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"STUDY ON EFFECT OF NAVIGATIONAL ACTIVITIES ON DOLPHIN IN THE NATIONAL WATERWAY-1"

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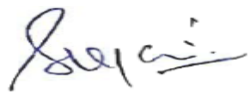
Signature					
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ABBREVIATIONS

APHA	American Public Health Association
BDU	Best Designated Unit
BOD	Biochemical Oxygen Demand
CIFRI	Central Inland Fisheries Research Institute
cm	centimetre
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
dB	Decibel
DO	Dissolved Oxygen
DWT	Dry Weight Tonnage
DWT	Dead Weight Tonnage
EC	Electrical Conductivity
EMoP	Environmental Monitoring Plan
EQMS	Environment Quality Management System
GIS	Geographical Information Systems
gm	Gram
GoI	Government of India
GPS	Global Positioning System
GLM	Generalized Linear Modelling
GW	Ground Water
Hz	Hertz
IS	Indian Standards Published by Bureau of Indian Standards
µPa.	Micropascal
IUCN	International Union for Conservation of Nature
IWAI	Inland Waterways Authority of India
IWT	Inland Waterway Transport
KLD	Kilolitre per Day
LCT	Layered Coding Transport
km	kilometre
kHz	Kelohertz
LAD	Least Available Draft
Leq	Equivalent continuous sound pressure level in dB
m	Metre
mg/l	Milligram per litre
mL	Millilitre
MPN	Most Probable Count
NMCG	National Mission for Clean Ganga
NTU	Nephelometric Turbidity Unit
NW	National Waterways
ºC	Degree Celsius
PFA	Principal Component Analysis
ppb	parts per billion
PTS	Permanent threshold shift

ppm	parts per million
RET	Rare Endangered and Threatened Species
RIS	River Information System
RO-RO	Roll on and Roll Over
STP	Sewage Treatment Plant
SW	Surface Water
TDS	Total Dissolved Solids
TTS	Temporary threshold shift
TPD	Tonnes per Day
UP	Uttar Pradesh

EXECUTIVE SUMMARY

The National River "Ganga" originates from Gangotri Glacier of the Himalayas streaming over 2525 km across the states of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal before flowing into the Bay of Bengal. It is the largest river in India in terms of basin area with an area of approximately 1,00,0000 sq.km spread across 11 Indian states. The River Ganga and its tributaries, viz., Yamuna, Gomati, Ghaghara, etc. are main sources of water for domestic as well as irrigation purposes in most of these states. Along with such cultural and economic significance, the Ganga is also abode to several ecologically significant species, such as the Ganges River Dolphin (***Platanista gangetica gangetica***), three species of Otters (***Lutra lutra, Lutra aperspicillata, Aonyx cinereus***), Mugger (***Crocodylus palustris***), Gharials (***Gavialis gangeticus***), several species of Turtles, Water birds and breeding birds (**WII-GACMC, 2018**). Amongst them, the Ganges river dolphin is especially essential to the river ecosystem as it is a flagship as well as an indicator species. Despite this and its endangered status in the IUCN Red List, the species is facing numerous threats and is on the brink of extinction due to habitat fragmentation. Under these conditions, it is necessary to identify detailed and consistent information about the species ecological requirements throughout its distribution range and its response to anthropogenic and natural environmental disturbances for designing and implementation relevant conservation strategies before any developmental project. The area covering National Waterways-1 (NW-1) extends to about length of 1620 km and is intended for planned development to aid for transportation of goods through cargo movement. This study was therefore carried out to identify the effects and potential risks of navigational activities on the Ganges River Dolphin in the NW-1 stretch between Varanasi to Farakka.

NW-1 is the longest inland waterway in the country and is currently operational zed on a smaller scale catering to the requirements for the thermal power plants, cement companies, fertilizer factories, oil refineries and Food Corporation of India. IWT terminals (25) of NW-1 have comparatively good connectivity to the road as well as railway network. The first Inland multi-modal terminal was inaugurated on the Ganga River on November 13,2018, at Ramnagar, Varanasi. Construction of three other terminals is in progress at Sahib Ganj, Haldia and Gazipur respectively. These terminals will enable commercial navigation of vessels with total capacities of 1500-2000 DWT. However, the potential of NW-1 needs to be comprehended to resolve the growing demand of waterway transportation of vast quantities of coal, fly-ash, food grains, cement, stone chips, edible oil and over-dimensional cargo.

In consideration that the stretch of Ganga River manifests important habitats for Ganges River Dolphin, ecological sustainability of NW-1 needs to be furthermore investigated to ensure long-term sustenance of the waterways and augment cargo movement. High sensitivity to imperceptible anthropogenic disturbances in the riverine ecosystem makes the Gangetic River Dolphin more vulnerable aquatic mammal. Thus, the effects of navigational activities on these species need to be studied in-depth before any planned developmental activity.

Henceforth, this study was designed with the following objectives to study impact of NW-1 on the aquatic wildlife of River Ganga (especially Ganges River Dolphins):-

- General population dynamics, abundance and distribution of the Gangetic Dolphin in NW-I stretch.
- Identification of breeding grounds and habitable environment for Ganges dolphins in NW-1 stretch based on primary surveys and consultation with relevant stakeholders.

- To examine risks and impacts of navigational activities of large vessels on breeding grounds and populated sites of pod (Group of Dolphins).
- To assess diversity and abundance of food-material prey-base of the Dolphin.
- To identify impacts of these vessels on the abundance of Ganges dolphin’s prey base.
- To study the impact of underwater noise on Ganges dolphins depending on size and speed of the vessel.

The present study is based on primary data collected from the field sites complemented by literature review to prepare a Consolidated Report on impact of NW-1 on aquatic wildlife of the River Ganga. Good habitats for Ganges dolphins have been prioritized using habitat suitability models. Critical examination of the impact of navigation of large vessels on NW-1 on Ganges dolphin’s habitats have been carried out including short and long term effects, risks of injury and death due to collisions, oil spills, increased anthropogenic influences, vibration and sediment disturbances.

The Gangetic River Dolphin has been classified as “Endangered” in IUCN Red List and is also being protected under “Schedule-I” of the Wildlife (Protection) Act, 1972. Prey availability and water depth in the area were found to be limiting factors for the occurrence of species. Habitat fragmentation due to the construction of dams and barrages has led to loss of connectivity and thereby decrease in their abundance and population structure. They are also highly vulnerable to poaching and accidental killing. Gangetic dolphins are carnivores in nature, feeding on small fishes like *Mystus sps., Barbus sps., Channa sp., Puntius sp., Xenentodon cancila* etc. They inhabit Ganga, Brahmaputra, and Indus along with their tributaries. They prefer deep water areas and pools, with at least 4 m depth. Habitat selection by dolphins is a complex and dynamic function of food requirement, mate availability, avoidance from predators and competitors, and ability to move between habitat patches. The distribution, abundance, and diversity of prey species are one of the most important factors that influence the dolphin’s choice of habitat. **The Vikramshila Ganges Dolphin Sanctuary (VGDS)**, Sultan Ganj and Kahalgaon, Bihar (*notified on 7th August 1991 as a Wildlife Sanctuary under the Wildlife Protection Act, 1972 for the protection of Gangetic River Dolphins*) is the only riverine protected area in the eastern Gangetic Plains. Earlier studies have also noted a high encounter rate of dolphins from VGDS.

Baseline assessment Gangetic River Dolphins distribution among the river was carried out to estimate the presence of the species in the River Ganga from Varanasi to Haldia. **Kriging method** was used for spatial interpolation which led to the identification of dolphin congregation and potential breeding sites. It was established that **Patna is the best site for Ganges Dolphin breeding**, as many tributaries like Ghaghra, Gandak, Sone and Punpun meets with the Ganga in this region. It was estimated that approx. 2304 numbers of dolphins were present in between Varanasi and Farakka, with the highest (81 numbers) of Gangetic River Dolphins at Patna .

Dolphin prey abundance and water quality was also assessed in 10 intensive sampling sites along with major cities alongside Ganga and jetties of the NW-1 where major vessel movement will occur. These sites were: Varanasi, Buxar, Patna, Bhagalpur, Kahalgaon, Sahib Ganj, Farakka, Tribeni, Godakhali, and Diamond Harbour. A total of 95 fishes belonging to 102 genera and 50 families were recorded from the stretch of the Ganga river between Varanasi to Farakka during May to June 2018. The highest diversity of fishes was observed at Farakka with 62 species of freshwater fishes and the lowest was observed at Buxar with 27 species of fishes. A gradual increase in fish diversity was observed from Varanasi to Farakka, which may be accounted for by the availability of good water depth and suitable water parameters in the downstream of the river.

The abundance of dolphins in habitat has been assumed to be related to food availability in the area. The presence of phytoplankton's in the area is indirectly related to food availability as well as the productivity of the dolphin habitat. In many cases, an abundance of phytoplankton's and aquatic vegetation supports large quantities of aquatic insects, mollusks, crustaceans, and small fishes, which ultimately becomes the dolphin diet. Major fish species routinely consumed by Dolphins include smaller sized fishes belonging to species of *Catla, Labeo rohita, L. calbasu, L. bata, Cirrhinus mrigala, Heteropneustes fossilis, Cyprinus carpio, C. reba, Puntius ticto, P. conchonius, P. sarana, P. sophore, Danio devario, Glossogobius giuris, Tenulosailisha, Hilsa kelee, Coilia dussumieri, Setipinna phasa, S. taty, Mugil cephalus, Ailiacoila, Eutropiichthys vacha,* catfishes like : *Mystus vittatus, M. cavelleri, M. teengara, M. aor, Anabas testudenius, Mastacembelus sps., Chana gachua, C. punctatus, C. striatus, Chela labuca,* and *C. atpar, X. cancila, Notopterus notopterus, N. chitala, Nemacheilus sps., Nandus nandus, Wallago attu, Rita rita, A. mola, Rasbora daniconius,* myriad categories of trash fish species (nearly twenty such fish species whose size ranges between 5 cm to 10 cm.), prawns of various species, crabs, and even smaller sized soft freshwater turtles.

It has been inferred that river stretch with muddy bed relatively serve better habitat for fish food, followed by the Dolphins as compared to sandy or rocky beds. Dense aquatic vegetation, rich planktonic population, and fishes, etc. were observed in the river stretch with muddy beds. Many realms around Varanasi ghat, Buxar, Sultanganj, Kahakgaon, and Ghazipur showed a higher degree of eutrophication on account of shallowness, overexploitation by local population, vicinity of the river to discharge output centers of municipality sewage drains, hovering masses of dead animals & human carcasses on the river, over-usage of detergents and soaps around the banks of river at ghats by local population. However, such polluted areas are generally avoided by the Dolphins due to inappropriate conditions like shallowness of water, higher turbidity, low oxygen contents, higher BOD, foul smell, and higher temperature.

Chlorophyceae was found to be the dominant among phytoplankton group in pre-monsoon season, while *Bacillariophyceae* was observed to be the dominant group in the monsoon and post monsoon season. *Rotifera* is the dominant group of zooplanktons inspected during all three seasons for the study period (2018).

Surface water samples were collected and analyzed from upstream and downstream of the proposed terminals/ lock locations and environmentally sensitive receptors present all along NW-1. Eight physico-chemical parameters, viz., pH, DO, conductivity, temperature, turbidity, and TDS were estimated using **Water and Soil Analysis Kit – Model no. 191**", Transparency was estimated using **Secchi-disc Method** and River water Velocity was estimated using **Float Method**. The assessment reveals that water quality in the inspected stretch of the Ganga River meets with BDU "**Class D Criteria**" defined by CPCB, except few parameters, such as pH and DO which meets "**Class A Criteria**". The concentration of Metallic and pesticide levels is within the prescribed limit of **Drinking water Standard**. The analysis concludes that the river water is good for propagation of wildlife and fisheries.

The effect of dredging activity on water quality was also estimated by sampling upstream and downstream of the river at a different distance from operating dredger in the study period. During the study period, dredging was operational only in Farakka navigational lock channel. Turbidity and total suspended solids increase in downstream of the dredging location up to 700 m, which gradually gets normalized at 1000 m from the dredging location. However, in the upstream side of the river, no major changes were observed for these parameters. However, heavy metals like iron, copper, cadmium, and lead were also detected in traces in water sample close to the dredging location in the downstream locations. No variation was observed in other water quality parameters due to dredging.

In short, Patna station covering a stretch of about 8.0 km of the Ganga River indicated good water quality and also high abundance of dolphins. Besides, anthropogenic influences were comparatively less in this part of river, only next to Kahalgaon area. While Buxar station indicated high levels of pollution with highest TDS and turbidity along with low DO and transparency.

It can be concluded from these studies that while few parameters have a direct bearing on the distribution pattern, presence or absence, and ultimately the population dynamics of the Gangetic Dolphins in the studied area, the eco-biological components have an indirect influence on diverse variables. It signifies that there exists a positive or sometimes negative- balance synchronization among all categories of characteristics. Any deviation for any single characteristic, from the most impacting one to most minimum affecting factor may subtly influence the movement and thereby population dynamics of phytoplankton's, then Zooplankton's, fish prey, fingerlings, smaller herbivore fishes to carnivore fishes, and ultimately to the foraging behavior and population dynamics of the Dolphins as an apex body predator. In short, unless all the physicochemical components are not in order, the trophic level biological constituents cannot be in their best presence and population guided individual behavior.

The underwater vessel noise measurements were conducted at four field locations, viz., Varanasi, Patna, Sahibganj and Rajmahal during July 2018. Underwater noise generated by bigger vessel was measured at Rajmahal.

Band Level noise was measured in the frequency range of 100Hz to 100kHz considering the click frequency of the Gangetic River Dolphins of 50 kHz to 60 kHz. Apart from the vessel noise, the underwater ambient noise was also measured at all the field locations. The measured underwater noise was analyzed in different frequency bands and rms vessel sound source level at 1m was also calculated for all frequency bands. The measured underwater noise was analyzed in different frequency bands and rms vessel sound source level at 1m was also calculated for all frequency bands. The comparison charts of vessel rms sound level with average rms ambient noise level in all frequency bands for all field locations are presented in this report. It was observed that the underwater noise generated by the 92 and 2200 tonnage vessels are almost similar. Smaller vessels produce more noise in the 50-200 m range while moving upstream, while moving downstream the effect of the underwater noise was observed in the 50-250 m range. Noise generation from the vessel movement is continuous type. Noise generation from vessel movement (1500-2000 DWT) vary from 110-140 dB. This order of noise generation may have an impact on behavior of various aquatic organisms and may lead to other injuries like tissue injury, temporary & permanent hearing loss. However, physical impact on aquatic species is not anticipated as the aquatic species moves away from the source of disturbance (barge) and usually do not come close. Vessel movement speed in the sanctuary areas is to be restricted to 5-10 knots only.

Prevailing legislations in the country, although detailed, has not yet been implemented solemnly to reflect the limitations and restrictions imposed by them. The entire studied stretch has also been managed by the National Mission for Clean Ganga under "**NAMAMI GANGA PROGRAM**", GOI through pollution mitigation and prevention measures such as diversion and source reduction of municipal sewage, management of solid waste, and religious offerings through the construction of Sewage Treatment Plants (STPs), skewers and waste segregation.

Summarizing, vessel movement, and the sound produced thereof, and dredging activities will have some impact on the aquatic species of the River Ganga. It may also have acute and long-term impacts on the riverine ecosystem. However, as cargo movement through NW-1 is currently necessitated, the aim should be to reduce the impacts of vessel movements through pre-emptive measures. Thus, action plan for aquatic wildlife protection has been proposed in the following section. The action plan consists of Hotspot-wise threat identification and mitigation plan. Dolphin monitoring units should be formed in association with local communities and management authorities in the identified important dolphin habitats. The units should be encouraged to closely monitor the dolphins and their habitats. Detailed studies should be undertaken on the dolphin by-catch mortality. Steps should be undertaken to modify the identified fishing gears and practices. Steps should be taken to protect these seasonally migrating dolphins. Poaching area and poachers should be identified, and strong legal actions should be taken against poaching. As the vessel traffic will increase, a continuous monitoring of the behavior of the Ganges dolphins and its food base, i.e. fishes shall be taken up by research institutes and IWAI. Then only, a concluding management plan can be proposed. As of now, based on existing information, the precautionary measures have been proposed.

CHAPTER 1. INTRODUCTION

1.1. Background

The National River "**Ganga**" originates from the Gangotri glacier of the Himalayas known as "**Bhagirathi**". The other headwater source, the Alaknanda, Bhilangana, Dhauliganga, Mandakini, Nandakini and Pindar progressively joins at various Prayag. Finally, the Alaknanda and Bhagirathi joins at Dev Prayag to form the Ganga. Descending in the plains, the river flows approximately southeast and is joined by several large streams such as Ramganga, Yamuna, Kosi, Gandak, Gomti, Sone, Karamnasa and Ghaghra to become an immense river in the plains below Allahabad. The river then flows through the Raajmahal hills and divides into two streams. The eastern branch – River Padma – flows southeast through Bangladesh to join the Brahmaputra and Meghna rivers before flowing into the sea. The south-flowing branch in West Bengal – River Hooghly – is joined by Rivers Damodar and Mayurakshi before reaching the sea. The combined outfall of the two branches together forms the world's largest delta "**The Sundarbans Delta**" covering about 60,000 sq.km. and spread across Bangladesh and West Bengal. The river flows through 2525 km across Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal before flowing into the Bay of Bengal. It is the largest river in India in terms of basin area with an area of approximately 1000000 sq. km spread across 11 Indian states (**Fig. 1.1**).

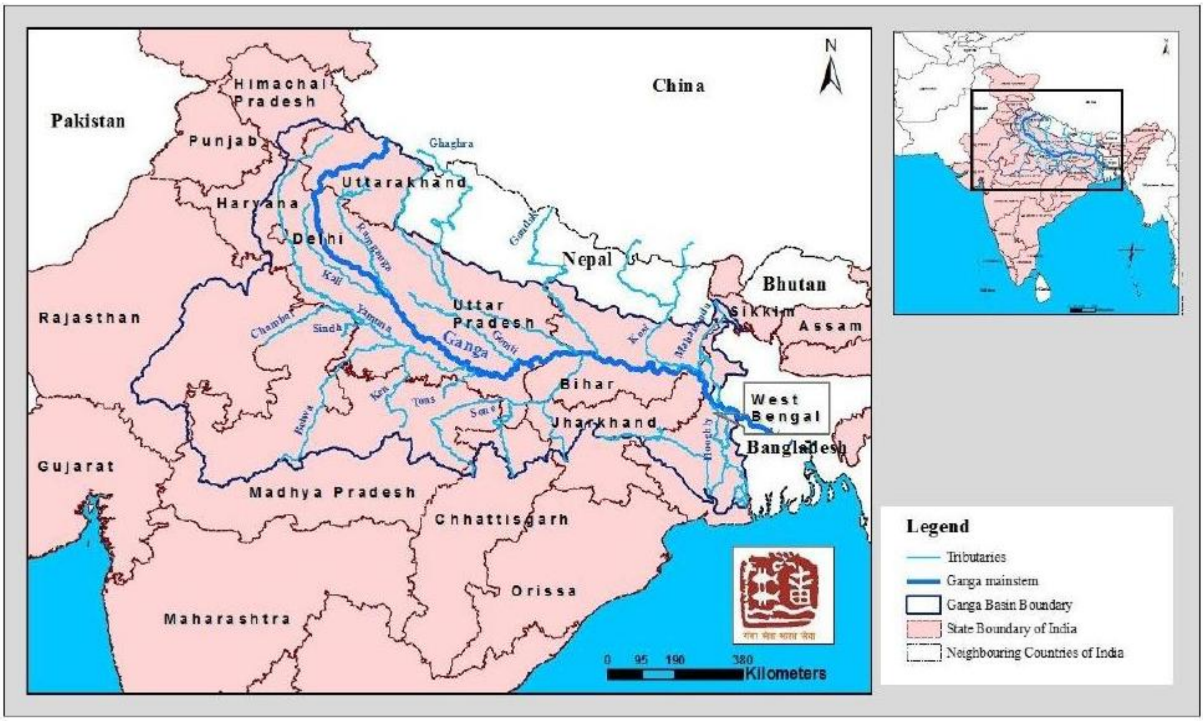


Figure 1.1 : Ganga basin and major tributaries. (Source: nmcg.nic.in)

The River Ganga and its tributaries, *viz.*, Yamuna, Gomati, Ghaghara etc. are the main source of water for domestic as well as irrigation purposes in most of these states. In a country like India whose economy is mainly based on agriculture, the river plays a particularly important role. Known for its fertile alluvial soil, the Ganga river basin produces a wide variety of crops supporting the lives and livelihoods of more than 500 million people. The major crops cultivated in the area include rice, lentils, sugarcane, potatoes, oilseeds and wheat. Along with the tributaries, the Ganga river harbors numerous wetlands and lakes on its floodplain which provides a rich environment for crops like legumes, chilies, sesame, mustard, sugarcane, and jute. Fishing is another major source of livelihood in the basin, and several fishing zones exist along the river.

The Ganga is also abode to several ecologically significant species, such as, the Gangetic River Dolphin (*Platanista gangetica gangetica*), three species of otters (*Lutra lutra, Lutra perspicillata, Aonyx cinereus*), mugger (*Crocodylus palustris*), gharials (*Gavialis gangeticus*), several species of turtles, water birds and breeding birds (WII-GACMC, 2018) (**Fig. 1.2**)

Figure 1.2 : Ganges river dolphin near Patna

Otter **Gharial** **Turtle**

Figure 1.3 : Aquatic animals of River Ganga

Among these aquatic species, the Gangetic River Dolphin is particularly essential to the river ecosystem as it is a flagship as well as indicator species. It was also declared as the National Aquatic Animal on 5th October 2009. Despite this and its endangered status in the IUCN Red List, the species is facing the numerous threats and is on the brink of extinction due to habitat fragmentation. Under these conditions, it is necessary to identify detailed and consistent information about the species ecological requirements throughout its distribution range and its response to anthropogenic and natural environmental disturbances for designing and implementation relevant conservation strategies before any developmental project. The area covering National Waterways-1 (NW1) extends to about length of 1620 km and is intended for planned development to aid for transportation of goods through cargo movement. This study was therefore carried out to identify the effects and potential risks of navigational activities on the Ganges River Dolphin in the NW-1 stretch between Varanasi to Farakka.

1.2. Study Area

Project area under NW-1 includes entire stretch of the Lower Ganga River from Varanasi to Farakka including the areas proposed for development of project related facilities and infrastructure, *i.e.*, terminal sites, lock site, Ro-Ro jetty sites and sites for other planned development. The national waterway is about 1620 km in length and passes through the states of Uttar Pradesh, Bihar, Jharkhand, and West Bengal. The whole part of this waterway is intended to be used for the transportation of goods.

1.3. Background of NW-1 project

Cargo movement through waterways is considered as one of the cheapest modes of transportation, as the rates are incredibly low in India as compared to the international scenario. To augment the capacity of waterways transportation in India, Govt. of India has constituted Inland Waterways Authority of India (IWAI) through IWAI Act in 1985. Since then, IWAI with the empowerment under above mentioned Act has identified potential waterways and has further undertaken the task to develop, maintain and regulate the waterways for navigation. IWAI has identified 5 river stretches as national priority and notified these stretches as National Waterways (NW) 1 to 5. Amongst the five notified waterways, NW-1 falls between Allahabad to Haldia stretch of the Ganga river (Ganga-Bhagirathi-Hooghly river system). It is the longest waterway, passing through the states of Uttar Pradesh, Bihar, Jharkhand, and West Bengal. NW-1 is of prime importance considering its location and was declared as a national waterway vide National Waterways Act 1982 (49 of 1982). The waterway, inaugurated on 27th October 1986 covers major cities along the Ganga such as Haldia, Howrah, Kolkata, Bhagalpur, Patna, Ghazipur, Varanasi, Allahabad, their industrial hinterlands, and several industries located along the Ganga basin. Currently, NW-1 is catering to the requirements for the thermal power plants, cement companies, fertilizer factories, oil refineries, the Food Corporation of India. It carries products like coal, fly-ash, cement and clinker, stone chips, edible oils, petroleum products, food grains and other cargos. IWT terminals (25) of NW-1 have comparatively good connectivity to the road as well as the railway network. The Varanasi Terminal was inaugurated on 12 November 2018 and Sahib Ganj terminal was inaugurated on 12 September 2019. Two other terminals are under construction at Haldia and Gazipur. These terminals will enable commercial navigation of vessels with capacities of 1500-2000 DWT (**Fig. 1.4**).

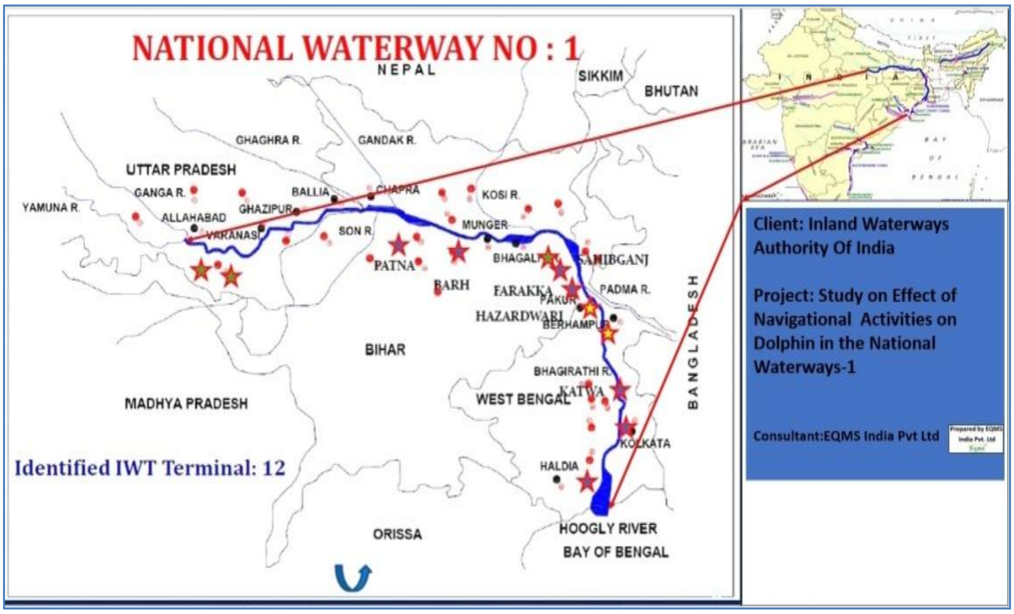


Figure 1.4 : National Waterway-1 (Varanasi to Haldia)

1.4. Need for NW-1 project

There is an urgent demand to operationalise NW-1 right up to Allahabad as many potential shippers such as thermal power plants, cement companies, fertilizer companies, edible oil companies, Food Corporation of India have picked up interest to use NW-1 waterways channel, if it is developed with adequate infrastructure to facilitate navigation.. Although the above-mentioned items are currently being transported in some stretches of NW 1, its potential needs to be fully realized. In the recent past, a substantial demand for waterway transportation has emerged which includes coal, fly-ash, food grains, cement, stone chips, edible oil, and over dimensional cargo. These are some of the cargos which can be transported on NW-1 in large quantities.

Depth on the navigational channel is the foremost requirement for making a waterway navigable and commercially viable. Several tributaries of the Ganga, *viz.*, Son, Gomati, Ghaghara, Gandak, Burhi Gandak and Kosi meets NW-1 after Allahabad. Drainage pattern of the NW-1 is being controlled by these rivers. By the time Ganga reaches the head of its delta at Farakka (after Rajmahal) in the state of West Bengal, its water flow and volume increase substantially due the contribution from these tributaries. Due to increased water availability in the lower reaches of the Ganga, abundant populations of aquatic wildlife including the Gangetic River Dolphin, India's national aquatic animal can be found. Therefore, this stretch of the river also forms important habitat for aquatic wildlife, particularly for Ganges dolphins, which are highly sensitive to slight anthropogenic disturbances in the riverine ecosystem.

1.5. Objectives of the study

The study was carried out to study the impact of NW-1 on the aquatic wildlife of the River Ganga, particularly to Gangetic River Dolphins. To study this, the following objectives were designed: -

- Identification of breeding grounds and habitable environment for Ganges dolphins in NW-1 stretch based on primary surveys and consultation with relevant stakeholders.
- To examine risks and impacts of navigational activities of large vessels on breeding grounds and populated sites of pod (Group of Dolphins).
- To identify the impacts of these vessels on the abundance of Ganges dolphin's prey base.
- To study the impact of underwater noise on Ganges dolphins depending on size and speed of the vessel.

