

**See through sound: Understanding the pattern of  
habitat use by Gangetic river dolphin in the  
Kaziranga part of Brahmaputra river**

*Dissertation submitted to Saurashtra University, Rajkot*

*in Partial fulfilment of*

*Master's Degree in Wildlife Science*

*Submitted by*

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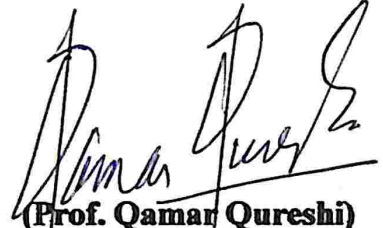


## CERTIFICATE

This is to certify that Mr. **Abhishek B** of the Wildlife Institute of India has carried out a piece of original research work entitled “**See through sound: Understanding the pattern of habitat use by Gangetic river dolphin in the Kaziranga part of Brahmaputra river**”, in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot. These investigations were carried out under our supervision at the Wildlife Institute of India from December 2018 to June 2019. We also certify that this work has not been submitted for any other degree of any university.

  
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## DECLARATION

I, **Abhishek B**, hereby declare that the research work entitled “**See through sound: Understanding the pattern of habitat use by Gangetic river dolphin in the Kaziranga part of Brahmaputra river**”, carried out in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot is an original piece of research work. This research work was carried out under the supervision of **Dr. J A Johnson, Dr. Abdul Wakid and Prof. Qamar Qureshi** at the Wildlife Institute of India from December 2018 to June 2019. I hereby declare that this work has not been submitted for any other degree of any university.

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## ABSTRACT

Studying the habitat and its associated features is important because of its driving factors that limits the abundance and distribution of a species. This study mainly focuses upon the abundance, distribution, activity and habitat use pattern of Gangetic river dolphins in part of the Brahmaputra River that flows through Kaziranga National Park. The abundance of Gangetic river dolphin and its relatedness to the different habitat features of the river and fish species were studied. The 92 km length of river in the study area was divided in to 43 segments, which were further broadly classified in to different river morphology. Out of 43 studied segments (2km each), wide channel was the most frequent river type (17 segments). The average depth and velocity were  $4.83 \pm 1.28$  meters and  $0.50 \pm 0.14$  m/s respectively, estimated in the lean water period. The shallow areas provide refuge sites for fishes. The total of 40 different fish species (871 individuals) were recorded in the river stretch, in which size class of 1-10 cm has the highest count of fishes. The species richness was also highest in same class sizes. The abundance of Gangetic river dolphin in the study area was estimated to be  $125 \pm 24.33$  individuals (including Adult, Sub-adult and Calf) using double observer mark recapture technique. Dolphin uses echolocation for their activity, the level of phonating at particular area was used to understand the intensity of habitat usage in both spatial and temporal scale through acoustic recording using hydrophone. Total of 3447 hours of acoustic recording in 43 segments showed that Gangetic river dolphin was active throughout 24 hours. However, the activity time period varied with different habitat types. Dolphins were more active in daytime in Confluences, meanders and mid-channel island but in Narrow channel type the activity was more during night time. Combining all the information, the distribution of the Gangetic river dolphin was found to be influenced by river depth, velocity and fish in the area. Complex habitat structures like confluence, meander and Mid-channel island were found to be important in terms of dolphin habitat use pattern.

**Keywords:** *Gangetic river dolphin, Habitat features, Fish diversity, Activity pattern, Habitat use.*

# 1. INTRODUCTION

Ganges river dolphin (*Platanista gangetica*) is the only fresh water cetacean present in the Indian subcontinent. Their populations are restricted to Ganga and Brahmaputra river basins and are subjected to very high anthropogenic disturbances (Smith 2000; Sinha *et al.*, 2014). There are four species of fresh water dolphins around the world (Cassens *et al.*, 2000). *Platanista gangetica* species found in South Asia, *Inia geoffrensis*, *Inia boliviensis* and *Sotalia fluviatilis* in South America. *Platanista* genus has two sub species of dolphin “*Platanista gangetica gangetica* and *Platanista gangetica minor*” (Smith 2000; Sinha *et al.*, 2014). Yangtze river dolphin (*Lipotes vexillifer*) is the first cetacean species which stated as functionally extinct from the wild in 2006 due to the range of anthropogenic pressures (Samuel *et al.*, 2007). In the country, potential habitat that supports high abundance of dolphins is very less. There are protected stretches of river like Vikramshila Gangetic Dolphin Sanctuary in Bihar, Hasthinapur wildlife sanctuary in Uttar Pradesh, Kaziranga national park and Orang national park in Assam, and National Chambal sanctuary in Madhya Pradesh, Rajasthan & Uttarpradesh. Fresh water ecosystem and its dependent biodiversity are prone to decline at a faster rate than terrestrial ecosystems (Dudgeon *et al.*, 2006). Changes in land use also impacts the hydrology of the river systems, which in turn alters the morphology and subsequently the biota present in the rivers (Allan *et al.*, 2007). While it is proposed that the distribution of cetacean populations is closely related to the habitat features, more quantitative information is needed to understand this (Hastie *et al.*, 2004).

Gangetic river dolphin is locally known as “*Susu*” in North India and “*Hihu*” in the state of Assam. Globally, the species is listed as “Endangered” by International Union for conservation of Nature (Smith 2012; IUCN Red list). Declared as the National Aquatic animal in 2009, and listed under the “Schedule-I” species of the Wildlife protection act, 1972 (WPA, India), Gangetic river dolphin receive the highest protection and conservation priority level in the country. However, the incidental entanglement of river dolphin in fishing gill nets and use of dolphin oil and body parts as bait for catching fishes are increasing, which pose a main threat to dolphin’s survival, apart

from threats to its habitat with increasing anthropogenic pressure and shipping traffic (Smith 2000).

While majority of the studies on this species provide information on status and distribution of the species, very few studies explain the ecology and its habitat. Gangetic river dolphin abundance varies seasonally and increases mainly during the peak dry seasons in the main channel (Kelkar *et al.*, 2010). The geomorphology and hydrology of the habitat have a significant role in the presence of dolphin and its usage (Braulik 2012). An occupancy study indicates that site use by the dolphin varies with river depth among three river system across two seasons in Nepal (Paudel *et al.*, 2015). The hydro-biological factors near the confluences and eddy currents inturn influences large-scale assemblages of fish and of dolphins, providing a suitable habitat (Biswas *et al.*, 2000).

Gangetic river dolphin feeds on a variety of aquatic fauna. The gut content analysis of 8 individuals from the Ganga river reveals around 45 species of prey (identified up to *Genus* level) including fishes, prawns, molluscs, etc (Kelkar *et al.*, 2018). The dolphin preferred sites with high productivity of small fishes and also supported by the gut analysis which shows more species of small sized fishes (Kelkar *et al.*, 2010). A spatial overlap between the dolphin habitat use and fishing intensity were observed. This is because, fishing intensity acts a surrogate for the availability of food for Gangetic river dolphin in terms of fishes, crustaceans and other aquatic fauna, which are also of interest to fishermen.

Gangetic River dolphin has only rudimentary eyes and is almost blind. It uses biosonar (high frequency sound) for foraging, navigating, communicating and other activities important for its survival. A unique behavior of side swimming to explore their surrounding is also observed by Pilleri *et al.*, 1977. The first report on behavioral studies in wild recorded six types of surfacing pàterns and a mean diving time of 120 secs, which suggests that the oxygen intake restricts them to a specific diving depth under water during the its activity time (Sinha *et al.*, 2010).

Previous studies which have informed us on the quality of habitat, distribution status and level of anthropogenic disturbances have gathered evidences on the basis of visual

observations and encounter (Bashir *et al.*, 2010). While the studies on habitat and distribution of species have explained the status, distribution and the level of disturbance, knowledge from these studies largely stem from visual observations and encounter rates. With these traditional methods, it is difficult for an in-depth understanding of dolphin ecology, as dolphin surfaces for a very short period of time (Sinha *et al.*, 2010).

Recent advancement in technology provides us with an opportunity to understand the ecology of the species using better tools and techniques, especially given the developments in the field of acoustic monitoring. Given that acoustics play a major role in the life history of dolphins, using acoustic monitoring tools like hydrophones will provide us with a unique opportunity to understand the ecology of this endangered species.

The current study was planned in a protected area, and provides us with valuable information on the ecology of the species in a natural riverscape system, rather than the human altered environment where majority of the studies are focused on.

## ***1.1. Objectives***

With this background, the main aim of the study is:

***“Assessment of the abundance, occurrence pattern, fish availability, activity and habitat usage pattern of the Gangetic river dolphin”***

Main objectives of the study are:

1. To estimate the Dolphin abundance and distribution (occurrence pattern) in the part of Brahmaputra river stretch along Kaziranga National Park?
2. To study the pattern of habitat usage by Gangetic river dolphin in the study area.

The research questions which will help to achieve my objectives are as follows:

1. What are the riverscape features (depth, flow, discharge) in study area?
2. What is the abundance and distribution pattern of dolphin in the study stretch?
3. What are the available fish species in the river stretch?
4. Is there any spatio-temporal variation in activity pattern of dolphin?
5. Do habitat features and fish availability influence the pattern of habitat usage by Gangetic river dolphin?

## 2. STUDY AREA

### 2.1. Study area: Brahmaputra River stretch in Kaziranga National Park, Assam



Figure 2.1: Map showing 92km length of study area of Brahmaputra River flows along the northern boundary of Kaziranga National Park, Assam

Study area is the stretch of Brahmaputra river (Figure 2.2) situated on the northern boundary of Kaziranga National Park in Assam starting from latitudes  $26^{\circ}30' N$  to  $26^{\circ}45' N$  and longitudes  $93^{\circ}08' E$  to  $93^{\circ}36' E$ ). The study was focused on the river stretch of length  $92.55 \pm 0.70$  km starting from the Kameng river confluence (Figure 2.3) from downstream.

**Kaziranga National Park** is one of the few protected areas which supports a good population of India's big five terrestrial species and also extends its protection to the National Aquatic Animal "The Gangetic river dolphin" – which holds a significant population in the river (Qureshi *et al.*, 2018). The presence of more dolphin in this area is mainly due to the less disturbance and anthropogenic activities (fishing, sand mining, etc), and also added by additional protection by the Forest Department. Hence, the area acts as a control site for studying the Gangetic river dolphin activity in its natural environmental conditions with less pressure from fishing or anthropogenic activities directly. It is however acknowledged that there will be influences from upstream.

**Study period:** The study was conducted between December 2018 and April 2019, which has lean water flow due to the winter in the high-altitude area, resulting in minimum water flow. The water is below 1m in most of the side channels, which drives dolphins to congregate in the main channel.

