developed at Hazira area. The survey conducted for a specific fisherman community living near the river bank in Surat city. The main aim of the study is to find out the impact of weir and industrial belt development near the mouth of the river on earning capability or economic disruption of fisherman families and their common property rights, changes in the fisheries business practices, changes in the gender roles, migration of families and incidences of disease (i.e., dengue and malaria). The paper argues that, reduction in water supply in the downstream of weir on Tapti river and industrial development at Hazira have given a great socio-economic impact on the specific fisherman community; an environmental impact and on the disease level of the city. By highlighting the socio-economic dimension of water restriction by weir and polluted effluent discharged into the river, the paper contributes to the growing body of literature on downstream impact of weir / dams on river and development of cluster zone of industries near to seacoast and river mouth in Surat (South Gujarat). Even though, this study is a kind of preliminary survey but represents the valuable information on socio-economic impact of weir / dam on its downstream and environmental and health issues of industrial development, some of the conclusions drawn can be useful to other researchers and also will be useful for the nearby river Narmada where Sardar Dam construction is under progress. Apart from this one can use the same for other rivers of India. In addition, it has significant implications for new policy formulation and its implementation in the area of rehabilitation, common property rights (traditional rights of fishermen), education and business awareness, providing the alternative employment opportunity to a fisherman community and to take measurable action for maintaining public health issues, mainly water-born diseases such as malaria and schistosomiasis.

**Keywords:** Socio-economic, Environmental Impact, Tapti River, Fisherman Community

### 1. Introduction

Rivers are a part of civilization and plays valuable role as a support system for the development urban areas across the globe [1]. The rivers are still valuable in

those areas where their ecology and biodiversity is maintained [1]. Healthy river system provides directly or indirect vital support to socio-cultural needs and well beings of society [1]. Today, due to the industrial development and anthropogenic activities, most of the river systems across the globe are badly damaged [1].

Rivers are the ordinary homes for aquatic life and very significant factor for human beings also but the rapid urbanization, industrialization, and chemical uses in agricultural activities has increased the level of Sewage water discharge into the river, agricultural runoff contains higher level of pesticides and chemicals and effluent discharge from industries in to the river [2]. These pollutants worsen the river water quality and are the main cause of pollution in the rivers [2]. In view of the same and managing the sustainable development, water quality is one of the significant characteristics for aquatic organism and human beings [2].

Untreated sewage discharge in river water increases the chances of contamination with E. Coli bacteria in water which is dangerous for human health to use such water for drinking, also such contamination damages the aquatic life [2]. For the healthy aquatic ecosystem, the river water quality play's important role for deriving the sustainability and appropriateness for human uses [2]. The river water quality mainly depends on its uses and can be evaluated by various physico-chemical and biological parameters [2]. River water quality assessed in light of various parameters by numbers of researchers [2]. [3] have studied the impact of municipal sewage on the river Cauvery in Tiruchirappalli city of TN. [4] have reported the impact of the industrial effluents and domestic sewage in the river bank of Ganga in Allahabad of UP. [5] had studied the case of industrial pollution in river Pandu and concluded that the river is highly contaminated due to the discharge of untreated industrial effluents in river.

Dams and weirs constructed on rivers to meet the industrial requirements [6] and accordingly, in Surat city of Gujarat state, weir cum cause way constructed to satisfy the industrial need of Hazira belt industries. Large dams have social and environmental cost [6], but they provide a support for irrigation, flood control and production of electricity with negligible pollution [7].

Small dams such as check dams and weirs are generally constructed for meeting the requirements of water for irrigation, human consumption, industrial use, aquaculture, navigability, ground water recharge and drinking water purposes [8,9]. Weirs have posed more of a liability than the benefits in terms of flood control, supplying water for human use and for irrigation [10]. Though the small dams, check dams and weirs are used since a long time but very limited research has been carried out regarding their impact on the socio-economic and environmental ground [7,11].

Some of the research studies have shown that even small dams and weirs can have significant socio-economic benefits [12] as well as adverse socio-economic effects [13] and environmental impacts similar to large dams, such as, habitat diversity [14], water quality [14], disruption of natural flow regime [14], dewatering of rivers [10], environmental consequences across the watershed [10], increase waterborne diseases [12,15], damages to fisheries and aquatic ecosystems [15].

The development of weir structure on river can seriously influence the riverine habitats and, as a result, affect the fish populations [16,17] and other ecology in rivers [18,19]. [20] have studied the fish production scenario, before and after the construction of compound gauging weir in Villaveta Township (Navarra, North of Spain) in the river Erro (Ebro River Basin) and found that in an upstream of weir, fish density increased but fish assemblage structure has been severely altered.