1.6. Scope of work

The present study aims to prepare a consolidated report on the impact of NW-1 on aquatic wildlife of the River Ganga based on primary data collected from the field site as well as complemented by extensive literature review. Good habitats for Ganges dolphins will be prioritized using habitat suitability models. Critical examination of impact of navigation of large vessels on NW-1 on Ganges dolphin's habitats will be carried out, including short and long term effects, risks of injury and death due to collisions, oil spills, increased anthropogenic influences, vibration and sediment disturbances. The results of this study will help in the framing of site and species-specific strategies for the management and governance of these stretches, and risk mitigation despite of navigational activities on NW-1.

Chapter 2. GANGES RIVER DOLPHINS: ECOLOGY AND BIOLOGY

2.1. Ganges River Dolphin

The Gangetic River Dolphin (*Platanista gangetica gangetica*) is a largely solitary and non-gregarious species, occasionally found in small groups. They are essentially blind and hunt by echolocation. They have a sturdy yet flexible body with large flippers and a low triangular dorsal fin weighing up to 150 kg. Calves are chocolate brown at birth and then they develop grey-brown smooth colour & hairless skin as adults. Females are larger than males and give birth once every two to three years to only one calf (*Herald et al., 1969*).

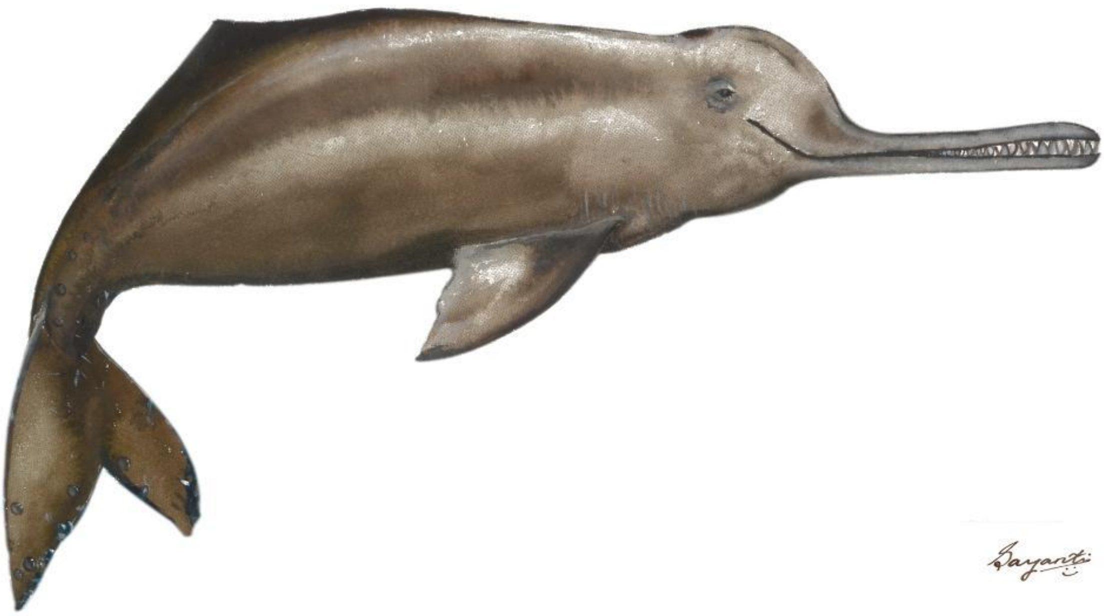


Figure 2.1 : The Ganges river dolphin is essentially blind and move through echolocation (Photo provided by NGO Help Earth)

It is an iconic as well as flagship species and was declared as the "**National Aquatic Animal**" on 5th October 2009. Being a top predator, it shapes aquatic species communities particularly benthic and fish communities. Prey availability and water depth are limiting factors for their occurrence (WII-GACMC, 2018). Habitat fragmentation due to the construction of dams and barrages has led to loss of connectivity and thereby decrease in their abundance and population structure. Also, they are highly vulnerable to poaching and accidental killing (WII-GACMC, 2018).

2.2. Classification

Sl. No.	Parameter	Class
1	Order	*Artiodactyla*
2	Family	*Platanistidae*
3	Genus	*Platanista*
4	Species	*Gangetica*

5	Sub-Species	*Gangetica*

2.3. Status of Ganges dolphin

Due to its plummeting population, the Gangetic River Dolphin has been classified under the "***Endangered Category***" in the IUCN Red List (**Fig. 2.2**). It is also protected under "**Schedule-1"** of the Wildlife (Protection) Act, 1972.

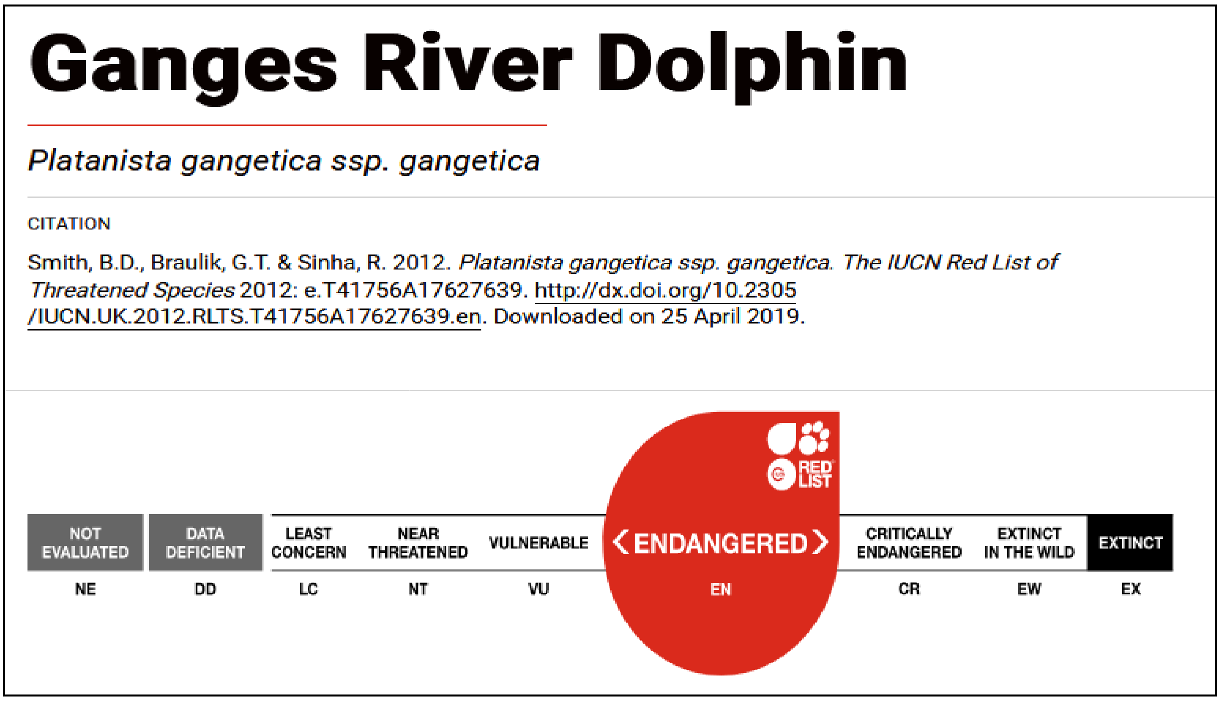


Figure 2.2 : IUCN status of Ganges river dolphin

2.4. Habit and Habitat

Gangetic River Dolphins are carnivores, feeding on fishes like *Channa sp., Puntius sp., Chanda nama, Xenentodon cancila etc.* They prefer smaller sized fishes from families Cyprinid and Perciform for easy swallowing. They do not chew their food, but sometimes may take a bite and swallow. Small sized turtles are also preyed by dolphins. They prefer to breed during pre-monsoon or post-monsoon periods, although they can breed throughout the year. Gestation period has been reported between 9-10 months and after which a single calf is delivered.

They inhabit the Ganga, Brahmaputra, and Indus river systems along with their tributaries. They migrate to tributaries and return to larger river channels in the dry, winter season (*Smith 1993; Sinha et al. 2000; Sinha and Sharma, 2003*). They prefer areas of the river that create eddy countercurrents, such as small islands, sand bars, river bends, and convergent tributaries (*Sinha et al., 2014*). They prefer deep water areas and pools, with at least 4m depth (*WII-GACMC, 2018*).

The life span of the Ganges river dolphin is thought to be about 26 years. Habitat selection by dolphins is a complex and dynamic function of food requirement, mate availability, avoidance from predators and competitors, and ability to move between habitat patches (Davis et al., 2002; Schofield, 2003). Prey Distribution is likely one of the most important characteristics that influences the choice of habitat.

2.5. Conservation of the species: Vikramshila Dolphin Sanctuary, Bihar

The **Vikramshila Ganges Dolphin Sanctuary** (VGDS) was notified on 7th August 1991 as a Wildlife Sanctuary under the Wildlife Protection Act, 1972. It was implemented for protection of Gangetic River Dolphins (**Fig. 2.3**). VGDS is the only riverine protected area for conservation in the eastern gangetic plains. VGDS includes parts of middle Ganga between Sultan Ganj and Kahalgaon, Bihar (25.254°N to 25.282°N and 86.738°E to 87.229°E) **(Fig. 2.4**). A 10 km area around VGDS is the default Eco Sensitive Zone spawning across the total length of about 30 km in Bhagalpur district, Bihar.

Figure 2.3 : Ganges river dolphins in VGDS

2.6. Historical distribution of Ganges dolphins

Prior to initiation of water resource development activities in Ganga River during the 19th century, Gangetic River Dolphins were observed to be distributed between 77^{o}E and 88^{o}E, throughout the Ganga, Brahmaputra/ Meghna and Karanaphuli rivers and their tributaries in India, Nepal and Bangladesh (*Sinha et al., 2000*). In the Ganga river, their distribution range from Haridwar to the Sundarbans and in the Yamuna river, the species was reported to be spotted up to Delhi (*Anderson, 1878; Sinha et al., 2010*). During the late 19th Century, about 10,000 Ganges river dolphins were estimated to be thriving in the Ganga and its tributaries (*Anderson,1878*). However Sinha and Kannan (2014) estimated their population to be 3526 number during the early 2000s.

According to these studies, the encounter rate of dolphins was highest in the Vikramshila Ganges Dolphin Sanctuary (1.8/km) area and lowest between Bijnor and Narora (0.36/km). The abundance of the Gangetic River dolphin in the VGDS was noted to be 179 and 270 in the mid and peak dry seasons, respectively. (*Kelkar et al., 2010*).

Table 2.1 : Past and present status of the Ganges river dolphins (Adapted from WII-GACMC, 2018)

River Stretch	**Encounter Rate (Individuals/km)**		
	Previous Studies	**---**	**Previous Studies (2017)**
Allahabad to Buxar	0.48	*Sinha (1999)*	0.77
Buxar to Maniharighart	1.62	*Sinha et al. (2010)*	0.36
Vikramshila Ganges Dolphin Sanctuary	1.8	*Choudhary et al. (2010)*	0.65
Maniharighat to Farakka	1.64	*Sinha (1999)*	0.22
Farakka Feeder Canal	0.55	*Sinha et al.(2000)*	0.10

2.7. Threats to Gangetic River Dolphins

- Poaching of the species for their oils, used as fish attractant. The species is also highly susceptible due to accidental trapping in fishing nets.
- Destruction of breeding grounds of fish and resulting decline in fish population.
- Diversion of river water for different purposes such as irrigation, hydropower projects etc. eventually resulting in low flow and depth in the river below the minimum requirements of the species.
- Water pollution from both point and non-point sources and hereby increasing the toxicity levels, increasing risks for aquatic wildlife.
- Construction of dams and barrages has dramatically affected habitat connectivity and hence abundance and population structure of this species. Moreover, dams and barrages degrade downstream habitat and create small reservoirs with high sedimentation and altered assemblages of fish and invertebrate species.

2.8. Potential risks and impacts due to navigational activities on populated sites of Ganges river dolphins along NW-1

- Sound producing vessels may change the behavior of dolphins.
- High speed of Vessel may cause harm to dolphin population.
- Oil spills may change the water quality of river which will certainly be harmful to the whole aquatic ecosystem.
- Dredging may damage the breeding ground of fishes which may certainly lead to declining in dolphin populations.
- Constructional activities may fragment the habitat of dolphin.

2.9. Legal responsibilities for protection of dolphins with respect to the project

As the Gangetic River Dolphin has been classified under the “**Endangered Category**” in the IUCN Red List and also protected under “**Schedule-I**” of the Wildlife (Protection) Act, 1972. With respect to NW- 1, the legal responsibility of concerned departments shall be as below:

IWAI shall be solely responsible for following the rules and regulations as per Wildlife Protection Act 1972, while implementation of these rules and regulations will be sole responsibility of the forest department.

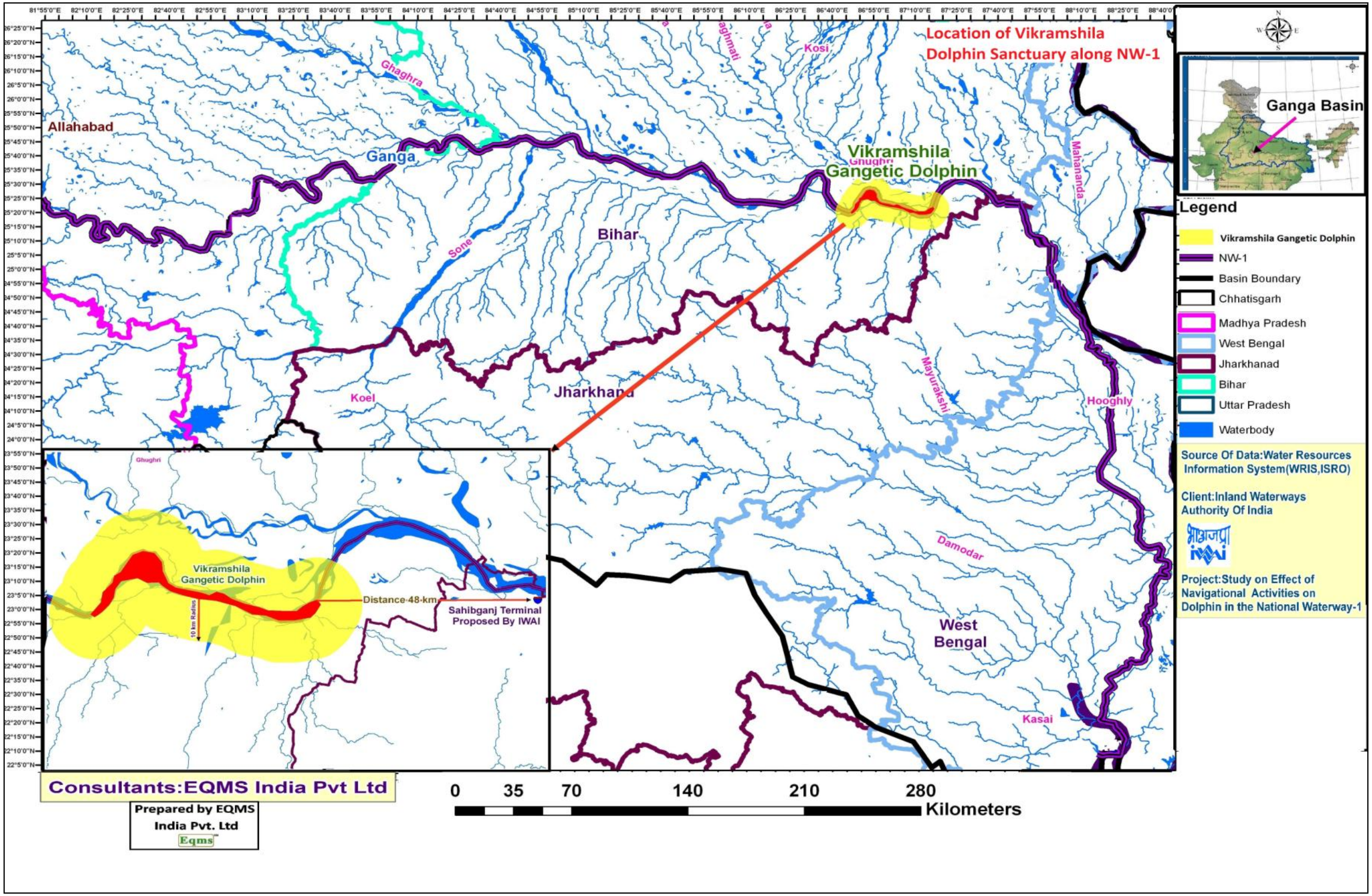


Figure 2.4 : Location of Vikramshila Ganges Dolphin Sanctuar

CHAPTER 3. DISTRIBUTION OF GANGES DOLPHINS, HABITAT AND POTENTIAL BREEDING SITES

3.1. Introduction

A baseline assessment of the distribution of the Ganges dolphins was obligatory to estimate the presence of species in the River Ganga from Varanasi to Haldia. Species distribution is determined by habitat features in a landscape. For riverine species, the depth and discharge of the river are major determinants apart from food, shoreline topographies and water chemistry. This chapter deals with the distribution and encounter rate of Ganges dolphins in the River Ganga at selected intensive and randomly selected sites along the NW-1 stretch along with the habitat features.

3.2. Intensive survey sites

There were eight intensive study sites where Ganges dolphins were observed. A boat-based survey technique following standard protocol was adopted for the visual count of the Ganges dolphins. Simultaneously, habitat features were also collected in the Ganges dolphin sighting locations. Secondary information was also gathered from published works on the River Ganga. The detailed information was collated as follows.

3.3. Intensive monitoring sites

Varanasi: Varanasi lies at the coordinates of Latitude: 25.31760°N and Longitude: 82.97390° E in the state of Uttar Pradesh. At Varanasi, the span of the Ganga River varies between 700 to 1500 m.

Gangetic River Dolphin: During more than 10 km at Varanasi, beyond Ramnagar and Ghats, there were only nine encounters of Gangetic River Dolphins. There were no sightings of the species within 3 km of Banaras Ghats upstream or downstream. Three encounters were spotted between Ghat Area and Ramnagar while other six were sighted beyond 2 km of Ramnagar terminal site.

Habitat: The depth of river varies throughout the cross section of river. In the mid-stream, the depth is about 7 – 10 m and near the banks about 2.5 – 4 m. The average depth of the Ganga River at Varanasi appears to be 3.5 m and the water velocity was 132 cum/sec. Excessive siltation and decrement in water volumes in the Ganga River is evident in this area, which is further complicated with widening of river span at various places and increased meandering of the stream.

Human activities: Approximately 200-300 human corpses are being burned at Manikarnika Ghat, daily. Mining has been prohibited in this region, and hence, good sand bars and banks were observed. According to fishermen and local people, Ganges dolphins are now rarely being seen near Varanasi Ghat. However, they are present in substantial numbers in the upstream and downstream areas. Pollution, low water depth, improper dredging etc. might be responsible for their decline in this part of River Ganga.

Analyzing the water samples at Dashshwamedh Ghat Varanasi

Analysis of physicochemical parameters at Mankarnika ghat, Varanasi

Ghazipur: Ghazipur lies at coordinates of Latitude: 25.58400° N and Longitude: 83.57700° E in the state of Uttar Pradesh. It has the narrowest span in comparison to all other stations.

Gangetic River Dolphin: There were good sightings of Ganges dolphins within the 17 km stretch of the river at Ghazipur. Almost 43 Ganges dolphins with 5 small calves were observed in this region during the study period.

Habitat: Temperature was found to be in higher ranges where the channel was shallow. Throughout the stretch, the river span widens and narrows. The width of the river is about 600 m. In this region, water flowing in the river was scant. Water flows at an average of 154 cum/sec and depth of water was observed to be 5.3 m in this part of river.

Human activities: No major human activity such as fishing or sand mining was observed in Ghazipur. However, the river is used for daily ablutions and bathing.

Water quality assessment at Ghazipur

Buxar: It lies at coordinates of Latitude: 25.56470° N and Longitude: 83.97770° E in the state of Bihar. It is a border town with Uttar Pradesh on the north bank of River Ganga and Bihar on the south bank.

Gangetic River Dolphin: 31 encounters of the Ganges dolphins have been sighted in a stretch of about 22 km was observed.

Habitat: The water level showed wide variations. Total width of the River Ganga at Buxar is approximately 700-1000 meters. The depth of the water varied from 2.3-7 m. It was incredibly low on the city side riverbanks. The whole stretch was highly eutrophic during summer. Algal blooms were floating with river grasses up to middle of the river width.

Human activities: Approx. 17 human corpses were sighted in a 1 km stretch of the Ganga river near Ram Rekha Ghat. Dogs, crows, and other birds were feeding on the cadavers. Six sewer drains are falling directly in the Ganga River at Buxar, which polluted the water quality of the river.

Boys standing up to 200 meters from the Ganga bank showing the shallowness of Ganga River at Buxar

Human corpses near Ram Rekha Ghat, Buxar

Water quality assessment at Buxar

Patna[1]: Patna lies at coordinates of Latitude: 25.59410°N and Longitude: 85.13760°E in the state of Bihar. There was substantial amount of water present in the Ganga as compared to earlier three

1

stations. This increment in water flow is mainly due to the confluence of two major tributaries, Ghagra and Gandak rivers with the Ganga River between Varanasi and Patna.

Ganges dolphin: 81 encounters were recorded in 18 km stretch of the Ganga river at Patna. More population of Ganges dolphins was observed in the mid-streams of the river above Gai Ghat.

Habitat: This area seems to provide good habitat for Ganges dolphins. The river depth goes up to 10 m (as reported by local people and staff of IWAI Vessels), and varying river width up to 2 km at places and narrowing to around 700 m at other places. This results in varying speed of water flow, giving slower and faster flow to the river as the river spreads and narrows down. This further provides diversity of habitat for variety of aquatic biota.

Human activity: At Gai Ghat, the pontoon bridge connecting Patna and Hazipur serves as great source of noise. Besides vibrations, remarkably high movement of traffic on the bridge is also a source of disturbance to aquatic animals. This is especially a hindrance to Gangetic River Dolphins as their echolocation might get distracted by the sound of traffic and movements around it.

Ganges dolphins near Gai ghat, Patna

At Kanelganj ghat, Patna

Fish Breeding ground near Gai ghat, Patna

The river stretch in and around Patna has numerous river confluence which act as corridor for dolphins. The disturbances in terms of human activities are limited to shoreline and banks, and may not hamper dolphin navigation. Fishing activities do not deter dolphins, as more fish attract more dolphin and similarly intensity of fishing activity increases. The river near Patna is channelized, while the channel near to Patna might have disturbances in terms of human activities, however the other channels have low human activities and are nearer to the confluence of other rivers.

Bhagalpur: Bhagalpur lies at coordinates of Latitude: 25.3478°N and Longitude: 86.9824° E in the state of Bihar. The water flow in the area comparatively low to Patna, as the river water was divided into different channels and there is a split midstream of the river that forms a channel island.

Ganges Dolphin: 30 encounters were recorded in 28 km stretch of River Ganga near Bhagalpur.

Habitat: The depth of the river at Bhagalpur was 5-8 m and water velocity were almost 1018 cum/sec in this region. A thick riparian vegetation dominated by grass community was seen in the banks with good sand deposition. The water quality was comparatively better as compared to Buxar, Varanasi and Ghazipur. Eutrophication was not observed along city riverbanks. For water quality analysis and sampling, observations were done at 4 km upstream and 4 km downstream of the river of Barari ghat (Table 3.1).

Human activity: Unsustainable fishing activities using mosquito nets are being practiced for collecting the fish seed locally called as *Zeera*. Fishermen capture the fish seeds in large quantities at an early stage, while these have yet not turned into fingerlings. This deprives river system from new fish crops and is a strong cause of depletion in fish population in river.


Divided Ganga near Barari ghat, Bhagalpur

Kahalgaon: Kahalgaon lies at coordinates of Latitude: 25.26270° N and Longitude: 87.23660° E in the state of Bihar. At Kahalgaon, the width of the river is very wide- widest among all stations under study. The Vikramshila Ganges dolphin Sanctuary tails down here.

Ganges dolphin: This area provides a wide and well spread aquatic ecosystem for Gangetic River Dolphins. Due to its deep length and good amount of aeration, the area provides a habitable environment for rest and comforting peace for the creatures. Kahalgaon also provides wider and safer areas for the young and newborn Ganges dolphin calves. A generous number of Gangetic dolphins were sighted around temple site, even seen up to 4 km upstream and downstream as well. 37 Ganges dolphins were recorded in a stretch of about 10 km and around the temple at Kahalgaon. More population of Ganges dolphins were observed near temple as compared to other sites. Local people informed that Gangetic Dolphins appear in higher number during monsoon months and adults accompanying their calves are being sighted more during monsoon and post monsoon months.

Habitat: The water was deep in this region with a range of 7-11 m. There were much meandering and braiding of river and the water current was almost 1206 cum/sec. The water quality information is given in Table 3.1.

Human activity: The river near Kahalgaon and township were jammed with human activities from religious ablutions to day-to-day activities. Mining in the sand banks and fishing were also observed at certain places. Illegal capture of fish seed is a nuisance over here.

Sampling at Temple site, Kahalgaon

Sahib Ganj: Sahib Ganj lies at coordinates of Latitude: 24.98020° N and Longitude: 87.61860° E in the state of Jharkhand. The water level is low as the river diverts into four channels upstream of Sahib Ganj. This reduces the water depth, nonetheless, several fish breeding sites are present in the area.

Ganges dolphin: 27 encounters of dolphins were sighted in the 18 km stretch between Bijli ghat and Samdha ghat. Higher numbers of encounters were noted towards Samdha ghat, with increase in depth. According to local people, Ganges dolphins are seen in higher numbers during the monsoon season when water level of river was high.

Habitat: The channel was wide with good depth and water flow. The average depth was 7.8 m and the water current was almost 2410 cum/sec.

Human activity: Unsustainable fishing using mosquito nets to capture fish eggs and fingerlings was frequent in this region. There is regular boat service from Mansahi ghat to Maniharanpur of LCT transport. Oil spills were found around the vessel. Solid waste was also rampant especially at the ghats.

With officials of IWAI at Sahibganj

With officials of Fisheries Department at Sahibganj

At IWAI, Sahibganj

IWAI- Vessel: SamdaGhat, Sahibganj

Farakka: Farakka lies at coordinates of Latitude: 24.7828° N and Longitude: 87.9041° E in the state of West Bengal. Feeder Canal is a canal associated with Farakka Barrage. It is located in Murshidabad district, West Bengal. The canal is 38.3 km long.

Gangetic Dolphin: This region also provides good habitat for Ganges dolphins, especially near security post and downstream about 3-5 km of the barrage. A total of 29 encounters were observed in the stretch of 10 km at Farakka.

Habitat: Depth of Ganga river feeder canal is about 6.4 m which is good for Ganges dolphins as well as for navigation. The water current was measured at 1239 cum/sec.

3.4. Random sampling sites

There were 19 rapid assessment sites that were evaluated during February-March 2019 for information on Gangetic Dolphin occurrence, distribution and occurrence of female-calf pair (**Table 3.1**). The sites were Varansai, Ghazipur, Buxar, Patna, Munger, Bhagalpur, Kahalgaon, Sahibganj, Farakka, Mangalhaat, Pakur, Hazardwari, Katwa, Shantipur, Tribeni, Howrah, Godakhali, Diamond Harbour, Hoogly River Upstream of Terminal Site and Green Belt Canal (Haldia).The occurrence of female-calf pair facilitated to assess the potential breeding grounds of the Ganges dolphins.

In all sites, the water depth and the flow of the river were also evaluated following standard flow measuring methodology. It was necessary to assess the flow of the river as it is determinant of the depth of the channel.

3.5. Dolphin distribution and assemblage

The dolphins were distributed across the whole stretch from Varanasi to Haldia. However, they were not evenly distributed. A dolphin distribution map (**Fig. 3.1**) was prepared to identify dolphin congregation locations and common movement areas inhabited by these animals during most of the seasons (information of Intensive and random locations). The Gangetic Dolphin sighting information of intensive sites and random locations were put together in a GIS domain, and it was inferenced that larger dolphin assemblages were observed near Ghazipur, Buxar, Patna, Munger, Bhagalpur, Kahalgaon and Farakka. Highest numbers of dolphins were sited near **Patna**. The Feeder Canal also had a good number of dolphins and even calves.