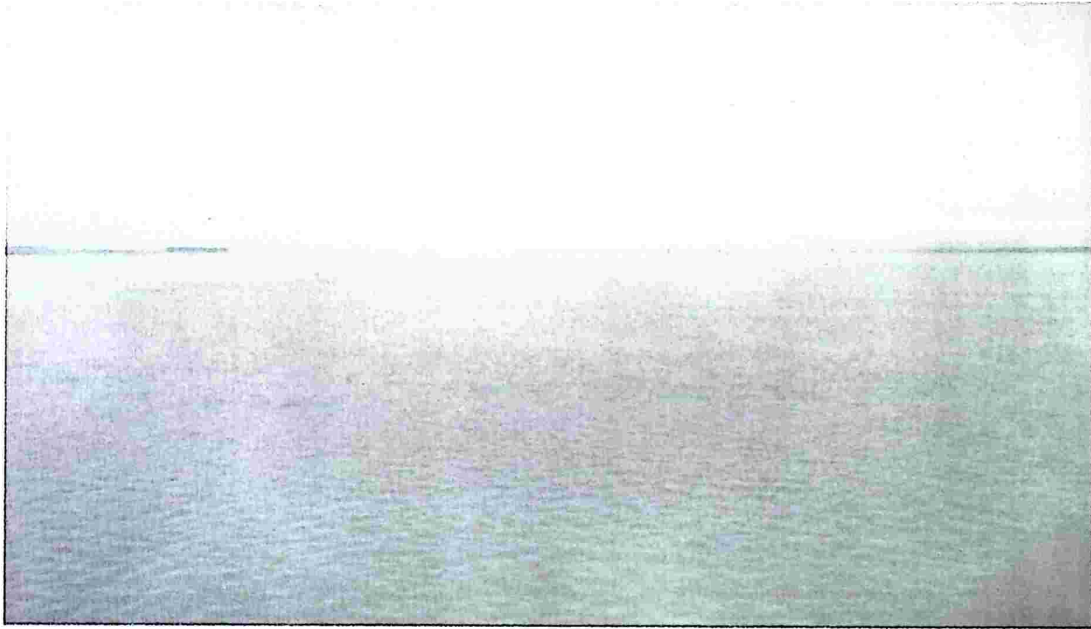


Figure 2.2: Brahmaputra river in Kaziranga National Park

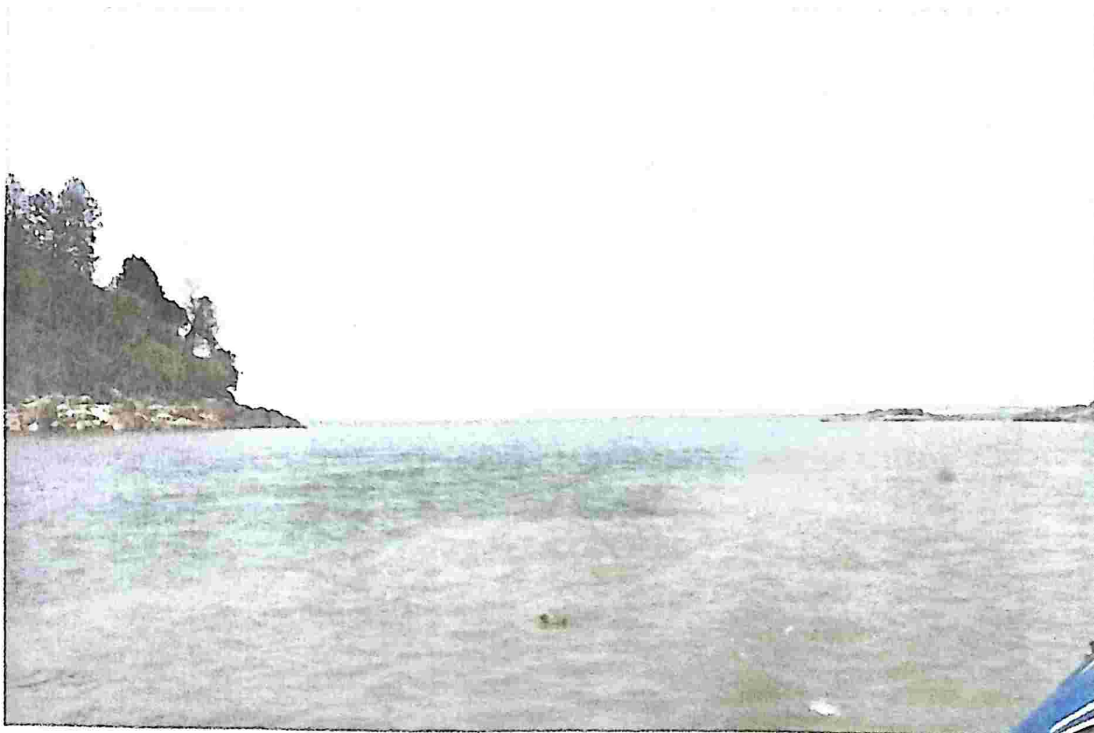


Figure 2.3: Kameng river confluence in Kaziranga national park

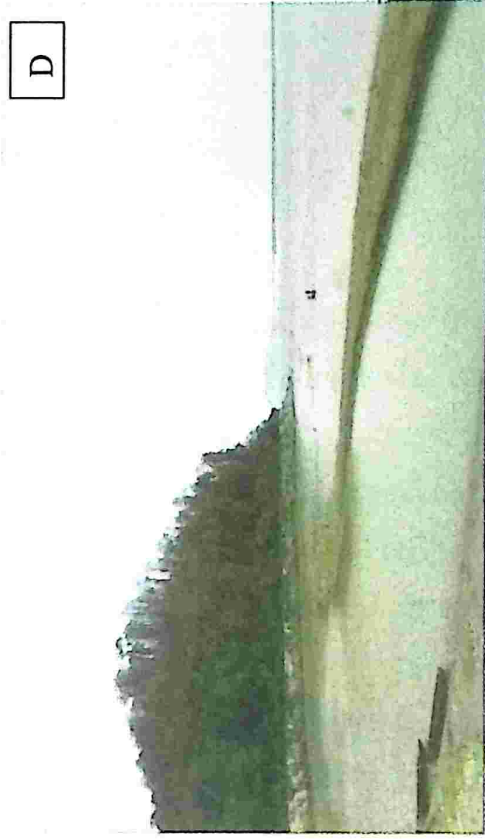
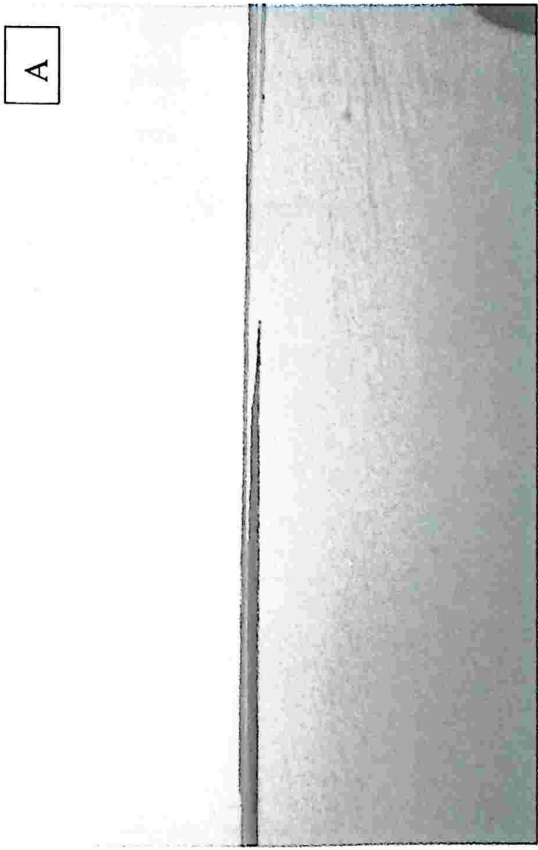


Figure 2.4: A- Shallow pool, B- Rocky substrate pool, C- Shallow debris pool, D: Shallow pool with vegetation

## 3. METHODS

### 3.1. Dolphin abundance estimation

#### 3.1.1. Field Method

Gangetic river dolphin abundance was quantified using a Double observer method (Wakid *et al.*, 2013; Q. Qureshi *et al.*, 2018). The boat survey was carried out from upstream of the river stretch, with constant boat speed (Approximate 10km/hr). Each team is independent of each other in recording the data. Each team consists of a single recorder and two observers covering the 90-degree view angle of each side, completing the semi-circle view. The boat survey is replicated thrice from upstream to downstream to identify the occurrence pattern and reduce the bias through replicates in the study area. These surveys started around 8- 9 AM from the same starting point, i.e., eastern most boundary of the Kaziranga National Park- upstream of the river stretch (Figure 2.1).

For these surveys, ocular distance calibration of each observer was carried out before the survey because range finder cannot work on the river surfaces. Random measurable objects in the surrounding environment are identified and marked for the distance estimate.



Figure 3.1: Boat survey for Gangetic river dolphin abundance estimation

The primary and secondary observer teams record the data from the respective position in the boat (Figure 3.1). GPS units of both the team are initiated at the same time. The initial GPS location and time are recorded to estimate the survey effort. Entire stretch of  $92.55 \pm 0.70$  km was covered in two days, where day one covered 50 to 60% of the stretch. In case of emergency, stoppage was done due to bad weather. At each dolphin encounter during the survey, information of observer name, boat speed, trip odometer, time, GPS location of boat, distance and angle bearing of dolphin, group structure and distance of boat from the bank were recorded by the individual team.

### 3.1.2. Data Analysis

The data of Gangetic river dolphin sightings from both the observer teams are matched in the following manner, to arrive at the “least count” and abundance estimate. The encounters of dolphins from each of the teams are considered as “Captured individuals”, as these are independent observations. “Recapture” individuals are determined based on matching the similarity of the following parameters from both the observers:

1. Odometer reading - Lat, long and distance (km) covered from the starting point
2. Time:  $\pm 5$  sec
3. Radial distance:  $\pm 50$  meters
4. Radial angle:  $\pm 20^\circ$
5. Group structure – Adult/Sub-adult/Calf/Newborn

With the defined variance in the above-mentioned parameters, if all the parameters coincide with primary and secondary team data - those specific individuals are considered as “Recaptured individuals” (R). The remaining individuals are considered as “Unique individuals”.

After the matching of individuals from both teams, dolphin abundance per survey is estimated through the following procedure:

The Modified Lincoln-Peterson Estimate (L-P estimate) or Chapman estimate (Anne *et al.*, 2008; Brittain *et al.*, 2009). This estimate is based on the hyper geometric model,

the LP estimator is modified and derived to adjust the bias or variance caused due to the smaller recapture (R),

$$N = \frac{(M + 1)(C + 1)}{(R + 1) - 1}$$

The Variance of this estimate is calculated by,

$$Var(\sigma) = \frac{(M + 1)(C + 1)(M - R)(C - R)}{(R + 1)^2(R + 2)}$$

Standard deviation:

$$Std. dev = \sqrt{Variance(\sigma)}$$

Where,

N- Population size estimate; M- Marked Individuals; C- Captured Individuals; R- Recaptured Individuals.

### **3.2. River mapping and classification**

#### **3.2.1. GIS method**

To understand the structural morphology the river was classified into seven different types based on the location and structural features. Mapping the area gives a broader insight into the river and helps plan the sampling strategy. (M. Rinaldi *et al.*, 2016).

The entire study area was divided into “*segments*” of 2km length (approximate). These segments are considered as a single sampling **unit** for measuring the physical parameters or variables of the river (flow, depth, discharge and velocity). The segments are then classified into the following river classifications (Figure 3.2):

- Braiding confluence: The confluence area in the river channel, where two or more side channels meet at a single point.
- Channel braiding: The part of river main channel splits into two or more side channels.
- Confluence: The area where two different rivers meet, a junction point where mixing of two river components (sediments, flow, fishes) takes place.

- Meander: The winding curve of the river stretch (Main channel) which changes the flow direction.
- Mid channel island: Formation of temporary sandy landforms in the river during low discharge time. This formation changes the flow dynamics of river in the area.
- Narrow channel: If the width of channel below 500-600 meters is considered as a narrow channel, as the cross-sectional area reduces, thereby increasing the velocity of water flow in the area, forming a bottle neck.
- Wide channel: A width of >700meters is considered as a wide channel. Here, the cross-sectional area expands, and the flow velocity of the river reduces due to expansion.

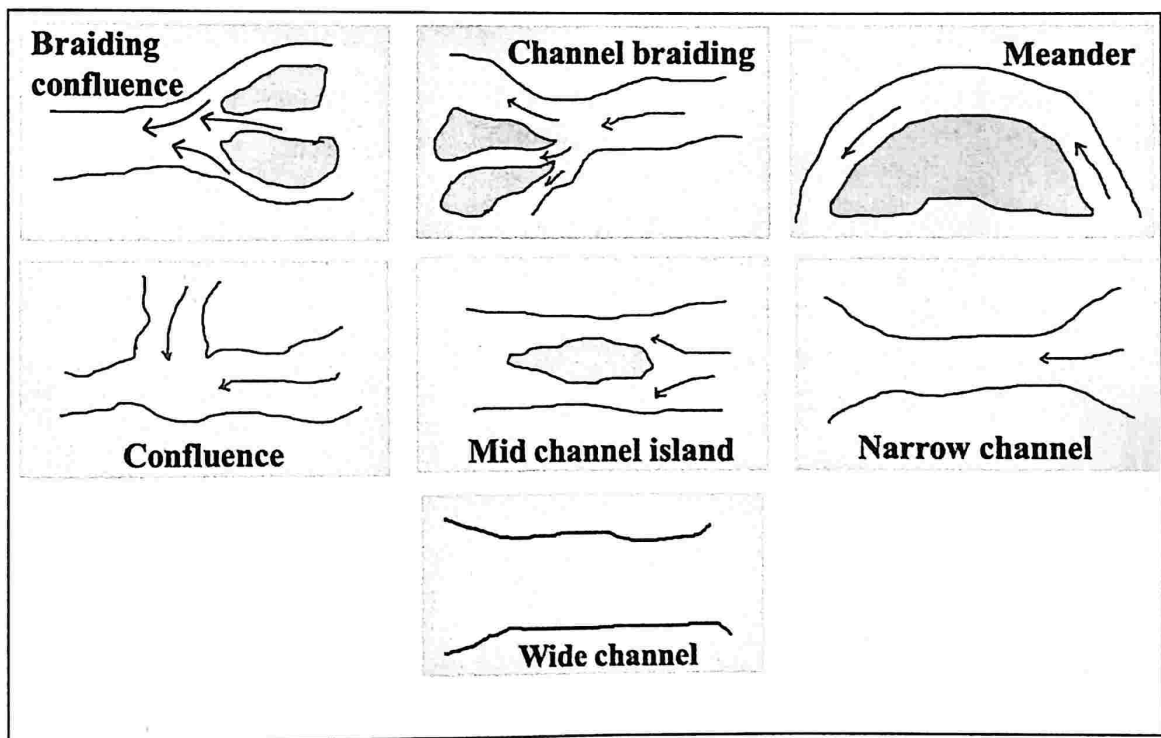


Figure 3.2: Pictorial representation of river type classification

Characteristics of each two km cross sectional segments were mapped and digitized using ArcGIS (version 10.6.1) tools. Brahmaputra flows through a flood plain which covers huge area and this flow course shifts during monsoon. A buffer of 5 km from the main channel was mapped and analyzed for water flow, side channels, shifting sand bar and vegetation cover. These parameters are also important to understand the river

structure which changes every monsoon, forming new islands and shifts the main channel flow of river.

The Sentinel-2 data of the February, 2019 was used for mapping, which provides the current river flow structure of the study time. Band of Blue (2), Green (3), Red (4) and Near Infrared (8 bands are used for the unsupervised classification using the ERDAS Imagine software (*Hexagon Geospatial group*) tool of the different land cover type. The vector file of the classified map is used for further analysis.

### 3.2.2. Field method

The entire river stretch flows through the study area was divided into 2km segments, which resulted in a total of 43 segments. The sampling effort and data for physical parameter were measured and collected for 42 river segments excluding the last segment from downstream. The depth of the column and velocity of the water flow are measured using the different instruments (Table 3.1).

Table 3.1: Measurement of parameters in each segment

Sl. No	Parameter	Data type	Data	Unit of measurement	Measured or calculated
1	River type classification	Categorical	Braiding confluence, Channel braiding, Confluence, Mid channel island, Meander, Narrow channel, Wide channel	Category	Visual and GIS mapping using ArcGIS 10.6.1 and ERDAS Imagine software.
2	Depth	Continuous	Numerical	Meter (m)	Depthtrax (HawkEye company) and

					Humminbird helix 12 SONAR instrument (Humminbird Fishing Electronics & Mapping company)
3	Velocity	Continuous	Numerical	Meter per sec (m/s)	Flow meter (Global water company)
4	Discharge	Continuous	Numerical	Cubic meter per second (m <sup>3</sup> /s)	Calculated from depth and velocity

**Cross sectional measurements:** The depth of the river column was measured for each 50m interval from the starting point of the cross section in each segment. The water flow velocity was measured at a depth of 1ft from the surface using flow probe (Table 3.1). The measurement of velocity was made once for every four intervals of depth measurement. The depth and bathymetry scan were done with Humminbird helix 12 SONAR instrument (Table 3.1) using a country motor boat with an average speed of 10km/hr moving perpendicular to river flow. The cross-section measurement provides sectional depth profile across the river channel and also enables the calculation of the amount of water flow or discharge in that particular segment. All the above-mentioned variables are repeated for every segment, which amounts to a total of 84 cross section data of river column.

### 3.2.3. Data analysis

The cross-sectional data provides the depth and velocity which are used to calculate the following (WMO-No. 1044, 2010):

Cross sectional area is calculated using the formula:

$$Area(A_i) = \frac{d_i \times (b_{i+1} - b_{i-1})}{2}$$

Where,  $A_i$  = Area of the cross-section segment portion

$b_{i+1}$  &  $b_{i-1}$  = distance from the initial or starting reference point “i” of cross section from the river bank;  $d_i$  = vertical depth at the segment “i”

For end section,

$$Area(A_{near\_end}) = \frac{d_{i-1} \times (b_i - b_{i-1})}{2}$$

$$Area(A_{far\_end}) = \frac{d_i \times (b_i - b_{i-1})}{2}$$

Sectional discharge:

$$q_i = v_i \times A_i$$

Where,  $q_i$  = water discharge for section ( $m^3/s$ );  $v_i$  = velocity of segment ( $m/s$ )

$A_i$  = Area of segment ( $m^2$ )

Flow discharge of the segment

$$Q = \sum_i^n q$$

Where,  $Q$  = Discharge of the segment ( $m^3/s$ )

Through the above-mentioned equation, the average depth and velocity of each segment is estimated. These measurements are used to understand and quantify the physical features of each habitat.

The actual distance, depth and velocity are used in the calculating the total discharge volume of water in each segment. Further, these measurements are also used for addressing the research Question-5, regarding the intensity of habitat use by Gangetic river dolphins.

### ***3.3. Fish distribution***

#### **3.3.1. Field Method**

To quantify the diversity, distribution and abundance of fish species, several methods were used in combination as single method cannot capture existing possible fish diversity and size classes. Since Gangetic river dolphin has a limited gape size, can catch or consume specific size class of fishes (Anders 1996; Cozzi *et al.*, 2017). So, the current study design is to check whether the varying abundance of specific size class fish correlate the presence of dolphin in the habitat. Fishes of 1-10 cm size are largely caught by the cast net, while gill nets capture all the classes specifically fishes of 10-30 cm. Abundance of particular sizes class is counted for every site which is used for later analysis.

**Gill net method** was used to capture fishes that use different column guilds. The preferred net size (length and width) were decided based on a reconnaissance survey (Table 3.2). Based on the reconnaissance survey, the drifted gill net was used (the gill nets were specially designed, which suits for river Brahmaputra). These nets were deployed in different habitat types (Figure 3.3) found in each segment, for a duration of one hour (Johnson *et al.*, 2012). GPS location, depth, deployment time, flow and habitat type were recorded at the time of net deployment. Later nets were retrieved and fishes were carefully collected in the water container for further identification and analysis. (Jayaram 2010)

**Cast net method** was used for sampling fishes in calm water conditions, which include the habitat type of shallow pools, slow flowing water, sandy bank and backwater areas (Figure 3.3). These nets have limited casting range and target smaller size fishes. The sampling location and habitat type for each casting is recorded. Ten replicates of cast net are made in each site. After casting the net, fishes are collected separately for recording the measurements.

In both cast and gillnet deployment, fishes were collected alive and handled carefully for the data collection. The total numbers of fishes captured were counted for each method in a segment. The photographs and standard morphometric measurements such as head-tail length, head-snout, dorsal and ventral fin ray count, body scale count, snout position and weight were recorded for the species identification and size classification.