Development of weir on river and the destruction of the banks of a river and submerged flora are some of the main reasons for the reduction of some of the specific fish populations [21]. Also, such types of structures form a blockage to fish migration [22] and, as a result, affect their population formation and ultimately it has a long term socio-economic impact on fisherman community at large.

Fish production is a basic element in the economy of many river-line communities. Gujarat has around 970 fishing landing centers with a production of 8.16 Lakhs tons and Rs. 6233.89 Crores p.a. [23] and Surat is one of the important fishing centre. Important commercial varieties of fish namely Pomfret, Jew fish, Bombay duck, Shrimp, Lobster, Squid, Cuttle fish, Silver bar, Hilsa, Shark, Catfish, Mulletts, etc. are caught in large quantities in these areas [23]. Surat contributes around 8% of the fish production of South Gujarat [24].

Dams have three effects on fisheries: first, dams affect the physical stability of river channels; second, dams affect fisheries through impacts on water quality; declines in water quality can have serious consequences for human health and the economies that rely on the river's natural resources; and third, and most importantly, dams affect fishing communities by

changing natural flooding patterns [1,7,25]. Previous research studies have found that dam development projects aimed at reducing poverty or improving economic opportunities benefit many people while deepening poverty and hunger for others [26].

Across the world, numbers of researchers have conducted researches on the impact of dam on various issues such as Environmental Impact Assessment (EIA), Socio-economic Impact Assessment (SIA), enumeration, ecological value, biodiversity, and Environmental Management etc. One of such study for SIA has been conducted by ICFRE [27] for Tapovan Vishnugad Hydro Power Project. [28,29] found that, large dams can drastically reduced fish population in both river channel and floodplain, which in turn reduces the economic return to fish catchers. Similar finding reported by [30], [31], [32] and [33]. [34] reported that reduced fish population as a result of Urra Dam on the Upper Sinu River in Columbia has impacted approximately 60,000 fishing families. River flow changes had a significant impact on the aquatic ecology of mangroves in the delta, as well as the fishery that relied on them [34,35].

[36] found that, in various parts of world, floodplain fisher-folk have had to move to new fishing grounds, often in the reservoir created by the dams, also in this research he noted that, few studies has been conducted on the impact of dams on livelihood outcomes and level of incomes. [37] has studied the socio-economic impact on urban and rural communities due to ravine lands. [38] found changes in household's socio-economic status of people living in two main target areas, an expecting reservoir area and the beneficial areas of Kwae Noi Dam in Thailand and concluded that, land uses in deciduous and mixed deciduous forests increase and due to the governmental efforts (GIS) and community participation, no conflict has been observed. [39] has developed a computer based simulation software (DSS), according to the recommendation made by world commission on dams [6], which enables to maintain the balance between hydro-power generation and maintaining the common property rights of various stakeholders. [40] discovered in their study of the Mekong River that the socioeconomic situation in the area is extremely complex, and that the people are deeply dependent on water and related natural resources, particularly aquatic resources and rice, for their livelihood, which has a significant impact on society. In a study of [41] to mitigate the socio-economic issues pertaining to dam, they have developed a 'fish passage' in view of common property rights of fishermen. In Malaysia [42,43] underwent a resettlement program for the affected communities by dam. [44] has observed a great impact on fisheries of Narmada and Brahmaputra after dam construction. [45] and [46,47,48] and [49] have observed that, industrial pollutants discharged into the river can cause fish poisoning. Similarly, [50] have

observed the heavy metal pollution around the island city of Bombay and concluded that it is mainly due to the rapid urban development and such practices are not good for the aquatic life. [51] has also observed that due to discharge of domestic wastes and sewage, effluents from industries, oil tanking depots and also from maritime activities of Jawaharlal Nehru Port Trust (JNPT), the aquatic life near the Mumbai coast is highly affected and because of the same, macro benthic fauna from mangrove ecosystems of Uran is facing the threat due to anthropogenic stress. [52] found that Asian coast is under threat from two opposing directions – nature as well as man-made. [52] further stated that due to the chemical pollution, both in south and southeast Asia, the biological system is in danger of severe domino effect almost mimicking the Minamata mercury episode more than half a century ago.