It can be concluded that Gangetic Dolphins are covering most of the stretch. The past studies reveal that there is a decline in the encounter rates of the dolphins as compared with the current study during 2017 (**Table 3.1**). Previous studies in the NW-1 also reveal that this stretch of the river has always been a major habitat for Ganges dolphins (**Table 3.2**). However, their encounter is always noteworthy at Buxar to Maniharighat and in the Feeder canal.

Table 3.1 : A comparative assessment of dolphin encounter rate of past studies and study during the lean season during 2017. A definite reduction in the encounter rate has been observed.

River Stretch	Encounter Rate (Individuals/km)		
	Previous Studies	Author	Previous Studies (2017)
Allahabad to Buxar	0.48	*Sinha (1999)*	0.77
Buxar to Maniharighart	1.62	*Sinha et al. (2010)*	0.36
Vikramshila Gangetic Dolphin Sanctuary	1.8	*Choudhary et al. (2010)*	0.65
Maniharighat to Farakka	1.64	*Sinha (1999)*	0.22
Farakka Feeder Canal	0.55	*Sinha et al.(2000)*	0.10

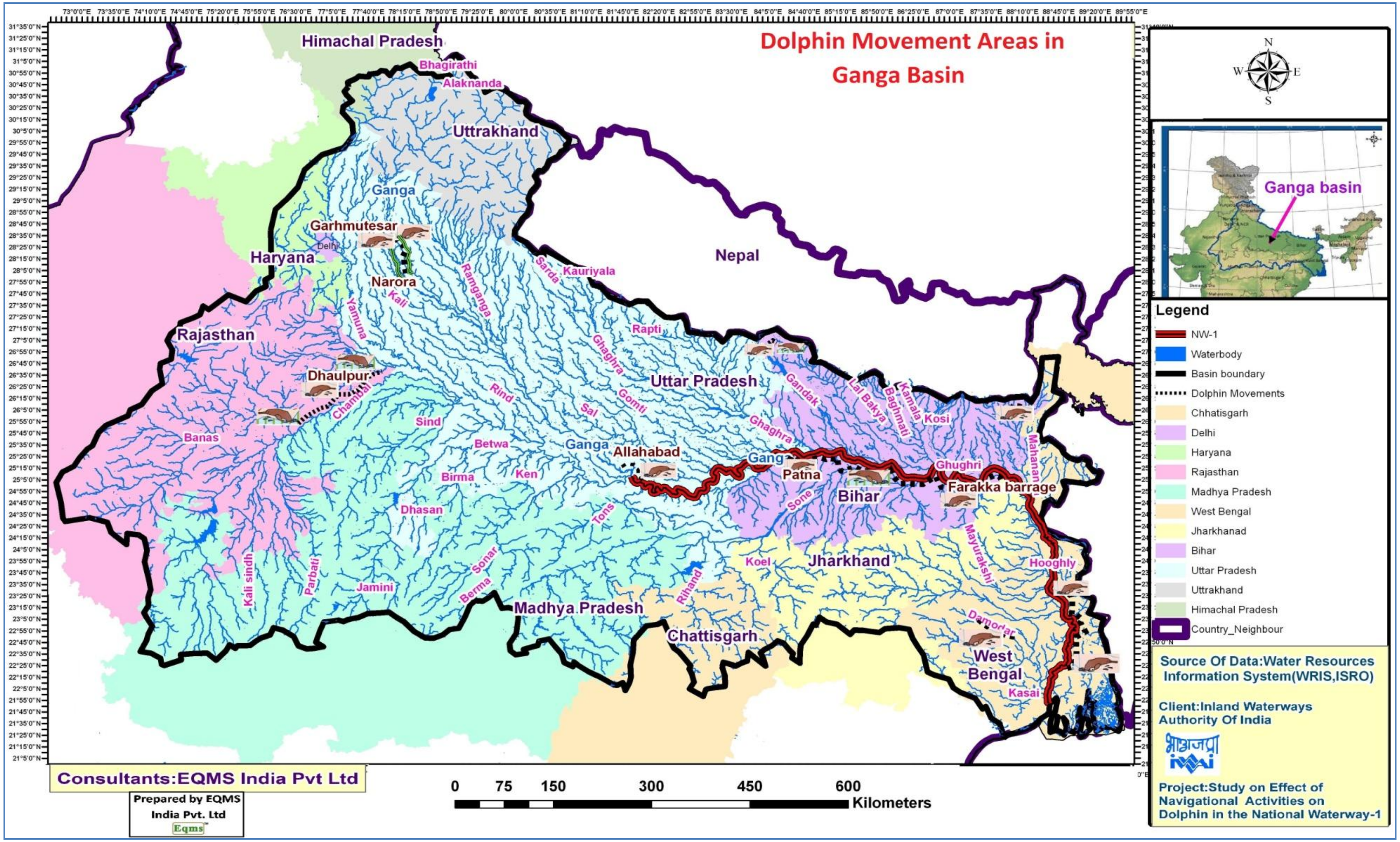


Figure 3.1 : Dolphin movement and distribution range in River Ganga at NW-1.

Table 3.2 : Population status of dolphins in NW-1

Sl. No.	Name of the river	Length of the river surveyed	Dolphin Number	Source
1	The Ganga (Allahabad to Buxar)	425 km	172 (d/ssurvey)	*Sinha et al. (2000)*
2	The Ganga (Buxar to Maniharighat)	500 km	808 (u/ssurvey)	*Sinha et al. (2000)*
3	The Ganga (Maniharighat to Farakka)	100 km	24 (d/ssurvey)	*Non-published data of Dec. 2004(Sinha, 2004)*
4	The Farakka Feeder canal	38 km	21 (d/ssurvey)	*Sinha et al. (2000)*
5	The Bhagirathi (Jangipur Barrage to Triveni)	320 km	119 (d/ssurvey)	*Sinha et al. (2000)*
6	The Hooghli (Triveni Ganga Sagar)	190 km	97 (d/ssurvey)	*(pers. comm. G. Sharma 2008)*

Source: Status of higher aquatic vertebrates by Indian Institute of Technology

The present study at 21 sites revealed almost similar findings (**Table 3.3**). The sighting records of the female-calf pairs were observed almost throughout the stretch (**Table 3.3 and Fig. 3.2 & 3.3**). The dolphin calves are always in a playful mode. After the breeding season during **November to February 2018**, the newborn calves get older and are always accompanied by mothers. The calves are easily seen during **February-March** and thus the final study was carried out during this period.

Table 3.3 : Ganges dolphin sightings and water depth and flow of the river in the same locations. It is observed that water flow increase after Buxar enabled many dolphin assemblages near Patna, Munger, Bhagalpur and Kahalgaon

Locations	ID	Ganges dolphin Adult	Ganges dolphin calf	Ganges dolphin observed per km	Water depth	Water flow
Ganga River upstream of Gurha Nala and proposed Terminal site (Varanasi)	IS1	3	0	0.6	7	132
Ganga River downstream of Gurha Nala and proposed Terminal site(Varanasi)	IS2	6	0	1.2	10	132
Ganga River Upstream of proposed Terminal site at Ghazipur	IS3	15	3	1.8	4.4	154
Ganga River Downstream of proposed Terminal site at Ghazipur	IS4	23	2	3.6	6.2	154
Buxar	IS5	30	1	1.4	4.65	135
Patna	IS6	75	6	4.5	10	900
Munger	RS1	26	2	2	7.5	2466
Bhagalpur	RS2	27	3	1.9	6.5	1018
Kahalgaon	RS3	33	4	2.1	9	1206
Ganga River Upstream of Terminal site near Samda village (Sahibganj)	IS5	11	4	1.5	6.04	2406
Mangalhat	RS4	6	0	0.6	9.5	1818
Ganga River Upstream of existing Farakka lock site (Farakka)	IS7	27	2	2.9	6.4	1239
Pakur	RS5	5	1	1.2	10	1156

Locations	ID	Ganges dolphin Adult	Ganges dolphin calf	Ganges dolphin observed per km	Water depth	Water flow
Hazardwari	RS6	6	2	1.6	8.6	1142
Katwa	RS7	7	2	1.8	6.6	1140
Shantipur	RS8	4	1	1	7.2	1145
Tribeni	RS9	5	2	1.4	10	1145
Howrah	RS10	8	1	1.8	20	1142
Godakhali	RS11	4	0	0.8	8.9	1134
Diamond Harbour	RS12	2	0	0.4	17	1133
Hoogly River Upstream of Terminal Site and Green Belt Canal (Haldia)	RS13	0	0	0	11.4	1136

A total number of **359** dolphins were observed in 21 intensive study locations. It was also observed that jumps of the dolphins were also helpful in predicting the size of the dolphins. Smaller splashes may indicate calves during this season, whereas smaller wallows are indicators of surfacing larger dolphins.

When in a group (pod), the calves are easily identified from size comparison and counting is also possible in a pool of water. As water level is comparatively low during March, enumeration of more precise numbers were possible.

Figure 3.2 : Female-calf pair at Gaighat

Figure 3.3 : Female-calf pair near Patna

3.6. Good habitats of the Ganges dolphins through habitat modelling

The endemic and temporal selection of habitat by dolphin is a complex and dynamic function of search and requirement of food, mates, avoidance of predators and competitors and the ability to move between habitat patches(*Davis et al., 2002; Schofield, 2003*). The distribution of the habitat such as deep-water pools, flow of the river, meanders, and availability of food are the most important characteristics that influence distribution of Gangetic Dolphins.

It was observed that depth of the channel good for dolphins and remain almost 6 m from Patna to Haldia. High flow also coincided with higher encounters of dolphin (**Fig. 3.4**).To evaluate the assumption that the depth and flow are major influencing parameters that determine the presence of Ganges dolphins in the Ganga, a habitat model on the basis of the depth and flow of the river was developed (**Fig. 3.5 & 3.6**).

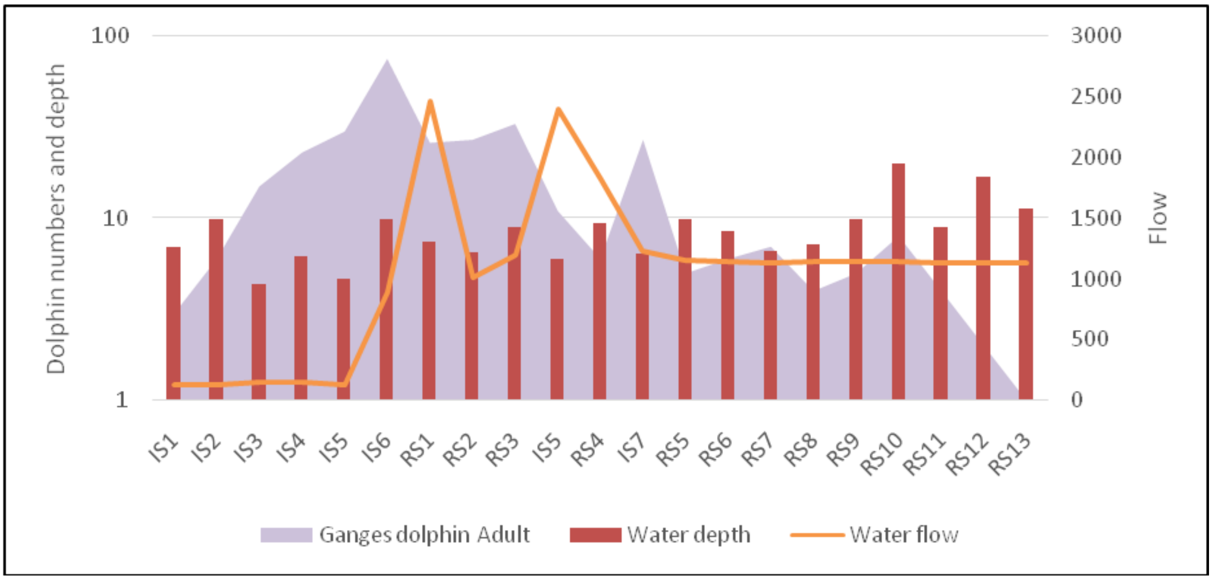


Figure 3.4 : It is clear from the graph that the higher depth regimes and flow has high dolphin encounters in the River Ganga

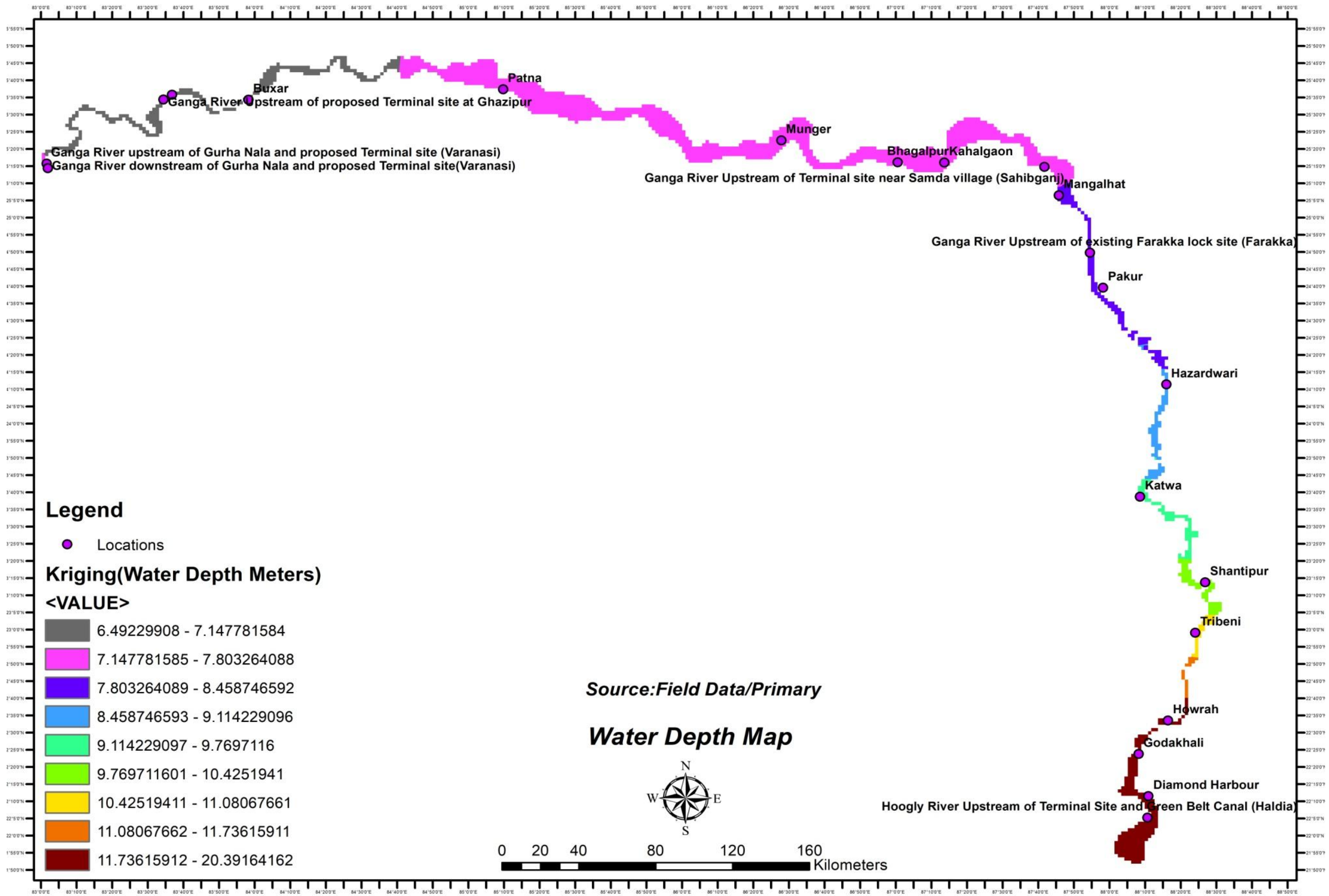


Figure 3.5 : Depth distribution model based on field study and regression model

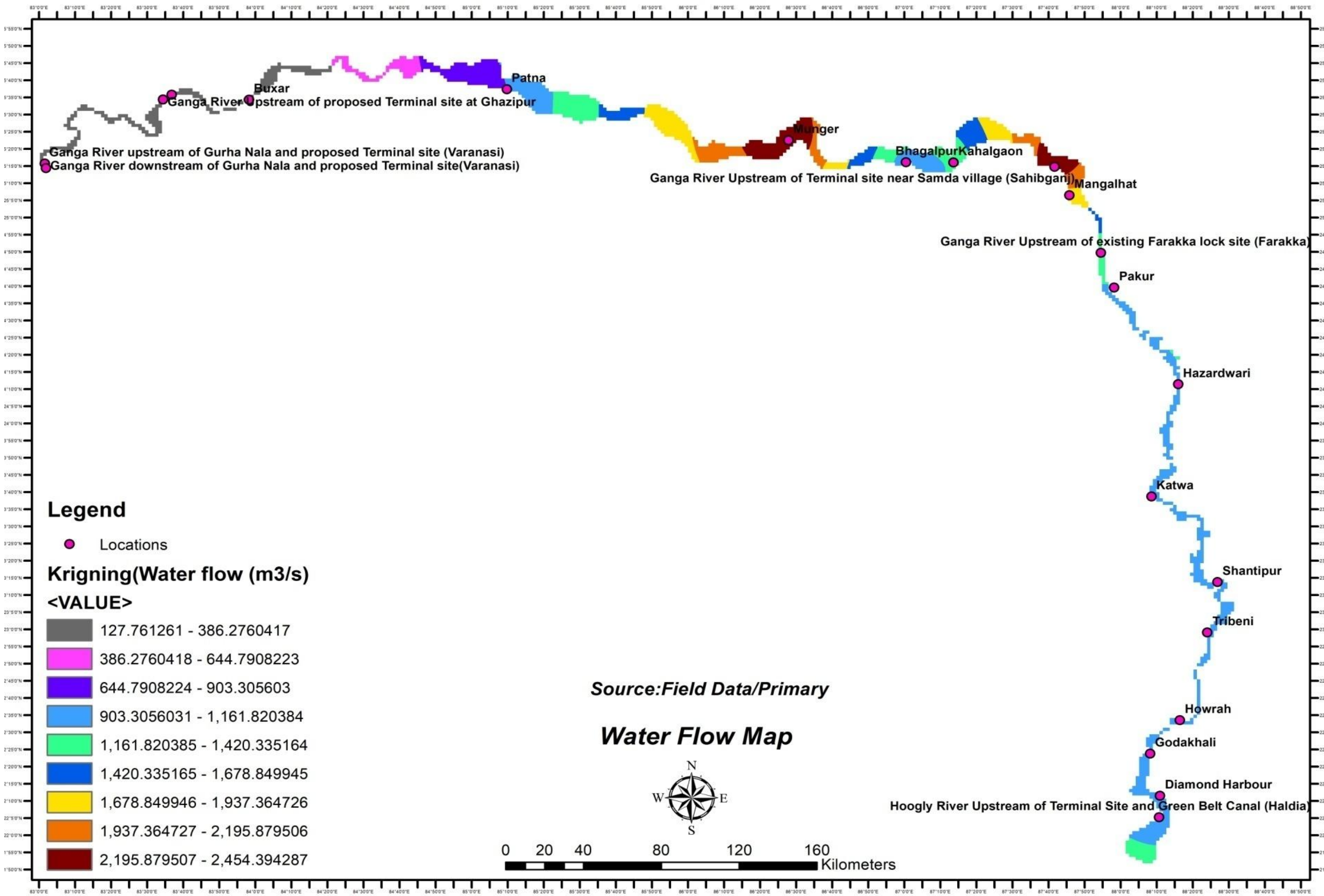


Figure 3.6 : Flow distribution model based on field study and regression model

Our studies showed the preferred habitats chosen by Gangetic Dolphins are in deep sections of river, where the water current is weak, in deep water pools, along the mouths of irrigation canals and sharp meanders, near bathing Ghats, cremation Ghats and in channels with muddy, rocky substrates.

3.7. Ganges dolphin distribution model and identification of breeding habitats

The **Kriging method** was used in GIS domain to assess dolphin assemblages along the study stretch. Kriging is a method of spatial interpolation that originated in the field of mining geology named after South African mining engineer Danie Krige. Kriging is one of several methods that use a limited set of sampled data points to estimate the value of a variable over a continuous spatial field (*Nhu & Zidek, 2006; Rogers & Sedda, 2012*). It uses spatial correlation between sampled points to interpolate the values in the spatial field. The interpolation is based on the spatial arrangement of the empirical observations. Kriging also generates estimates of the uncertainty surrounding each interpolated value. Generally, the kriging weights are calculated at points nearby to the location of interest that are given more weight than those farther away. Clustering of points is also considered, so that clusters of points are weighted less heavy (in effect, they contain less information than single points). This helps to reduce bias in the predictions (**Fig. 3.7**).

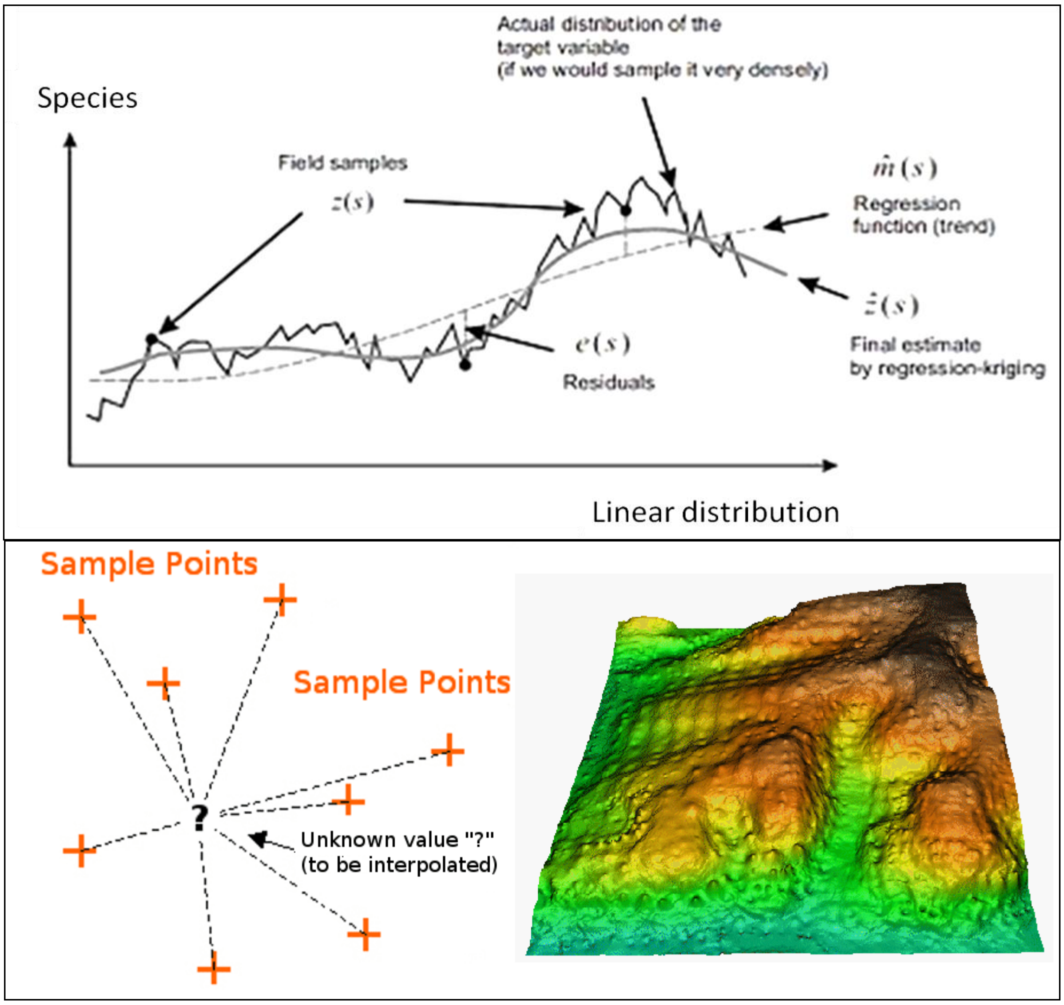


Figure 3.7 : Kriging Method for Spatial Prediction

The Kriging Predictor is an “**Optimal Linear Predictor**” (*Auchincloss, 2007*) & an exact interpolator, indicating that each interpolated value is calculated to minimize the prediction error for that point. The value that is generated from the kriging process for any sampled location will be equal to the observed value at this point, and all the interpolated values will be “Best Linear Unbiased Predictors (BLUPs)”. Kriging interpolation resulted in identification of dolphin congregation and potential breeding areas along the Ganga in NW-1 (**Fig. 3.4**).

3.8 Conclusion

It was observed that Dolphins were sighted in almost all the study points. A total of **359** sightings were observed, which shows that dolphins are proliferating in this section of the river. 36 calf sightings across the area indicated a growing population. It was found that **Patna** is the best site for Gangetic Dolphin Breeding since many tributaries like Ghaghra, Gandak, Sone and Punpun meets with the River Ganga in this region. These tributaries provide fish and essential connectivity to the Ganges dolphins. Dolphins, especially adults seem to be present in deep water of 10 m and more often sighted in that depth.

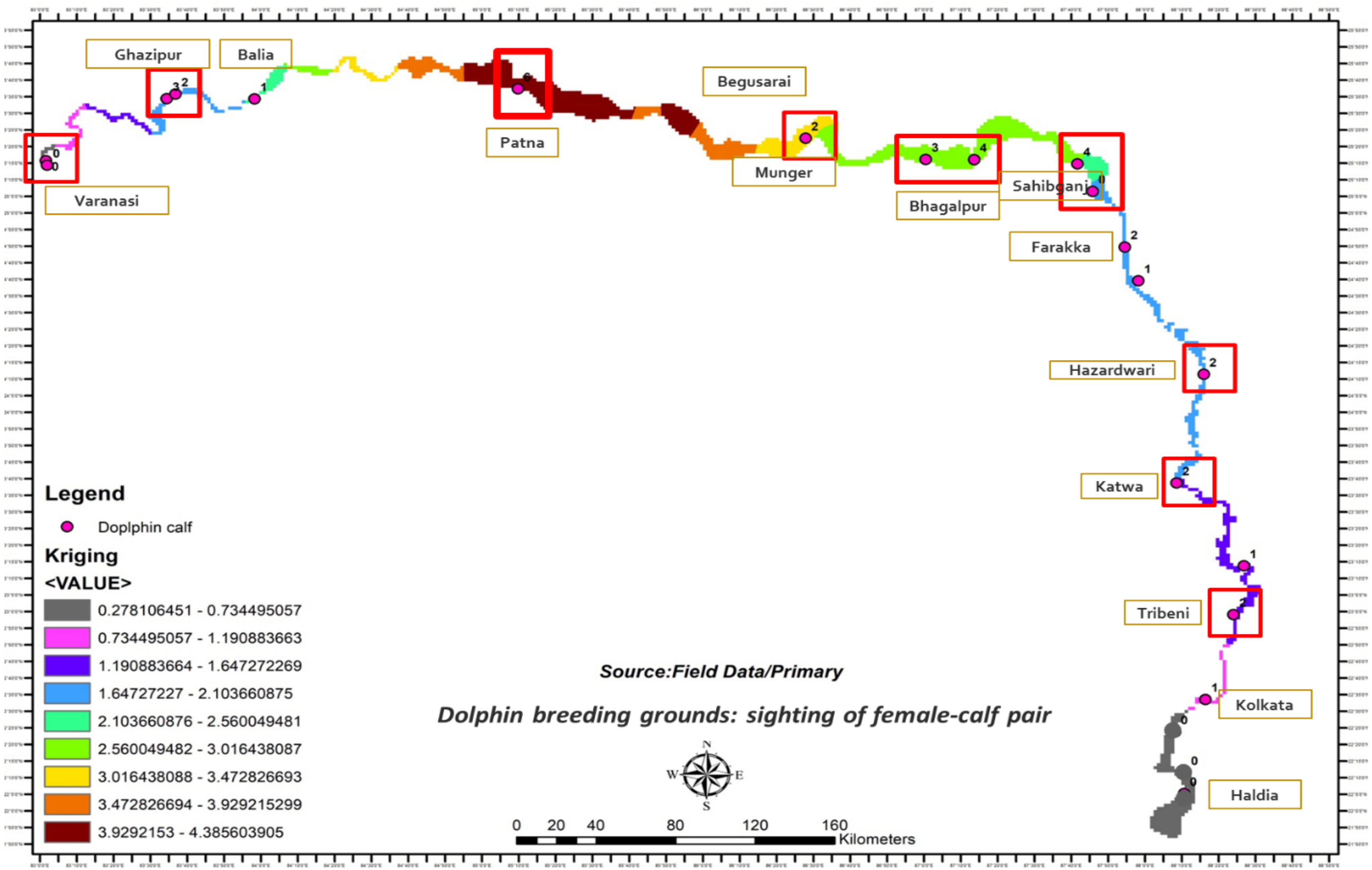


Figure 3.8 : The predicted Kriging model for dolphin congregation and potential breeding sites. Locations with dark red to yellow have dolphins' groups of > 2 animals per km of the stretch. The red squares depict breeding sites. The sites Patna, followed by Bhagalpur and Sahib Ganj seems to be good breeding grounds

Chapter 4. GANGES RIVER DOLPHINS: ECOLOGY AND BIOLOGY

4.1. Introduction

Gangetic River Dolphins are wide-ranging feeders, although they chiefly feed on fishes (*Sinha et al., 1993*). They are active hunters and often seen hunting in groups on shoals of fishes. Thus, abundance of fish fauna is one of the major defining factors in the distribution of the species. On the other hand, abundance and distribution of the fish fauna largely depends upon water quality and planktonic diversity and assemblage.