Table 3.2: Specification of net size used for the fish sampling

Net type	Mesh size (mm)	Length (m)	Height (m)
Monofilament Gill net	20	70	1
Monofilament Gill net	35	70	1.2
Monofilament Gill net	50	70	1.5
Cast net	16	3	-

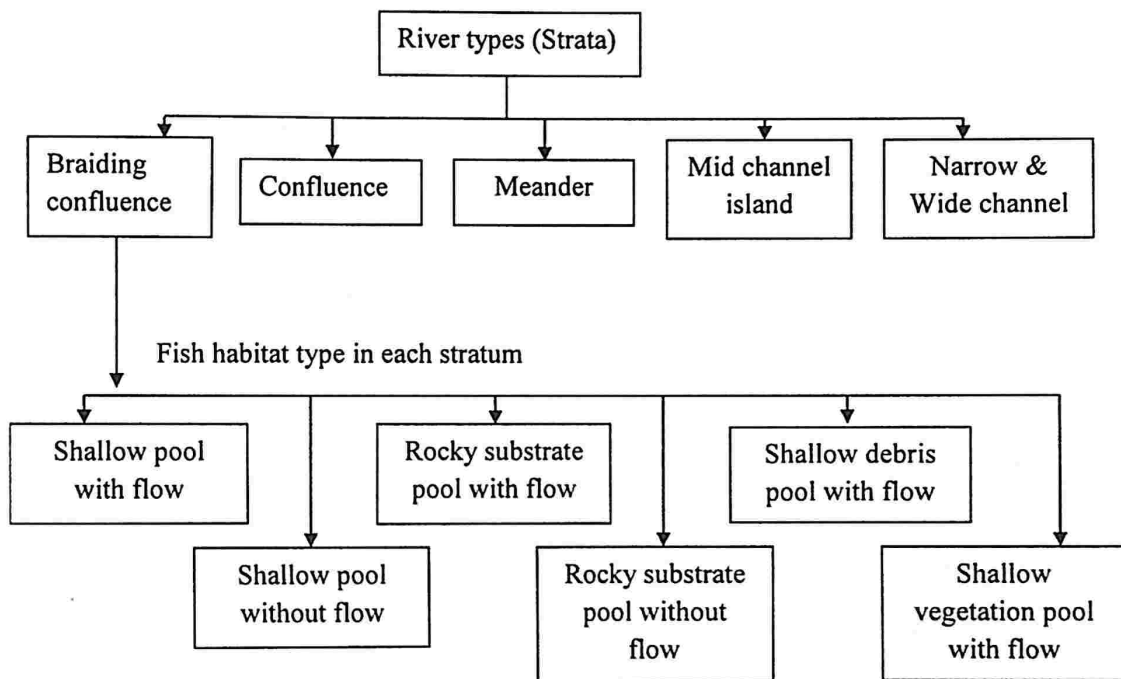


Figure 3.3: Fish habitat type classification in the stretch of Brahmaputra River in Kaziranga National Park, Assam

Fish sampling followed a stratified sampling protocol, where different river morphologies were treated as “*Strata*” (Figure 3.2) within each of these strata, different fish habitats (Figure 2.4 and Figure 3.3) were sampled. This sampling was spatially replicated for each stratum across the entire stretch.

### 3.3.2. Analysis

Fish species identification was carried out by comparing photograph to published literature. All the fish species from different net sizes were considered for the analysis. The fishes were first divided into 3 size class 1-10cm, 10-20cm and >20cm. This was

to understand different size class of fishes in different habitats and in turn how this influences the dolphin presence. The total count of fishes per segment are added together. In segments having multiple habitat types, the average was taken. Species richness was calculated for each of the size classes.

The richness per fish sampling site was used for plotting the species accumulation curve. The number of species in a segment and total number of individuals are used to estimate “Shannon diversity index” – which provides information on the diversity of the sampled site.

Species richness and diversity index was calculated using R (version 3.6.0) software and abundance of each size class per segment is used for further analysis to address the research question 5 regarding intensity of habitat use by dolphins.

### ***3.4. Activity pattern of Gangetic river dolphin***

#### **3.4.1. Field method**

The amount of time spent by a species in a particular habitat or location can be used as a proxy for “intensity of habitat use” (Clay *et al.*, 2018; Temple *et al.*, 2016; Sasaki *et al.* 2013, Bailey *et al.*, 2010). In case of river dolphins, which are difficult to monitor visually, the time spent in particular habitat can be passively recorded by deploying hydrophones in the location.

C-Porpoise Detector (here after “CPOD”) manufactured by “*Chelonia Limited group, UK*” is a hydrophone instrument used to record acoustic signals emitted by Gangetic river dolphin called “Click”. It is a data logger which record the emitted sound signals in the environment, converts and stores the received sound signal into digital format. CPOD measures the frequency (KHz), pressure level (Pa) and duration (millisecond) of continuous sound bits called “train” (Ref: CPOD manual).



Figure 3.4 CPOD (hydrophone) instrument

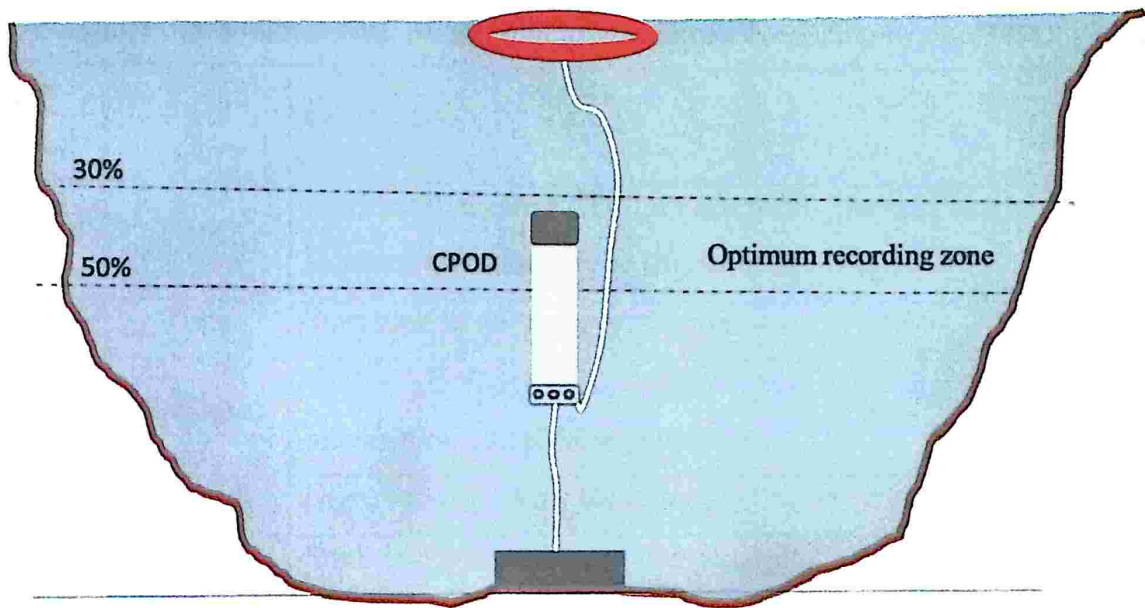


Figure 3.5 CPOD (hydrophone) deployment in the river column

CPOD (Figure 3.4) is Omni directional sound recording hydrophone with the detection range of 400m radius (for Porpoise), so covering a recording range of 1km buffer approximately. The entire river stretch was 43 segments of 2km each. CPOD was deployed in all the segments for 3-7 days (Only 1-4 segments for 7days) for 24 hours for understanding usage of habitat at different time duration. To reduce the spatial auto correlations between the two instruments, the CPOD is deployed 2 km apart from each other. CPODs were deployed using an anchor in particular location at 30 to 50% of the water column (Figure 3.4). For spotting and safety purpose, a buoy was attached to it, which indicates the exact location above the water surface. (Ref: CPOD manual). Data from the CPOD is retrieved using CPOD software (developed by “*Chelonia group*”). The raw output file is a custom “.CP1 file” format which is used to extract the information.

### 3.4.2. Analysis

The.CP1 file contains all the raw acoustic information received during recording, using the KERNO classifier which works on the principle of log-likelihood for the detection of dolphin clicks. All the detections are categorized in to different classes (high, moderate, low). “High” train classes have the likelihood of  $\geq 75\%$  belonging to dolphins (Ref: CPOD manual).

Table 3.3: Full train details of the dolphin acoustic recording using CPOD

Sl. No	Field	Explanation
1	TrnID	An identifier range (ID) for each train. The only use of this is to match this summary to details of each click.
2	Time	Start time as dd/mm/yyyy hh:mm
3	SpClass	'NBHF', Dol, SONAR, Unidentified – based on preset information and KERNO classifier
4	TrClass	High, Mod and Low based on likelihood percentage
5	Start	Start time within minute, in microseconds.
6	TrDur_us	Total duration of train in microseconds. Can be used to calculate overall average ICI = duration / (NofClx – 1)
7	NofClx	This includes 'virtual clicks' that are inferred by the train detector where the real clicks may have been 'knocked out' by a noise spike. Including these makes the calculation above valid.
8	Clx/s	Average click rate, rounded to whole number of clicks per second
9	modalKHz	Modal frequency of train clicks in kHz.
10	avSPL	Average SPL of clicks in train in raw units, not corrected for frequency.
11	MaxICI_us	The first and last ICIs (inter-click-intervals) are excluded as these are more often incorrect.
12	TimeLost	% of logging time lost due to minutes maxing out.
13	ClksThisMin	Total number of clicks in the CP1 file for the minute

The processed file is in “.CP3 file” format which provides information on full train details of all the variables (Table 3.3) collected. The information consists of all the categorical data of classification

The data received was scanned using multiple filters provided in the software, which checks for sediment noise and quality of the dolphin clicks recorded. Once the relevant dolphin data was identified, additional information like phase, segment ID, river type and time conversion are added. Data sets were compiled and correlated to the specific habitat type.

Total number of clicks recorded in an area gives the amount of time spent by the Gangetic river dolphins in a given area. The amount of time spent was used as surrogate for defining the intensity of habitat usage. Also, the sound frequency bandwidth used by the dolphins was compared for different river type. The time duration spent in each sector also provides information on the activity in the particular area. The overall Diel activity pattern is observed through the click rate or Detection positive minutes (DPM) in particular hour.

The Kolmogorov–Smirnov test (*ks.test*) was used to check the distribution range of frequency used between different river type structures. Density overlap test was done for different river type and Area under the curve was estimated to check the difference of activity time in the habitat structures, using the package “overlap” (Mike *et al.*, 2018) in R 3.6.0.]

### ***3.5. Habitat use of Gangetic river dolphin***

#### **3.5.1. Analysis**

To arrive at an understanding regarding habitat use by dolphins, I needed to combine information from each of the research questions, regarding river morphology, dolphin abundance and distribution, fish distribution, and habitat use. For this, the compiled information was first standardized using Z transformation, due to different scale metrics of each dataset.

Exploratory analysis was done to see the association of depth, discharge, velocity, fish and river types with river dolphin usage. (Ref: Annexure 5)

Generalized Linear model (GLM) was used to check the significance of the predictor variables (depth, discharge, velocity and fish count) with the response variable (Dolphin activity) using the poisson distribution with log function.

The time spent by the Gangetic river dolphin in an area was considered as a surrogate for the intensity of habitat use. It is measured by,

$$Usage\ intensity = \frac{Detection\ positive\ minutes}{Total\ minutes\ of\ recordings}$$

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National Institute of Wild Life, India - Dehra  
संख्या/No. WF9623  
दिनांक/Date 18-6-2020  
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## 4. RESULTS

### 4.1. Habitat

Based on the classification the 42 segments, seven river types were identified (Figure 3.1). Wide channel was observed in 17 segments, which is highest compared to all other river types. Channel braiding was observed in only one segment, which was the least. Confluence and Mid-channel Island were recorded in 2 segments each (Figure 4.1).

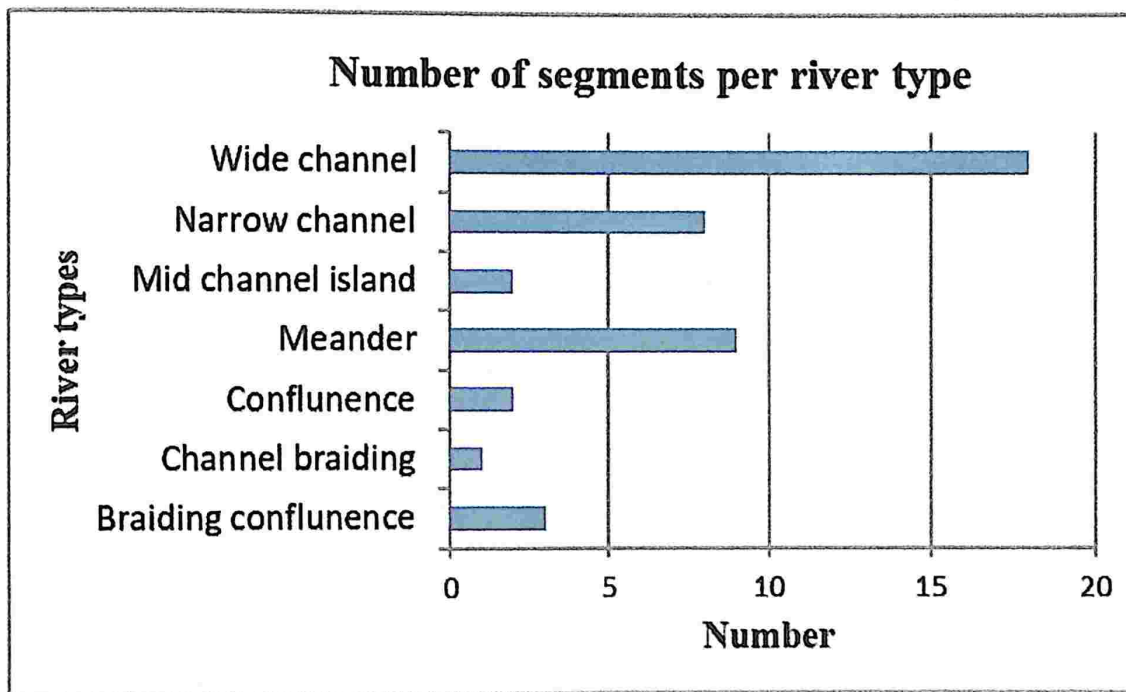


Figure 4.1: The Number of segments that are classified under the different river types, in the study are of Brahmaputra river stretch in Kaziranga National Park.

The cross-sectional depth measured recorded in the entire study area varied from 0.6 to 12.9m. The average depth was  $4.83 \pm 1.28$  meters varying in different habitats (Figure 4.2). Average velocity recorded in in different channel types are presented in Figure 4.3. The average velocity was  $0.5 \pm 0.14$  m/s. Highest velocity was in narrow channel and least in channel braiding.

