The Change Of Channel Morphology And Evolution Of An Ecotourism Region-A Case Study On Hooghly River From Sajiara (Block-Purbasthali II, Dist.-Burdwan) To Mayapur (Block-Nabadwip, Dist.-Nadia), West Bengal, India

Ayan Kumar Maity, Souvik Das

Abstract: Channel morphology refers to different fluvial aspect like relief, surface, discharge of water, volume of water, cross section, hydrological regime etc. Ecotourism means sustainable tourism maintaining proper guidelines of the environmental ethics. Channel shifting is a common phenomenon mainly in plain land. It helps to develop or modification of various form of channel and their characteristics. Present paper is mainly discussed, with the passage of time the change of morphological characteristics of river Hooghly and formation of an ecotourism environment between Sajiara to Mayapur river, bank of this river. The landsat imagery data with GIS processing, field survey, questionnaire survey and various primary and secondary data has given a proper idea about this changing riverine phenomenon. This wetland has developed due to effect of some Geo-morphological phenomenon but based on these morphological features, local people of this region are depends on different types of economy, mainly agriculture based, fishing activities as well as gradual development of tourism of this particular area considering bird sanctuary and other natural tourism activities like natural landscape based tourism scenario.

Keywords: Ecotourism; Discharge; Ox-Bow-Lake; River shifting; Channel morphology; Bird sanctuary

1.0 Introduction

River channel display widely varying characteristics in both space and time. These reflect their geographical location within particular catchment and fluvial system. Different kinds of factors controlled the river channel morphology. These Morphometry can analyzed by linear aspect, relief aspect, areal aspect, surface aspect; especially example as volume of water, hydrological regime, channel bed and banks, drainage function, relief function, channel cross section, channel gradient and various channel parameters, so on. River channel are gradually changing due to equilibrium of river channel as well as Geo-morphological sustainability (Chris Solisby). River channel migration is a natural phenomenon and related to lateral erosion across to flood plain. This process is mainly driven by combination of bank erosion and point bar deposition over time. This shifting of channel Hooghly in different courses, is very dangerous and threats for human settlement and human resources (Md. Julfikar Ali, Subrata Roy). At plain area, rivers tend to take the easiest way, the rout least resistant due to obstruction of river bed, the speed of flowing water between two banks becomes different. Now, the meandering process starts. Actually bank erosion starts the meandering formation of channel (Fridkin 1945). The low gradient, little discharge and very low stream power are main factors to transform the channel into a curvature pattern. If this curvature or sinuosity index number is more than 1.5, it’s called a meandering channel (Yen, B. C.1965). Generally, due to changing course of river in different decades, the meandering loop is cut off from main channel. This cut off loop is called Ox-Bow-Lake. The channel migration and related phenomenon are very common at Hooghly river basin. Channel shifting effects on channel morphology as well as humans and animal life (Bora and Kar 2013). With the passage of time river channel migration, bank erosion, changing land-use landcovers are very common phenomenon and interconnected to each other at lower bank of Hooghly River (Islam 2013). But static supply of water on irrigation, industries and various primary and secondary purposes, this river is called lifeline of southern West Bengal. Highest sinuosity, acute meandering, paleo channel formation are also important characteristics of lower basin of River Hooghly (Mallick 2016). Various changing features, different Morphometry, dissimilarity of lithology and dynamic nature and characteristics of different course of channel, are main evidences of channel shifting or channel migration. Various scholars, (Rennell 1781, Colebrooke 1779, Sherwill 1858, Hunter 1870, Hirst 1915, Mukherjee 1938, Sanyan 2008, Rudra 2010, Islam 2013, Laha 2015, Roy 2015, Mallick 2016) are associated with several Geo-morphological works related to Morph-dynamic characteristics of lower Hooghly basin. Two types of avulsion are very significant in Hooghly River, one is Channel shiftings mainly lateral erosion of channel and another is meandering cut-off (Schumm 1999, Sligerland and Smith 2004, Allen 1965). With the passage of time, heavy siltation occurred at Hooghly’s off take point. As a result in upland area, amount of discharge and carrying capacity have reduced. Movement of channel mainly depends on sediment composition, flow of water, discharge, which helps to identify proof on avulsed of channel or channel cutoff and related phenomenon (Anderson et al. 1996; Keen-Zebert et al. 2013). So, from upper to lower region of Hooghly basin, channel courses has continuously changed over time since independence of India (James Rennell 1788, Fergusson 1863, Garret 1910, Hirst 1915, Adams and Williams 1915). Various stratigraphic conformity is also important as an evidence of explanation on Channel morphology and flood mechanism (Sinha 1996, Ghosh 2012). The studies on dynamic Morphometry of river channel, becomes more authentic through processing of SRTM, LANDSAT and ALOSPELSAR DEM data with various GIS techniques as like as, image classification, overlay analysis, NDVI, TVI,
PCA and so on (Sinha R, Ghosh S (2012)). The Hooghly river system is controlled by Monsoon. This Monsoon is very important for controlling river discharge variability throughout the year (Sanyal and Lu 2005). Various anthropogenic features like dam construction, rail, road, water-bridge etc are influenced on river’s dynamic morphology in past few decades (Williams and Wolman, Kondolf 1997, Kinghton 1998, Kondolf et al. 2002, Gregory 2006, Schumm 2007, Xu et al. 2007, Kiss et al 2008, Kiss and blanka 2012, Vndenberghe et al. 2012). The main research problem of this study is the shifting of channel as well as changing course of Hooghly River from Sajjara to Mayapur (Study area) and evolution of an Ox-Bow-Lake and transformation of this Ox-Bow-Lake as an ecotourism region (Chupi-Char) as well as sustainable tourism of this region (Sen Koustav; Mandal Rimpa) which is solely depends on local agriculture, wetland ecosystem (Prasad S.N.,Ramchandra T.V., Ahalya N., Sengupta T., Kumar ., Tiwari A.K., Vijayan V.S. and Vijayan. l 2002). There is an intricate correlation between channel morphology, shifting course of river channel as well as evolution of ecotourism based Chupi settlement.