To evaluate the status of food chain of these dolphins, intensive sampling sites were selected at major cities along the Ganga and jetties of the NW-1 where major vessel movement will occur.

4.2. Intensive sampling sites

Ten sites were assessed intensively for phytoplankton, zooplankton, and fish diversity. These sites were: Varanasi, Buxar, Patna, Bhagalpur, Kahalgaon, Sahibganj, Farakka, Tribeni, Godakhali and Diamond Harbour (**Figure 4.1**). The sites are described in detail in the following sections.

4.3. Fish abundance and species distribution

Fish samples were collected through **stratified random sampling** using experimental fishing and landing centre approach. The fishes were captured through various selective and non-selective gears. For landing centre approach consecutive fishing boats were randomly selected from the landing centre of the given sites. The total collected samples were further enumerated by number of fishing boats operating in the given fishing zone of that stretch. The collected samples were either identified on spot, such as major carps, silurides, perciforms, snakeheads, notopterids, or preserved in 10% formalin and transported to the laboratory for further analysis. When the species could not be identified by the team, it was done with the help of *Dey (1889)* and *Talwar and Jhingran (1991)*. Species assessment was carried out through market survey. At each station samples were identified, separated from the lot, and counted for individual species, as how many types of different fishes were being caught from local fishing grounds that have reached fish market. The same was done along river line where fishermen were available with their haul.

4.4. Assessment of fish species in River Ganga

95 fishes belonging to 102 genera, 50 families were recorded from the stretch of the Ganga river from Varanasi to Farakka during the survey from **May to June 2018**. Highest diversity of fishes was found to be at Farakka with 62 species of freshwater fishes and lowest was at Buxar with 27 species of fishes. It was observed that there is a gradual increase in the fish diversity from Varanasi to Farakka. This may be accounted by availability of good water depth and suitable water parameters in the downstream of the river. The fishes observed and recorded in the study are presented in **Plate 4.1.**

Varanasi: The total fish diversity in the area was recorded as **54**. Most of the fish population in the site is showing a declining trend. Main species included: four species of IMC *viz.*, *Labeo rohita*, *Cirrhiunus mrigala*, *Catla catla* and *L. Cala basu*, *Rita rita*, *L. bata*, *Notopterus chitala*, *Notopterus notopterus*, *Mastacembelus armatus*, *M. aor*, *M. vittatus*, *M. cavasius*, *Cyprinus carpio*, *Tilapia mossambicus* etc. exotic species such as *Clarias gariepinus* and *Tilapia sp*. are increasing numbers in the area. Rare fishes observed in the area were *Mystus tengara* and *Noto pterus* sp. Fish generally lay their eggs in shallow freshwaters near the banks of river, where water velocity is relatively low, and currents are never fast, and whirling is absent. Varanasi city area did not have any such favorable area where fish may breed. However, an area of about 3-5 km beyond Ramnagar location have sites where minor as well as major fishestob can breed, mostly at undisturbed zones. No breeding ground was found near the Ghats of Varanasi.

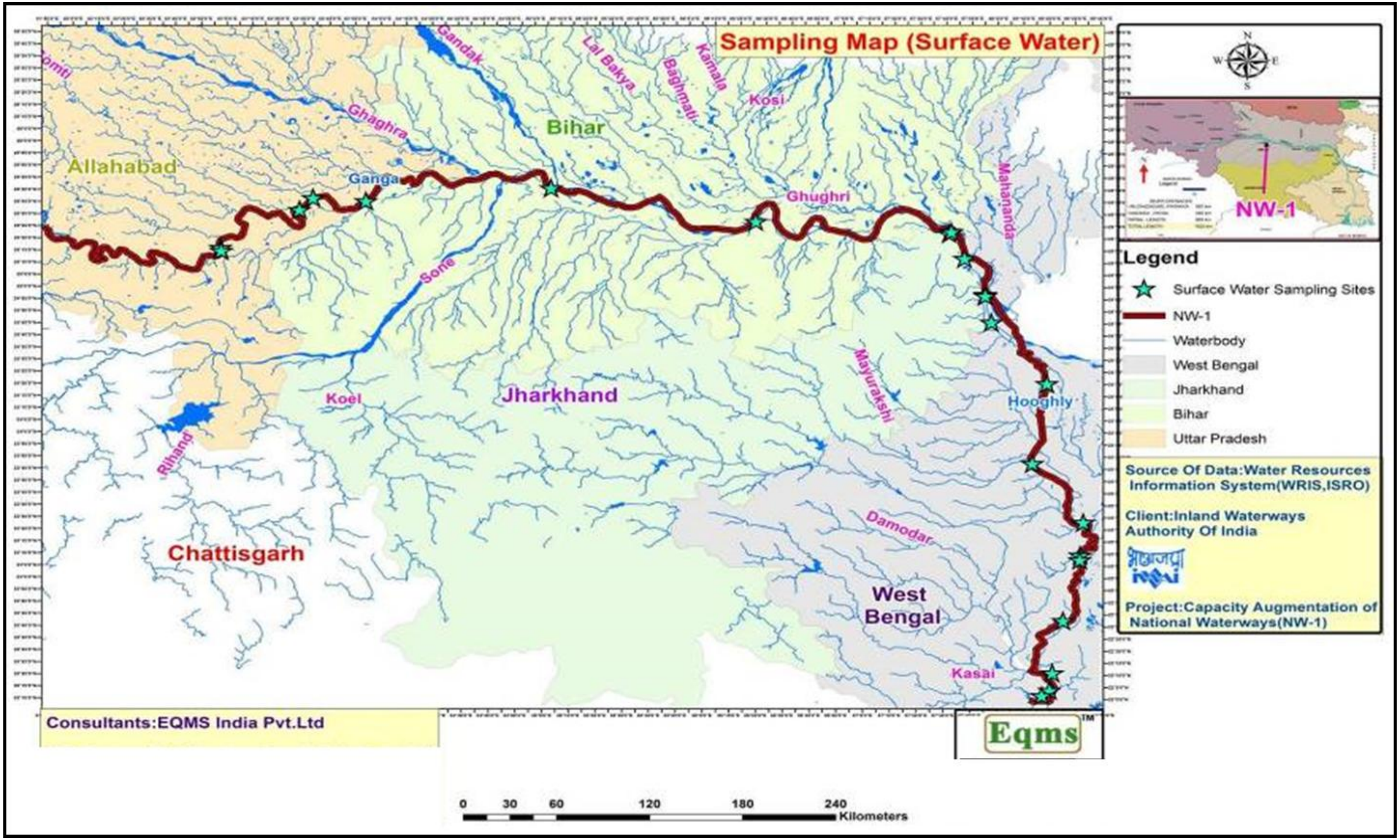


Figure 4.1 : Locations for prey base and intensive water quality assessment

About 150-200 fishermen depend on fishing around the city. Main fish markets are Chowk Ghat, Dashshwamedh Ghat etc. The fish of these markets generally come from Ganga river. The Chowk Ghat is the major hub for fish trading, which usually opens in the afternoon hours. It is a major fish landing site, with interstate and marine fish trading. The fishing intensity is high, even during spawning season. It is one of the main causes for depletion in majority of fish species. The daily fish haul on an average around Varanasi was reported between 75 to 150 kg only.

Fish breeding ground at Varanasi

Ghazipur: Fishing was reported to be exceptionally low as only 35 species were recorded. Main fish species of this region are: *Labeo* sp., *Channa* sp., *Mystus* sp., *Noto pterus* and *Tilapia mossambicus*. Most of these fishes were mainly found in the monsoon season. Ghazipur has two fish markets: Taxi stand fish market and Bus station fish market. The fish market near the bus station was almost empty. This spot markets fishes hauled from river Ganga around Ghazipur. Fishermen were also scarce with only about 40-50 fisherman, showing an overall low productivity of the area in concern of fisheries market. The fish catch at Ghazipur was informed about 20 kg per day. The fish market also had a few interstate and marine fish boxes on sale.

Sampling in Ghazipur

Fish breeding location in Ghazipur

Buxar: At Buxar, 27 species of fishes were observed, This station predominated cat fishes from different families, dominated by *Clarias batrachus, Clarias garipinus, Rita rita, Mystus vittatus, M. aor, M. cavasius, M. tengra, Anabus* species, *Mastacem belusarmatus, P. sophore, P.ticto, P. stigma,, Xenentodon cancila*. Prawns were also dominant in this region. Despite highly polluted condition of river water around Buxar, there were few good breeding locations upstream of Ram Rekha ghat. As fish generally lay their eggs in shallow freshwaters near riverbanks, there were locations about 5-6 km upstream of the ghat with calm freshwater areas which could be possible locations for breeding.

These fishes were being sold by fishermen at three places, all hauled from Buxar Ganga waters. Individual fishermen, on an average, capture 3 - 4 kg of fishes. However, on some days they are unable to harvest even a single kg of fish.

Patna: The fish community showed diversity along Patna regime of river Ganga. It was even though fishermen repeatedly said that fish population is declining. We were able to count 58 species of fishes being caught at three-four places of the market and along Ganga banks with fishermen on boats. Main species of the region were all major carps viz, *L. rohita*, *L. calbasu*, *C. mrigala*, *Catla catla,* besides of course good sized *W. attu*, *M. tengra*, *M. aor*, *Rita rita*, and variety of trash fishes. Population of *Mystusten gara* and, *W. attu* as well as those of major carps was reported falling by the local people. There is about only 200-300 kg fish catch from Ganga river, per day. It is maximum in comparison to other stations. According to locals, turtles were also seen at times in Patna region of river Ganga.

Fish breeding site near Gai Ghat

Bhagalpur: 41 fish species were reported from Bhagalpur. These were mainly trash fishes, silurids, and Tilapias. IMCs were scanty. The local fish market, Station Fish Bazaar, showed poor fish haul. Daily capture varies between 25 kg to 70 kg. The market was dominated by pond culture fishery and marine fishes. Increasing siltation and the Farakka Barrage are speculated to be responsible for the decline in fishery.

Fish Breeding ground near Barari Ghat, Bhagalpur

Kahalgaon: 42 fish species were observed in Kahalgaon. Dominant fish species include *Labeo rohita, Labeo calbasu, Mystus tengara, Mystus vittatus, M. aor, Xenentodon* sp., *Mastecembelus* sp., *Tilapia sp., Anabas* sp., *Barbus* sp. And *Puntius* sp..Despite high diversity, fish diversity and density was poor at the local fish markets. It may be attributed to decline in fish catch due to unsustainable fishing practices. As a result, the fish markets land only around 50-75 kg of fish on an average per day. Approximately 2-3 kg fish catch per person were recorded at Kahalgaon.

Sahib Ganj: 45 fish species were recorded from Sahib Ganj. Dominant species of this region include *Labeo rohita,* Labeo bata, *Catla catla, Mystus vittatus, M. aor, M. cavasius* etc. Rare species include fingerlings and even eggs from the breeding sites have led to major decline in fish population in the region. Main breeding grounds of fishes are Maharajapur and Bijli Ghat. Approximately 1000 fishermen are registered in Sahib Ganj region.

Fish Breeding ground near Janta Ghat, Sahibganj

Farakka: 62 fish species were recorded in Farakka, highest diversity in the whole stretch. Dominant species include *Labeo rohita, L. bata, Clariasgariepinus, Mystusvittatus, M .aor, M. cavasius, M. tengara and Tilapia mossambica*. More varieties of fishes were found in Farakka as compared to other sites. Small fish species include *Mastacembelus armatus, Xenetodon cancilla, Puntius sp., Heteropneuteus fossilis, Channa* sp. Rare species such as *Hilsailisha* were also found here. Three fish markets with high fish diversity were recorded where highest varieties and amount of interstate fishes-marine as well as freshwater fishes were observed. Yield of Hilsa was substantial with a size class ranging from 20 cm – 40 cm.

Plate 4.1. Fishes in Ganga River

Notopterus notopterus

Mastacembelus armatus

Rita rita

Labeo bata

Prawn (Jhinga)

Pangasius pangasius

Anabas testudineus

Plate 4.2. Fishes in Ganga River

Labe orohita

Catla catla

Tenualosa ilsha

Separata aor

Oreochromis niloticus niloticus (Tilapia)

Clarias batrachus (Linnaeus)

Sperata seenghala

Anabas testudineus

Plate 4.3. Fishes in Ganga River

Notopteruschitala

Puntius sophore

Heteropneusteus fossilis

Hilsa ilisha

Mystusaor

Rita rita

Table 4.1 : Fish diversity at different sampling sites of the Ganga river

Sl No.	Stations	Coordinates in degree	Fish richness	Dominant fish species
01.	Varanasi	25.3176452 N 82.9739 E	43	*Salmophasia bacaila, Cyprinus carpio, Oreochromis niloticus*
02.	Buxar	25.5647103 N 83.9777 E	21	*Cabdio morar, Cyprinus carpio Gudusia chapra, Goniolosa manmina Pachypterus atherinoides, Clupisoma garua*
03	Patna	25.5940947 N	25	*Cabdio morar, Puntius sophore*

		85.1376 E		*Clupisoma garua, Eutropiicthys vacha, Ailia coila*
04.	Bhagalpur	25.3478004 N 86.9824 E	14	*Cabdio morar, Cirrhinus reba Eutropiicthys vacha, Clupiso magarua Gudusia chapra, Corica soborna*
05.	Farakka	24.8006687 N 87.9090 E	25	*Johnius coitor, Cabdio morar, Puntius sophore*
06.	Tribeni	22.9867069 N 88.4025 E	17	*Apocryptes bato, Tenualosa ilisha*
07.	Godakhali	22.3932057 N 88.1426 E	12	*Tenualosa ilisha, Otolithoides pama, Odontamblyopus rubicundus*
08.	Diamond Harbour	22.1987268 N 88.2023 E	12	*Setipinna phasa, Polynemus paradiseus*

Total 95 fish species belonging to 102 genera and 50 families were recorded during the first site visit during May and June 2018. It was observed that **maximum diversity was recorded in the Farakka region while minimum was in Ghazipur where only 35 species of fishes were noted**. It was observed that there is a gradual increase in the fish diversity from Varanasi to Farakka.

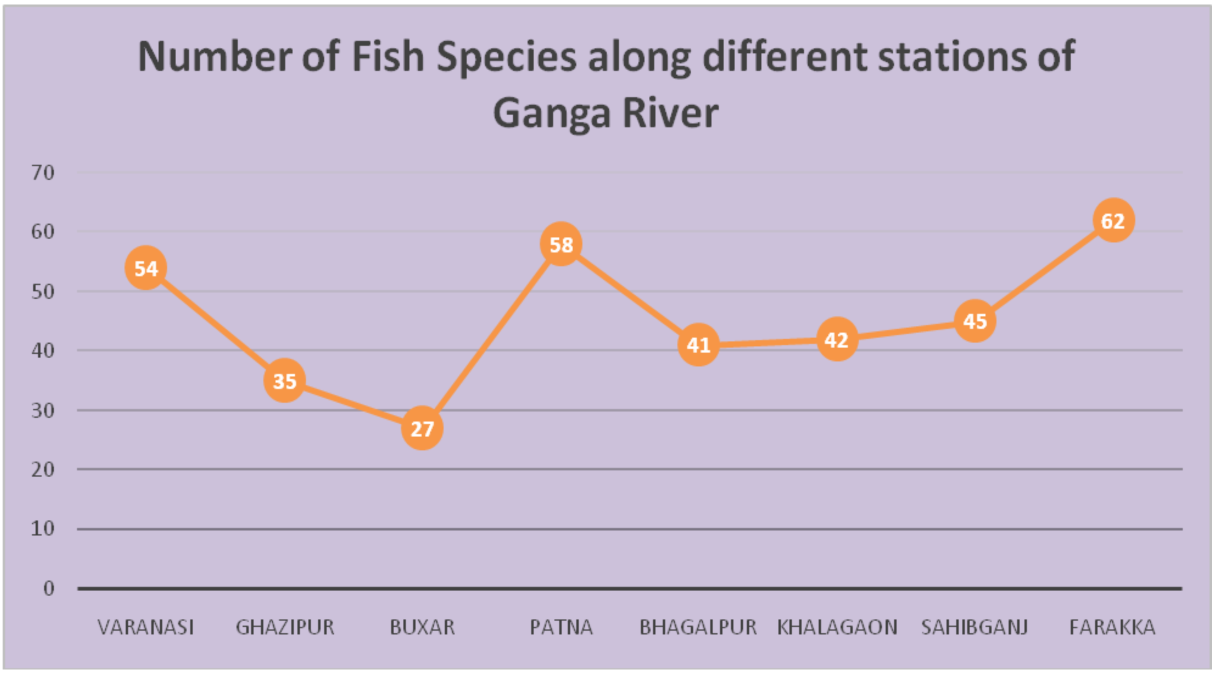


Figure 4.2 : Abundance of fish fauna along intensive survey sites in NW-1

4.5. Food Component of Ganges Dolphins

The abundance of dolphins in a habitat is assumed to be in relation with food availability in that habitat. The presence of phytoplankton's is indirectly responsible for the food availability as well as productivity of the dolphin habitat and thereby plays a key role.. In many cases, abundance of phytoplankton's and aquatic vegetation supports large quantities of aquatic insects, mollusks, crustaceans, and small fishes, which ultimately becomes the dolphin diet. Among the fish species routinely consumed by Dolphins include smaller sized fishes belonging to species of *Catla*, *Labeorohita*, *L. calbasu*, *L. bata*, *Cirrhinus mrigala*, *Heteropneustes fossilis*, *Cyprinus carpio*, *C. reba*, *Puntius ticto*, *P. conchonius*, *P. sarana*, *P. sophore*, *Danio devario*, *Glossogobius giuris*, *Tenulosailisha*, *Hilsa kelee*, *Coilia dussumieri*, *Setipinna phasa, S. taty, Mugil cephalus, Ailia coila, Eutropiichthysvacha*., catfishes like : *Mystusvittatus, M. cavelleri, M. teengara, M. aor, Anabas testudenius, Mastacembelus sps., Chana gachua, C. punctatus, C. striatus, Chela labuca,* and *C. atpar, X. cancila, Notopterus notopterus, N. chitala, Nemacheilus sps., Chanda nama, Nandus nandus, Wallago attu, Rita rita, A. mola, Rasbora daniconius*, myriad categories of trash fish species (nearly twenty such fish species whose size ranges between 5 cm to 10 cm.), Prawns of various species, crabs and even smaller sized soft freshwater turtles .

It is inferred that river stretch with muddy bed relatively serves better for fish food, followed by the Dolphins, compared to sandy or rocky beds. Presence of dense aquatic vegetation, rich planktonic population and fishes etc. were observed in the river stretch with muddy bed. Many realms around Varanasi ghat, Buxar, Sultanganj, Kahakgaon, and Ghazipur showed a higher degree of eutrophication on account of shallowness, overexploitation by local population, vicinity of the river to discharge output centers of municipality sewage drains, hovering masses of dead animals & human carcasses on the river, over-usage of detergents and soaps around the banks of river at ghats by local population. However, such polluted areas are generally avoided by the Dolphins due to inappropriate conditions like shallowness of water, higher turbidity, low oxygen contents, higher BOD, foul smell, and higher temperature.

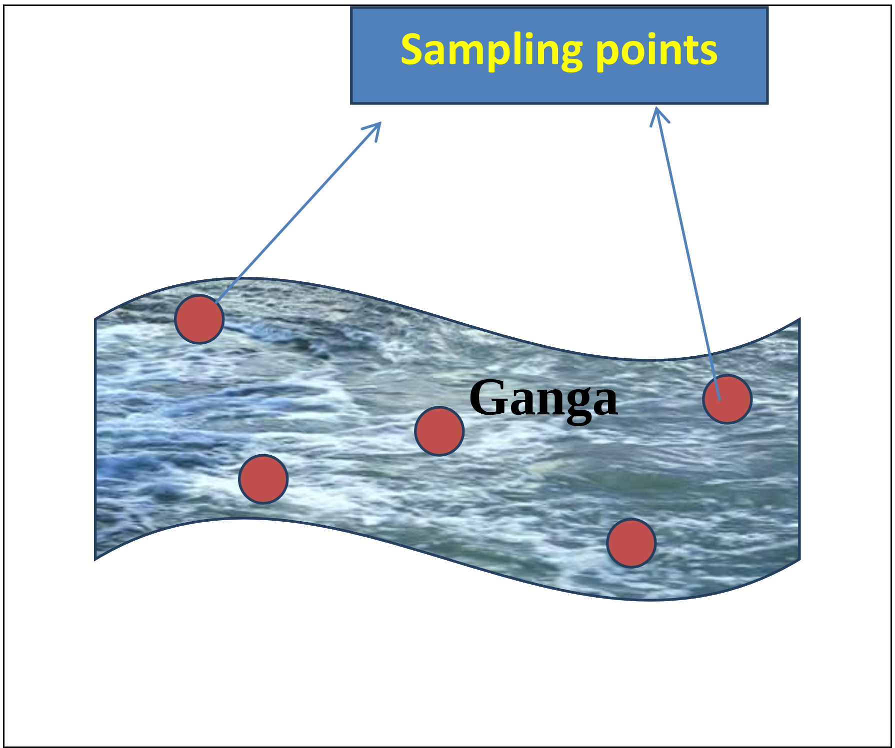
4.6. Food quantity consumed by a Dolphin

There are no specific reports on this aspect by any Indian researcher. However, we have an authentic report, given by *Dr. Gopal Sharma*, while he was involved in translocation of two Dolphins- stranded in a small tributary (*Donk*), in Kishanganjdistrict- at Baldiyahat, few years back .*Sharma (2013)* said , he fed the two Dolphins aging around 20-21yrs with a body weight of 125 and 126 kg and found these Dolphins consumed about 5-6 kg of fishes, offered within 20-24 hours (during two days of his observations). This is around 5 % of the body wt. of the Dolphin, almost a normal standard amount of body wt. for most of the mammals, who normally feed almost in a ratio of 4 to 8 percent of their body wt. per day (24 hrs.) However, this diet varies for males and females, their age, and breeding and gestation periods. Similar observation has been made on experimental basis for Dolphins under human care by *Kasteleinetal., (1994)* who reported 1870.0 kg of fish food per year for the Dolphin of 3 yrs of age. They reported that the amount of food consumption increases with age to certain, after which it nearly becomes static. They have found that food consumption of Dolphins is related to their life stages and energy requirements like infant, juvenile, pregnant, lactating and adult males and females.

4.7. Plankton study in the Ganga river stretch under NW-1

4.7.1. Methodology for sample collection

10 litres of water sample were collected at five different points in the Ganga river stretch between Varanasi to Farakka, at a gap of 1 km between sampling stations. The water samples were pooled in a container and filtered through fine plankton net of mesh size (45µm). The filtered concentrated river water with planktons was then stored in an airtight container. The samples were fixed and preserved by adding 4% formalin solution. Planktons were counted using **Drop Count Method.**



4.7.2. Results

It was observed that **Chlorophyceae** is the dominant group in the pre-monsoon season, Bacillariophyceae is the dominant group in the monsoon and post monsoon season (**Table 4.2**). Rotifera is the dominant group of zooplankton in all the three seasons for the period 2018 (**Table 4.3**)

Table 4.2 : Seasonal dominance of phytoplankton in the river stretch Ganga at different sampling sites during 2018

	Premonsoon		**Monsoon**		**Post monsoon**	
Site	**Dominant Group**	**Dominant Genus**	**Dominant Group**	**Dominant Genus**	**Dominant Group**	**Dominant Genus**
Buxar	Chlorophyceae	Pediastrum	Cyanophyceae	Microcystis	Bacillariophyceae	Cyclotella
Bhagalpur	Chlorophyceae	Pediastrum	Cyanophyceae	Microcystis	Cyanophyceae	Oscillatoria
Patna	Cyanophyceae	Microcystis	Bacillariophyceae	Navicula	Bacillariophyceae	Cyclotella
Farraka	Chlorophyceae	Eudorina	Bacillariophyceae	Navicula	Bacillariophyceae	Aulacoseira
Triveni	Chlorophyceae	Spirogyra	Bacillariophyceae	Navicula	Bacillariophyceae	Aulacoseira
Godakhali	Bacillariophyceae	Aulacoseir a	Bacillariophyceae	Coscinodisc us	Bacillariophyceae	Coscinodis cus
Diamond Harbour	Bacillariophyceae	Coscinodis cus	Bacillariophyceae	Coscinodisc us	Bacillariophyceae	Coscinodis cus

Table 4.3 : Seasonal dominance of zooplankton in the river stretch Ganga at different sampling sites during 2018

	Premonsoon		**Monsoon**		**Post monsoon**	
Sites	**Dominated Group**	**Dominated genus**	**Dominated Group**	**Dominated genus**	**Dominated Group**	**Dominated genus**
Buxar	Rotifera	Brachionus	Rotifera	Brachionus	Rotifera	Brachionus
Bhagalpur	Rotifera	Polyarthra	Rotifera	Nauplii	Rotifera	Nauplii

Patna	Rotifera	Nauplii	--	--	Rotifera	Brachionus
Farraka	Rotifera	Keratella	Rotifera	Nauplii	Rotifera	Nauplii
Triveni	Rotifera	Nauplii	Rotifera	Brachionus	Rotifera	Nauplii
Godakhali	Rotifera	Nauplii	Rotifera	Polyarthra	Rotifera	Nauplii
Diamond Harbour	Rotifera	Nauplii	Rotifera	Nauplii	Rotifera	Nauplii

Plate 4.2. Phyto- and zooplankton species encountered during the survey

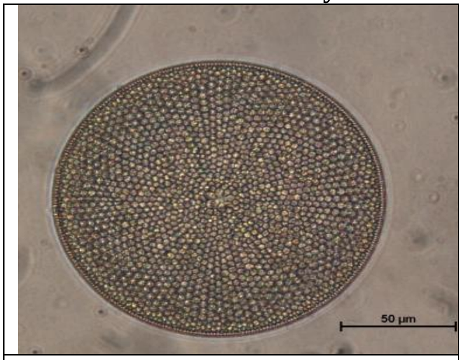
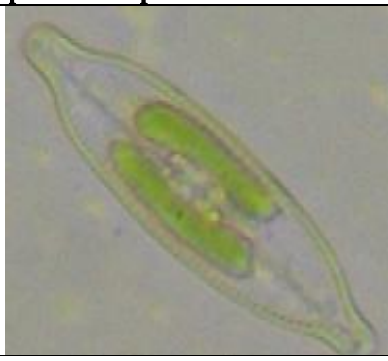
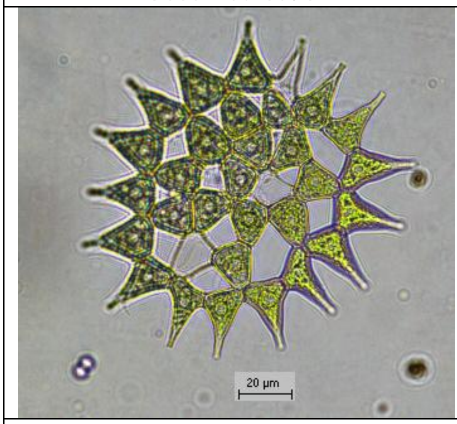
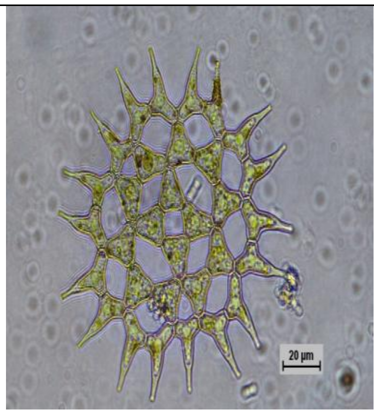
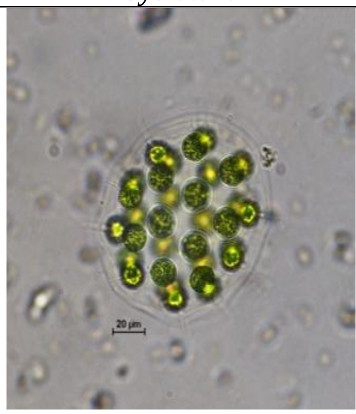
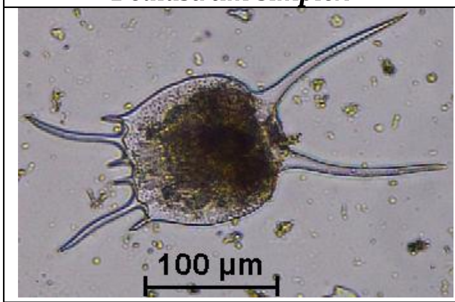
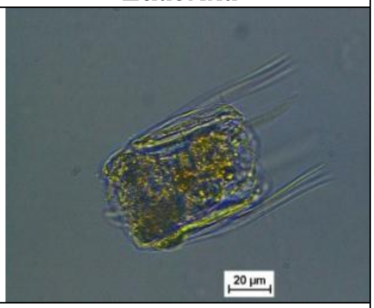
		
Coscinodiscus	***Navicula***	***Cyclotella***
		
Pediastrum simplex	***P. duplex***	***Eudorina***
		
Brachionusfalcatus	***Keratella sp.***	

Table 4.4 : Abundance of fish and planktonic flora and fauna in NW-1

Location	ID	Avg. Fish richness	Avg. Fish abundance	Avg. Zooplanktons (u/l)	Avg. Phytoplankton (u/l)
Ganga River upstream of GurhaNala and proposed Terminal site (Varanasi)	IS1	42.7	64277.3	106.0	570.0

Ganga River downstream of GurhaNala and proposed Terminal site (Varanasi)	IS2	49.2		70.0	4346.1
Ganga River Upstream of proposed Terminal site at Ghazipur	IS3	53.4		38.5	400.3
Ganga River Downstream of proposed Terminal site at Ghazipur	IS4	45.9		51.7	126.3
Buxar	IS5	21.3	113973.3	34.0	2345.0
Patna	IS6	25.0	712800	25.66	258
Munger	RS1	93.1		80.4	3441.0
Bhagalpur	RS2	14.3	42220	94.33	501.66
Kahalgaon	RS3	17.5		48.0	315.3
Ganga River Upstream of Terminal site near Samda village (Sahibganj)	IS5	43.9		43.4	1005.8
Mangalhat	RS4	47.3		88.3	385.2
Ganga River Upstream of existing Farakka lock site (Farakka)	IS6	25.3	105266.67	33.66	37.33
Pakur	RS5	31.9		47.6	551.5
Hazardwari	RS6	41.0		48.7	854.6
Katwa	RS7	56.6		45.4	2213.3
Shantipur	RS8	43.8		19.7	4355.6
Tribeni	RS9	17.0	110800	16.33	103.33
Howrah	RS10	51.3		92.9	127.4
Godakhali	RS11	12.3	36472653	22.33	94.67

4.8. Water Quality of Ganga River in NW-1 Stretch

Water chemistry is a major detrimental factor of abundance and distribution of aquatic species. Spill overs from various human activities such as agriculture, drain discharge, discharge from industrial effluents etc. alter the natural water chemistry, disrupting the habitat of aquatic species. It is evident from literature that movement of heavy vessels also disrupts the water quality through resuspension of bottom sediments and spillage of oil and grease. Thus, monitoring of water chemistry at regular intervals through an identified standard is necessary for sustainable operationalization and management of NW-1.