[53] discovered that accumulated aquaculture pollution can cause biological growth retardation in wild fish stocks. [54] discovered that accelerated industrial development in Southeast Asia over the last few decades has negative environmental consequences, such as extensive mangrove conversion to ponds, changes in hydrologic regimes in enclosed waters due to the proliferation of aquaculture structures, and discharge of high levels of organic matter into coastal waters. [54] further said that the deterioration of coastal water quality caused by the discharge of domestic, agricultural, and industrial wastes into coastal waters has an impact on aquaculture production and profitability. [55] investigated the heterogeneous effects of environmental pollution on mariculture growth in 53 Chinese coastal cities from 1994 to 2018 and discovered that increasing marine environmental pollution reduces the growth rate of marine cultured output, with significant regional differences.

From above, it can be concluded that, majority of the studies conducted on the upstream of dam where as very few researches across the world are conducted for its downstream such as, impact on fisheries and fish catcher communities in tropical rivers, which indicates that, there is a need to go for researcher in depth to find out the impact on various socio-economic dimensions.

In the context of Surat city, due to the development of weir cum cause way on Tapi river, major industrial development took place in Hazira belt area and has provided a support in economic development of Surat city, similar findings reported by [56]. But there is a need to evaluate the socio-economic and environmental impact of this weir on urban community of Surat [7].

After referring the available literature, it can be said that very few studies have focused on the analysis of the impact of the weirs on fisherman community. The

aim of this research study is to fill the said gap by addressing : what are the socio-economical and environmental impact of weir constructed on Tapi River and industrial zone developed at Hazira of Surat on fisherman community ?

After 1985, in view of natural gas availability from HBJ pipeline, large scale industries have been set up at Hazira area of Surat. This industrial growth and earning opportunities in the city has attracted the people across the India, which results into a high population growth. Both industries of Hazira and population demand huge water for process and drinking respectively. As per the information from hydraulic department of SMC and Surat City Resilience Strategy (2011), during the high tide time, the salinity of sea moves to inner side of 30 Kms from its mouth, which leaves problems at the water works of SMC, also the drinking water demand was 100~150 MLD in 1991-93, which has grown to 350 MLD in 1994. Before the construction of weir, the Hazira area industries were receiving water from Kakrapar Canal, which has lots of issues and conflicts pertaining sharing of water with farmers and villagers of Hazira coastal belt, similar problem of water sharing observed by [57]. To overcome both these problems, Hazira area-based industries and SMC has jointly constructed a 'Weir cum Causeway' in 1995 with a permission from Central Water Commission, New Delhi. The height of the weir is 5 mtrs. (top of crest 6 mtrs) and length is 580 mtrs [58,59].

Surat, Gujarat, is well-known for its textile trade, diamond cutting and polishing industries. Surat Municipal Corporation (SMC) efforts transformed the city from one of the filthiest (following the Plague in 1994) to the third cleanest in the country. Surat has experienced unprecedented growth in the last 56 decades, with one of the highest growth rates in the country and a 10-fold population increase. The city is now the eighth largest in the country [60]. It was chosen as the first smart IT city and received the IBM Smarter Cities Challenge Grant recently. It is covered under a smart city Smart Cities Mission and Surat is number one resilient city in India.

**Population Growth :** In last six decades, i.e. 1961 to 2020, the population has grown from 3.11 Lakhs to 45 Lakhs with a growth of more than 84% in the last decade of this century [60]. At present, according to the official of SMC the Surat city population is around 45 Lakhs [60].

**Economic Base :** Surat's economic foundation is made up of textile manufacturing, diamond cutting and polishing industries, intricate Zari works, chemical industries, and petrochemical and natural gas-based industries at Hazira established by leading industry houses such as ONGC, Reliance, ESSAR, and Shell.

## 2. Research Problem

Through experience, it has been found that, after the construction of weir on Tapi river (near Singanpore-Rander Village Surat), the water flow in the downstream reduced to a great extent, also industries located at Hazira has created a problem of water pollution, which has created a big threat to the fisherman community residing near the river bank. This Fisherman community enjoys the traditional rights over the river before the weir construction; they use to enjoy fishing for freshwater fish and sea fish (during high tide). It has been found that, industries located at Hazira Area, discharged their polluted (high COD) effluent adjunct to the mouth of Tapi river located in a delta region of coast, which restricts the flow of sea fish into river channel and also hampers on breeding.

The present study provides benchmark information on the status and trends of the socio-economic conditions of fishermen communities in delta region of Tapi river in Surat, which are directly linked to changing status of land use practices due to weir construction near to the delta of the river and riparian habitats in the river ecosystem, and information on social vulnerability of the communities related with their livelihood activity

## 3. Materials and Methods

We present this case study which analyses the integrated socio-economic and environmental impacts of weir from downstream and river delta zone perspectives, focusing on the specific community of fisherman. The present status of lack of sufficient data on impact of weirs on socio-economic and environmental impacts challenges the decision-making regarding construction of weirs. For this, we have carried out an exploratory survey among the fishermen community as our main methodology of research. The exploratory research provides flexibility to and allowed the volunteers to outline the discussions under a macro view of research themes.