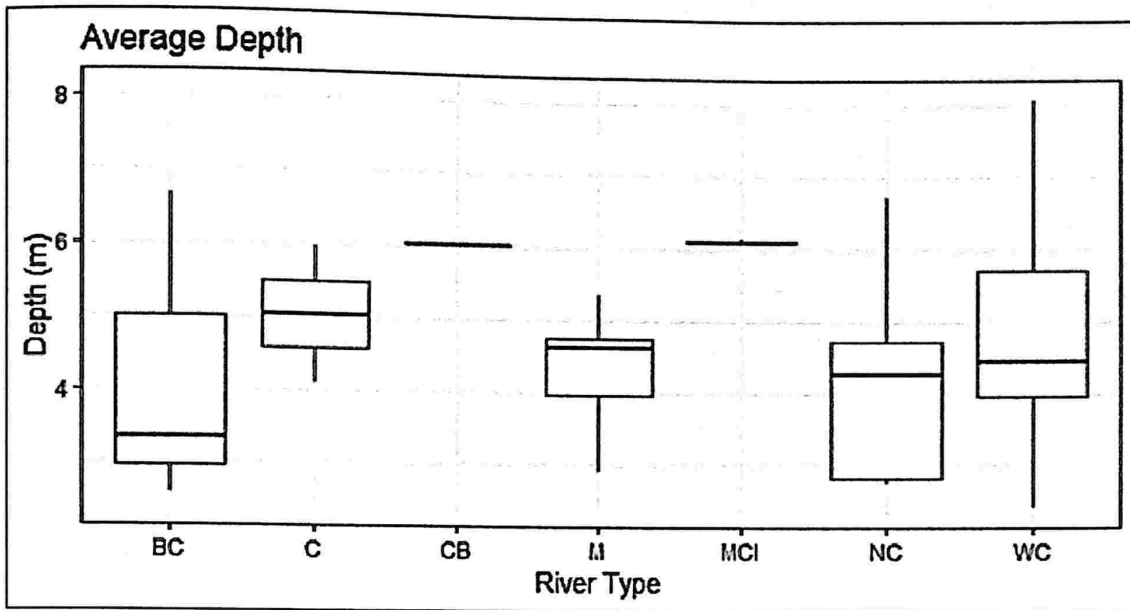


Figure 4.2: Average depth (in meters) of all the river types (BC-Braiding Confluence, C- Confluence, CB –Channel Braiding, M – Meander, MCI –Mid channel island, NC – Narrow Channel, WC – Wide Channel), across all the segments in the study area of Brahmaputra river stretch in Kaziranga National Park.

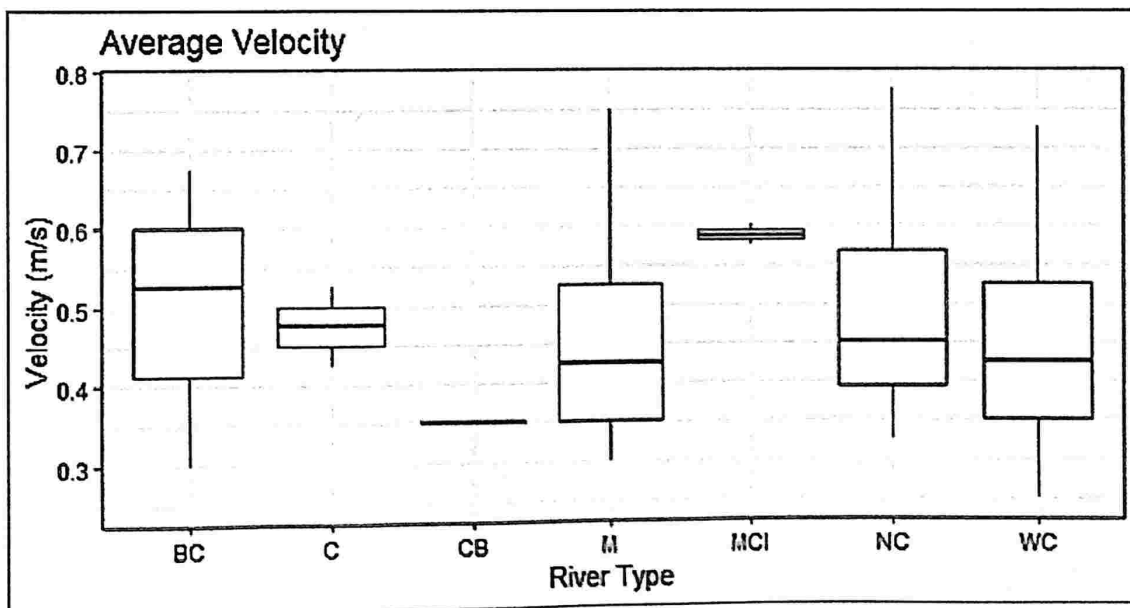


Figure 4.3: The average velocity of all the river types (BC-Braiding Confluence, C- Confluence, CB – Channel Braiding, M – Meander, MCI –Mid channel island, NC – Narrow Channel, WC – Wide Channel) across all the segments in the study area of Brahmaputra river stretch

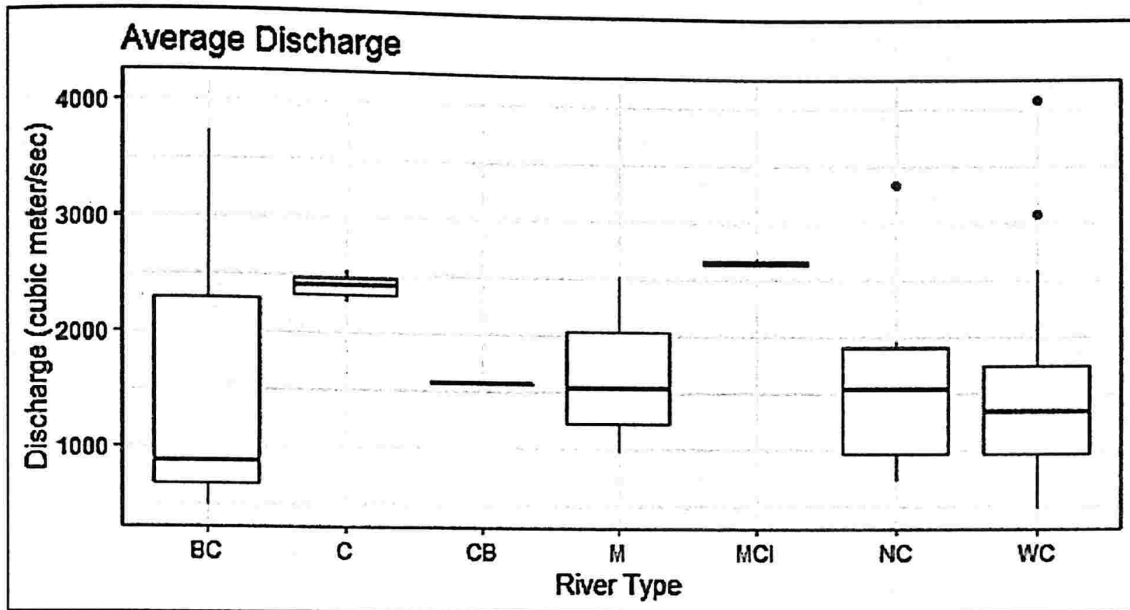


Figure 4.4: The average discharge of all the river types, (BC-Braiding Confluence, C-Confluence, CB –Channel Braiding, M – Meander, MCI –Mid channel island, NC – Narrow Channel, WC – Wide Channel), across all the segments in the study area of Brahmaputra river stretch

Using the Sentinel -2A data of the February 2019 month, the riverine classification of the river channel, sand bar, river scrub and related water bodies in the buffer of 5km range from the main channel is mapped (Figure 4.5)

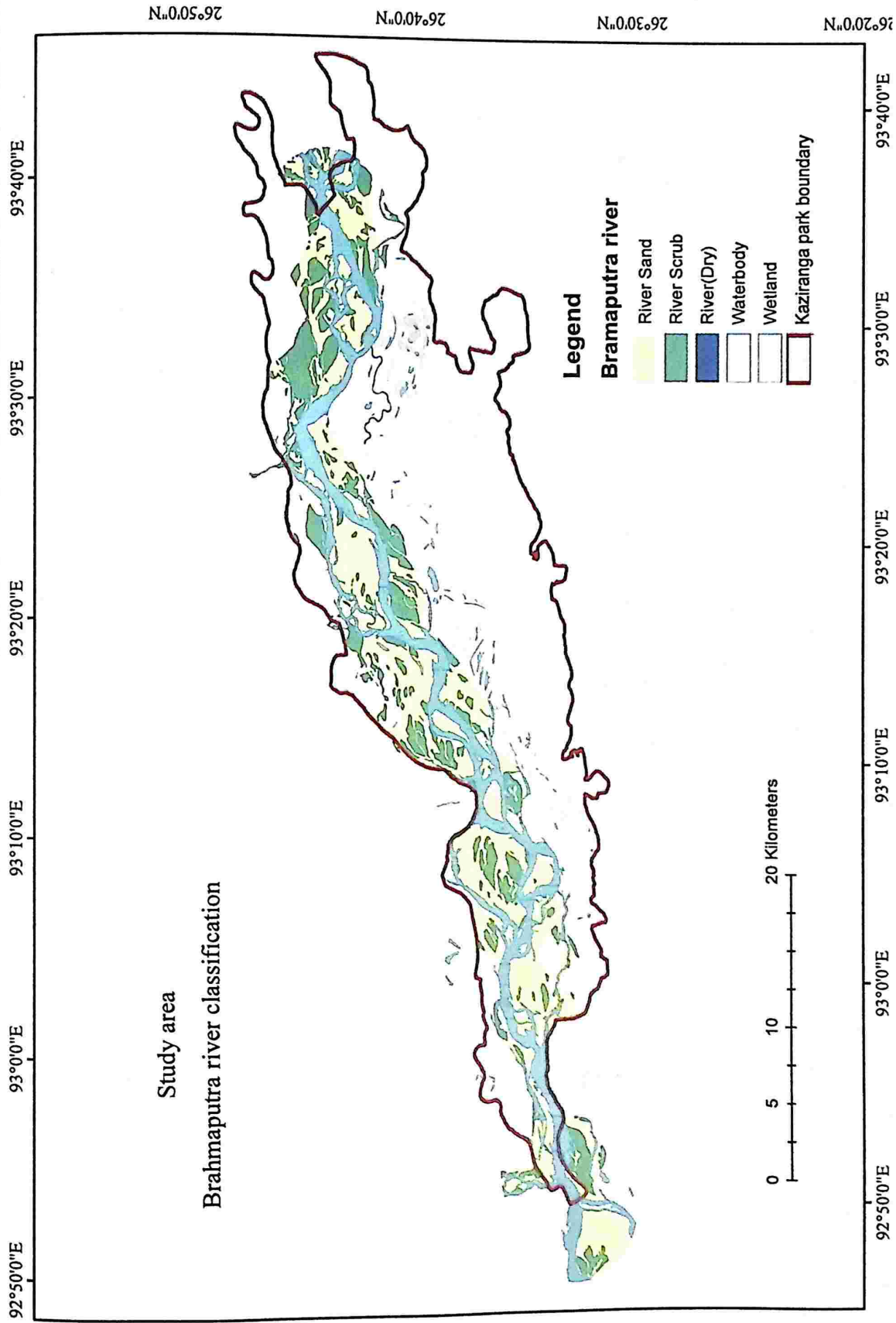


Figure 4.5: The classification of Brahmaputra River in Kaziranga National Park

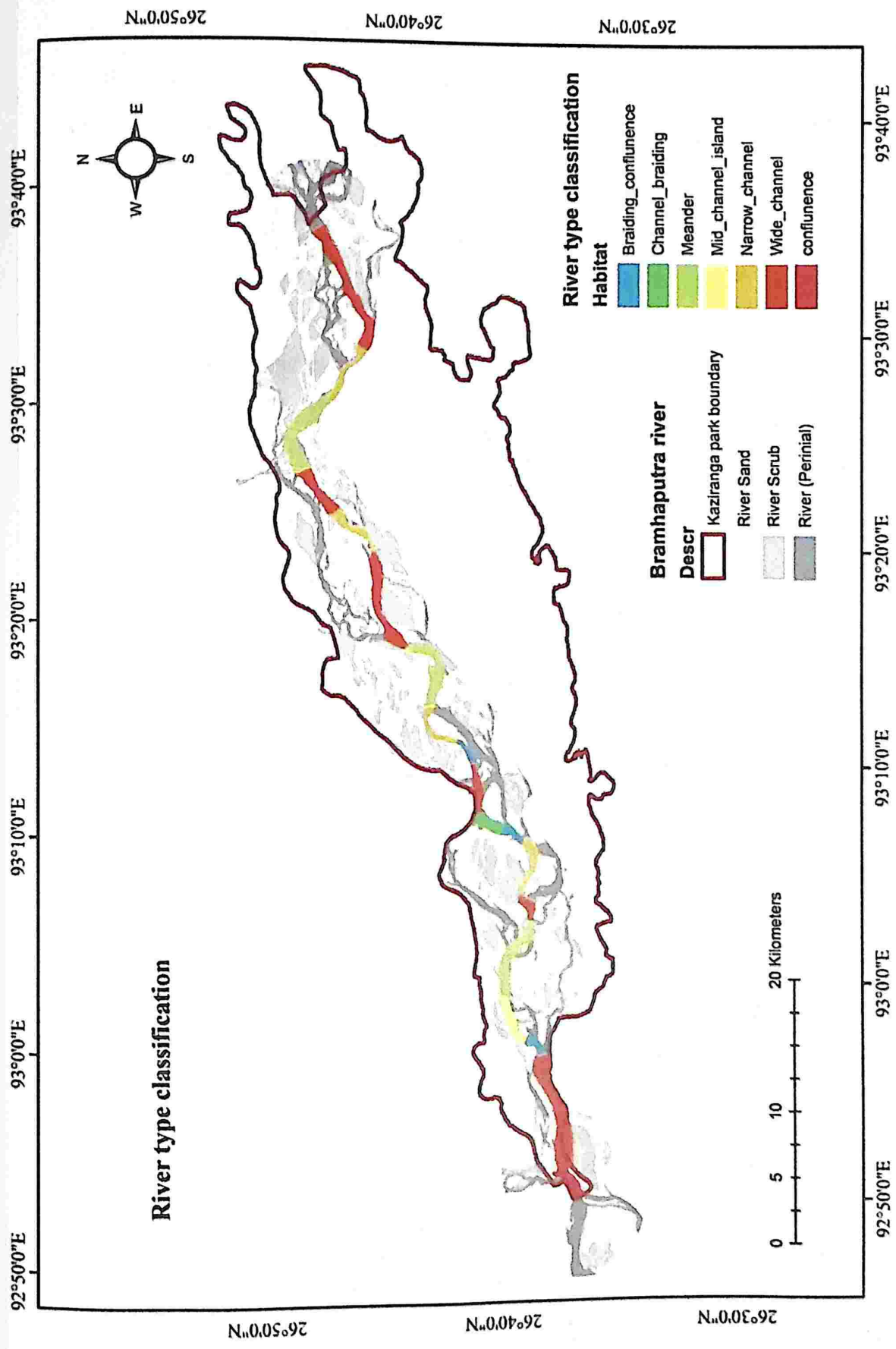


Figure 4.6: Classification of river type (Main channel) in the stretch of Brahmaputra River in Kaziranga National Park

## 4.2. Fish availability

Forty-two sites are sampled across the river stretch which is covered in 33 segments of the river (Figure 4.10). Remaining segments couldn't be sampled due to the high river flow and eroding sand bars. Most of the fishes were identified up to species level. Seven species were identified up to genus level.

Total of 871 individuals of 40 different species (Ref: Annexure 2) were collected at 42 sites. Size of 1-10 cm has the highest count 529 individuals comprising of 22 species. The confluence river type had the highest abundance of fishes with size class of 1-10cm. The narrow channel yielded a greater number of 10-20 cm size class fishes (Figure 4.7).