CPCB guideline evaluates the water quality of the river for its Best Designated Use (BDU) and classifies it into five classes considering its chemical properties (**Refer Table 4.5 for standards**).

Table 4.5 : Best Designated Use Standard (source: CPCB)

Designed Best Use	**Class of Water**	**Criteria**
Drinking Water Source without conventional treatment but after disinfection	A	Total Coliform Organism MPN/100ml shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6mg/l or more Biochemical Oxygen Demand 5 days 20°C 2mg/l or less
Outdoor bathing (Organized)	B	Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/l or more

		Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/l or more Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Propagation of Wildlife and Fisheries	D	pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	pH between 6.0 to 8.5 Electrical Conductivity at 25°C micro mhos/cm Max.2250 Sodium absorption Ratio Max. 26 and Boron Max. 2mg/l

4.8.2. Literature review and analysis

The water quality of the Ganga River was monitored by CPCB at different locations along NW-1(**Table 4.6**). As per CPCB, water quality parameters such as DO & pH – meets the water quality criteria for bathing at most monitoring locations. DO varied from 4.8-12.8 mg/l and was found within the permissible limits. BOD ranges from 1.1-8.2 mg/l, and maximum value of BOD was recorded at Diamond Harbor. Fecal coliform ranged from 230-650000 MPN/100ml. The total coliform values ranged from 490 MPN/100ml at Mirzapur to 85,0000MPN/100ml at Howrah. It is mostly above 5000 MPN/100ml/coliform limit for category 'C' - BDU.

Table 4.6 : Water Quality at different cities along NW-1

Locations	**State**	**Temperature °c**		**DO (mg/l)**		**pH**		**Conductivity (µmhos/cm)**		**BOD (mg/l)**		**Fecal coliform (mpn/100ml)**		**Total coliform (mpn/100ml)**	
		Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Water Quality Criteria C (Category for Drinking water source after conventional treatment and disinfection)															
		-		> 4 mg/l		6.5-8.5		-		< 3 mg/l		< 2500 mpn/100ml		< 5000 mpn/100ml	
At Allahabad (Rasoolabad)	UP	21.0	29.0	6.0	9.8	7.4	8.4	278	488	2.8	6.0	3000	3500	7000	9000
Ganga d/s, Mirzapur	UP	18.0	33.0	5.1	10.3	7.3	8.2	207	555	2.9	4.5	230	7000	490	17000
Varanasi u/s (Assighat)	UP	18.0	27.0	7.5	7.8	7.5	7.8	224	266	3.7	4.2	8000	8000	13000	13000

Ganga at Trighat (Ghazipur)	UP	19.5	28.5	7.0	7.4	7.9	8.2	232	270	4.1	4.4	13000	13000	17000	21000
Ganga at Buxar, Bihar	Bihar	16.0	31.0	7.8	9.0	7.6	8.5	287	402	2.7	2.8	1100	9000	2800	16000
Ganga at Khurji, Patna u/s	Bihar	17.0	32.0	8.0	8.9	7.9	8.6	262	416	2.6	2.8	1300	5000	2400	16000
Confl. Sone Doriganj, Chapra	Bihar	16.0	25.0	7.9	9.3	7.1	8.1	214	380	2.7	2.8	1100	3000	2200	5000
At Patna d/s (ganga bridge)	Bihar	18.0	32.0	7.9	8.7	8.0	8.6	292	495	2.7	3.0	3000	9000	9000	24000
Ganga at Fatuha	Bihar	18.0	31.0	8.0	8.8	8.1	8.7	282	420	2.7	2.9	1400	5000	3000	16000
Ganga at Mokama (u/s)	Bihar	20.0	30.0	7.1	8.7	7.8	8.2	339	389	2.6	2.8	1100	5000	2200	16000
Ganga at Munger	Bihar	20.0	28.0	6.2	8.6	7.7	8.1	298	366	2.6	2.9	800	5000	2200	9000
Ganga at Sultanganj, Bhagalpur	Bihar	20.0	27.0	6.4	8.7	7.6	8.1	354	384	2.7	2.8	1300	3000	2200	5000
Ganga at Bhagalpur	Bihar	20.0	27.0	6.2	8.6	7.7	8.1	355	395	2.6	2.9	1300	9000	2200	90000
Ganga at Kahalgaon	Bihar	19.0	30.0	6.4	8.7	7.7	8.2	286	372	2.7	2.9	1100	9000	2800	24000

Ganga at Baharampore	WB	14.5	32.0	6.9	11.2	7.2	8.4	209	360	1.0	3.9	17000	240000	26000	300000
Tribeni burning ghat	WB	20.0	32.0	4.8	13.4	7.0	8.5	185	354	0.8	2.9	700	11000	900	14000
Ganga at Howrah-Shivpur	WB	19.0	32.0	4.8	12.8	7.5	8.2	194	370	2.4	8.2	33000	650000	34000	850000
Ganga at Diamond harbor	WB	18.0	32.0	5.4	8.5	7.5	8.5	261	10240	1.1	5.1	8000	80000	11000	110000

Source: (NMGC / CPCB Ganga Water Quality Assessment -2011)

4.8.3. Present study

The present study assesses the surface water quality of the Ganga River along the stretch of the NW-1.

4.7.4.1. Data collection& analysis

Surface water sample were collected from upstream and downstream of the proposed terminals/ lock locations and environmental sensitive receptors present all along t NW-1. One water sample were also collected from each of the existing Ro-Ro/Jetty/Floating terminals. Water samples were examined for physicochemical parameters as well as for bacteriological parameters. Samples were analyzed for various parameters using CPCB's BDU Criteria. Locations of water sampling are given at **Table 4.7** and shown in **Figure 4.3**. The analysis results of surface water are presented in **Table 4.8 to 4.10**.

Table 4.7 : Locations of Surface Water Sampling along NW-1

Sl. No.	Terminal Location	Surface water sampling Location	Location Code	Source
Proposed and Planned Terminals				
1.	Haldia Terminal, West Bengal	Hoogly River Upstream of Terminal Site and Green Belt Canal	SW-1	Hooghly River
		Hoogly River downstream of Terminal Site and Green Belt Canal	SW-2	Hooghly River
2.	Tribeni Terminal, West Bengal	Ganga River Upstream of proposed Tribeni Terminal Site	SW-3	Ganga River
		Ganga River downstream of proposed Tribeni Terminal Site near Shibpurghat	SW-4	Ganga River
3.	Farakka Lock, West Bengal	Ganga River Upstream of existing Farakka lock site	SW-5	Ganga River
		Ganga River downstream of existing Farakka lock site	SW-6	Ganga River
4.	Sahibganj Terminal,Jharkhand	Ganga River Upstream of Terminal site near Samda village	SW-7	Ganga River

		Ganga River Downstream of Terminal site near Samda village	SW-8	Ganga River
5.	Gazipur Terminal, Uttar Pradesh	Ganga River Upstream of proposed Terminal site at Ghazipur	SW-9	Ganga River
		Ganga River Downstream of proposed Terminal site at Ghazipur	SW-10	Ganga River
6.	Varanasi Terminal, Uttar Pradesh	Ganga River upstream of GurhaNala and proposed Terminal site	SW-11	Ganga River
		Ganga River downstream of GurhaNala and proposed Terminal site	SW-12	Ganga River
Existing Ro-Ro/Jetty/Floating Terminals along NW-1				
1.	West Bengal	Diamond Harbour	SW-13	Ganga River
2.	West Bengal	Howrah	SW-14	Ganga River
3.	West Bengal	Shantipur	SW-15	Ganga River
4.	West Bengal	Katwa	SW-16	Ganga River
5.	West Bengal	Hazardwari	SW-17	Ganga River
6.	West Bengal	Pakur	SW-18	Ganga River
7.	Jharkhand	Magalhal	SW-19	Ganga River
8.	Bihar	Buxar	SW-20	Ganga River
9.	Bihar	Munger	SW-21	Ganga River
10.	Bihar	Patna	SW-22	Ganga River
Sensitive Locations (Turtle, Vikramshila Dolphin and Hilsa Sanctuaries)				
1.	Near Sanctuary Areas	Three locations per Sanctuary areas	-	Ganga River

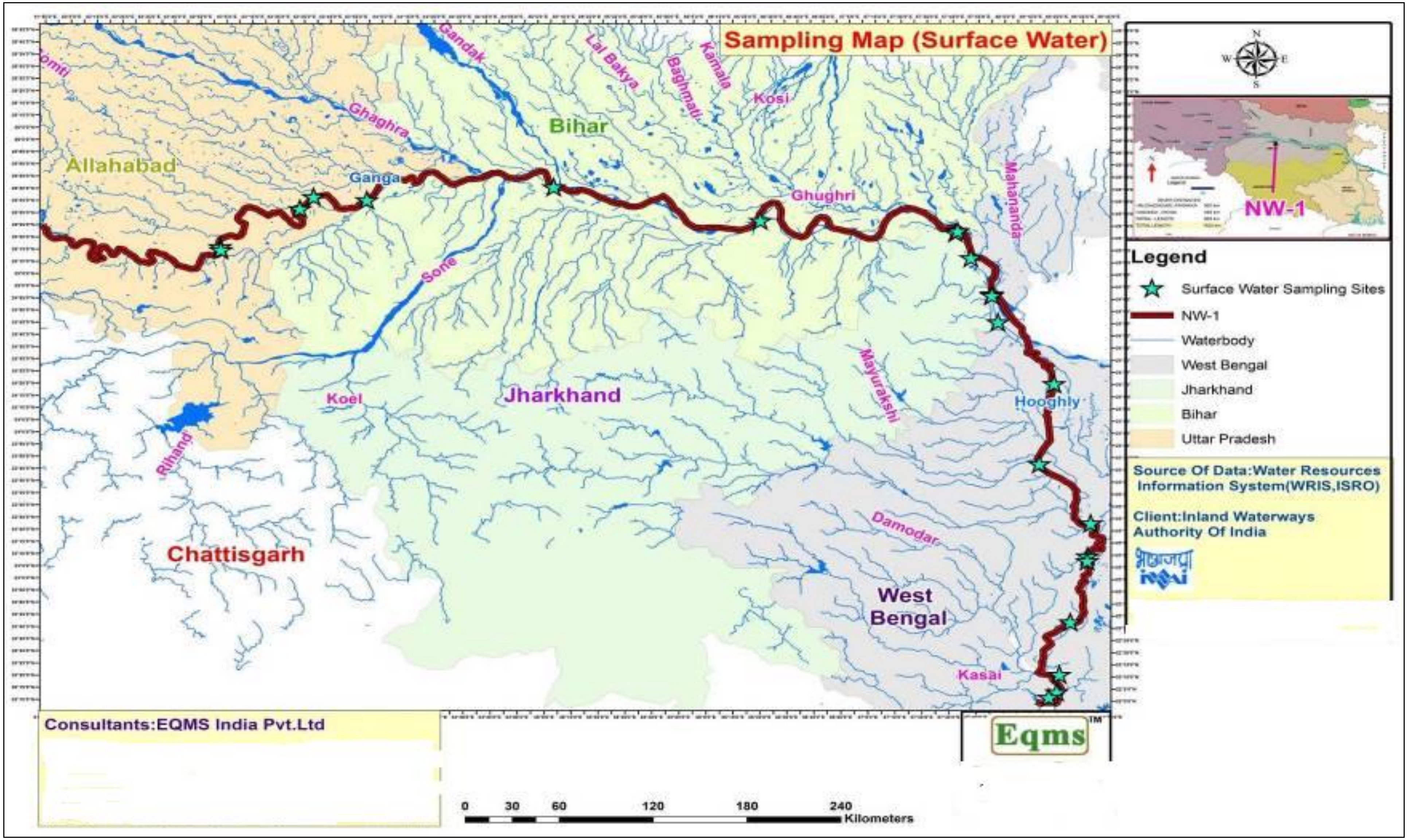


Figure 4.3 : Surface Water Sampling Locations

Among habitat quality parameters, eight physicochemical parameters (**Table – 4.1**) were estimated. Mean values of four observations were taken for all parameters at each station using "**Water and Soil Analysis kit – Model number 191**" mfd. by Electronics India. These assessments were carried out during morning / forenoon hours. Standard methodology was used to determine various parameters, as given by *APHA (2012),* wherever possible. pH, DO, conductivity, temperature (also separately using handheld mercury thermometer), turbidity and TDS were measured/estimated using this equipment. Transparency was estimated using **Secchi-disc method**, while river water velocity was estimated using **Float Method**. Fishes were identified with the help of *Gopal ji Srivastav's book (The Fish fauna of eastern Uttar Pradesh)* and *Day's Fish Fauna manual (of British India).* For river water temperature, normal manual thermometer was used at the depth of about 10-12 cm. At some certain places with depth about 30-35cm, temperature was also measured.

Table 4.8 : Ganga Water Quality NW-1 (near proposed and planned Terminal Site location)

		Haldia West Bengal		Tribeni West Bengal		Farakka, West Bengal		Sahibganj Jharkhand		Ghazipur Uttar Pradesh		Varanasi Uttar Pradesh	
Sl.No.	**Parameters**	**SW-1**	**SW-2**	**SW-3**	**SW-4**	**SW-5**	**SW-6**	**SW-7**	**SW-8**	**SW-9**	**SW-10**	**SW-11**	**SW-12**
1	pH	7.12	7.52	7.22	7.19	6.68	6.54	7.04	6.98	7.8	7.4	7.46	7.45
2	Temperature 0C	24.1	24.6	23.8	24.2	26.2	25.9	25.4	25.8	25.1	25.3	-	-
3	Conductivity, µmhos/cm	858	880	304	335	288	298	340	354	258	262	509	499
4	Turbidity (NTU)	2.1	3.2	3.1	2.5	1.8	1.9	1.6	1.5	1.2	1.8	-	-
5	Total Dissolved solids, mg/l	484	497	189	208	192	198	208	214	170	178	339	355
6	Total Suspended solids, mg/l	8	18	12	10	6	8	8	9	12	10	-	-
7	Dissolved Oxygen (mg/litre)	6.9	6.2	7.0	7.6	7.1	6.9	6.9	7.2	7.6	7.4	6.0	6.2
8	BOD, (for 3 days at 27^{0}C) (mg/litre)	4.1	2.6	3.6	3.9	2.2	2.3	2.4	2.1	4.8	4.3	7.43	6.85
9	COD, (mg/litre)	13.2	8.6	12.1	13.0	8.4	8.2	8.6	8.2	15.7	16.2	-	-
10	Total Hardness, mg/l	219	268	180	192	123	116	123	128	114	116	-	-
11	Oil & grease, mg/l	0.2	0.6	0.5	0.4	0.2	0.2	0.4	0.3	0.5	0.3	-	-
12	Chloride, mg. l	172	168	28	26	14	16	14	16	14		-	-
13	Nitrates as NO3, mg/l	1.9	2.4	0.86	0.88	0.16	0.14	0.21	0.20	0.30	0.28	-	-
14	Iron as Fe, mg/l	0.13	0.19	0.42	0.49	0.31	0.33	0.28	0.25	0.41	0.36	-	-
15	Zinc as Zn, mg/l	0.2	0.6	2.2	2.3	2.9	2.8	3.4	3.5	2.9	2.8	-	-
16	Calcium as Ca, mg/l	72	79	37	38	24	22	26	28	22	26	-	-
17	Magnesium as Mg, mg/l	18	19	21	24	15	14.4	14	13	14	12	-	-
18	Cadmium as Cd, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
19	Copper as Cu, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
20	Nickel as Ni, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
21	Lead as Pb, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
22	Mercury as Hg, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-
23	Total Chromium (Total as Cr), mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-
24	Arsenic as, mg/l	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-
25	Silica, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-
26	Fecal coliform MPN/100ml	3920	4370	5462	4370	3890	3940	3429	3390	8756	9472	12300	15400
27	Total coliform MPN/100ml	10234	11343	12300	11343	12324	12574	11489	11206	14520	16120	-	-
28	Pesticides (Present /Absence)	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	-	-

Source: Data sampling & Analysis by JV and NABL accredited Lab

Table 4.9 : Water Quality of Ganga river along NW-1 (near Existing Ro-Ro/Jetty/Floating Terminal sites)

		West Bengal						Jharkhand	Bihar		
Sl.No.	**Parameters**	**SW-13**	**SW-14**	**SW-15**	**SW-16**	**SW-17**	**SW-18**	**SW-19**	**SW-20**	**SW-21**	**SW-22**
1	pH	7.20	8.1	7.45	7.80	7.65	7.54	7.31	8.1	7.7	8.2
2	Temperature 0C	25.0	26.0	25	24.8	23.8	25.0	24.8	23.8	23.8	24.0
3	Conductivity, μmhos/cm	1230	320	315	405	345	319	327	305	318	290
4	Turbidity (NTU)	2.4	4.2	3.5	4.7	3.1	3.1	2.7	2.5	2.1	4.8
5	Total Dissolved solids	840	201	195	260	204	198	204	196	204	188
6	Total Suspended solids	14	6	5	11	9	11	9	8	10	13
7	Dissolved Oxygen (mg/litre)	5.8	6.5	7.6	6.5	7.2	7.8	7.1	7.8	6.7	8.1
8	BOD, (for 3 days at 27^0C) (mgl)	2.6	5.4	3.5	2.6	2.0	2.4	2.8	2.1	2.3	2.8
9	Chemical Oxygen Demand, (mg/l)	9.4	19	10.6	9.3	7.8	8.9	10	7	8.4	10.4
10	Total Hardness, mg/l	322	168	164	214	168	160	168	156	158	152
11	Oil & grease, mg/l	0.2	1.1	0.3	0.7	0.4	0.4	0.1	0.2	0.4	0.6
12	Chloride, mg. l	212	26	24	34	28	24	26	22	26	22
13	Nitrates as NO3, mg/l	1.6	2.45	2.68	1.87	1.90	2.91	1.68	1.28	1.14	1.10
14	Iron as Fe, mg/l	0.14	1.45	1.28	0.56	0.98	2.21	2.31	1.20	1.08	1.34
15	Zinc as Zn, mg/l	0.22	0.87	0.25	0.45	0.40	0.29	0.45	0.50	0.34	0.67
16	Calcium as Ca, mg/l	92	34	32	38	34	32	34	28	30	31
17	Magnesium as Mg, mg/l	22	20	20	29	20	19	20	21	20	18
18	Cadmium as Cd, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
19	Copper as Cu, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
20	Nickel as Ni, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
21	Lead as Pb, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
22	Mercury as Hg, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
23	Total Chromium (Total as Cr), mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
24	Arsenic as As, mg/l	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
25	Silica, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
26	Fecal coliform MPN/100ml	6120	18456	6450	8760	7890	4580	3890	2340	2460	3890
27	Total coliform MPN/100ml	11720	45680	12400	12988	11340	9890	8790	5430	5980	8790
28	Pesticides (Present /Absence)	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent

Source: Data sampling & Analysis by JV and NABL accredited Lab

Table 4.10 : Water Quality near sensitive locations along NW-1

		Hilsa Sanctuary Area			Dolphin Sanctuary			Kashi Turtle Sanctuary		
S.No.	**Parameters**	**Farakka Barrage**	**Near Diamond Harbour**	**Near Katua**	**Sultanganj Ghat**	**Near Vikramshila setu, Bhagalpur**	**Ganga ghat near Kahalgaon**	**Near Dashashwamegh Ghat**	**Near Tulsi Ghat**	**Near Assi Ghat**
1	pH	7.10	6.95	7.67	6.85	7.43	6.47	7.65	7.23	7.72
2	Temperature 0C	25.4	24.8	24.5	25.2	24.6	24.8	23.6	24.2	24.3
3	Conductivity, μmhos/cm	304	838	400	335	436	368	545	486	532
4	Turbidity (NTU)	2.1	3.0	3.8	1.2	3.8	1.8	6.7	7.2	8.0
5	Total Dissolved solids	200	465	254	208	275	222	368	328	352
6	Total Suspended solids	8	10	9	11	4	6	12	8	14
7	Dissolved Oxygen (mg/litre)	6.7	7.5	7.0	7.8	6.9	7.9	7.3	7.8	7.0
8	BOD, (for 3 days at 27^0C) (mg/l)	2.8	3.1	2.8	2.2	2.0	3.1	6.8	5.2	7.2
9	COD, (mg/l)	9.0	11.3	10.8	6.4	5.8	11.8	19.8	17.2	23.0
10	Total Hardness, mg/l	130	210	208	176	192	170	234	208	222
11	Oil & grease, mg/l	0.4	0.2	0.4	0.1	0.5	0.2	2.1	1.6	2.4
12	Chloride, mg. l	16	158	32	28	48	30	48	32	40
13	Nitrates as NO3, mg/l	0.23	2.3	1.98	0.89	3.82	0.88	0.89	0.67	1.10
14	Iron as Fe, mg/l	0.45	0.67	0.58	2.31	2.50	1.25	1.20	0.98	1.16
15	Zinc as Zn, mg/l	2.45	1.23	0.68	1.06	0.78	1.28	1.10	1.12	1.21
16	Calcium as Ca, mg/l	28	68	34	35	38	36	58	46	48
17	Magnesium as Mg, mg/l	15	10	30	22	24	19	22	23	25
18	Cadmium as Cd, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
19	Copper as Cu, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
20	Nickel as Ni, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
21	Lead as Pb, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
22	Mercury as Hg, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
23	Total Chromium (as Cr), mg/l	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
24	Arsenic as As, mg/l	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
25	Silica, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
26	Fecal coliform MPN/100ml	3100	4560	4560	2340	2200	2980	8670	5680	7988
27	Total coliform MPN/100ml	11876	13467	24356	10120	12340	12650	14790	13210	14218
28	Pesticides (Present /Absence)	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent

Source: Data sampling & Analysis by JV and NABL accredited Lab

4.8.4. Results of Surface Water Quality Assessment

The surface water quality assessment indicated that water quality in the studied stretch of the Ganga River meets with **BDU Class D** Criteria defined by CPCB, barring a few parameters, such as pH and DO which meets **A Class** criteria. Metallic and pesticide level is within prescribed limit of Drinking water standard. The results of this study are like the secondary data analyzed. The analysis concludes that the river water is good for propagation of wildlife and fisheries (refer **Table 4.11**).

Table 4.11 : Water Quality at different stations of Ganga River from Varanasi to Farakka in relation to fish catch.

Parameters Stations	Temp(^{0}C)	pH	Vel. (m/s)	Cond. (µmhos /cm)	TDS (mg/l)	Depth	Trans. (cm)	Turbidity (NTU)	D.O (mg/l)	No. of Fish sps. found
Varanasi	31.4	7.8	0.93	224.0	370.0	2.0	30.0	15.0	6.5	54
Ghazipur	31.9	8.2	0.89	232.0	320.0	1.6	26.0	30.0	6.1	35
Buxar	30.5	8.5	1.00	345.0	412.0	1.0	24.0	44.0	5.2	27
Patna	28.6	8.6	1.02	292.0	240.0	7.0	46.0	12.0	7.2	58
Bhagalpur	31.2	8.1	0.75	355.0	259.0	6.6	30.0	16.0	7.0	41
Khalagaon	30.1	8.2	0.89	286.0	210.0	10.7	32.0	10.0	7.0	42
Sahibganj	29.5	8.1	0.88	276.0	309.0	9.00	32.0	12.0	6.7	45
Farakka	29.0	8.4	1.05	310.0	205.0	10.6	36.0	8.0	7.1	62

The every parameter that has been analyzed in the intensive sites are describes as below.

Water Temperature (^{0}C)**:** Temperature is one of the most important parameters to determine water quality. Temperature changes the metabolic activities of all the organisms. All the organism especially poikilothermic (fishes) can survive only at specific temperatures. Dolphins are also sensitive to temperature, according to several studies dolphins can survive at 8.0-33^{0}C temperature. During our study, the lowest and highest average value of temperature of the Ganga River during the study period was recorded as 28.6^{0}C and 31.9 ^{0}C at Patna and Ghazipur (**Fig.-4.4**), respectively.