The water samples for this study were collected during August 2020 to May 2021 at morning hours (6.30 to 9.30 AM) from the upstream of the weir, from the downstream of the weir (at Makka-e-pool) and from the delta region of the Hazira. In the downstream of the weir, there is a mixing of estuarine water and fresh water. These water samples were used to analyze the important water quality parameters including (temperature, pH, turbidity, conductivity, and dissolved oxygen). Out of these parameters' temperature, pH, and dissolved oxygen were analyzed in situ and for remaining parameters (turbidity and conductivity), samples were preserved and transferred to the research laboratory G N Techno Consultant, Surat, Gujarat. The protocol for the water analysis explained by [61] and [62] were followed for meeting the analytical need.

This research study is mainly focused on the traditional fishermen communities dependent on the local Tapi river for their livelihood, which is under a threat from the change in land use due to the weir construction and industrial pollution at the delta region. Therefore to study socio-economic condition of fishermen community in Surat, Gujarat, a social survey of fishermen communities was undertaken. Random sampling survey method supported with interview was used for this purpose. The interview schedule comprising of 20 relevant questions was prepared for individual feedback of fisherman, which included personal biographical information, traditional fishing practices, past and present status of fish species, past and present status of ecosystem, change in river catchment landuse etc. Initially pilot schedule was field tested and further improvements were made in the final schedule. Survey of traditional fishermen was conducted in the Surat city where they are actively engaged in traditional occupation.

This sociological study provided a valid tool to understand life condition of fishermen communities better in the context of changing environmental and socio-economic aspects impacting their traditional livelihood. During the study interaction was made with several groups of the people living in the study area.

A total of 150 fishermen household from the location of Nanpura (a colony of fisherman) were interviewed. In addition, extensive personal observations were made during the field study. The collected data of questionnaire survey analyzed through Microsoft Excel package.

## 4. Impact of Weir on Fisherman Community And Ecology of the Tapi River of Surat City

After referring the History of Surat City (2015), Book published by Surat Municipal Corporation, Surat, it can be concluded that, fishermen community residing (near to river bank) in the area of Ducca Ovara and Assurbeg Chakla for more than 700~800 years. Also it has been noted in the history that, the 'Fishermen (Machhi)' and 'Koli' communities are the original inhabitants of the city and resides since 1250 A.D. Surat developed as a port after 1500 AD and emerged as a trading hub of India, which has attracted other communities to migrate from diff. parts of India. City further developed after the entry of Britishers in 1610 A.D. [59].

According to the 1991 data of SMC [60] around 2720 people were involved in fish catching and selling business. As per the information provided by fishermen community member during this survey, around 400 families are residing in the adjunct area of river bank. After personal visit to their residential area, it can be concluded that, majority of the family believes in joint family pattern with 3~4 earning persons in a family, in majority of the cases, both husband and wife are

earning. The level of education is very low in community. Average members in the family are 12~15 persons. Hence, total population of around 8,500 people [60].



Fig -1: Map of Gujarat - India indicates area of study



Fig -2: Map of Tapti River, its Flow pattern in city with weir location

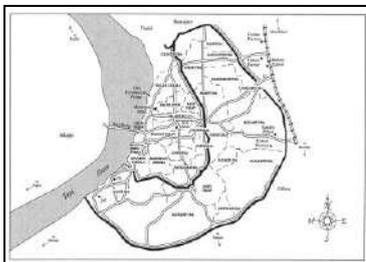


Fig -3: Map of Fishermen community residing near the river bank



Fig -4: Photo of weir constructed on Tapti River

During the survey, community members revealed that, even after the construction of Ukai and Kakrapar dams on river, they were getting sufficient water in river, which enables them to maintain their hereditary profession of fish catching and selling but after the construction of weir near Singapore village, the water flow is very minimal. Low flow of water has increased

the salinity near their catching area. Also due to the polluted effluent discharged by Hazira based industries near the mouth of the river, the population of sea fish during the tide has been reduced to a great extent. Also, with the rising industrialization, their movement on coast has become restricted; these giant units became fiefdoms in themselves violating fishermen's traditional rights [63]. They also revealed that, due to the exponential increment in population of the city (post 1995); the no. of 'Ganesha-statue' during Ganesh Chaturthi has increased to a great extent. The Hindu customs of statue submerge ('murti visarjan') in water is responsible for river depth reduction (due to the sedimentation of 'plaster-of-paris' used for statue making) and water quality problems. They also revealed that, since last five years, submergence of statue of other Hindu Gods and Goddesses has also been increased. Earlier when the population was low and sufficient water flows with velocity in river channel, a problem of sedimentation was not there but today is a reverse case. They also revealed that, during the summer season, one can cross the river by walking.