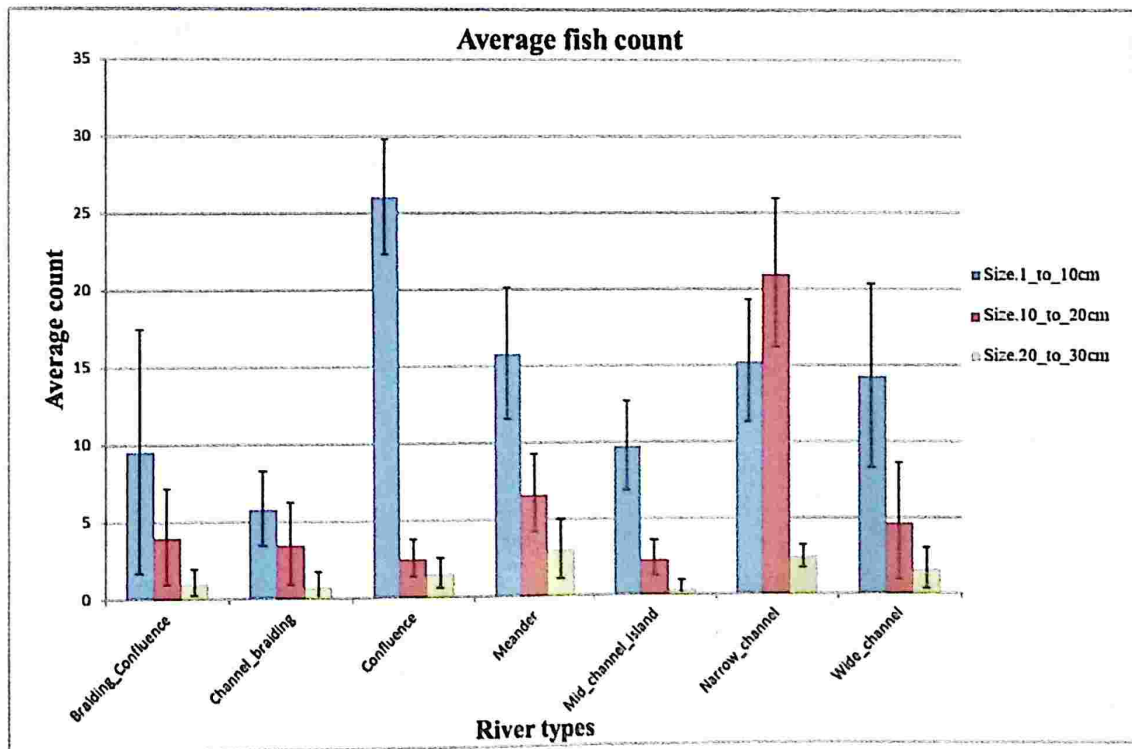


Figure 4.7: Average count of fishes collected in each river type of the stretch of Brahmaputra River in Kaziranga National Park

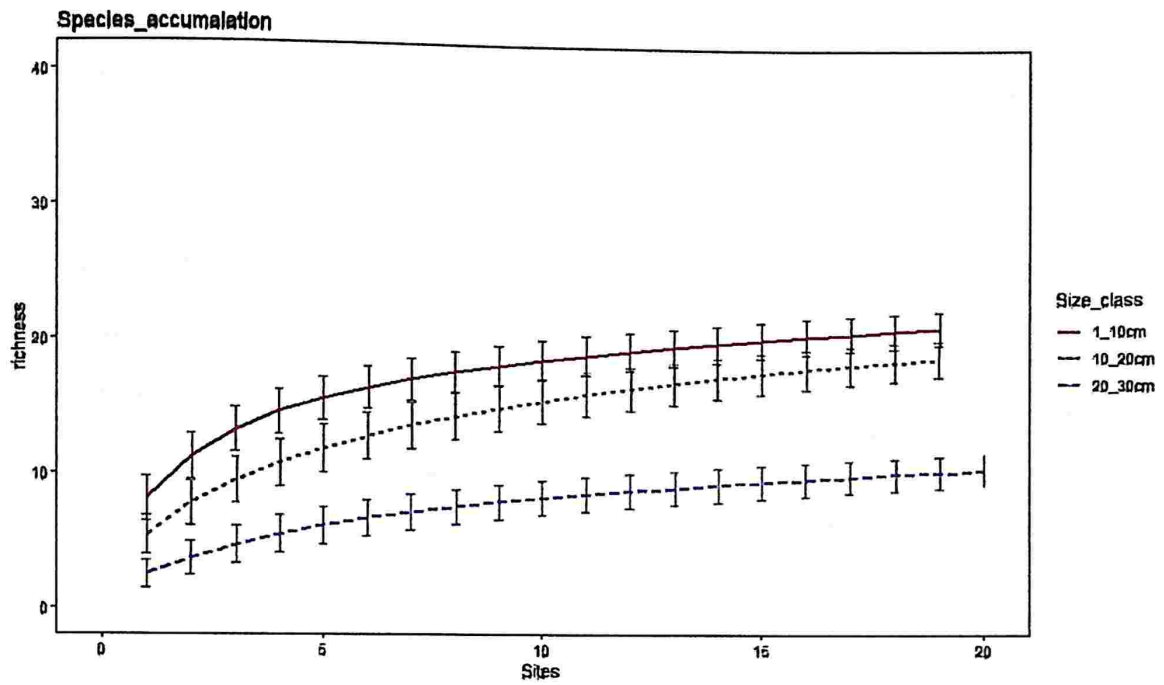


Figure 4.8: Species accumulation curve of different size class fish in sites sampled in the stretch of Brahmaputra River in Kaziranga National Park

The species richness of the large size fishes (20-30cm) were  $15.36 \pm 1.48$ , whereas the richness of small (1-10 cm) and medium (10-20cm) size class fishes were  $26.72 \pm 1.58$  and  $25.01 \pm 1.59$  respectively (Figure 4.8). Species wise number of individuals collected from sampling sites was depicted in Figure 4.9.

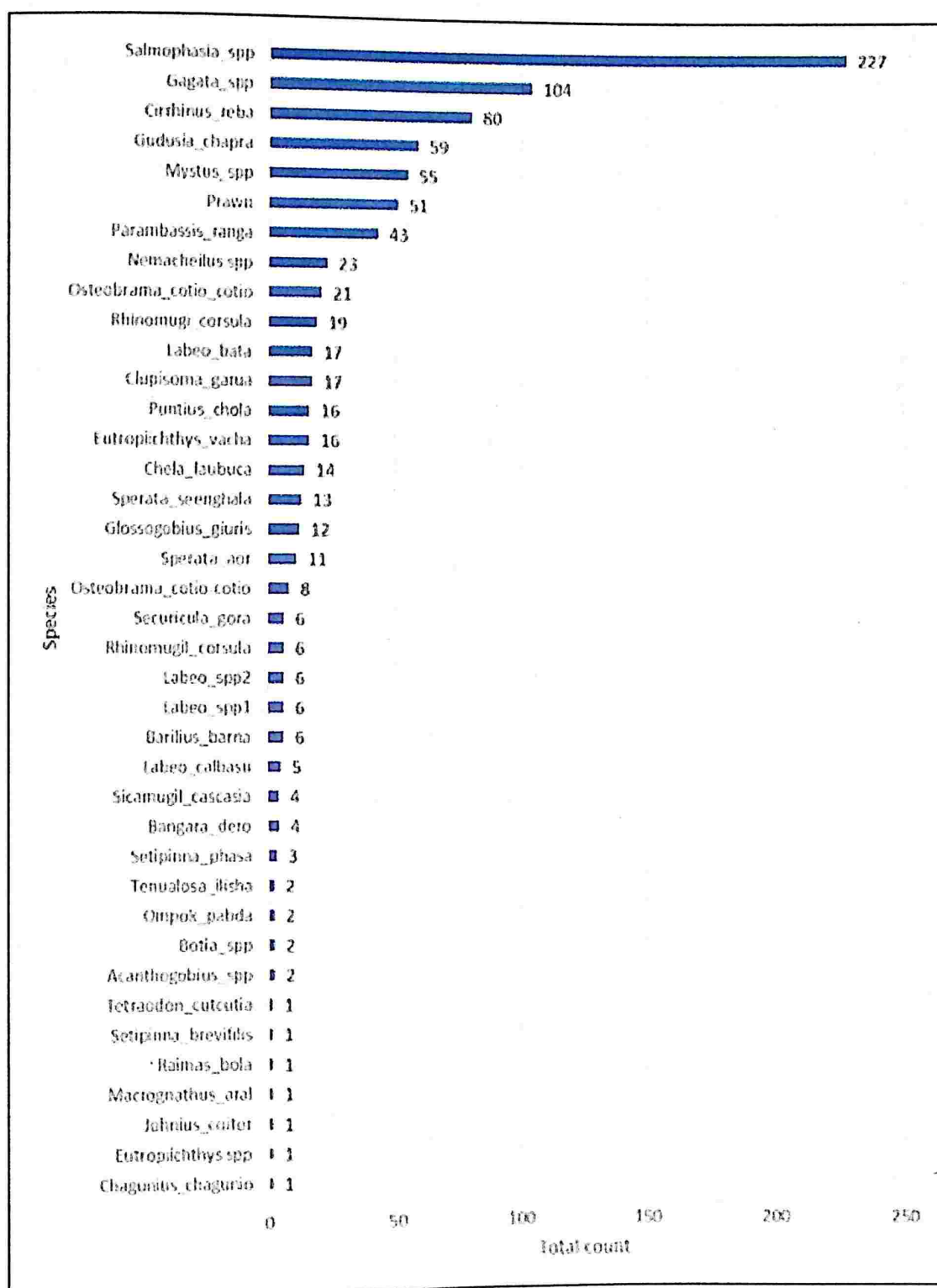


Figure 4.9: Total fish collected in all the sites sampled in the stretch of Brahmaputra River in Kaziranga National Park.

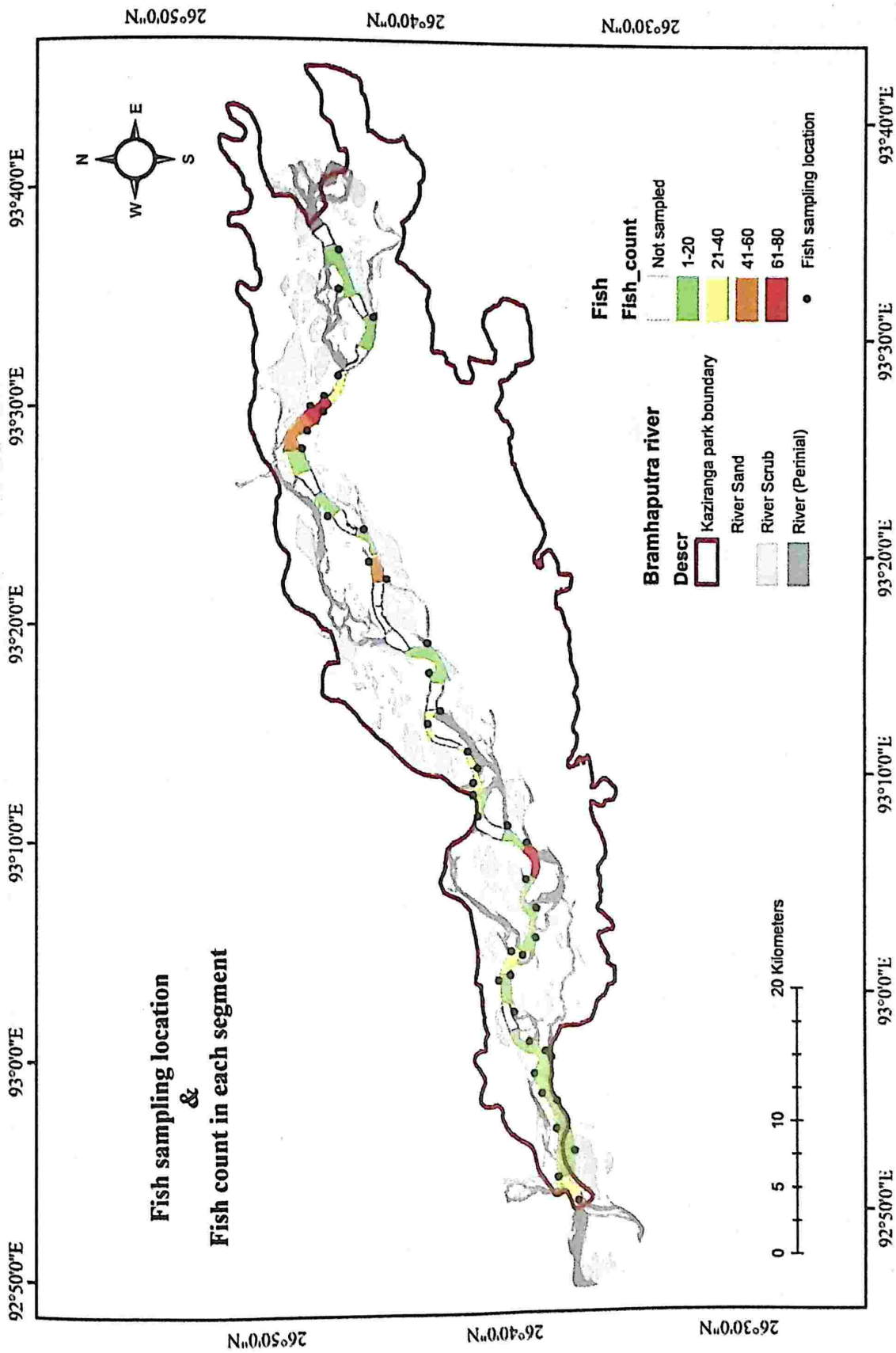


Figure 4.10: Fish sampling locations and total fish collected in each segment in the study area which is the stretch of Brahmaputra River in Kaziranga National Park

### 4.3. Gangetic river dolphin abundance

The three-river survey were carried on 26/1/2019 & 27/1/2019 (1<sup>st</sup> survey), 2/2/2019 & 3/2/2019 (2<sup>nd</sup> survey), and 6/2/2019 & 7/2/2019 (3<sup>rd</sup> survey) respectively in the Brahmaputra main covering  $92.55 \pm 0.70$  km. The marked and recaptured individuals were identified and the abundance estimation per survey for both calf and adult are tabulated (Table 4.1).

Table 4.1: The estimated abundance of Gangetic river dolphin in Kaziranga part of Brahmaputra River

Survey	Group structure	Abundance	Probability of detection (p)	Variance	Standard deviation	Confidence interval (95%) $\pm$
Survey 1	Adult/Sub-adult	64.25	0.39	106.65	10.33	20.29
	Calf	63.00	0.48	53.33	7.30	14.35
Survey 2	Adult/Sub-adult	55.00	0.47	79.33	8.91	17.50
	Calf	60.94	0.42	44.53	6.67	13.11
Survey 3	Adult/Sub-adult	70.25	0.24	239.47	15.48	30.40
	Calf	71.33	0.40	140.95	11.87	23.32

The abundance estimate from all the three survey varies from  $64.25 \pm 0.39$  to  $70.25 \pm 15.47$  (n=3) for the adult dolphin and  $60.94 \pm 6.67$  to  $71.33 \pm 11.87$  (n=3) for calf (Table 4.1 and 4.2).

### 4.4. Gangetic river dolphin distribution

The GPS location of the Gangetic river dolphin in the survey recorded are plotted on the map. Plotting all three survey's location together – it's clearly observed that dolphin sightings are clustered at specific locations (Figure 4.11). Visual sighting provides a short-term view or information of dolphin being present in the location. Passive recording of dolphin clicks provides more insights in use of these river types (Ref: Chapter 3.4).

Table 4.2: Overall effort and total abundance estimation of Gangetic river dolphin including both adult and calves.