**Graphical Abstract**

![Graphical abstract](image1)

**Figure 1: Graphical abstract**

**2.0 Study area**

![Location Map](image2)

**Figure 2: Location Map**
The study area is at Purbasthali (Sajiara to Mayapur), Purba Barddhaman, West Bengal, India. Latitude & Longitude are from (23°29'2.09"N - 88°20'424.93E) to (22°25'22.97"N - 88°22'55.27''E). The main channel is River Hooghly, locates 8 km distance from town Nabadwip Dham. The study area has focused on general riverine features; dynamic nature and characteristics of channel Hooghly, especially from Sajiara, Block- Purbasthali II to Mayapur, Block-Nadia. Last 40 years, various changes have noticed in this area. In year of 1978, the main channel Hooghly flowed on proper Purbasthali, Bhandartikuri regions. But with the change of time, the main channel has shifted and now it flows on Sajiara, Rudrapara and Mayapur regions. The previous detachment part of this Channel is locates as named as Chupi-Char. In this lake, have a huge number of organisms and due to abundant supply of food, insects, mollusks, fishes; a large number of Bird comes to here during winter season, in every year. And due to for gather of various attractable colorful hilly birds, this lake have formed as an Ecotourism place. Tourists are comes in winter for its attraction throughout the year.

3.0 Objectives
The major objectives of this paper are followings:
(1) Changing course of river, channel shifting process and channel morphology of Bhagirathi-Hooghly river system between Sajiara to Mayapur.
(2) Correlation between channel shifting, formation of Ox-Bow-Lake as well as evolution of Chupi settlement.
(3) Significant of wetland ecosystem of Chupi-Char and there relevant with reference to sustainable tourism.
(4) Impact of Chupi Ox Bow Lake as a wetland ecosystem on local economy and tourism.

4.0 Hypothesis
All the objectives are based on "Null hypothesis" that is "no difference hypothesis". After verifying the database, we should try to invent the rejection process or alternative hypothesis.