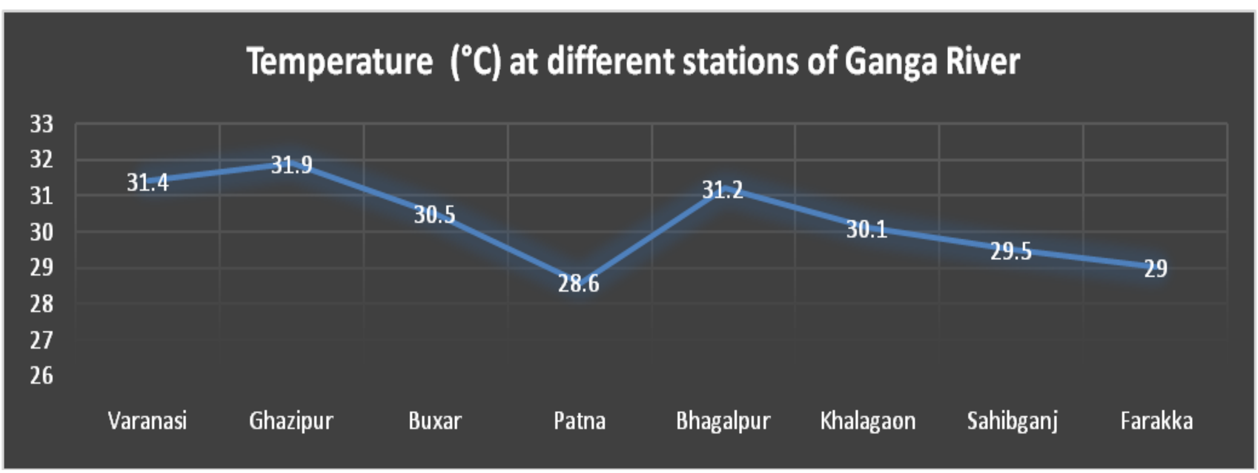


Figure 4.4 : Water Temperature at different sampling sites at NW-1

pH: pH measures the acidity or alkalinity of water. The pH of the Ganga river ranges from 7.8 to 8.6 (Table3.2). During the study, the lowest and highest average value of pH of the Ganga River was recorded as 7.8 and 8.6 at Varanasi and Patna, (**Fig. 4.5**) respectively.

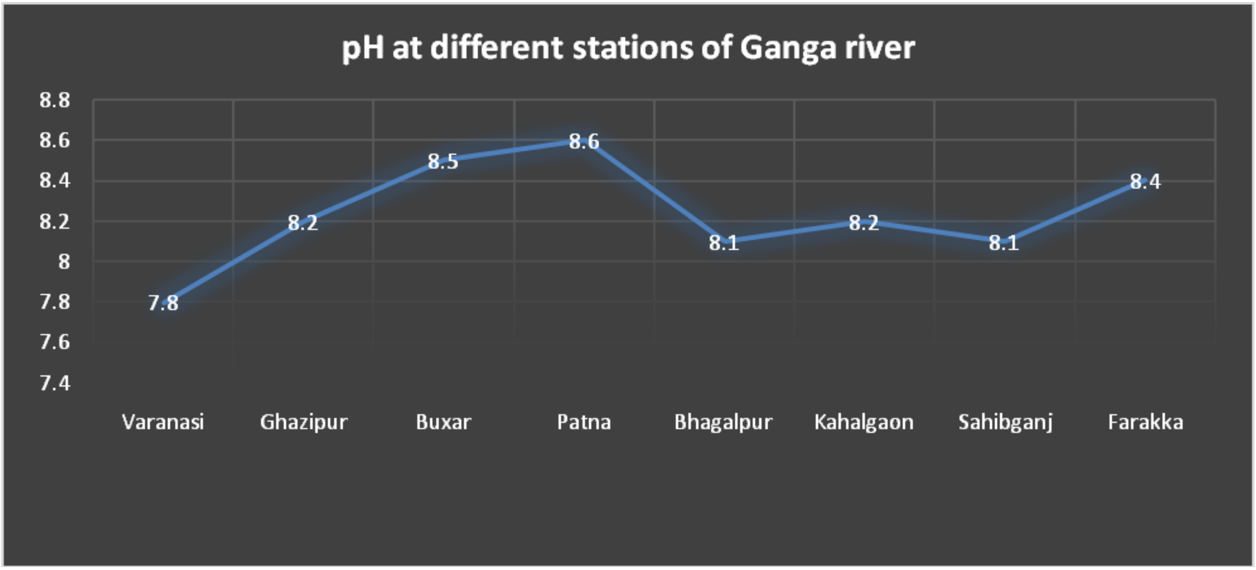


Figure 4.5 : pH value at different stations of Ganga River in NW-1

Velocity (m/s): The velocity of the Ganga River ranges from 0.75 m/s to 1.05 m/s. The lowest value (0.75 m/s) was recorded at Bhagalpur and the highest value (1.05 m/s) was recorded at Farakka station (**Fig. 4.6**). Velocity is generally higher at the mid-stream of the river, compared to banks. Subsequently, high populations of dolphins were found in the mid streams of the Ganga.

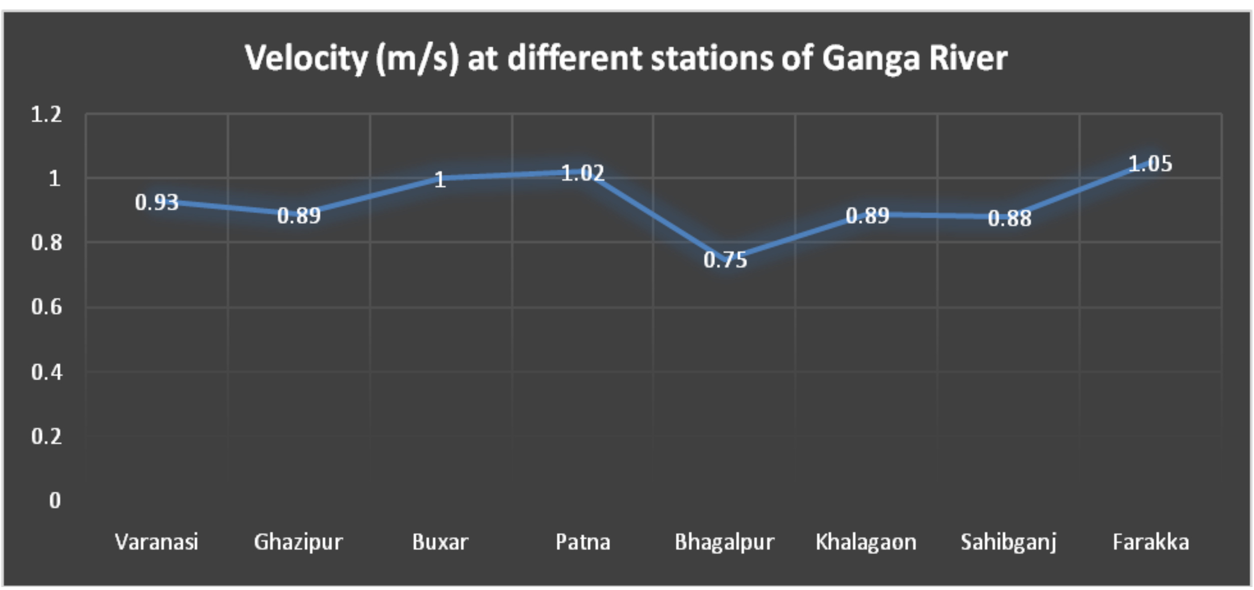


Figure 4.6 : Velocity at different stations of Ganga River in NW-1

Conductivity (µmhos/cm): Conductivity refers to speed of electric current in water. The conductivity of the Ganga ranged from 224.0 µmhos/cm to 355.0 µmhos/cm during the study period (**Table-3.2**).The minimum average value (224.0 µmhos/cm) of conductivity of the Ganga River was recorded at Varanasi and the maximum value (355.0 µmhos/cm) recorded at Bhagalpur (**Figure. 4.7**).

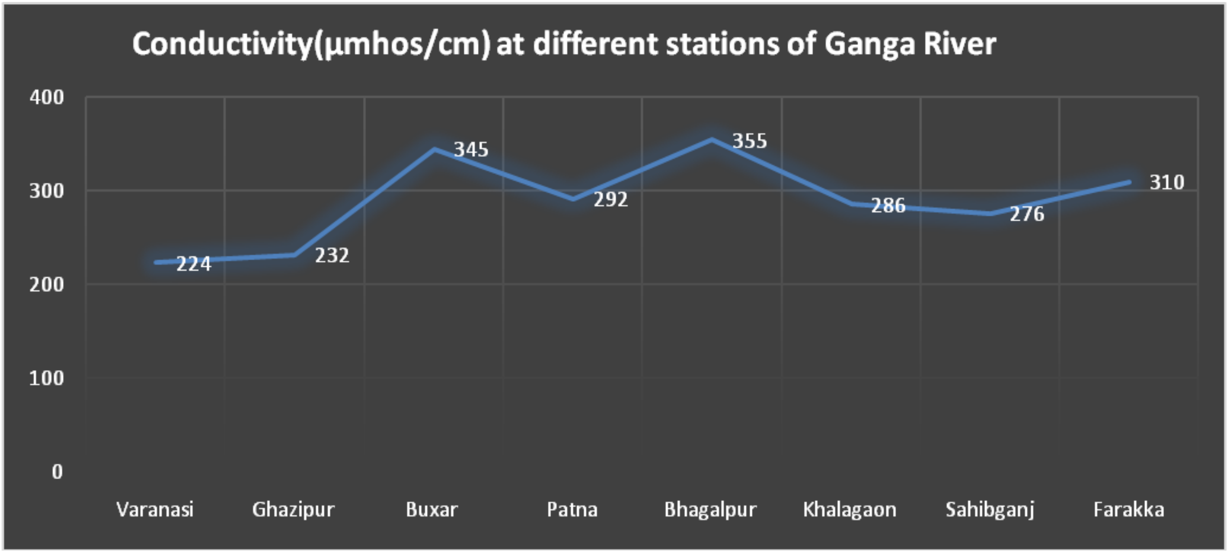


Figure 4.7 : Conductivity value at different stations of Ganga River in NW-1

TDS (mg/l): TDS (Total Dissolved Solids) is the amount of solid dissolved in water. TDS may include inorganic as well as organic compounds which provide a specific density to the water. It is mostly directly proportional to the rate and status of siltation in the river. The average value of TDS in the Ganga river water varied between 205.0 mg/l to 412.0 mg/l (**Table 3.11**). The minimum TDS value (205.0 mg/l) was observed in Farakka while maximum value (412.0 mg/l) was observed in Buxar (**Fig.4.8**). This may due to higher pollution level at Buxar as compared to other sites.

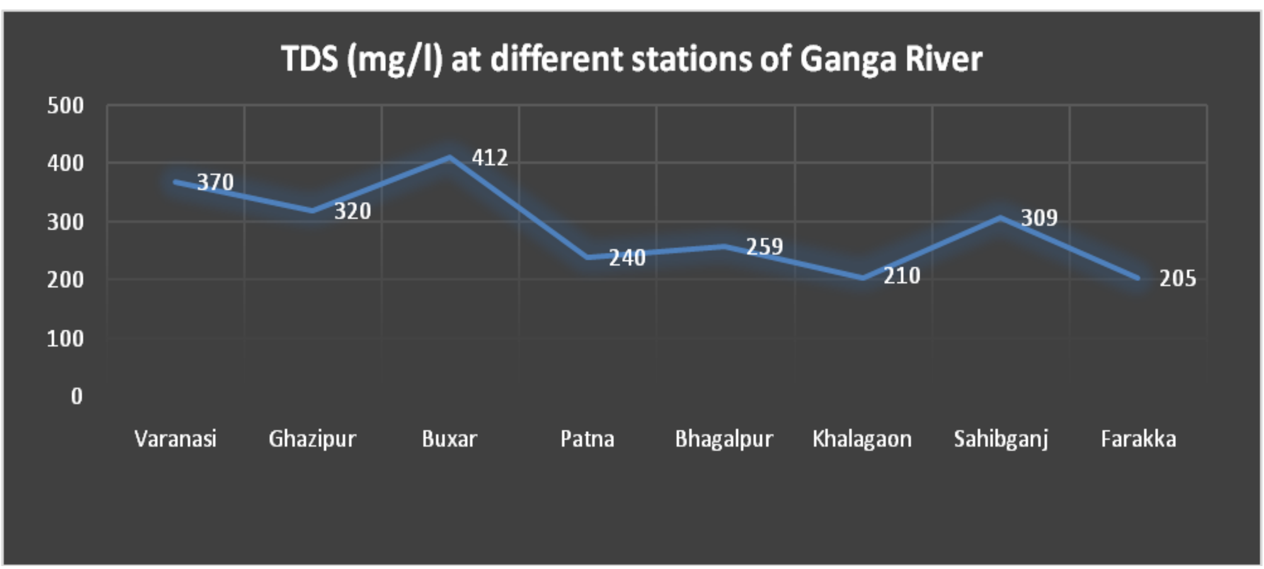


Figure 4.8 : TDS concentration at different stations of Ganga River in NW-1

Transparency (cm): Transparency shows how clear water is in any aquatic system. The highest and lowest average value of transparency of the Ganga River during the study period was recorded as 46 cm and 24 cm at Patna and Buxar respectively **(Fig.4.9)**. As mentioned earlier, Buxar has maximum pollution load which may be accounted for the low transparency at Buxar region as compared to other sites. It is also positively correlated with growth of phytoplankton and aquatic weeds in the aquatic ecosystem.

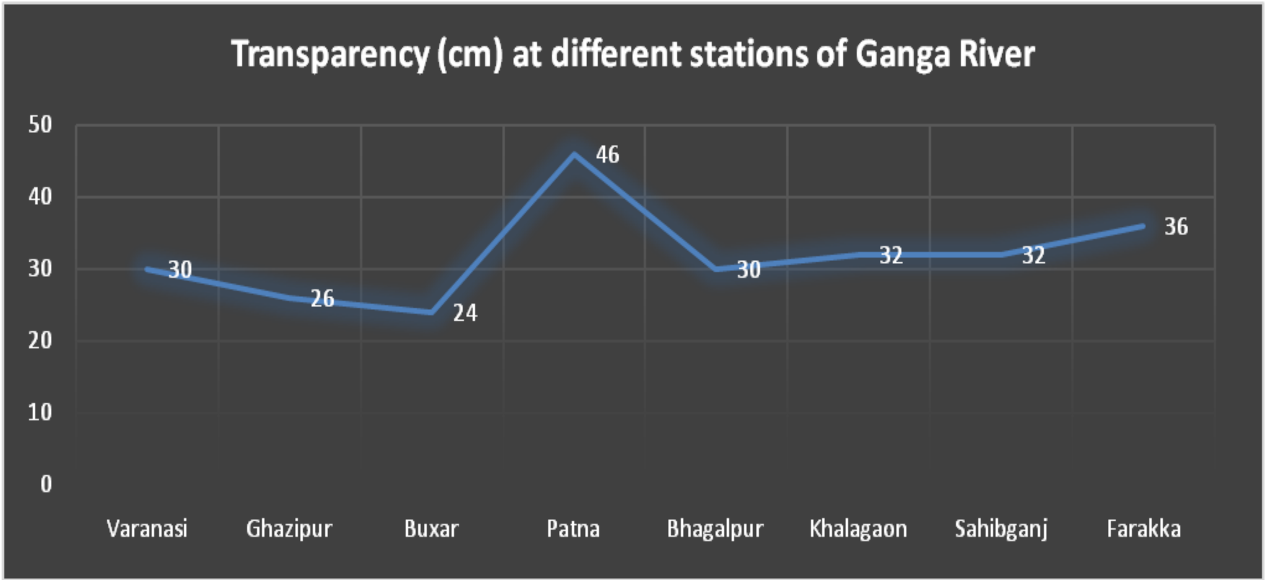


Figure 4.9 : pH value at different stations of Ganga River in NW-1

Dissolved Oxygen (mg/l): Dissolved oxygen (DO)is one of the most important parameters to determine water quality. All the aquatic organisms depend on DO for their survival. DO of the Ganga River ranged between 5.2 mg/l - 7.2 mg/l (**Table 3.11**). The lowest average value (5.2 mg/l) of DO was observed at Buxar (**Fig. 4.10**) while highest value (7.2 mg/l) was observed at Patna. Lowest value of DO at Buxar may be due to high pollutants, discharge of sewage and eutrophication. At Patna, high volume of water is added in Ganga River through the confluence with Gandak River.

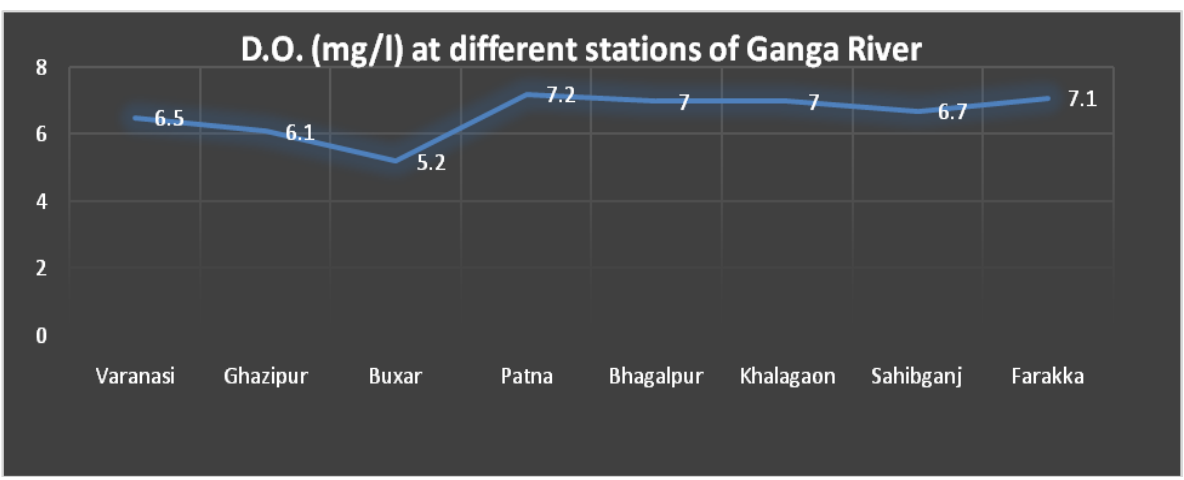


Figure 4.10 : D.O. concentration at different stations of Ganga River in NW-1

Depth (m): Depth of a river mainly depends on the type of the riverbed / strata and siltation in that part of the river. The depth of the Ganga River ranges between 1.0 m to 10.7 m. (**Table 3.11**). The lowest and highest average value of depth of the Ganga River during the study period was recorded as 1.0 m and 10.7 m at Buxar and Kahalgaon (**Fig. 4.11**) respectively. The Ganga at Buxar spans a wide area and has a low amount of water, which consequently leads to low depth in the area. After Buxar, several tributaries add up to the water flow in the Ganga and hence depth also increases which can be attributed for the increased depth at Kahalgaon.

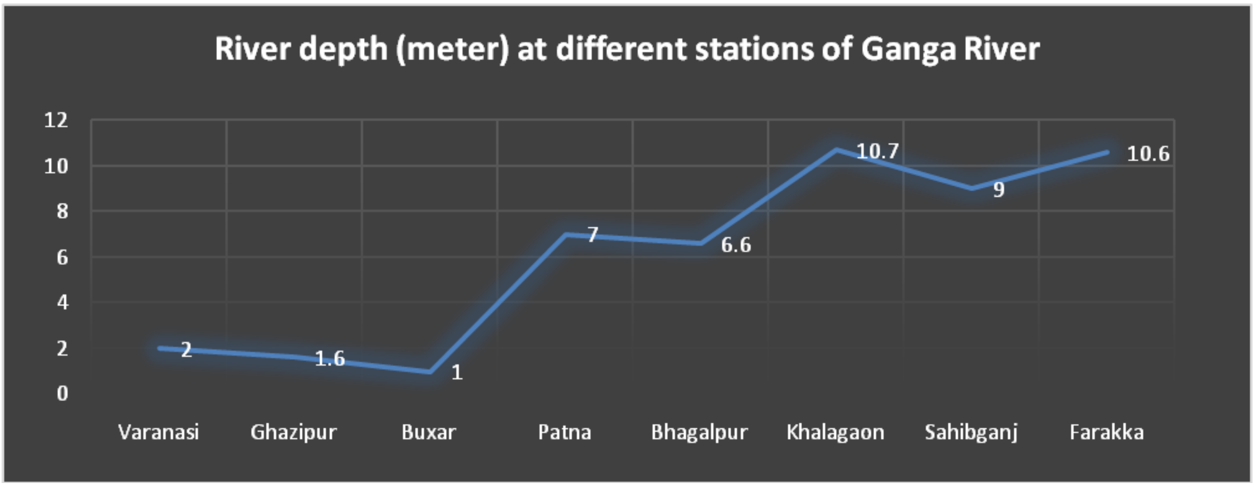


Figure 4.11 : River depth at different stations of Ganga River in NW-1

Turbidity (NTU): Turbidity is cloudiness and haziness of water in aquatic bodies. Turbidity is influenced by phytoplankton, total dissolved solids, total suspended solid and other organic matter in water. High turbidity is negatively correlated with transparency and DO. High turbidity also decreases the process of photosynthesis in aquatic ecosystem. The turbidity of the river ranged from 8.0 NTU -44.0 NTU (**Table 4.11**). The lowest value of turbidity (8.0NTU) in the studied stretch of the river was at Farakka and highest average value (44.0 NTU) was recorded at Buxar (**Fig. 4.12**) region. High turbidity at Buxar may be due to high numbers of sewer drains and contamination of water. About six sewer drains of the Buxar are directly falling in Ganga River in of 4 km stretch.

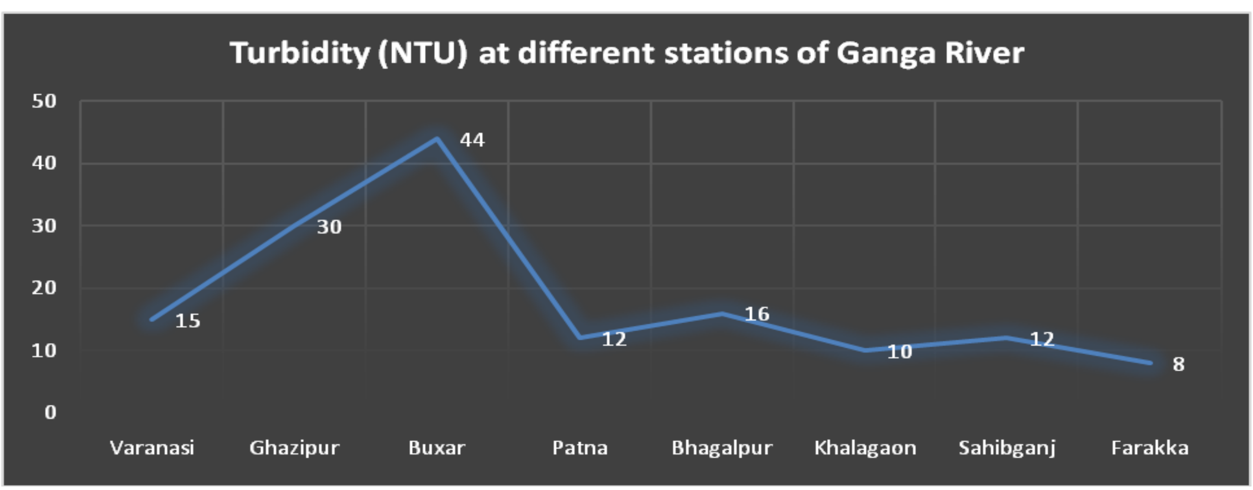


Figure 4.12 : Turbidity at different stations of Ganga River in NW-1

4.8.5. Water quality at random sampling sites for Water quality modelling

To assess the water quality in the pre-summer season and modeling dolphin distribution after the breeding season, 10 randomly selected locations were assessed in the upstream region of Farakka Barrage till Assi Ghat and 12 sites at downstream region of the Farakka barrage till Haldia. These locations were selected based on historical record of good dolphin siting.

In the upstream of the Farakka till Assi Ghat, it was observed that the pH remained in the alkaline range throughout the stretch may be due to surface runoffs from adjoining areas. The alluvium and occasional inflow of raw and treated sewage from rural and urban colonies along the river make the water alkaline. The TDS was on the higher range till Patna as the tributaries like Ghaghra, Son and Kosi put a lot of dissolved solids and suspended particles to the River Ganga. After Patna, the river becomes wide and deep, and without any major tributary, the TDS level declines. The DO is critical indicator of the water quality and DO at certain areas like Ghazipur, Dogriganj, Patna, Barh upto Bhagalpur in Bihar has low DO during daytime. This may be attributed to the biodegradation activities of the micro-organisms in the water.

Table 4.12 : Water Quality Assessment: Random assessment sites at dolphin locations: Varanasi to Farakka (March-April 2019)

S.N.	LOCATION	pH	TDS, mg/l	Temp. °C	DO, mg/l
1	Assi Ghat, Vanaras, U.P.	8.7	268	29.1	5.2
2	Ghazipur, U.P.	8.9	269	31.1	4.5
3	Balliya, U.P.	8.7	282	28.1	6.5
4	Dogriganj, U.P.	8.5	234	30.6	4.6
5	Patna (Gaighat), Bihar	8.3	201	31.9	3.1
6	Barh (Bihar)	8.6	188	30.9	4.3
7	Sultanganj (Agwanighat), Bihar	8.3	198	27.1	3.3
8	Kartik Nagar Choka (DPS School), Bhagalpur Bihar	8.3	174	31.1	3.4
9	BateshwarNathDhome (Bihar)/Kahalgaon/OriupChok)	8.1	184	30.6	2.2
10	Kali Mandir, Farakka W.B.	8.4	180	30.1	3

In the downstream of the Farakka till Haldia, it was observed that the pH remained in the neutral range throughout the stretch may be due to substantial tidal activity in the area. As there is no major tributary which input dissolved and suspended materials into the Hooghly branch, the TDS remained at the lower side. However, as the salinity increased significantly after Kolkata, the TDS increased. DO in this section of the river almost maintained a higher concentration and remained above 5 mg/l. This may be attributed to the tidal fluctuation and subsequent turbulence in the water.

Table 4.13 : Water Quality Assessment: Random assessment sites at dolphin locations: Farakka to Haldia (March-April 2019)

S.N.	Location Name	DO, mg/l	pH	TDS, mg/l
1	Hooghly - Ajay River confluence Point (Katwa)	7.5	7.48	175
2	Near MeteriGhat	7.8	7.60	175
3	-	6.9	7.66	174

4	Near Jalahati	7.0	7.74	173
5	Satgachhi	8.0	7.50	175
6	Near Raninagar	7.3	7.65	175
7	Bandel	6.8	7.68	174
8	Chandannagar	7.5	7.73	176
9	Panihati Ferry Ghat	6.2	7.85	176
10	Golabarighat (Howrah)	6.5	7.82	177
11	Falta	7.1	7.34	1390
12	Haldia	6.8	7.44	1960

4.8.6. Water quality modelling

Through kriging method the water quality parameters like pH, TDS and DO were modelled for the entire NW-1 stretch of the River Ganga. This information was further analysed during dolphin distribution according to the Habitat parameters. The Kriging maps of the pH, TDS and DO are presented in the **Fig. 4.13, 4.14 and 4.15,** respectively.