Survey	Effort (km)	Average boat speed (km/hr)	Team 1 least count	Team 2 least count	Encounter rate	Calf/Adult-sub-adult ratio	Total estimated abundance	Standard deviation	Confidence interval (95%) $\pm$	Coefficient of variance (cv)
Survey 1	93.10	11.09 $\pm$ 0.87	57	61	0.66	0.98	127.43	12.70	24.96	0.09
Survey 2	92.80	10.59 $\pm$ 0.66	53	56	0.60	1.11	101.60	8.46	16.61	0.08
Survey 3	91.76	10.53 $\pm$ 0.58	48	56	0.61	1.02	146.00	21.00	41.26	0.14
Average	<b>92.55 <math>\pm</math> 0.70</b>				<b>0.60</b>		<b>125.00</b>	<b>24.23</b>	<b>47.62</b>	<b>0.10</b>

The calf to adult/sub-adult ratio is almost 1:1 ratio, which provides the information on the survival rate of new individuals (calf) in the study location.

Combining all the survey efforts, the average estimated abundance of Gangetic river dolphin is  $125 \pm 24.22$  ( $n=3$ ) individuals in the Brahmaputra river stretch of  $92.553 \pm 0.7$  km ( $n=3$ ) that flows through Kaziranga national park (Table 4.2).

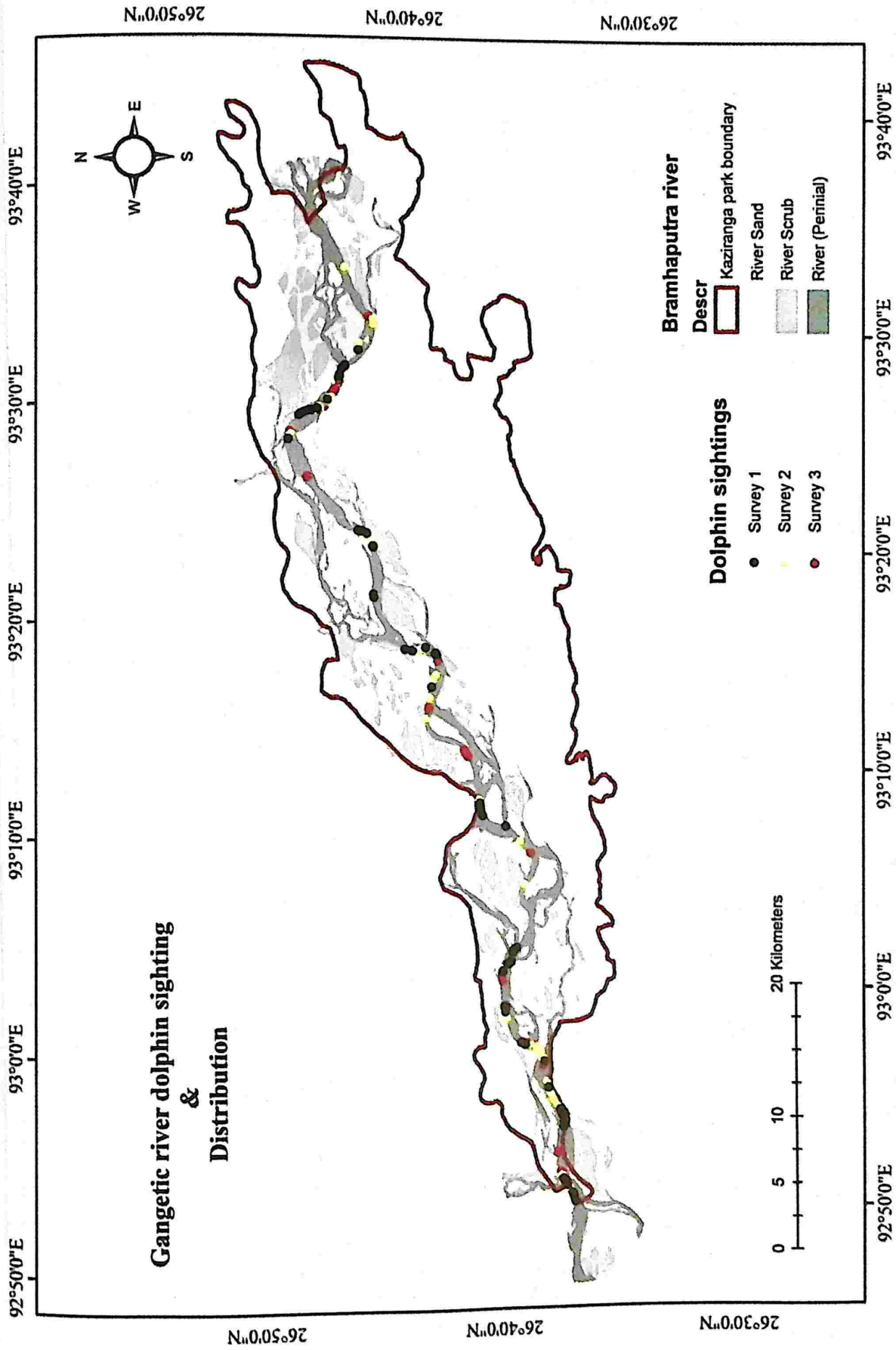


Figure 4.11: Distribution of Gangetic river dolphin in the stretch of Brahmaputra River in Kaziranga National Park

#### 4.5. Activity pattern of Gangetic river dolphin

Out of 43 CPODs only 16 CPODs recorded good quality data, 17 of them did not record any data of Gangetic river dolphins, this could be due to faulty instruments or problems during time of deployment or retrieval of data. The average deployment depth of CPOD was  $2.37 \pm 0.87$  meters which is mid column of the river segment (Ref: Annexure 3).

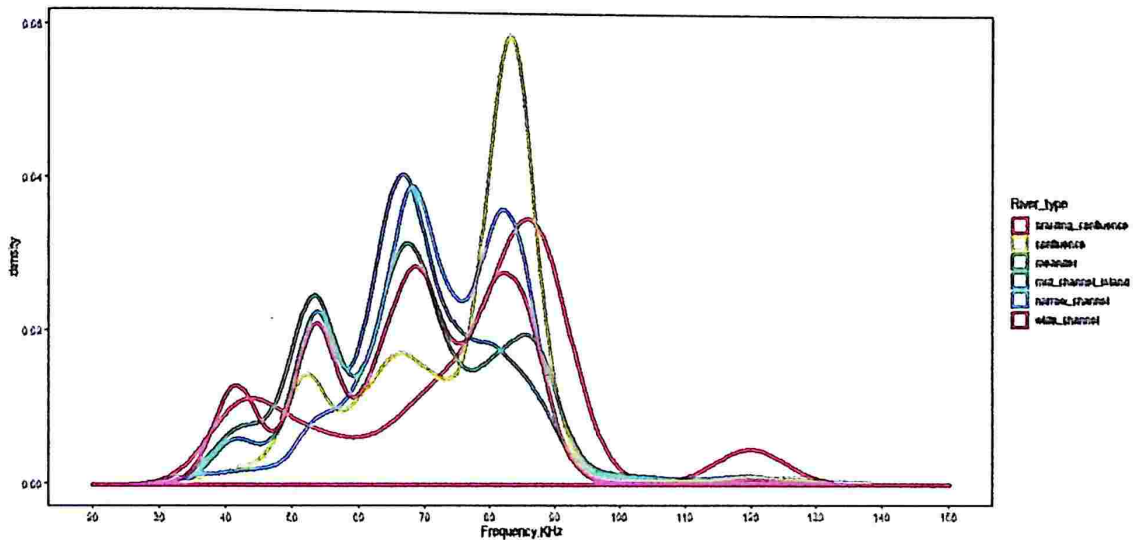


Figure 4.12: Overlap of Gangetic river dolphin from different river types, as recorded by the CPOD in the stretch of Brahmaputra River in Kaziranga National Park

A total of 3447.21 hours of dolphin activity (acoustic clicks) was recorded. The mean recording hours for all 43 CPOD is  $80.16 \pm 27.35$  hours.

Two-sided Kolmogorov–Smirnov test was used to check the difference in frequency usage of Gangetic river dolphin across different river types. The Sound frequency bandwidth of Gangetic river dolphin ranges from 20-160 KHz, but the usage of frequencies within range is significant for different river types. The p value for all the pairs of river types are below 0.05. The result shows that all the river type has significance difference in terms of frequency usage. (Ref: Annexure 4)

The activity time overlap test (Table 4.3) shows the amount of time use overlap between different pairs of river types. Maximum overlap has been observed between braiding and confluences. While least has been observed in Braiding confluence and Narrow channel, and Confluence and Narrow channel. The other pairs have varying degree of overlap.

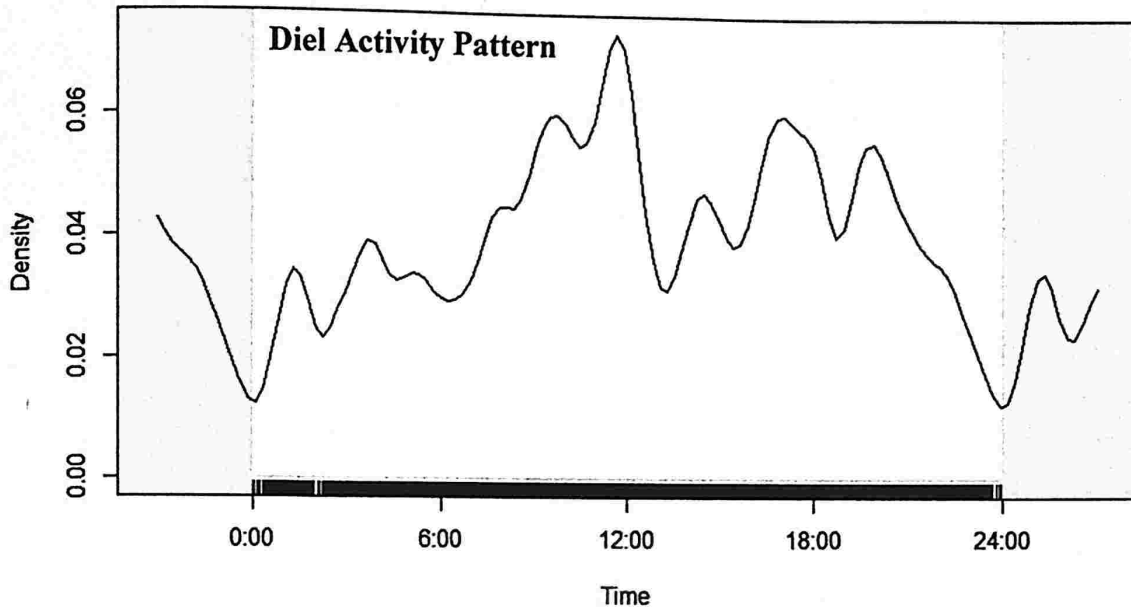


Figure 4.13: Overall diel activity pattern of Gangetic river dolphin, as observed through acoustic activity from 43 CPODs deployed across varying river morphologies in the stretch of Brahmaputra River in Kaziranga National park

Table 4.3: Activity Overlap of Gangetic river dolphin between two river types

Sl no	River type	D-hat value
1	Confluence-Meander	0.40
2	Confluence -Mid channel island	0.58
3	Confluence - Braiding confluence	1
4	Confluence - Narrow channel	0.13
5	Confluence - Wide channel	0.30
6	Meander - Mid channel island	0.77
7	Meander - Braiding confluence	0.40
8	Meander - Narrow channel	0.50
9	Meander - Wide channel	0.67
10	Mid channel island - Braiding confluence	0.58
11	Mid channel island - Narrow channel	0.37
12	Mid channel island - Wide channel	0.40
13	Braiding confluence - Narrow channel	0.13
14	Braiding confluence - Wide channel	0.30
15	Narrow channel - Wide channel	0.60

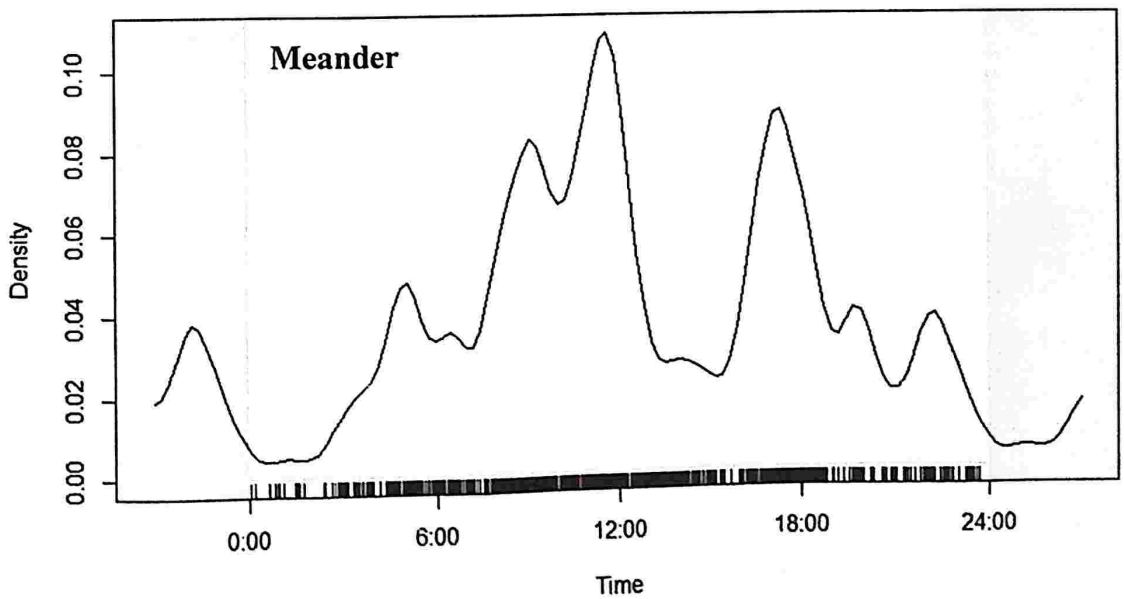
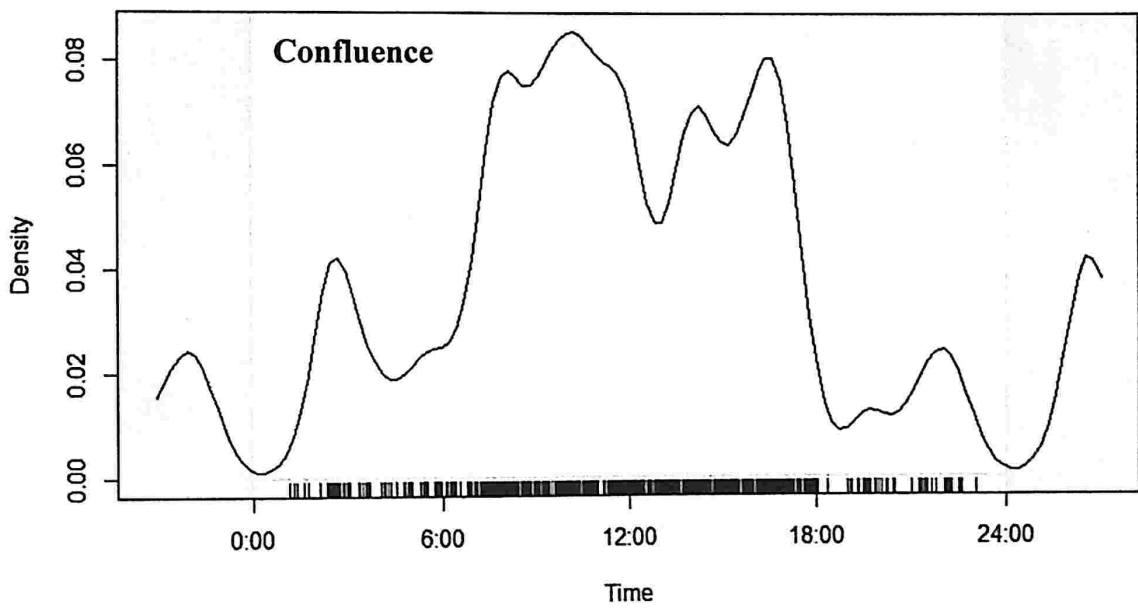
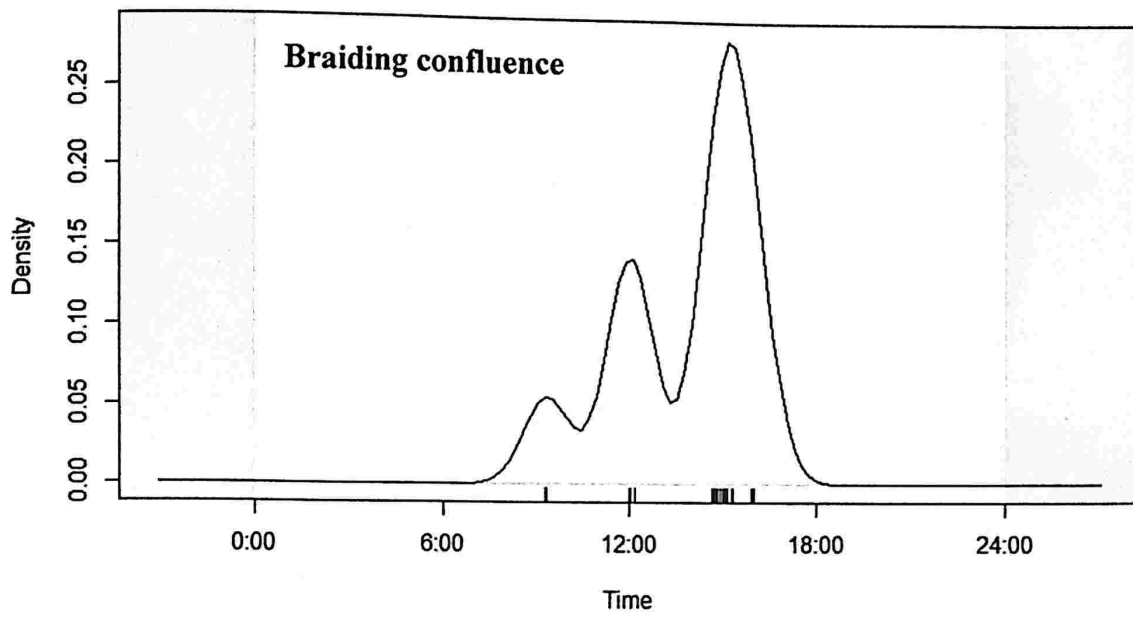