5.0 Database & Methodology

![Figure 3: Methodology Flowchart](image)

For analysis various kinds of surroundings features, nature and characteristic of channel, various methodology have followed. With field instrumental surveying, various primary data have been collected as like as velocity, stream power, discharge, carrying capacity, slope, aspect, bank full index, width etc. After collection of field data, these have analyzed with laboratory procedure. Various kinds of secondary data as like as Google earth pro data, Satellite imagery, SRTM DEM, ALOSPELSAR DEM, Topographical map have collected for basin identification, land use land cover analysis, river channel cross profile in different sections, shifting trend of river channel, different features in different course of flowing channel and so on. By help of GPS and Google map; Latitude-Longitudinal location, direction, orientation have measured. GIS data are also so important for proper calculation and proper generalization of riverine data. Theodolite, Tape, Staff, Dumpy-level, Current meter, ranging rod etc also have used for proper field surveying...
and measurement of and dynamic nature and characteristics of channel morphology. Several natural criteria have measured also with some proper formula and techniques.

5.1 River velocity
River velocity is the speed of flowing water across the channel. With the change of course of a channel, velocity becomes also change. Velocity depend on some interconnected factors like channel gradient, shape of channel, amount of water or bank full discharge, depth, rate of friction, channel width etc. The rate of velocity can be measured by different kinds of units as like as liters/sec (lps), cubic feet/sec (cfs), gallons/min (gpm), cubic meters/sec (cms). This flow water or velocity is very important for analyzing micro hydro system, wastewater system, rainwater catchment, water auditing, and water table statistics analysis and so on. The quality and various riverine activities depend on velocity of water (K. Schulze . M. Hunger P. Döll 2005). For measurement and analysis the river velocity, for assess the quality, for abnormalities various kinds of methods follows (Goring and Nikora 2002). For proper measurement of velocity of a particular basin area, Current meter is very useful instrument.

Velocity = Discharge/Area
(Where: V is velocity; D is river discharge and A means total area). In Hooghly river basin at Sajijara to Mayapur region the velocity rate is very high in Rainy-Monsoon and late Monsoon season but in summer and winter season the velocity rate comparably low as the river Hooghly highly controlled by Monsoon.

5.2 River discharge
The water flowing volume over the channel of river is called discharge. This volume is changeable seasonally. Riverine activity, Storage factors in basin, amount of precipitation, evaporation these all factors control the discharge rate of channel. This rate can be measured in the unit “cubic meters per second (curems)”.

Discharge (D) = Area (A) * Velocity (V)
Discharge can also be expressed by mass and weight flow rate. For measurement the stream power of a channel the analysis of peak flow (Phillips and Slattery, 2007; Gartner, 2015), bank full flow (Forstad, 2003), mean annual flow (Finnegan et al., 2008; Larsen and Montgomery, 2012), mean annual maximum flow are so important. These flow occurs with a particular interval like 2-year, 10-year, or 100-years (Reinfelds et al., 2004; Phillips and Slattery, 2007; Phillips and Desloges, 2014). Divided channel method (DCM), single channel method (SCM), the coherence method (COHM) and the exchange discharge method (EDM) are also useful for discharge analysis (Sahu et. al.2011).

5.3 Carrying Capacity
The carrying capacity of a river depends on power of water flow in river channel. Due to degradation and huge pollution, the rate of capacity may reduce and the sustainability also can reduce. The rate of capacity depends on velocity, discharge rate, bank full index etc mainly. The tidal power also effects on carrying capacity. The stretchable length of tidal effects in Hooghly River is 175 miles up to Nabadwip dham. In Bhagirathi-Hooghly river basin, it have been noticed that the tidal interval, duration of tides, rate of tides are very affected on its carrying capacity. It also effects on formation of civilization and economic activity (Wang 2009). By instrumental field survey, with measuring rate of discharge and velocity, the capacity-power of this river has analyzed.

5.4 Slope analysis
Stream power, volume of water, tidal effects are very important for maintaining channel slope. Amount of annual precipitation, evaporation rate and various man-made activities are also important for drainage intensity, amount and direction of slope, gradient (Kempe et al 1996).

\[ \text{Slope} = \tan \theta - 1 \text{ (h/d)} \text{ or} \tan \theta - 1 (0.005) \]

5.5 Bank-full index
Bank-full index is the level of a flood plain of both banks a channel. When the rate of discharge becomes high and it flows at bank full level, it’s called bank full discharge. Actually the effective discharge and bank-full discharge are so equal.

\[ d = cQ^f \quad \text{&} \quad W = aQ^h \]

In channel of Hooghly (study area), the bank full level becomes very high in Rainy Monsoon season but it’s very low in winter and late monsoon period.