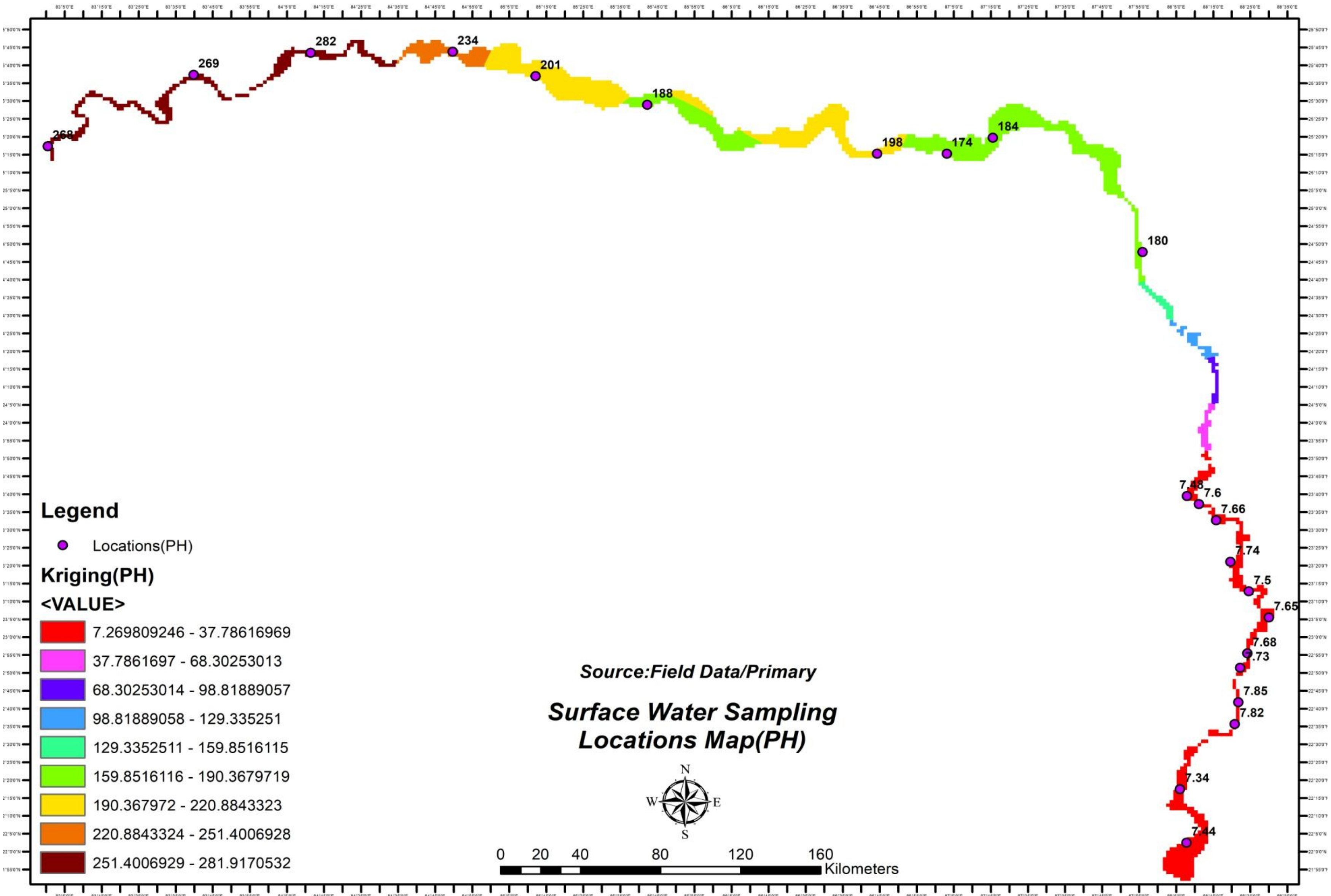


Figure 4.13 : Kriging interpolation of pH range in the NW-1

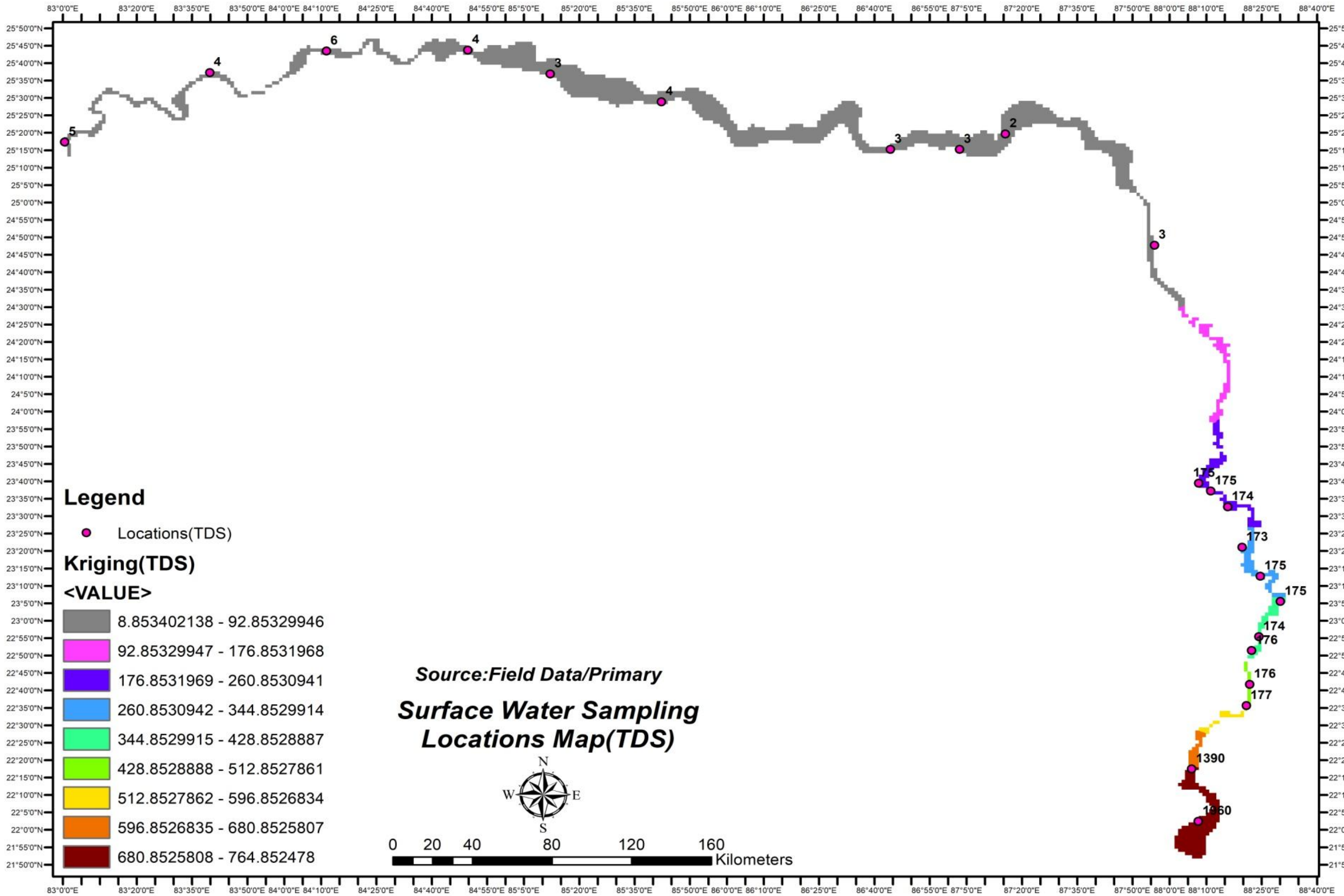


Figure 4.14 : Kriging interpolation of TDS range in the NW-1

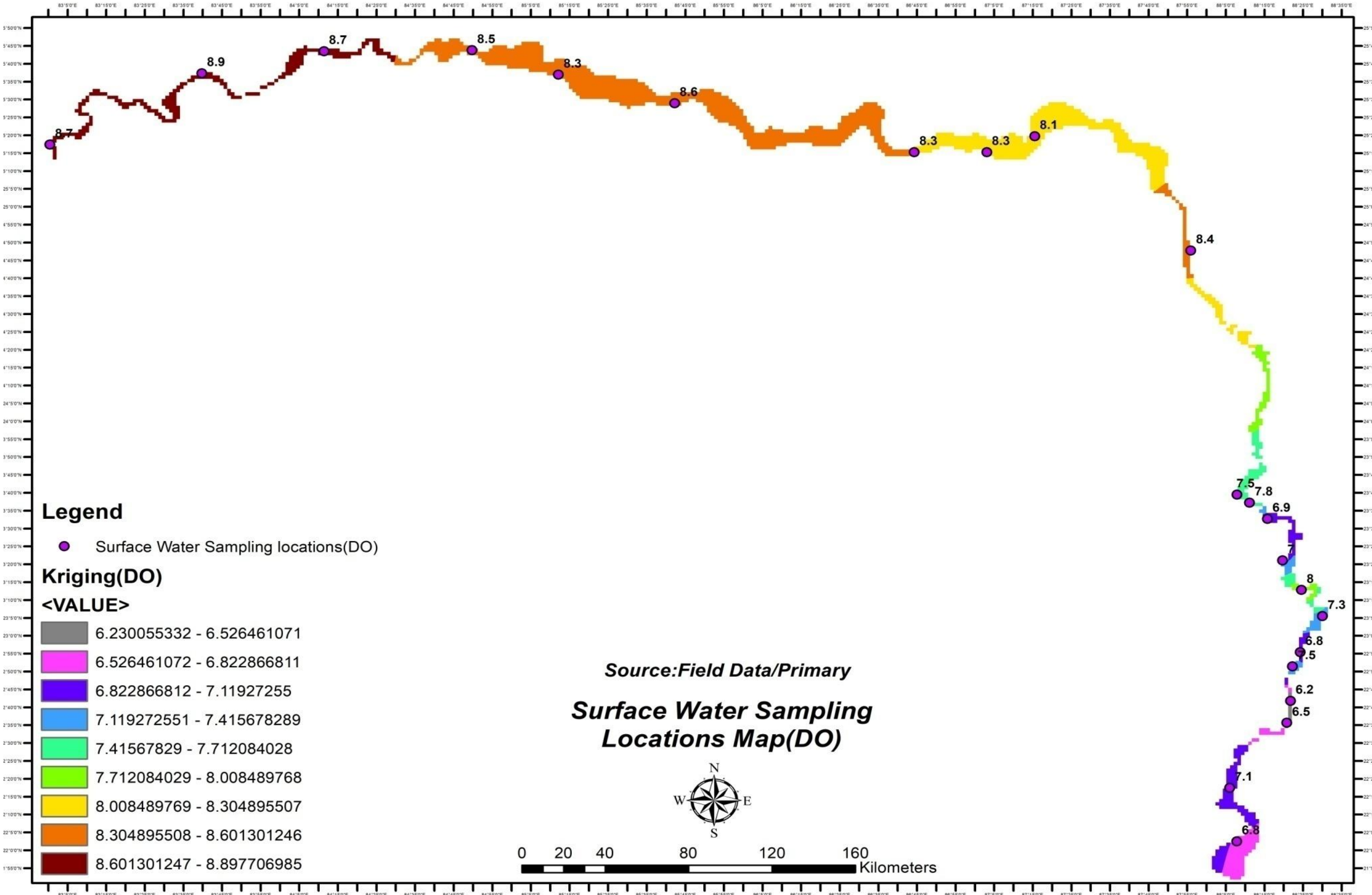


Figure 4.15 : Kriging interpolation of DO range in the NW-1

4.8.7. River Water Quality at dredging locations

IWAI undertakes dredging to maintain the LAD for effective navigation. To analyse the effect of dredging activity on water quality water samples in upstream and downstream of the river at different distance from the operating dredger were collected during the study period. During the study period, dredging was in operation only in the Farakka navigational lock channel. The details of sampling locations and analysis results are presented in Table 4.14**.** Photographs of dredging operation is provided at **Plate 4.3.**

Plate 4.3 Photographs of Dredging

Table 4.14 : Ganga Water Quality NW-1 (U/S and D/S of the Dredger

Sl. No.	Parameters	Location: 90^{O} of Farakka Navigational channel near existing Lock at Farakka Upstream of the Dredger			Location: 90^{O} of Farakka Navigational channel near existing Lock at Farakka (Downstream of the Dredger)			
		200 m u/s of Dredger	300 m u/s of Dredger	500 m u/s of Dredger	200 m d/s of Dredger	500 m d/s of Dredger	700 m d/s of Dredger	1000 m d/s of Dredger
1	pH	6.75	6.72	6.66	6.58	6.6	6.75	6.82
2	Temperature ^{0}C	25.4	25.6	26.0	25.2	25.3	25.5	26
3	Conductivity, µmhos/cm	292	288	294	298	295	305	293
4	Turbidity (NTU)	4.5	4.3	4.0	10.9	7.7	4.4	4.4
5	Total Dissolved	194	189	196	200	197	206	195

	solids							
6	Total Suspended solids	10	9	8.8	19	15	9.5	9.0
7	Dissolved Oxygen (mg/litre)	7.4	7.1	7.2	7.5	6.9	7.0	6.5
8	BOD, (for 3 days at 27^0C) (mg/litre)	2.3	2.4	2.2	2.5	3.0	2.3	3.1
9	Chemical Oxygen Demand, (mg/litre)	8.6	8.8	8.3	9.0	9.2	8.5	9.2
10	Total Hardness, mg/l	126	130	128	122	125	129	124
11	Oil & grease, mg/l	0.2	0.2	0.2	0.3	0.3	0.2	0.1
12	Chloride, mg. l	14	12	14	16	14	14	16
13	Nitrates as NO_3, mg/l	0.17	0.17	0.15	0.20	0.18	0.16	0.16
14	Iron as Fe, mg/l	0.49	0.50	0.48	0.98	0.69	0.50	0.49
15	Zinc as Zn, mg/l	2.64	2.45	2.57	2.82	2.72	2.52	2.59
16	Calcium as Ca, mg/l	26	27	24	23	25	25	23
17	Magnesium as Mg, mg/l	14.8	15.2	16.5	15.7	15.2	16.0	16.0
18	Cadmium as Cd, mg/l	0.04	<0.01	<0.01	0.08	0.02	<0.01	<0.01
19	Copper as Cu, mg/l	0.06	<0.01	<0.01	0.05	0.02	0.01	<0.01
20	Nickel as Ni, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
21	Lead as Pb, mg/l	0.08	<0.01	<0.01	0.10	0.09	0.03	<0.01
22	Mercury as Hg, mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
23	Total Chromium (Total as Cr), mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
24	Arsenic as As, mg/l	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
25	Silica, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
26	Fecal coliform MPN/100ml	3780	3680	3700	3840	3790	3800	4210
27	Total coliform MPN/100ml	12180	11890	11970	12340	12120	12250	12880
28	Pesticides (Present /Absence)	Absent	Absent	Absent	Absent	Absent	Absent	Absent

Source: Data sampling & Analysis by JV and NABL accredited Lab

4.8.6.1. Observations on Surface Water Quality during dredging operation

The river water quality observations reflect that the parameters like turbidity and total suspended solids increases in downstream of the dredging location up to 700 m, which gradually gets normalized at a distance of 1000 m from the dredging location. In upstream side of the river, however, no major changes were observed for these parameters. However, heavy metals like iron, copper, cadmium and lead were also detected in traces in water sample close to the dredging location in the downstream locations. No variation was observed in other water quality parameter.

4.8.6.2. River Sediment Analysis

For mapping the river bed sediment quality, about 110 river bed sediment samples were collected (average 3 samples per location up to the depth of 3m) across the NW-1 and analysed for various parameters/contaminants. (**Figure 4.16**). The summary of the test results of river bed sediment sample with USA standard[2] at different stretches of the NW-1 are graphically presented in **Figure 4.17 to Figure 4.24**.

[2] USA Standards prescribed for benthic sediment which were developed to reduce and ultimately eliminate adverse effects on biological resources and significant threats to human health from surface sediment contamination.

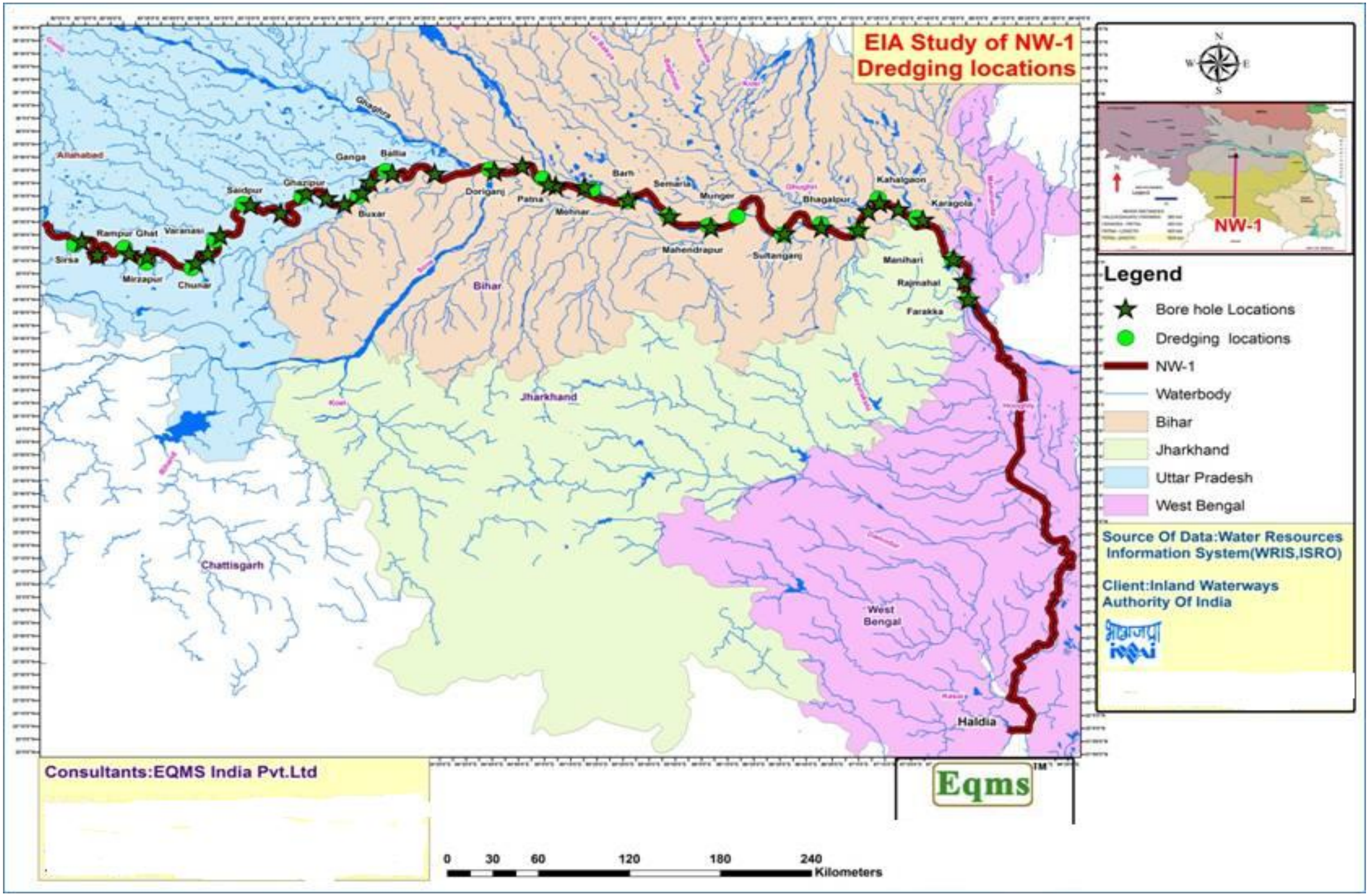
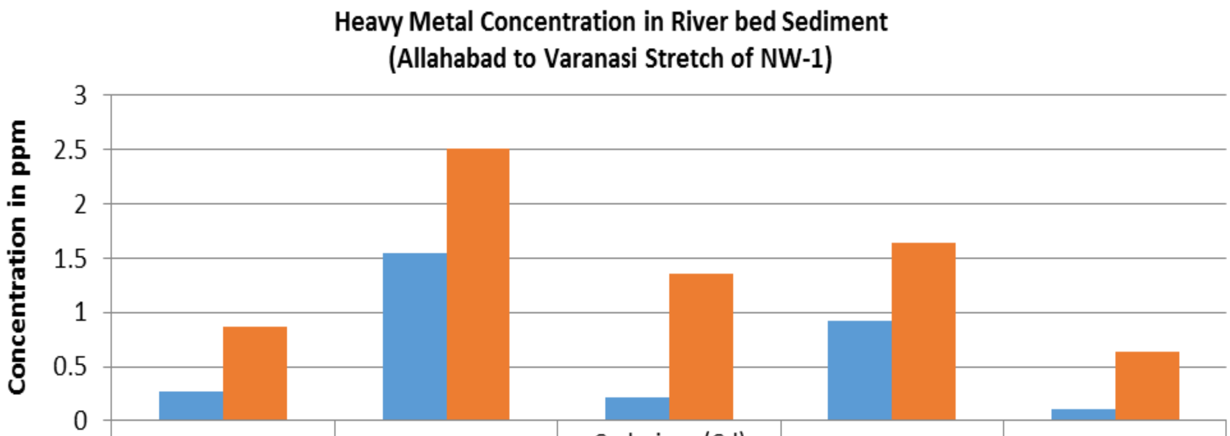
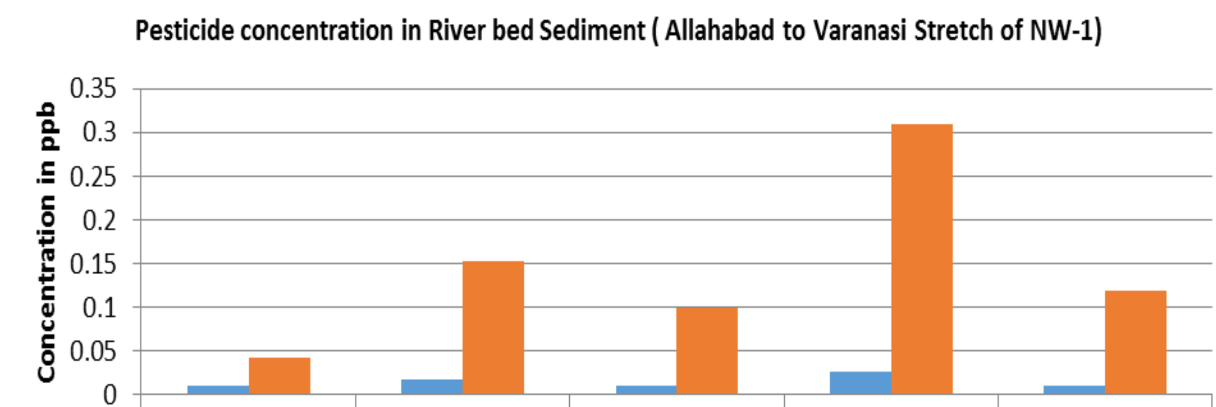


Figure 4.16 : Dredging and Bore hole locations along NW-1



	Lead (Pb), (USA Standard 33 ppm)	Iron (Fe)	Cadmium (Cd) (USA Standard 0.7 ppm)	Zinc (Zn) (USA Standard 105 ppm)	Copper (Cu) (USA Standard 68 ppm)
Min	0.27	1.54	0.22	0.92	0.11
Max	0.87	2.51	1.36	1.64	0.64

Figure 4.17 : River Bed Sediment Analysis for Heavy metals between Allahabad to Varanasi



	α Endosulphan (USA standard 5 ppb)	β Endosulphan (USA standard 5 ppb)	γ Endosulphan(USA standard 5 ppb)	Methyl Parathion,(USA standard 5 ppb)	Lindane,(USA standard 5 ppb)
Min	0.01	0.017	0.01	0.026	0.01
Max	0.041	0.152	0.099	0.31	0.118

Figure 4.18 : River Bed Sediment Analysis for pesticides between Allahabad to Varanasi

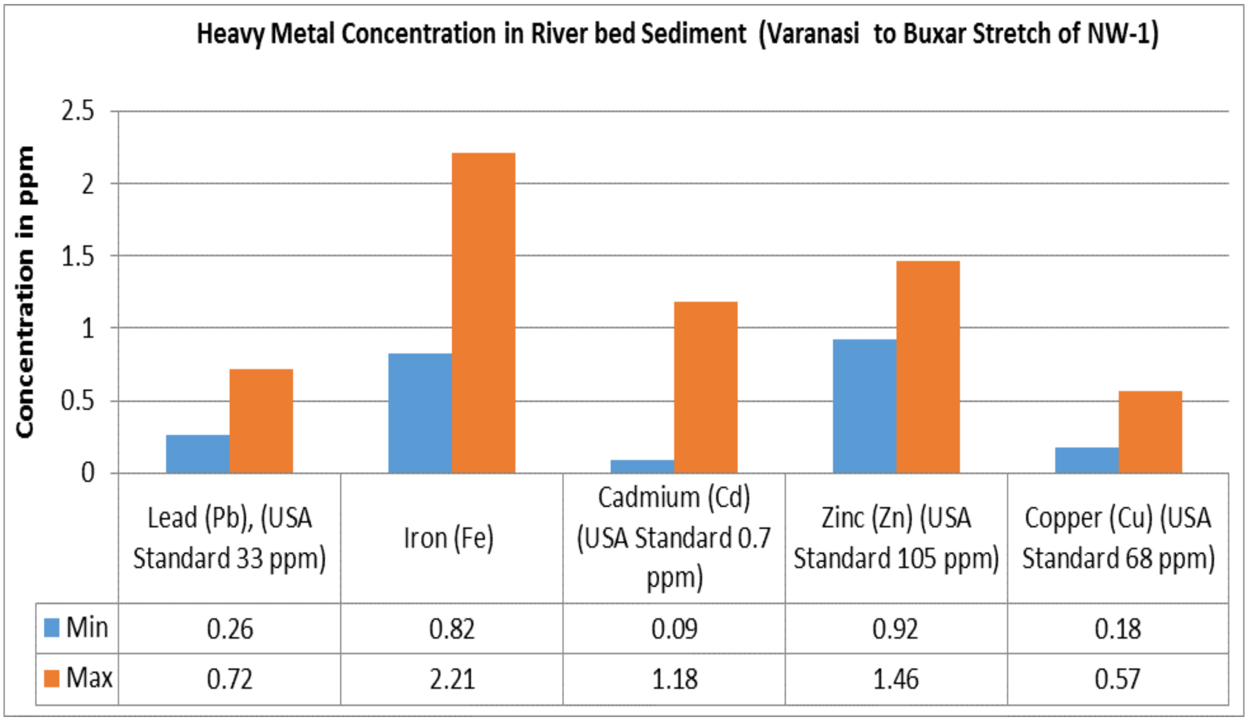


Figure 4.19 : River Bed Sediment Analysis for Heavy metals between Varanasi to Buxar

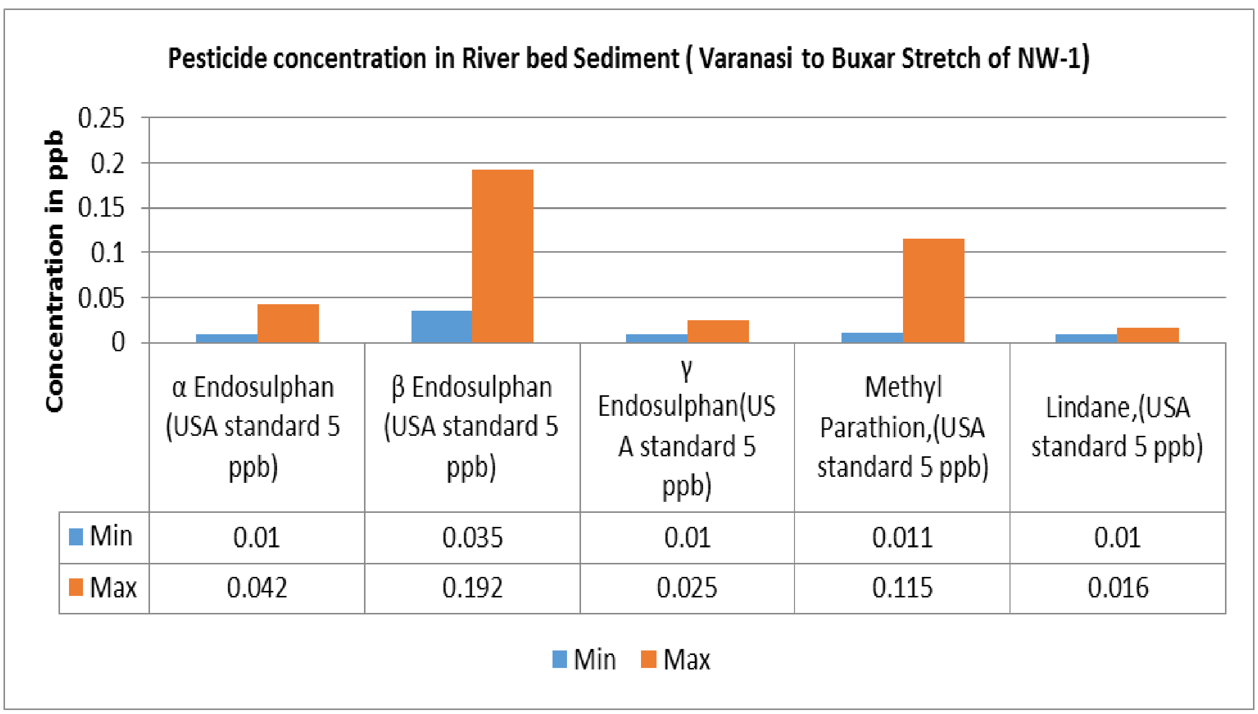


Figure 4.20 : River Bed Sediment Analysis for pesticides between Varanasi to Buxar