Figure 4.14 Diel activity pattern of Gangetic River dolphin in Braiding Confluence, Confluence and Meander river type

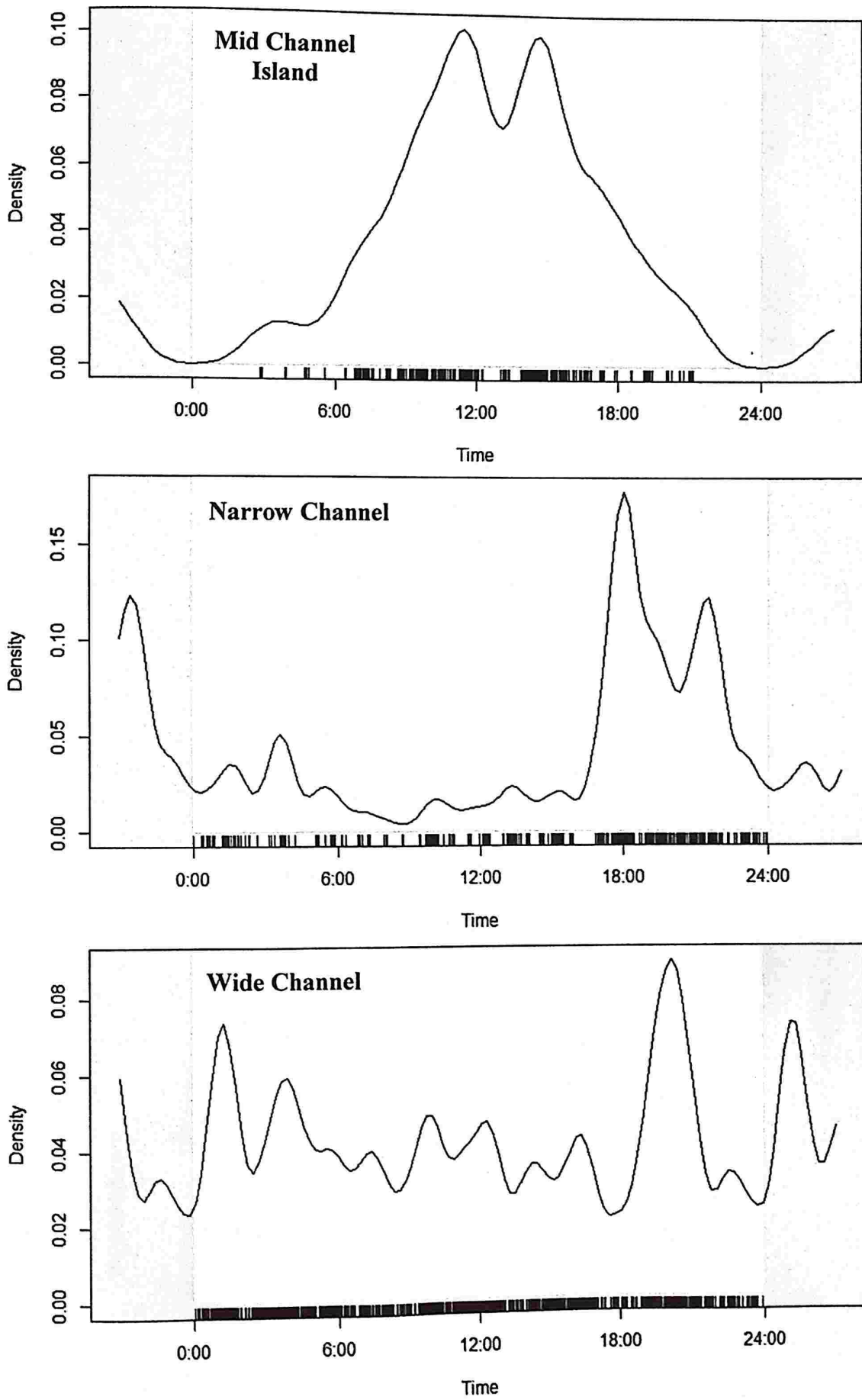


Figure 4.15 Diel activity pattern of Gangetic River dolphin in Mid channel island, Narrow and Wide channel types

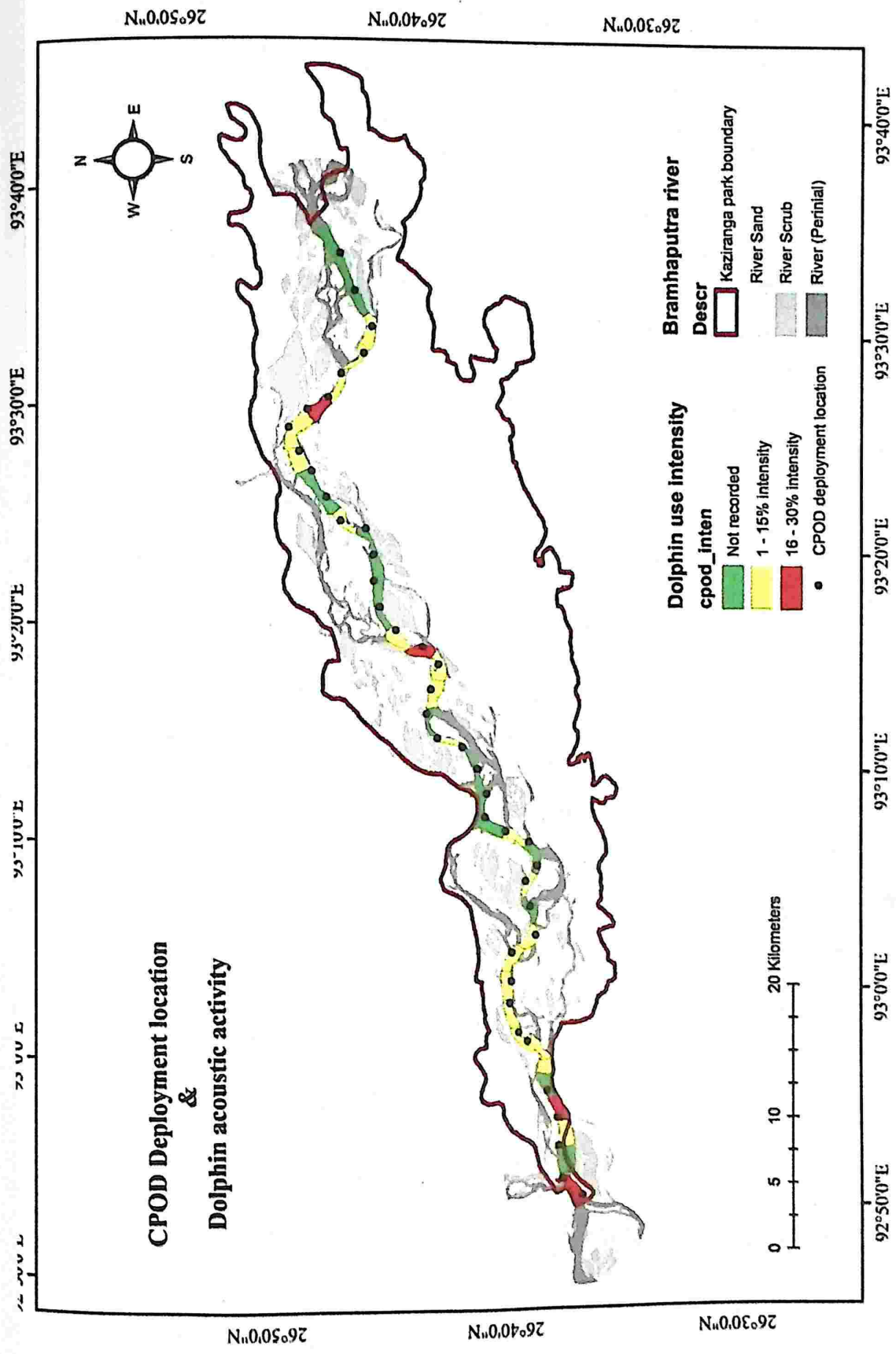


Figure 4.16: CPOD deployment location and the intensity of Gangetic river dolphin phonating in the stretch of Brahmaputra River in Kaziranga National Park

#### 4.6. Habitat use pattern by Gangetic river dolphin

The Generalized linear model provides the significance relationship of predictor variables which are independent of each other.

Table 4.4: Details of GLM models (total and size class wise fish count) to relate habitat features, fish availability to use of habitat by Gangetic river dolphins.

GLM model	formula	Distribution	AIC value	Delta AIC
Model 1	Dolphin intensity ~ depth + velocity + discharge + total fish	Poisson	258.38	0
Model 2	Dolphin intensity ~ depth + velocity + discharge + fish (size:1-10cm) + fish (size:10-20cm) + fish (size:20-30cm)	Poisson	259.09	0.71

The total and size class wise fish count have similar significance on the model. So, the overall fish count is considered and effect are explained in Table 4.5.

Table 4.5: Generalized linear model for all the variables and its significance effect

Variables	Coefficient estimate	Std. Error	Pr(> z )	Significance
(Intercept)	0.10	0.49	0.840617	
River type - Confluence	2.06	0.52	6.90E-05	***
Depth	0.75	0.13	2.06E-08	***
Velocity	0.46	0.13	0.000381	***
River type - Meander	1.69	0.53	0.001399	**
River type – Mid-channel island	1.05	0.53	0.046768	*
Fish	0.20	0.10	0.052755	‘.’

Discharge	-0.00	0.00	0.49952	
River type – Narrow channel	0.42	0.53	0.43145	
River type – Wide channel	0.60	0.50	0.228931	
Significance: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

The confluence, meander and mid Channel Island show a significant relation with Gangetic river dolphin use of these river types.

## 5. DISCUSSION

The Kaziranga national park stretch is the least disturbed stretch of Brahmaputra River. With less disturbance and extended protection from forest department, the area acts as a pristine habitat for Gangetic river dolphin with less anthropogenic disturbance.

### **Habitat:**

The Alluvial River like Brahmaputra is very dynamic, there are frequent changes in morphology based on rainfall pattern. Flooding is a common feature with severe flood every 2-3 yrs. Braiding and mid-channel island largely formed due to process of flooding (Kale 2003, Sharma 2005).

The habitat structure was classified based on the morphology of the river. Seven river types were classified and mapped. The river channel shifts after the monsoon season, so the channels during the study period are mapped. The changing riverscape alters the substrate, the shifting sand bars (loose sand) which in-turn alter the depth of the water column. The depth ranges from 0.6m to 12.9m in the study area with the velocity varying from 0.1 – 1m/s.

The average depth is  $4.83 \pm 1.28$  meters (Figure 3.2) which is ideal for Gangetic river dolphins. The average velocity is  $0.5 \pm 0.14$  m/s, estimate at lean period (Dec to April 2019) (Figure 3.3). The discharge ranges from 492 – 4081 m<sup>3</sup>/s (Ref: Annexure 1), which is entirely dependent on width of the channel and flow of the water. The water level is low during the study period (November – April) due to the winter and starts to increase in the summer due to monsoon and melting of snow in high altitude region. Studies in the monsoon season which effect both depth and velocity can provide more information on seasonal shift usage of dolphin.

The study area largely consists of wide channel river types, followed by meanders and narrow channels. Meanders, confluence and midchannel islands consists complex habitat areas due to their flow dynamics which leads to the creations of eddy currents.

### **Fish availability:**

The diet of the Gangetic river dolphin largely consists of fishes. The gut content analysis of 8 dolphin individuals reveals around 45 species of prey (identified up to *Genus* level) includes fishes, prawns, molluscs, etc. from the Ganga River. Most of the

species are in the size class of <5 to 30 cm length (Kelkar *et al.*, 2018). The preference of prey species still unknown. This study targeted the availability of specific size classes fish in the study area.

The maximum number of fishes recorded in the study area were in the size class 1-10 cm, which is largely distributed in confluence, braided channel and narrow channel. The most species caught belongs of the *Cyprinidae* family. The *Salmophasia* species has maximum count of 227 throughout all river type (Figure 5.4). Species richness of small (1-10cm) and medium (10-20cm) are  $26.72 \pm 1.58$  and  $25.01 \pm 1.59$  respectively. Total of Maximum species richness was found in the habitat of confluence and meanders. The activity of the *Cyprinidae* family fishes are largely during early morning and evening time. Most of catfishes are nocturnal, active during night time.

More information is needed on the preference of fish species and its size class. *Ailia coila* and *Ompok pabda* are the two Near-threatened fish species (IUCN status) found in the study area.

### **Gangetic river dolphin**

The three repetitive survey in an area provides an advantage to measure the variation in the estimate and also increases the precision of dolphin sighting in a particular location across temporal scale. The average estimate of Gangetic river dolphin is 125 individuals (including Adult / Sub-adult and young ones) (Table 4.2) within  $92.553 \pm 0.7$ km river stretch. The encounter rate of the current study is 0.63/km. To compare this estimate to other surveys in Brahmaputra river stretch, we used only encounter rate as it is the most abundant information available across different surveys in different years. The overall encounter rate of the Gangetic river dolphin across the entire Brahmaputra River is 0.84/km (Qureshi *et al.*, 2018). Vikramshila Gangetic dolphin sanctuary in Bihar has a population estimate of 328 (CI: 307 - 349) individuals with an encounter rate of 1.51, which is the highest compared to other sites so far surveyed. The population in the study area seems stable, with less mortality and threat. Many factors influence the presence of dolphin. Population assessment in regular intervals will provide us with information on the population trend. Protected areas play important role in Gangetic river dolphin conservation by providing safe place with abundant food resources.