Due to the above-mentioned reasons, the population of fish near the fish catching area has reduced to a great extent, which in turn results into low earning per family and a loss of common property rights over natural resources. A questionnaire based survey has been carried out to know the socio-economic and environmental impact of weir on Tapti river and its findings are summarized as follows :

Reduction in productivity of downstream river fishery. Due to the development of weir, the river flow in the downstream of weir has been drastically reduced, which has reduced the fish population. Also due to the pollution in the delta region of river, the fish migration from Arabian sea has been reduced. Due to this, even during the high tide level also, the fish population is very less. Direct discharge of Sewage water in the river at the Adajan and Pal area is also responsible for this reduction in population of fish.

Due to the pollution at mouth and low water flow from weir, lateral and longitudinal migration of fish towards the sea observed for breeding, i.e. a problem of ecology. The industries located at the Hazira are mainly hazardous process industries and discharging pollutant in the river, which has imbalance level of pH, low dissolved oxygen and higher COD. Due to these variation in the water quality in the delta region, the actual lateral and longitudinal migration of fish in river is absence and this has imbalance the cycle of ecology. This particular absence of the sea (guppy) fish in water river has increased the cases of Dengue and Malaria in the Surat city [64]. Guppy fish has an ability to control

the breeding of larvae of mosquitoes that cause dengue and malaria.

For measuring the water quality, we have collected the water samples were collected from various places from the upstream and downstream of the weir and also from the delta region of the river and analyzed in the laboratory, findings of the same for various quality parameters are mentioned below :

Temperature is not more important in the study related to the pure water because the aquatic life has a wide range of tolerance capability however, in case of polluted water it can effects on the dissolution of gases and biological process in aquatic ecosystem. Temperature of water observed are as follows. In upstream of Weir of Tapi River, it was observed maximum of 26 °C in May and minimum of 17.6 °C in January. In downstream of Weir of Tapi River, it was observed maximum of 27.6 °C in May and minimum of 17.2 °C in January. At the delta region of Hazira, it was observed maximum of 33.7 °C in May and minimum of 25.7 °C in January.

The observed values of the downstream, upstream and delta region are lower than the maximum permissible limit of [65], however, the temperature in the delta region was found near to the prescribed limit of [65] which may be due to the discharge of effluent from the Hazira industries in the creek of dumas which is near the delta region of Tapi river. The river temperature generally depends on the season, geographic location, sampling time and effluents entering the stream [66,67].

The variation in water temperature in the upstream and downstream of the weir is mainly due to the different intensity of solar radiation in different seasons of winter, summer and monsoon [68,69]. where as in the region of delta, it is also affected by the discharge of industrial effluents.

A turbidity level increased to a great extent; not suitable for fish to live and breed.

In upstream of Weir of Tapi River turbidity was observed (18.000 ~ 48.500 NTU) with average  $28.567 \pm 3.367$  NTU.

In downstream of Weir of Tapi River turbidity was observed (27.800 ~ 62.700 NTU) with average  $42.645 \pm 5.235$  NTU.

At the delta region of Hazira, turbidity was observed (48.700 ~ 92.500 NTU) with average  $69.2379 \pm 6.158$  NTU.

These results were compared with maximum prescribed limits (10 NTU) of [65] and found

significantly high that indicate of presence of pollution in the studied area [70].

Variation in turbidity observed during winter and monsoon and is a kind of seasonal fluctuation mainly due to turbulence and flow rate of river. Similarly, variation in turbidity observed by [71] in Manjara River, Dhanegaon (Maharashtra) and [2] in Tapi river of Surat. However in case of our study, the higher level of turbidity in the downstream of the weir is mainly due to the direct discharge of Sewage water in river and high tide water of sea.

A vast variation in pH level has been observed in the samples collected. pH is one of the important factors which determines the suitability of water for various purposes including the need of drinking, washing and industrial use.