5.6 Stream power
Stream discharge, stream slope, rate of velocity all of these are controlled by stream power. This power has a direct relationship with emotional and depositional process of channel. It has also a direct relationship with sediment transport and channel shifting.

\[ \Omega = p g Q s \]

(Where \( Q \) is the stream power, \( p \) is the density of water (1000 kg/m3), \( g \) is acceleration due to gravity (9.8 m/s2), \( Q \) is discharge (m3/s), and \( S \) is the channel slope). By measuring various tools and factors it have noticed that, the rate of stream power of Hooghly belongs in high scale level than surrounding rivers in lower Ganges region.

5.7 Size of grain and particles
By sediment sample collection and analysis with sheer techniques, grain or particle size of both bank of river has measured. This variation of sediment size affected on various physical, environmental and morphological activities related to the deltaic depositional system (Orton and Reading 1993). Mean analysis, sorting, skewness are very useful for calculating of grain-size analysis. Folk and word has given various formulas as like as mean deviation, standard deviation, skewness etc.

The mean deviation calculated by:

\[ M = \phi_{16} + \phi_{50} + \phi_{84} \]

The standard deviation \( \sigma \) is expressed by:

\[ \sigma = \phi_{84} - \phi_{16} + \phi_{95} - \phi_{56.6} \]

The coefficient of skewness expressed by:

\[ SK = \phi_{16} + \phi_{84} - 2\phi_{502}(\phi_{84} - \phi_{16}) + \phi_{5} + \phi_{95} - 2\phi_{502}(\phi_{95} - \phi_{5}) \]
5.8 Channel shifting
Channel shifting is a dynamic and natural geomorphic phenomenon. It is mainly controlled by different factors of channel. This area are locates under Bengal basin and part of lower Ganges region. So, the surface region is very flexible and lateral erosion is so active. In study area, land sat data year of 1978, 1989, 1999, 2019 have collected and by GIS software these all are analyzed. The sedimentation analysis, with different sediment sample collection and by year wise land sat imagery data shows the decadal changing course of channel.

5.9 Sedimentation analysis
Sedimentation is a process of submerging suspended materials. These materials are mainly clay, sand, silt and related particles, present in flowing water. The relation between rate of high velocity, high discharge, high bank full condition and sedimentation is negative respectively. Mainly sedimentation occurs due to powerless condition flow of water. On the basis of submerged suspended particles in different zone of river bank, four different sedimentation tank can be identified as like as Inlet zone, settling zone, sludge zone and outlet zone. Sediment control programmers’ and climatic change records are very important for given idea about stream of sediment sensitively (walling and fang 2003).

5.10 River Channel Cross profile
Due to change of riverine criteria, activities and factors, the bed features of channel Hooghly (Sajiara to Mayapur region) have changed with different passage of time. The analysis of different course of channel mainly shows the channel cross sectional variety (Ghosh & Mistri 2012). Various kinds of riverine features and morphological characteristics can be depicted by channel cross sectional profile. In the study area, the way of channel has changed with the change of time. By collection of DEM data, different cross profile have drawn on different position of channel and analyzed by GIS software.

5.11 Ox-Bow-Lake as an ecotourism region The channel shifting is main cause for formation of Ox-Bow-Lake. It is named as Chupi-Char. By deep observation, photography taking and spot interviewing method, these criteria have analyzed. It is an ecotourism place. Various tourists come here in every year. The questionnaire survey and face to face conversation has done with tourist people. Besides of it, various related information have collected by local people, hotel and motel supervisor, tour guide and door to door survey.