According to the acoustic activity, Gangetic river dolphins are active throughout the day (Figure 6.2), corroborating the findings of other studies (Sinha *et al.*, 2010). However, the intensity of activity varies across different habitats and times. They are more active in day time at confluence, meander and mid channel island river type (Figure 6.3). While nocturnal activity is observed in narrow and wide channel. The reasons for these variations in the activity across these habitat types are not clear. More intense study in these areas may able to provide information on their use pattern. The activity across these habitat structures are mapped (Figure 6.4). Sinha *et al.*, (2010) observed that dolphins are active throughout the day, and this is confirmed through visual observations, their feeding behavior has been largely observed during the morning and evening time. Some studies have also recorded their foraging activity during night time.

Gangetic river dolphin distribution is influenced by river depth, velocity and fish in the area (Table 7.2). Also, river types like confluence, Mid channel Island and meanders shows a significance importance in dolphin habitat use (Table 7.2). The effect may be due varying river flow dynamics in these areas, which creates complex habitat structures.

The average velocity of water in study area is  $0.5 \pm 0.12$  m/s because of the lean water period, which is minimum for the period. The Gangetic river dolphin tends to congregate in the main channel during the lean water period due to the decrease in water level in the side channels and tributaries. This provides an added advantage but also the prime bias of the study. Comparing with the high flow season and dolphin habitat usage at that time provides broad scale information on the free ranging dolphin.

Earlier studies show that Gangetic river dolphins are sighted in Eddy current and shifting currents areas, because of the nutrient reflux in these areas (Biswas *et al.*, 2000). This study also found similar trend. Current study has more objectively assessed the habitat usage in a composite manner having habitat structure (depth, velocity and discharge) and prey availability. Basically, river structure and fish abundance of small and medium fish size influence the pattern of habitat use by the dolphin.

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## 7. ANNEXURES

### ANNEXURE 1

#### THE ESTIMATED FLOW DISCHARGE OF ALL THE SEGMENTS

Segment ID	River type	Average depth (m)	Average velocity (m/s)	Cross sectional area (m <sup>2</sup> )	Water Discharge (m <sup>3</sup> /s)
Seg_1	Confluence	5.95±2.03	0.53± 0.050	4317.5	2266.69
Seg_2	Confluence	4.1±1.98	0.43± 0.050	5980.0	2541.50
Seg_3	Wide channel	8.05±1.64	0.35± 0.058	7390.0	2586.50
Seg_4	Wide channel	6.10±2.55	0.38± 0.050	4652.5	1744.69
Seg_5	Wide channel	4.80±3.21	0.45± 0.238	6855.0	3084.75
Seg_6	Wide channel	6.1±2.162	0.73± 0.096	5630.0	4081.75
Seg_7	Braiding confluence	6.65±2.58	0.68± 0.096	5520.0	3726.00
Seg_8	Mid channel island	6.06±2.46	0.58± 0.150	4675.0	2688.13
Seg_9	Mid channel island	6.13±2.52	0.60± 0.141	4365.0	2619.00
Seg_10	Meander	4.75±2.87	0.43± 0.096	3627.5	1541.69
Seg_11	Meander	4.04±2.76	0.60± 0.141	4207.5	2524.50
Seg_12	Meander	5.35±3.24	0.50± 0.141	1950.0	975.00
Seg_13	Wide channel	5±3.04	0.53± 0.050	937.5	492.19
Seg_14	Narrow channel	2.81±1.27	0.50± 0.082	1467.5	733.75
Seg_15	Narrow channel	4.95±2.67	0.48± 0.050	4135.0	1964.13
Seg_16	Braiding confluence	3.33±2.53	0.30± 0.082	2902.5	870.75

Seg_17	Channel braiding	6.02±4.42	0.35± 0.129	4475.0	1566.25
Seg_18	Wide channel	4.28±2.57	0.43± 0.126	3132.5	1331.31
Seg_19	Wide channel	5.81±1.53	0.40± 0.183	2415.0	966.00
Seg_20	Braiding confluence	2.57±1.25	0.53± 0.096	937.5	492.19
Seg_21	Narrow channel	2.75±1.45	0.33± 0.096	2722.5	884.81
Seg_22	Narrow channel	4.59±2.39	0.40± 0.216	4092.5	1637.00
Seg_23	Meander	4.91±1.69	0.35± 0.129	5820.0	2037.00
Seg_24	Meander	3.64±3.12	0.35± 0.191	3162.5	1106.88
Seg_25	Meander	4.74±3.48	0.38± 0.050	3290.0	1233.75
Seg_26	Wide channel	4.05±2.23	0.25± 0.058	2957.5	739.38
Seg_27	Wide channel	3.95±2.36	0.33± 0.050	2695.0	875.88
Seg_28	Wide channel	4.45±2.08	0.38± 0.050	3565.0	1336.88
Seg_29	Wide channel	5.00±2.99	0.58± 0.096	2905.0	1670.38
Seg_30	Narrow channel	4.65±3.71	0.38± 0.150	2700.0	1012.50
Seg_31	Narrow channel	3.95±1.89	0.43± 0.126	3390.0	1440.75
Seg_32	Wide channel	5.70±2.86	0.45± 0.058	3935.0	1770.75
Seg_33	Wide channel	3.7±1.64	0.30± 0.141	5022.5	1506.75
Seg_34	Meander	3.95±1.70	0.30± 0.082	4300.0	1290.00
Seg_35	Meander	2.91±1.33	0.53± 0.050	3072.5	1613.06
Seg_36	Meander	4.62±2.87	0.75± 0.058	2955.0	2216.25
Seg_37	Narrow channel	6.71±4.06	0.78± 0.150	4307.5	3358.31
Seg_38	Narrow channel	2.84±2.72	0.78± 0.050	2437.5	1889.06

Seg_39	Wide channel	4±2.40	0.70± 0.082	2232.5	1562.75
Seg_40	Wide channel	2.43±1.70	0.60± 0.082	1077.5	646.50
Seg_41	Wide channel	3.23±2.14	0.48± 0.050	2085.0	990.38
Seg_42	Wide channel	3.95±1.78	0.33± 0.150	3525.0	1145.63

## ANNEXURE 2

### LIST OF FISH SPECIES RECORDED IN KAZIRANGA NATIONAL PARK.

Sl. No	Family	Scientific name	IUCN Status
1	Ailiidae	<i>Ailia coila</i>	NT
2	Ambassidae	<i>Parambassis ranga</i>	LC
3	Bagridae	<i>Rita rita</i>	LC
4	Bagridae	<i>Sperata aor</i>	LC
5	Bagridae	<i>Sperata seenghala</i>	LC
6	Bagridae	<i>Mystus spp</i>	-
7	Belonidae	<i>Xenentodon cancila</i>	LC
8	Channidae	<i>Channa spp</i>	-
9	Clupeidae	<i>Gudusia chapra</i>	LC
10	Clupeidae	<i>Tenualosa ilisha</i>	LC
11	Cyprinidae	<i>Labeo spp</i>	-
12	Cyprinidae	<i>Labeo spp1</i>	-
13	Cyprinidae	<i>Salmophasia spp</i>	-
14	Cyprinidae	<i>Barilius barna</i>	LC
15	Cyprinidae	<i>Chagunius chagunio</i>	LC
16	Cyprinidae	<i>Chela laubuca</i>	LC
17	Cyprinidae	<i>Cirrhinus reba</i>	LC
18	Cyprinidae	<i>Labeo bata</i>	LC
19	Cyprinidae	<i>Labeo calbasu</i>	LC
20	Cyprinidae	<i>Osteobrama cotio cotio</i>	LC
21	Cyprinidae	<i>Puntius chola</i>	LC
22	Cyprinidae	<i>Raimas bola</i>	LC
23	Cyprinidae	<i>Securicula gora</i>	LC
24	Cyprinidae	<i>Bangana dero</i>	LC
25	Engraulidae	<i>Setipinna phasa</i>	LC
26	Engraulidae	<i>Setipinna brevifilis</i>	DD
27	Gobiidae	<i>Acanthogobius spp</i>	LC

28	Gobiidae	<i>Glossogobius giuris</i>	LC
29	Mastacembelidae	<i>Macragnathus aral</i>	LC
30	Mugilidae	<i>Rhinomugil corsula</i>	LC
31	Mugilidae	<i>Sicamugil cascasia</i>	LC
32	Nemacheilidae	<i>Nemacheilus spp</i>	-
33	Schilbeidae	<i>Eutropiichthys spp</i>	-
34	Schilbeidae	<i>Clupisoma garua</i>	LC
35	Schilbeidae	<i>Eutropiichthys vacha</i>	LC
36	Sciaenidae	<i>Johnius coitor</i>	LC
37	Siluridae	<i>Ompok spp</i>	-
38	Siluridae	<i>Ompok pabda</i>	NT
39	Sisoridae	<i>Gagata cenia</i>	LC
40	Sisoridae	<i>Sisor rhabdophorus</i>	LC
41	Tetraodontidae	<i>Tetraodon cutcutia</i>	LC

(IUCN status: LC = Least Concern, NT= Near Threatened, DD = Data deficient)

### ANNEXURE 3

TABLE: SUMMARY OF CPOD DEPLOYMENTS AND ACOUSTIC DATA

C-pod deployment stretch (km)	C-pod ID	River type	Latitude	Longitude	Water depth at deployed location (m)	Deployment depth	Acoustic duration (hrs)	Acoustic duration (mins)	DPM	% of recording	DPM/day
0	3049	C	26.60465	92.85993	8.00	4.00	167.62	10057.0 0	2274	22.61	325.60
2	3048	C	26.61819	92.87413	5.90	3.00	42.57	2554.00	0	0.00	0.00
4	3047	WC	26.61892	92.89995	5.00	2.50	164.25	9855.00	71	0.72	10.24
6	3046	WC	26.618436	92.921625	3.00	1.50	163.02	9781.00	2456	25.11	366.60
8	3046	WC	26.624386	92.942839	6.00	3.00	72.88	4373.00	1	0.02	0.32
10	3047	WC	26.63615	92.98212	4.00	2.00	110.97	6658.00	581	8.73	187.60
12	3048	BC	26.63615	92.98212	3.50	2.00	86.50	5190.00	37	0.71	12.33
14	3049	MCI	26.642014	92.989544	8.00	4.00	70.88	4253.00	217	5.10	74.17
16	3046	MCI	26.64682	93.01249	4.00	2.00	71.48	4289.00	374	8.72	125.60
18	3047	M	26.6444	93.02912	3.00	1.50	71.97	4318.00	101	2.34	33.68
20	3048	M	26.64245	93.0509	7.00	4.00	71.68	4301.00	339	7.88	113.50

22		3049	M	26.62423	93.06262	5.00	2.50	70.73	4244.00	251	5.91	85.16
24		3046	WC	26.62637	93.08479	5.00	2.50	102.60	6156.00	0	0.00	0.00
26		3047	NC	26.62835	93.10452	9.50	5.00	102.03	6122.00	375	6.13	88.21
28		3046	NC	26.61918	93.11553	4.50	2.50	72.12	4327.00	0	0.00	0.00
30		3047	BC	26.62369	93.13412	7.00	3.00	71.83	4310.00	181	4.20	3.00
32		3048	CB	26.63996	93.14399	4.00	2.50	43.02	2581.00	0	0.00	0.00
34		3354	WC	26.6536	93.1562	6.50	3.50	71.27	4276.00	0	0.00	0.00
36		3355	WC	26.65137	93.17403	4.80	2.50	71.07	4264.00	0	0.00	0.00
38		3356	BC	26.6561	93.19373	6.80	4.00	61.92	3715.00	0	0.00	0.00
40		3357	NC	26.66516	93.21137	4.00	2.00	70.95	4257.00	9	0.21	3.04
42		3358	NC	26.68232	93.21994	3.00	1.50	70.90	4254.00	0	0.00	0.00
44		3359	M	26.68834	93.23907	3.00	1.00	80.75	4845.00	8	0.17	2.38
46		3046	M	26.68404	93.25781	6.20	3.00	79.10	4746.00	93	1.96	30.53
48		3047	M	26.67742	93.27649	6.70	3.20	73.10	4386.00	818	18.65	268.90
50		3048	WC	26.688	93.291	4.20	2.00	72.13	4328.00	9	0.21	0.99
52		3349	WC	26.7055	93.30547	3.00	1.50	75.78	4547.00	0	0.00	0.00
54		3354	WC	26.71547	93.32416	4.80	2.00	33.58	2015.00	0	0.00	0.00
56		3355	WC	26.71808	93.34458	5.80	2.50	81.52	4891.00	0	0.00	0.00
58		3356	NC	26.71725	93.36461	4.50	2.00	72.20	4332.00	0	0.00	0.00

60	3357	NC	26.72102	93.38512	3.10	1.50	104.85	6291.00	13	0.21	2.27
62	3358	WC	26.73792	93.39294	4.00	2.00	63.68	3821.00	0	0.00	0.00
64	3359	WC	26.74654	93.41193	4.50	2.00	80.47	4828.00	0	0.00	0.00
66	3046	M	26.75541	93.43271	3.20	2.00	72.93	4376.00	52	1.19	17.11
68	3047	M	26.76314	93.44858	2.60	1.50	72.92	4375.00	20	0.46	6.58
70	3048	M	26.76905	93.46739	4.00	2.00	72.73	4364.00	1125	25.78	371.20
72	3049	NC	26.75522	93.48038	4.00	2.00	72.78	4367.00	550	12.59	181.40
74	3354	NC	26.74017	93.48766	3.30	2.00	71.93	4316.00	308	7.14	102.80
76	3355	WC	26.72996	93.50537	3.80	2.00	71.58	4295.00	7	0.16	2.35
78	3356	WC	26.71286	93.51972	4.00	2.00	71.63	4298.00	0	0.00	0.00
80	3357	WC	26.70574	93.53954	4.70	2.50	71.40	4284.00	0	0.00	0.00
82	3358	WC	26.71574	93.56822	2.50	1.00	70.78	4247.00	0	0.00	0.00
84	3359	WC	26.72403	93.5975	2.60	1.50	79.10	4746.00	2	0.04	0.61

BC – Braiding Confluence, C – Confluence, CB- Channel Braiding, M - Meander, MCI – Mid Channel Island, NC – Narrow Channel, WC – Wide Channel

**ANNEXURE 4**  
**KOLMOGOROV-SMIRNOV TEST RESULT**

Sl .no	River type	D value	p-value
1.	Confluence-Meander	0.29718	< 2.2e-16
2.	Confluence - Braiding confluence	0.29718	< 2.2e-16
3.	Confluence -Mid channel island	0.35616	< 2.2e-16
4.	Confluence - Narrow channel	0.19127	< 2.2e-16
5.	Confluence - Wide channel	0.25985	< 2.2e-16
6.	Braiding confluence-Meander	0.32922	5.41E-12
7.	Braiding confluence - Mid channel island	0.38277	2.89E-15
8.	Braiding confluence - Wide channel	0.3276	5.87E-12
9.	Braiding confluence - Narrow channel	0.31811	6.50E-11
10.	Meander - Mid channel island	0.07393	4.76E-06
11.	Meander - Wide channel	0.05943	3.18E-09
12.	Meander - Narrow channel	0.20101	< 2.2e-16
13.	Mid channel island - Narrow channel	0.2162	2.20E-16
14.	Mid channel island - Wide channel	0.10088	1.28E-11
15.	Narrow channel - Wide channel	0.18938	< 2.2e-16

## ANNEXURE 5

**PEARSON CORRELATION MATRIX: CORRELATING DOLPHIN INTENSITY WITH THE PREDICTOR VARIABLES.**