In upstream of Weir of Tapi River pH was observed is found slightly alkaline (7.90 - 8.39) with average value  $8.178 \pm 0.038$

In downstream of Weir of Tapi River pH was observed is found marginally alkaline (8.150 - 8.410) with average value  $8.325 \pm 0.178$

At the delta region of Hazira, pH was observed pH was observed is found highly alkaline (8.50 - 9.52) with average value  $8.753 \pm 0.695$

These results were compared with the standards of pH for various purposes and found that except the delta region of Tapi river, the pH of water found is alkaline and the value of the same is lower than maximum permissible limit of [65]. The data of pH in upstream and downstream of weir indicates that there is an absence of microbial activities and reduces the primary productivity of fisheries [66].

However, the variation in the pH of delta region and downstream of weir is mainly due to the presence of microbial activities and increase in primary productivity of fishers. This indicates that the fish of sea are migrating towards the delta region for breeding and because of the same microbial activities are having their presence. Similar findings reported by [66] for Tapi river of Gujarat and [72] for Cavery river of Tamilnadu and [73] for Cavery river of Karnataka.

For measuring the ability of an aqueous solution to carry current, generally test of conductivity is carried out. Higher values of electrical conductance indicates that there is a presence of the products developed from the decomposition and mineralization of organic materials [74].

In the present study for all, the three locations, the conductivity was observed in a range of 0.278 ~ 0.876 ms with the average value  $0.473 \pm 0.78$  ms which is

quite lower than the prescriber maximum permissible limit of [65] which is 1 ms. Similar findings reported by [66] for Tapi river of Gujarat and [72] for Cavery river of Tamilnadu and [73] for Cavery river of Karnataka.

Dissolved oxygen (DO) is one of the most significant aquatic environment health factors, and its depletion has a direct impact on the river ecosystem. DO is an indirect indicator of BOD and COD. As this study is to find the overall environmental impact, we have only focused on the DO and not on the COD and BOD as they increase the complexity of analysis and are time consuming. If DO is higher, COD and BOD are lower and vice versa. So when the DO is low, it is an indication of higher COD and BOD in water.

In upstream of Weir of Tapi River, DO was observed in a range of 4.89 to 7.18 mg/L with an average value of  $6.590 \pm 0.678$ .

In downstream of Weir of Tapi River, DO was observed in a range of 2.86 to 5.236 mg/L with an average value of  $4.290 \pm 0.879$ .

At the delta region of Hazira, DO was observed in a range of 3.22 to 6.83 mg/L with an average value of  $5.270 \pm 0.567$ .

The variation in DO is a seasonal variation for winter, summer and monsoon period.

Dissolved Oxygen (DO) in the upstream is little lower than maximum prescribed limits of [65], i.e., 7 mg/L. This is mainly due to the stagnation of water (less turbulence) at the upstream of the weir (low turbulence in non-monsoon period). The level of 5 mg/L DO is sufficient for optimum fish health [75]. This is a reason that fishermen are getting sufficient fish in this region of Tapi river.

The lower in the DO in the downstream is mainly due to the absence of bacterial presence, lower natural turbulence and mixing Sewage water. The DO level of above 5 were observed during the monsoon season and high tide days in the downstream. Sensitivity to low levels of DO is species specific, however, most species of fish are distressed when DO falls to 2~4 mg/L [75]. Mortality usually occurs at concentrations less than 2 mg/L [75].

Dissolved Oxygen (DO) at the delta region is 5.27 mg/L, which is mainly due to the higher level of turbulence of sea water generated due to the tides, which is sufficient for the fish health [2,76]. This might be one of the reasons of finding the fisheries in the delta region, even though it has pollutants and higher temperature of water. The presence of fisheries in this zone, promotes the primary productivity which produces sufficient oxygen by photosynthesis and active utilization in bacterial decomposition of organic matter [2,76].

Today the situation is that, almost no fish catching activity is being performed in that area of river bank located near to the fishermen resident colony, i.e., in the downstream of the river. As explained above the average DO level observed in this region is around  $4.290 \pm 0.879$ . As explained by [75], level of 5 mg/L DO is required for the fish to survive in water. This lower level of DO in this region is a main reason of the migration of fish towards the delta region where sufficient DO prevails. This particular situation has forced the fishermen to leave their traditional profession and join other activities. This is a big socio-economic impact on the fishermen community.

Majority of the fishermen have changed their profession of low skill job, such as auto-rickshaw driver, peon in office, worker in textile mills etc. where as some of the female members have started a job of home-servant.

Instead of fish catching, some of the middle-income families have started a business of fish trading. They use to procure fish from Porbandar, Veraval, Daman & Mumbai, which has reduced the profit margin to a great extent.