6.0 Result and Findings
6.1 Various criteria of River Hooghly at study area Sajiara to Mayapur

<table>
<thead>
<tr>
<th>Various Criteria of river Hooghly</th>
<th>Velocity (mt / minute)</th>
<th>Stream-power</th>
<th>Discharge (cubic mt. / second)</th>
<th>Carrying Capacity (mt^2/s.)</th>
<th>Slope (In degree)</th>
<th>Bank full-Index (mt^2)</th>
<th>Width (mt.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.70</td>
<td>102,566,746.68</td>
<td>15245.44</td>
<td>45.92</td>
<td>0.6865</td>
<td>650</td>
<td>332.00</td>
</tr>
</tbody>
</table>

Table 1: Comparisons between both the rivers on the basis of their selected criteria

6.2 Interrelation among those criteria
Figure 4: Interrelation trend line

6.3 Cross profile in different section of study area
7.0 Discussion

7.1 Course of river channel (Rupnarayan & Mundeswari) in different year
7.2 Channel shifting and formation of Ox-Bow Lake
Due to geo-tectonic movements, the channel of River Hooghly has changed in many times. In this zone the tectonic plates are located in a collision movement position. The Survey of India has published a topographic sheet in 1973 with the remote sensing images of 1989-90&1992-93, show the formation procedure and changing various geomorphic phenomenon of this wetland. Channel shifting is a natural dynamic phenomenon. Various kinds of factors and process are related on it. With GIS methods, by the land-sat data analysis from 1979 to 2019, it has noticed that, in-between Sajiara to Mayapur, the river Hooghly is not flowing in its previous course of way. This zone is the part of Bengal Basin. It is definitely a flexible zone and lateral erosion is so active. This river is highly dominated by Monsoon season. The seasonal variation of velocity and discharge transform the valley into unstable condition. It is actively creates bank erosion and this is the primary stage of channel movement. In the study area Sajiara to Mayapur, yearly variation of different channel course (Calculation by different landsat imagery) proves that, the channel has shifted in a particular decadal rate. In present, the detachment part is properly belongs as an Ox-Bow-Lake. This lake and its surroundings are named as Chupi-Char.

7.3 Present status of Ox-Bow Lake (Chupi-Char)
At Purba-Bardhaman district, Purbasthali is a large block adjoining with Ox-Bow Lake (Chupi-Char). It is 120 km distance from Kolkata and 8 km from holy town of Nabadwip. It belongs at Western bank of Hooghly River. It locates between the geographical coordinates from 88°19'45" to 88°22' E longitude and 23°26' to 23°26'45" N latitude. From the present main channel flow of Hooghly River, this Ox-Bow-Lake is locates at the distance of 1 km near of Chupi-kasthosali but in near of Sankarpur it is 530 mt distanced. This lake is the part of River Hooghly. In rainy season when the devastating flood occurs in river Hooghly, an overflowing situation occurs and flooded this lake completely. In pre-monsoon period, the spatial range of spatial extent of water is 2.075 sg.km to 3.15 sg.km. The water quality data of Purbasthali shows the excellent qualities of all the parameters in drinking water of this region. The vegetations of the area are portrayed by the arborescent species. For example; Neem (Azadirachta indica), Amlaki (Phyllanthus embica), Coconut (cocos nucifera), , Krishnachuda (Caesalpinia Pulcherrima), Am (Mangifera indica L.) and shrubby species likes Ashsheoda (Glycosmis pentaphylla Corr.) and so on ("Purbasthali" – news · newspapers · books · scholar · JSTOR; January 2019).