It has been found that, up to 2004, fishermen were catching fish but after 2006 in some of the families, male is engaged in a profession of auto-rickshaw driving, and female use to sell fishes in the unorganized markets located at Makkaipul-Dotiwala Lane [63], Kotsafil Road, Navsari Bazar and Saiyedpura. (a case of changed gender roles – supports the past study on dams) [29].

Some of the community members have joined a low skill job in middle-east countries as a turner and fitter.

More than 25~30% of the fishermen families have sold out their residential properties of this river bank area and shifted to suburbs of the city, such as Bhestan, Udhna, and Umra etc. (a case of migration due to lack of earning opportunities-supports the past study on dams) [29].

Also it has been found that, after 1996 the cases of water born disease, mainly Malaria in city increased to a great extent. The said fact is supported by local doctors, pharmacist, information officer of SMC and [60].

## 5. Results and Discussions

From the collected data and interview, it can be said that the weir which has been constructed on the Tapi river has leave a very strong impact on the fisherman community from the socio-economic perspectives and the river delta has been environmentally affected due to the pollution from Hazira based industries.

At the delta of the Tapi river, fishing activity is an age old livelihood activity and has been carried out by the three traditional fishermen communities namely Machhi, Kahar and Kharwa. Among these communities Kahar community (48.5%) dominates in population size and are spread in the entire study area of Nanpura. While Machhi (35.5%) and Kharwa (16%) communities are smaller in size and living with them in the same habitat area and have the matrimonial relations among them. Traditionally fishing was done as major source of livelihood in these communities, but later it was carried out as a side activities or substitutes after the construction of weir on river and establishment of industries in delta region of Tapi river, i.e. at Hazira. In the recent years some poor people from Muslim communities of Rander area, who are not traditional fishermen, have also entered in fishing activity in the upper side of the existing weir.

The literacy level of a population has revealed that they have the ability to develop and carry out the traditional livelihood with innovations or to opt for better occupational opportunities. And for the same they are utilizing the government schemes for their livelihood. The literacy levels of the respondents indicated that majority (78.2%) fishermen were literate. Whereas as expected most of the illiterate fishermen (21.8%) belonged to senior age group. Most (58.3%) of the literate fishermen had education only up to tenth standards.

Today mainly due to degradation of riverine ecology many fishermen families in the study area could not be totally dependent on their traditional occupation for survival and thus had to shift to several petty jobs. For example, Kahar community only some (23.2%) still continued with fishing while others did supplementary jobs such as driving auto rikshaw, selling of vegetables, washing and ironing of clothes. While people of Machhi (37.3%) and Kharwa (47.7%) community have adopted jobs in middle-east countries as technicians. Majority of the young people of the community are holding diploma (27.8%), ITI Certificates of trade (36.7) and PTC certificates (18.9%), and based on the same, they are employed in respective profession. This is mainly possible due to the other backward cast (OBC) reservation allotted to them under the constitution of India.

Poor income status of fisherman families with fishing as livelihood, even when market price of fish is high, normally indicated poor fish catch in the associated riverine systems. The income from fishing to the traditional fishermen from Tapi river has now become relatively meager. About (47.3%) fishermen had monthly fishing income of only between Rs.8000 to 15000 but those who are in the trading (23.5%) of fish

have a monthly income of around Rs 25000 to 48000. It was observed that young members of the community are mainly involved in the fish trading business. However, the total family income did not necessarily reflect income only from the fishing activity, as most of the fishermen families could not be solely dependent on income from fishing, and had to opt for supplementary or alternative source of income.

In the past few years, due to the construction of weir and development of Jetties at the delta of the Hazira region, there are significant land use changes in the river catchments and riparian habitats in of Tapi river of Surat city. This has resulted into river bed water level fluctuations, bank reclamation, habitat fragmentation and pollution of the riparian micro ecosystems and fish habitats. The cumulative consequence of these environmental changes is reflected in decline in riverine fish diversity, density and distribution. No wonder that most of the fishermen (79.3%) in the study area could not any longer dependent on rivers for their livelihood, but instead they had to do search for upstream of weir in the river for fishing and to opt for trading of fish business. Whereas the remaining fisherman had no option but still solely depend on the same riverine habitats for fishing. Recently observed that group fishing activities were mainly carried out in the Arabian Sea through motorized boats. Even during the days of high tide, the fishmen are getting marginal number of fishes in their nets and is mainly due to the pollution in delta region, similar findings reported by [1]. Also, it has been observed that the sewage waste of Adajan and Pal area is directly discharged into the riverine system, which is also responsible for the mass fish mortality due to concentration of polluted matters and oxygen depletion due to increased nutrient load as result of sewage pollution [1].

In the present research study, there was harmony in the respondents on hasty reduction, in last twenty-five years or so, in fish catch and fish diversity in the downstream of weir on Tapi river. For this, majority of the respondents (84.3%) has revealed that there was reduction in the fish catch as compare to past few years. It was further worried that fish species, earlier common, are now rarely recorded from the river waters. The comments on changing status of fish diversity in rivers in Tapi river bank are based on experience and knowledge of fishermen interviewed during the research study. This survey was targeted to take note of any possible change in fish diversity and its status during last 25 years [1]

During the survey, the fishermen said that during the monsoon and post monsoon seasons, they are getting good quality fish due to the water discharge from the

Ukai dam. So in view of the same, they are of opinion to construct another weir at the Rundh area, so that a water reservoir can be developed in the downstream of the existing weir. This will store sizable amount of water and will act as a reservoir of fresh fish, which will help them in their fishing activities in their adjacent area of habitat

The socio-economic condition of fishermen community of Tapi river bank of Surat city was entirely reliant on local fish variety, quality and accessibility. It was observed that due to habitat loss, construction of the weir near Rander has stagnate river water flow during summer and effluent pollution there was reduction in fish variety and yield in riverine fishery, a large number of fishermen families have already shifted to other professions for their living. This clearly indicated slow environmental deprivation of the riparian and riverine habitats in Tapi river bank of Surat City. Observations during the research study also portrayed that fishing activities carried out with the motorized boats by group of fishermen in the Arabian sea has raised more benefits to fishermen as compared to the limited fish from degraded riverine habitats. As a result traditional fishermen communities are today diverted from riverine fishery to motorized fishery, which has increased the financial burden on them.

Most fishermen (84.2%) preached that reduction in fish variety was a consequence of riverine pollution in the delta region of the river, discharge of Sewage water in the downstream of the weir at Pal and Adajan area and expansion of urban localities in the Adajan area. Around (74.8%) fishermen confirmed that there is increase in siltation in the downstream of the weir due to the less water flow from weir and ingress of sea water on high tide days. Due to the low work-related income from fishing activities and overall lethargy of the state and central government towards wellbeing of fishermen communities, youth of the fishermen community had switched to another substitute income of earning for managing their life. Most (84.7%) fishermen mentioned that their youth were engaged occupations other than fishing.

This situation of transformation in traditional fishermen livelihood to other occupations was forced due to insufficient income from fishing due to rapid degradation of riverine and riparian habitats making their traditional livelihood unsecured and non-viable.

There is a need to introduce environmental management measures by the government to alleviate deteriorating river water quality and the adverse environmental impacts of aquaculture development has now become a matter of urgency to the region in view of uplifting the socio-economic level of the fisherman community.

## 5. Suggestions to Improve the See Conditions

1. NGOs and govt. education officers can increase the awareness through 'street drama' and 'puppet show' for importance of education in society through social engineering program.
2. NGOs can educate youth and society for pollution caused by 'Hindu religious festivals' and its impact on ecology.
3. The Southern Gujarat Chamber of Commerce and Industry (SGCCI) – Surat can provide educational seminars on entrepreneurship and business potential in export market for fish.
4. Govt. can request NITs, IITs and other similar institutes to develop a DSS based system for maintaining the balance between water requirement of Hazira industry & SMC and common property rights [39].
5. Govt. and financial institutions must come forward for providing a loan to purchase boats and hi-tech equipments (cold storage and fish processing) for fishing in coastal area.
6. GPCB and CPCB can take legal action for polluted effluents discharged by Hazira based industries.
7. SMC should allow fishing in the upstream of weir (according to notification of Gujarat govt. gazette, it is restricted) to these affected community by developing a lease type contractual system [36,41,77].
8. SMC can develop a concept of 'Organized Fish Market' in their city development plan (similar to Reliance Fresh) to promote the employment to fishermen community.
9. SMC can develop a program of fumigation and to handle the issues of public health to control malaria.
10. State government support in the form of subsidy is needed for the procurement of latest tools of fisheries.
11. There is a need to construct another view near the Rundh area, so that the river water can be stored between the new weir and old weir. This will help to carry out fishing activities Nanpura area in a similar way the present fishing carried out in Rander area of the City. This will also help to recharge the traditional bore-well of the city and salinity of the water can be reduced due to the natural recharge of the bore wells.

## 5. Conclusions

Our research findings indicate that, socio-economic and environmental impact of weir and reduction of area at the delta of Tapi river are of variety at large. The weirs are largely perceived as negative for fish profusion and diversity, and positive for meeting the water needs for human consumption, ground water recharge and industrial need.

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