7.4 Chupi-Char (Ox-Bow-Lake) as an Ecotourism region
This Chupi-Char also named as Chupi wetland. It is the best habitat for visiting migratory birds. Various birds come to here in winter (Dec - Feb). During winter period, due to abandoned of various colorful migratory birds, this area has developed as an ecotourism place. In winter seasons’ suitable weather 108 to 110 bird species can observe (Amat J.A., Green A.J. 2010). The lake is resided by lots of local birds as well as bronze winged jacana, common redshank, cotton pigmy goose; black winged still are found in Purbasthali, Chupi-lake. Local birds such as common-ynya, spot wild dove, sacker falcon, kingfisher, and yellow-footed green pigeon, laughing dove, red vented bulbul, babbler and black kites, common tailorbirds are observed in Chupi- char area. Resident bird species includes pheasant tailed jacana, purple moorhen, purple heron etc (Ali, S. 2002). A huge number of tourists comes here in every year and various small guest house, private hotel, Boating facilities, watch tower for watching migratory birds, metal road, picnic spot etc has build for suitable staying and enjoying this place. Around of this region; Krishnan agar,
Mayapur, Kalna and Nabaidwip are also attracting tourists. Mayapur is famous for Lord Krishna. Nabaidwip is famous for being the birth place of the Hindu saint, Sri Chaitanya Mahaprabhu. Kalna is famous for Rajbari and various temples. Samudragarh and Natangram are very important for tourists for vast stretches of greenery and cultures of local villages. There have many hotels, lodge, home, cottages and this lake side’s environment is very suitable for enjoining tourists. It is very favorable place for bird lovers. Child- Park is a great attraction for kids. Watch Tower is significant for bird watching. The Ox Bow Lake, named as Chupi char is also significant for researchers. There have also various tour guides. The rates are 150/hours for boats and 100/hours for guides. For special attracting of this place various tourists come from Kolkata, Hooghly, Howrah, Purulia, Bankura, and Sundarban and out of West Bengal; a little number of tourist comes from Delhi, Madhya Pradesh, Bihar, Odisha in every year. This place is so suitable and favorable for tourists in winter season. And have a huge diversity of bird species (Gregory, R. 2006). But in present; due to pollution, environmental hazards, human effects, weathering disturbance have declined the appearance of these species (Rottenborn, S.C. 1999). Government and local people are very aware about this condition as it’s a suitable and cheerful region. It probably thinks that, it has a light future, formation as a glorious tourist spot, because from the present trend of tourist in every year, it can be identified as a special Ecotourism region.

7.5 Flow of tourist from WB and out of WB; seasonal variation of tourist and different bird species at Chupi-Char (Ox-Bow-Lake)

![Fig 7: Tourist flow chart](image-url)
Fig 8: Seasonal variation of Tourist and bird species

7.6 Chupi surroundings scenario

Fig 9: Chupi surrounding Scenario
Local landscape of that region is mainly nature centric. They are utilized the riverine flood place with subsistence farming. Migratory birds are coming within this wetland during winter from different parts of the world. Verities of birds are attracted by tourist and their mainly came within this place due to bird sanctuary, picnic, nature centric landscape and also for favorable tourist place within limit from this like Mayapur, Nabadwip, Kalna, Guptipara etc. This landscape is gradually modified by local people as well as government effort but very little transformation of the natural landscape. So therefore, development of tourism are mainly depends on principles of local ecosystem maintaining proper balance or harmony between man and nature. Wetland vegetation, deciduous varieties of species, solar project, pollution free water as well as greenies scenario are important characteristics of this tourist place. The area was developed mainly as an eco-village with wetland ecosystem.

8.0 Concluding Remarks

Fig 10: A- Main channel and mid channel bar; B- Tidal bar; C- Stable land; D- Channel curvature; E- Yazoo system stream; F- Stable point bar; G- Tidal and lateral sand bar; H- Mud flat region and vegetation cover region on stable mid channel bar
Considering channel shifting process from 1978-2019 that is 41 years span. It is interesting that course of river are gradually changing within this place based on principles of mechanism of Ox-Bow-Lake formation. This is very slow transformation of channel Morphometry but in course of time isolated Ox-Bow-Lake is important fluvial features. The other important fluvial features, due to shifting course of main channel are mud flat, channel cut off, Yazoo System River, mid channel bar, tidal bar etc. Formation If Ox-Bow-Lake is a natural phenomenon of channel morphology and it also identified the paleo channel of Main River as well as present situation of main channel and development of different morphological scenario and it is well known example between river shifting process as well as development of settlement based on paleo channel. The economy of that region is well known example of river based economy and there is a close interrelationship between river and man. But the main philosophy of the development of the area is nature centric that is wetland based economy with proper harmony with natural environment.

9.0 Reference

[3] Colebrooke RH (1797) Chart of the Ganges from Colgong to Harrisonkund exhibiting the state of its island and sands during the dry season, about 90° by 25°(measure later), 1 mile to 1 inch . In: Royal astronomical society (eds), vol2. London, pp 1-63
[7] Islam A (2013) Integrating Channel instability, bank erosion and landuse planning along the left bank of river Bhagirathi in Nadia district ,West Bengal. J river Res inst river behave control 34.11-6
[18] https://archive.org/details/ainiakbarivolum00mubgoog
confined river valleys in the eastern interior of South Africa. Geomorphology 185:54–66


[53] Tropical Ecology, 43(1),173-186