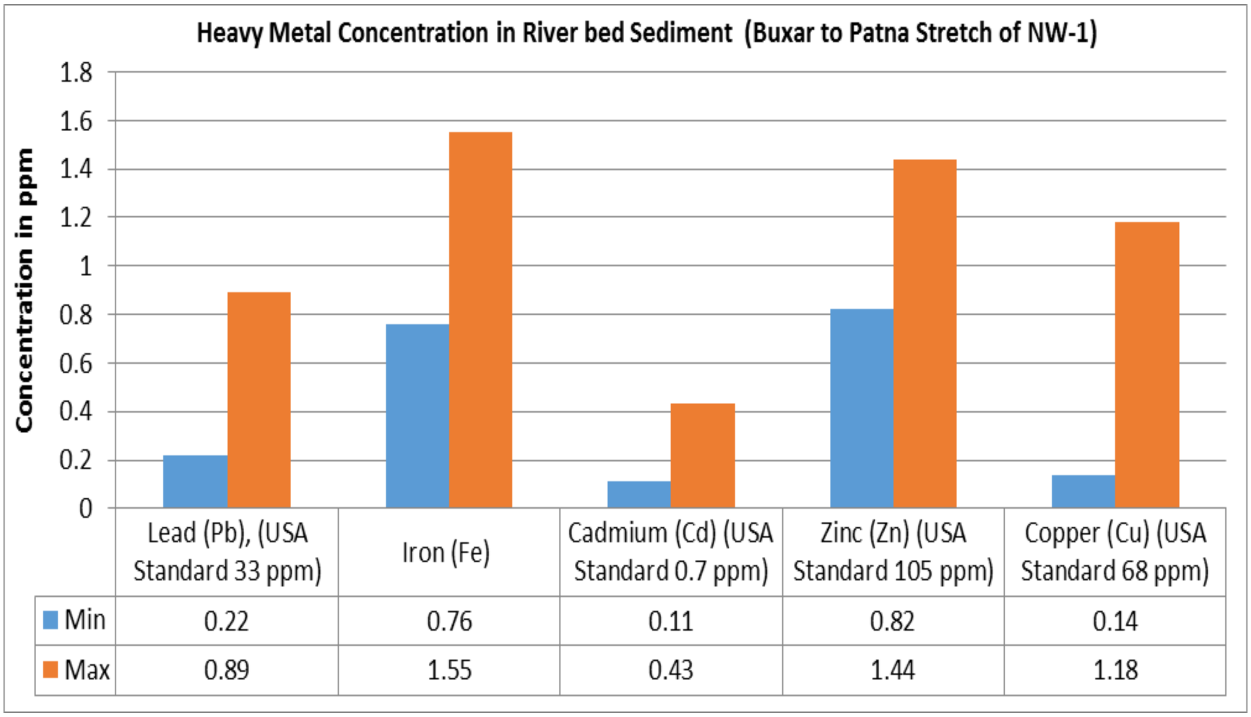


Figure 4.21 : River Bed Sediment Analysis for Heavy metals between Buxar to Patna

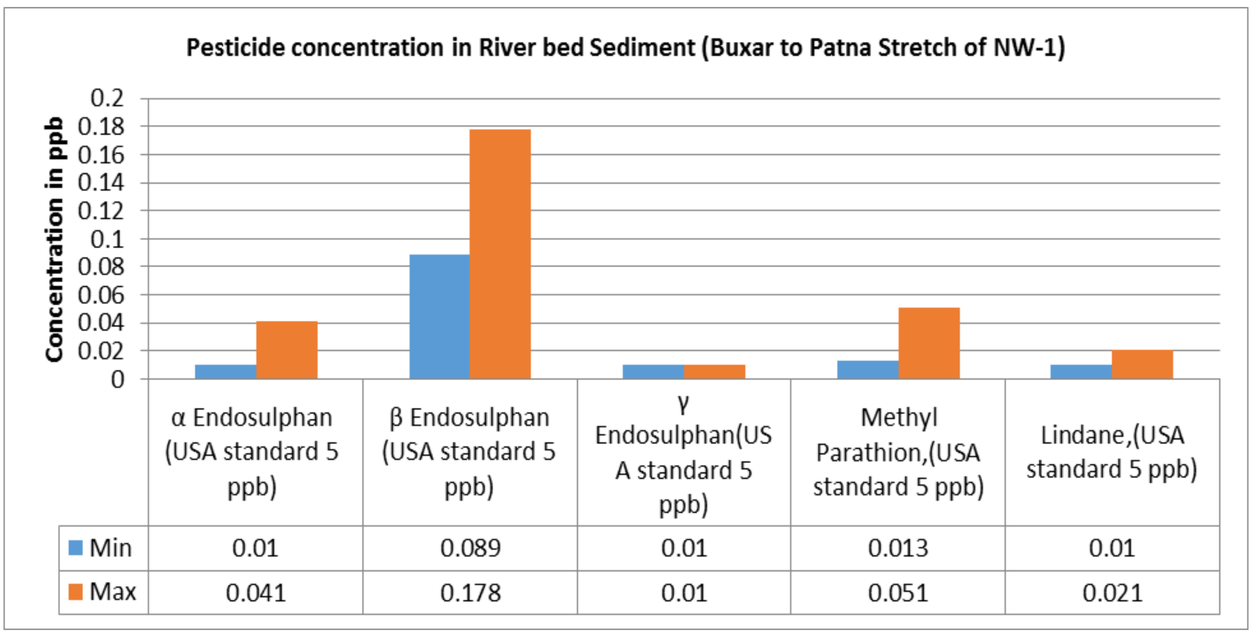


Figure 4.22 : River Bed Sediment Analysis for pesticides between Buxar to Patna

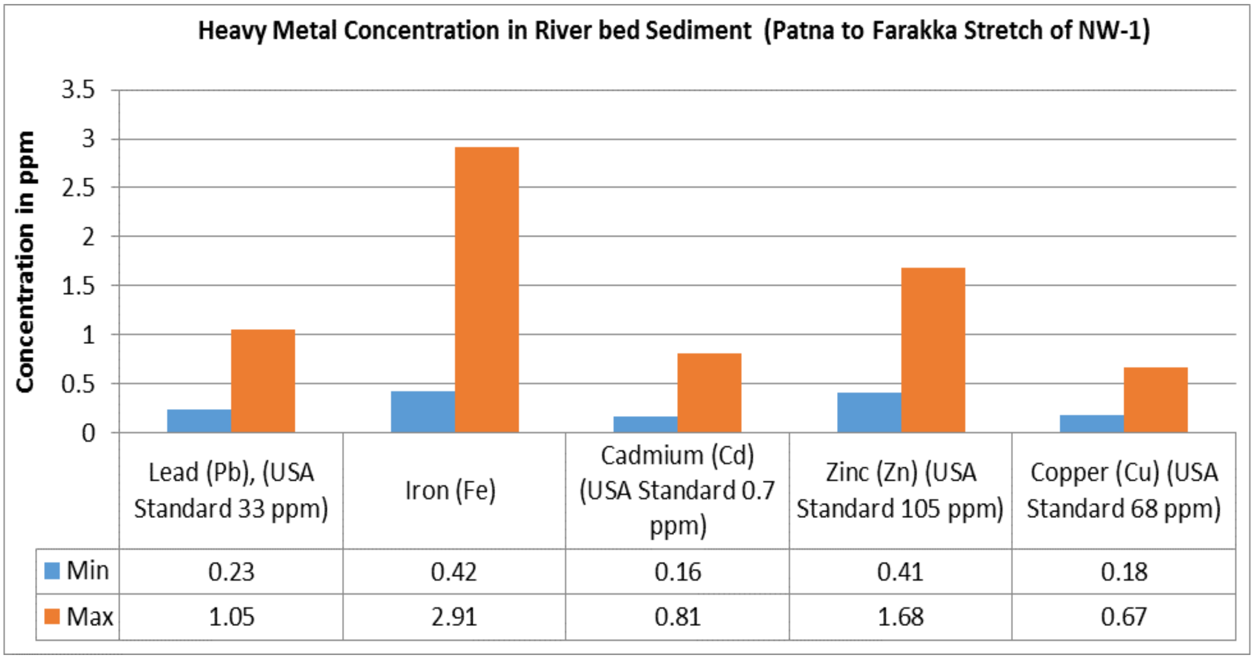


Figure 4.23 : River Bed Sediment Analysis for Heavy metals between Patna to Farakka

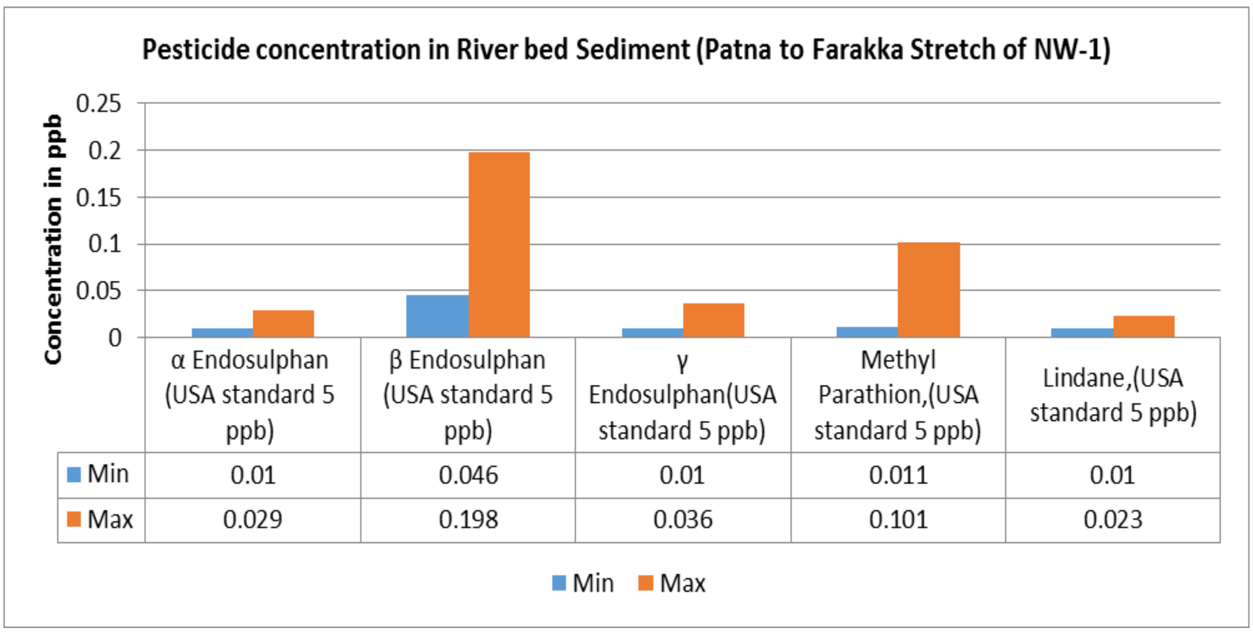


Figure 4.24 : River Bed Sediment Analysis between Patna to Farakka

Among the study sites, Patna station covering a stretch of about 8.0 km of the Ganga River showed good water quality and also highest number of dolphins. Besides, anthropogenic influence was comparatively lesser in this part of river, only next to Kahalgaon area. The Buxar station showed high levels of pollution, with highest TDS and turbidity, with low DO and transparency. This is well reflected in the state of eutrophication of the river in this part. Anthropogenic pressure was high with maximum number of city sewer drains falling in a stretch of about 4 km, besides dozens of human corpses and animal carcasses floats in the water in different stages of decomposition. With regards to siltation, Varanasi, Buxar, Ghazipur, Sahibganj, Farakka showed high volume of siltation spread through the length and breadth of the river. These areas around respective cities would require special attention for de-siltation.

4.9. Depth and water current in volume

The river depth and the water current in volume was procured from secondary sources. It was observed that the water flow increased drastically after the confluence of Ghaghra, Sone and Kosi rivers (**Table 4.15**). According to details of water sharing with Bangladesh, the Farakka barrage releases 50% water to the Feeder Canal which then flows through the Hooghly river, the major distributary of the Ganga.

Table 4.15 : The depth and water current in volume at different intensive and random sampling location

Location	Water depth (m)	Water Volume (cumec)
IS1	7.00	132.00
IS2	10.00	132.00
IS3	4.40	154.00
IS4	6.20	154.00
IS5	4.65	135.00
IS6	10.00	900.00
RS1	7.50	2466.00
RS2	6.50	1018.00
RS3	9.00	1206.00
IS7	6.04	2406.00
RS4	9.50	1818.00
IS8	6.40	1239.00
RS5	10.00	1156.00
RS6	8.60	1142.00
RS7	6.60	1140.00
RS8	7.20	1145.00
RS9	10.00	1145.00
RS10	20.00	1142.00
RS11	8.90	1134.00
RS12	17.00	1133.00

4.9.2. Depth and flow modelling

The information of randomly selected locations were interpolated to entire study stretches of the NW-1 through Kriging method. The spatial regression model analysis aided in study of detailed depth and flow profile of the NW-1 and thereby helped in identifying the good habitat condition that prevail at certain areas (**Fig. 4.25 and 4.26**).

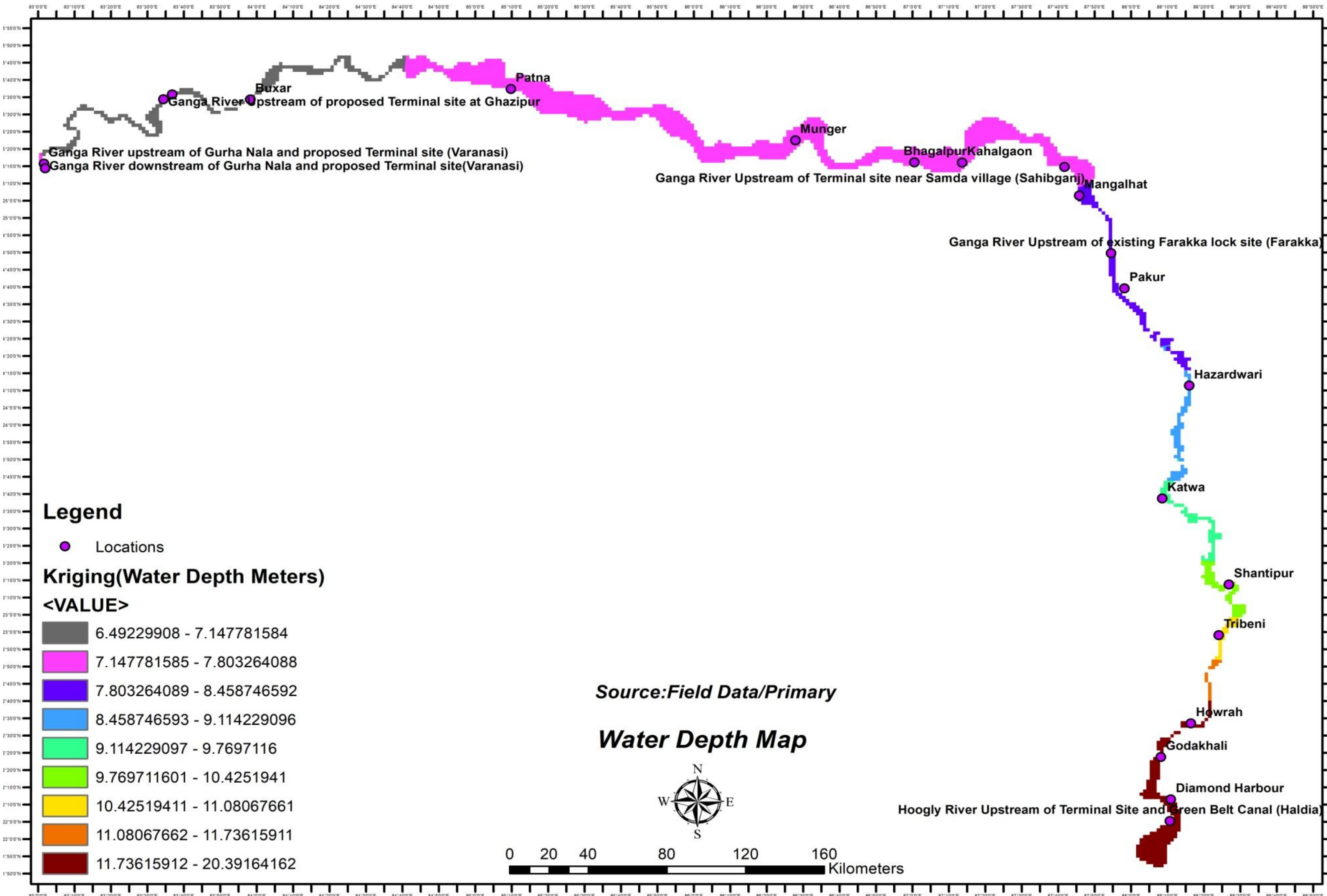


Figure 4.25 : Kriging interpolation of the depth of the NW-1

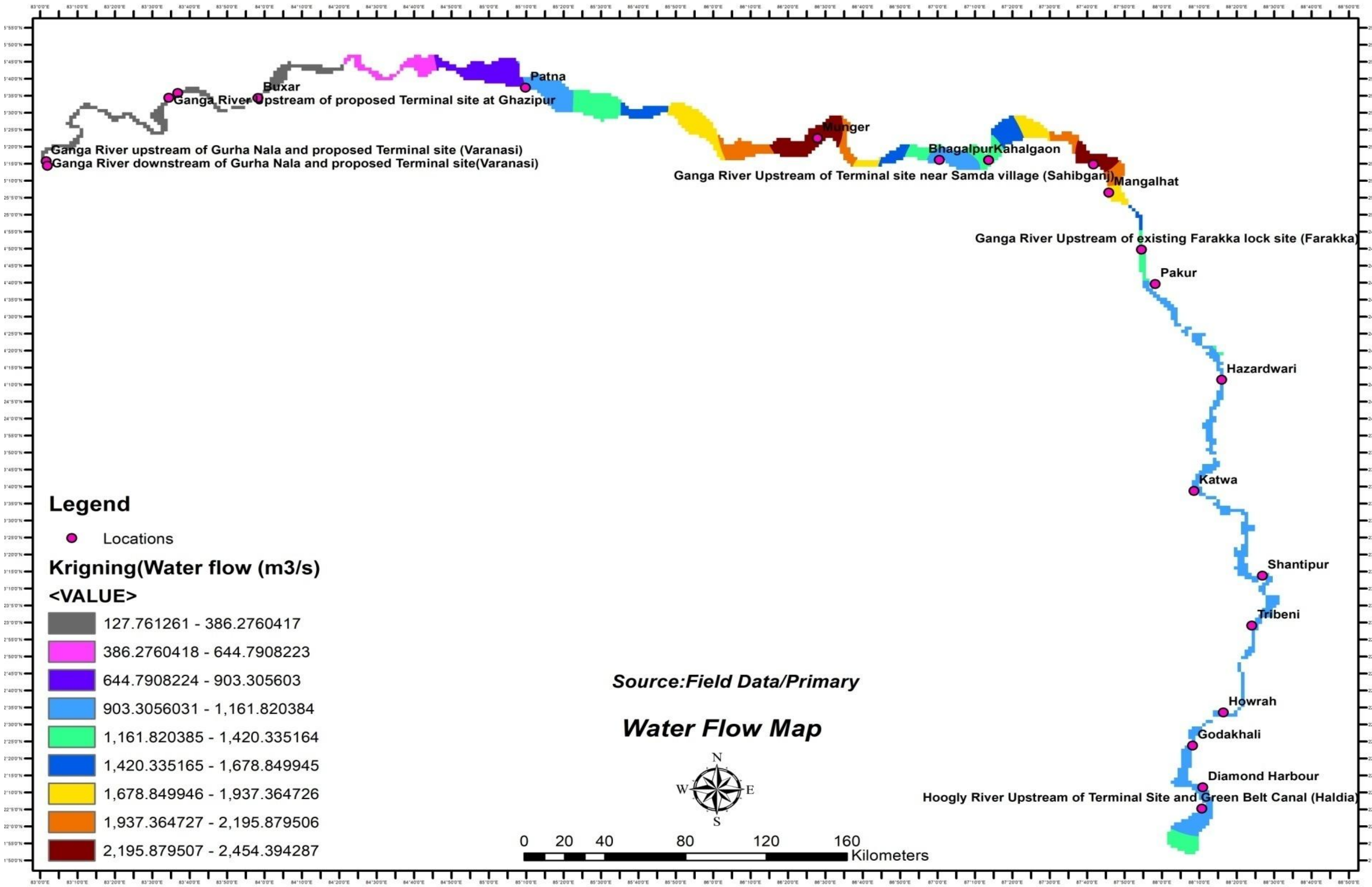


Figure 4.26 : Kriging interpolation of the water current (volume) of the NW-1

4.10. Influence of physicochemical parameters and fish abundance on dolphins sighting encounter

The water quality data sets on dissolved oxygen (DO),biological oxygen demand(BOD), Chloride, Temperature (Temp), Magnesium (Mg), Depth, Flow, Hardness, Total dissolved solids(TDS), Alkalinity and pH along with fish abundance and dolphin sightings were analyzed at studied sites *i.g.*, Varanasi, Bauxar, Patna, Bhagalpur, Farakka, Tribeni and Godakhali for 2018 were used for the model development and analysis. Diamond Harbour site has not been included in the model due to highly estuarine zone and treated as outlier. The water quality data was used from **NMCG Project** and dolphin sights encounter data were used from the report WII-NMCG (2018), Biodiversity profile of the Ganga River: Planning aquatic species restoration for Ganga River, Wildlife Institute of India, Dehradun.

The correlation between fish richness, phytoplankton and zooplankton abundance at different sampling sites were observed using correlation analysis. The variations in water quality parameters at different sampling sites of the river stretch were evaluated. Analysis indicated that the correlation between fish richness with zooplankton has been found to be significantly positive (0.69, $p<0.05$) and insignificantly with phytoplankton (0.33, $p>0.05$).

The influence of river water quality and fish abundance on dolphin sights were analyzed by the **combined statistical analysis approach** e.g.., Factor Analysis based on Principal Component Analysis (PFA[3]) and Generalized Linear Modeling.

The data reduction techniques e.g.., PFA was used for the variation study in the physicochemical parameters of waters in the river and found that four factors such as Factor 1, Factor 2, Factor 3 and Factor 4 altogether explained 93% variation in the data sets. Where, Factor 1 is dominated by positively correlation with DO, BOD, Chloride, Factor 2 is dominated by positively correlation with magnesium and depth, Factor 3 is dominated by positively correlation with flow and hardness while factor 4 is dominated by positively correlation with TDS of water (**Table 4.16**).

The Generalized Linear Modeling (GLM)[4] approach showed that all the four factors (Factor 1, Factor 2, factor 3 and Factor 4) and fish abundance having no significant effects on the dolphins' sights encounter in the river stretch. However, factor 1 (DO, BOD & Chloride) and factor 2 (Depth, Mg, Flow) and fish

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[3] Here DO and BOD are not moving separately as the coefficients of DO(0.83) and BOD(0.78) associated positively correlated with factor 1 (table 4.16) and figure 4.27 showing the variation in these both parameters is large compared to other parameters. Simultaneously temperature coefficient (-1.05) showed that temperature and DO has inverse relationship and temperature varies in large amount during the river stretch.

[4] When we have a number of water quality parameters, then it becomes difficult to find the cause and effect relationship for the response variable (here presence of number of Dolphin) directly using GLM approach due to multicollinearity of the variables that provide poor parameters estimate. Hence it becomes necessary to find the uncorrelated factors/variables first to remove the multicollinearity then further these variables/factors is used for the estimate the cause and effect relationship through Generalized Linear Modelling (GLM) approach. PFA is commonly used for identification of uncorrelated factors/variables. Hence, GLM approach cannot be performed separately. So, here joint application of PFA and GLM was presented.

abundance showing positive correlation with the dolphin sights encounter. These two factors (factor 1 and factor 2) showed in figure above. Besides this factor 3 (hardness of water and flow) and factor 4 (TDS) showed negative correlation in the model. The model can be represented as

*Dolphin =2.65E-01*Intercept+1.47E-01 Factor 1+ 3.71E-01 Factor 2 --9.00E-01*Factor 3--1.10E-01*Factor 4 + 3.31E-07 *Fish abundance*

The R^2value for the given model is 90% showing the good fitting of the model.

Table 4.16 : Correlation of physicochemical parameters of water quality of the river Ganga on the four factors analysed by Principal Factor analysis

Physicochemical parameters of water	Factor1	Factor2	Factor3	Factor4
DO	**0.83**	-0.24	-0.09	0.05
BOD	**0.78**	-0.17	-0.04	-0.21
Chloride	**0.70**	0.02	0.06	-0.09
Temp	-1.05	-0.22	0.00	-0.09
Mg	0.16	**0.97**	0.05	0.19
Depth	-0.27	**0.89**	-0.14	-0.17
Flow	-0.03	-0.19	**1.03**	0.13
Hardness	-0.05	0.23	**0.83**	-0.22
TDS	0.01	0.19	0.09	**0.96**
Alk	-0.09	-0.18	-0.11	0.88
pH	0.12	-0.06	0.21	-0.13

Table 4.17 : Estimates of model parameters (factor1, factor2, factor3, factor4) and fish abundance on dolphin sighting encounter at sampling sites in the river Ganga using GLM approach for the period 2018.

Parameters	Estimate	t value	Pr(>|t|)
(Intercept)	2.65E-01	0.628	0.643
Factor1	1.47E-01	0.324	0.801
Factor2	3.71E-01	1.387	0.398
Factor3	-9.00E-01	-1.189	0.445
Factor4	-1.10E-01	-0.588	0.662
Fish abundance	3.31E-07	1.128	0.462

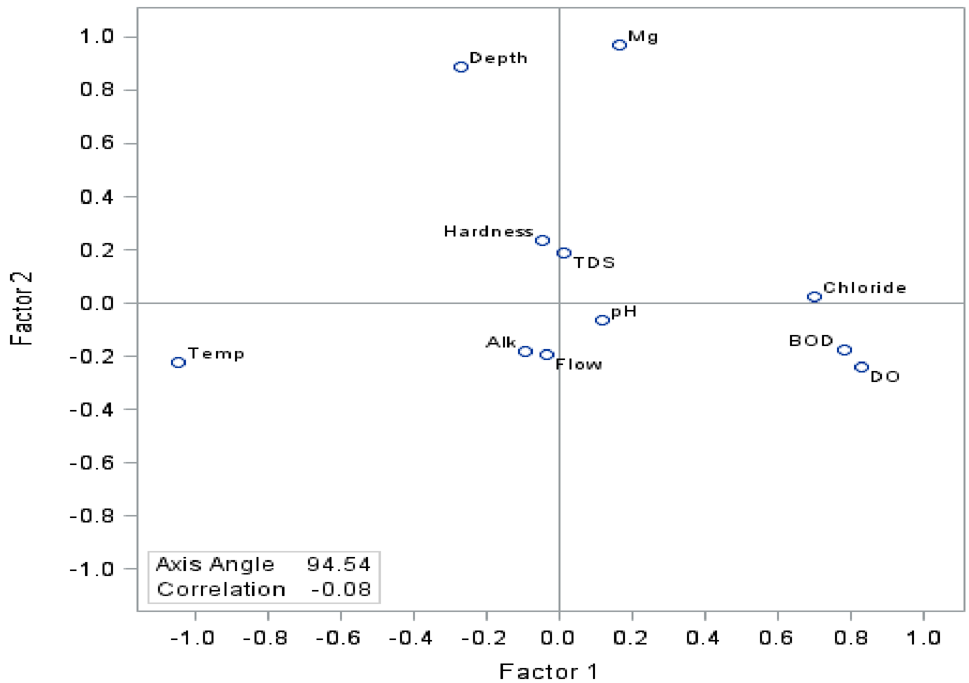

Figure 4.27 : PFA analysis showed, Factor 1 positively correlated with DO, BOD & Chloride and Factor 2 positively correlated with Depth and Mg in the river stretch, Ganga.

4.11 Conclusion

Fish is a major food for dolphins and records from intensive study sites showed that the fish is abundant in the region. However, absence of long-term fish catch data, it is difficult to assess the change in the fish population. The physicochemical water quality of the Ganga in the studied points show B to C class according to designated bast use. The BOD is on a higher side due to sewage drains. Dredging has a short-term effect as increase in turbidity, TDS, TSS and metals like Cadmium and lead. The increase in TDS and turbidity might affect the fish, but the effect will be temporary. However, increase in heavy metal concentration might pose risk to another organism. Although, long term study is needed to conclude the effect of heavy metals on fish or dolphin. It was also found that flow and depth are principle component that determine presence of Dolphins. Apart from that, DO, BOD, TDS are also major factors that determine Dolphin distribution. It was also observed that, polluted areas are generally avoided by the Dolphins on account of shallowness, higher turbidity, low oxygen contents, higher BOD, foul smell and higher temperature.

CHAPTER 5. VESSEL MOVEMENT, UNDERWATER NOISE AND EFFECT ON GANGES DOLPHINS

5.1. Dolphin Source Level and Spectrum and underwater noise measurement threshold

The mean reported peak-to-peak source level SLpp of Ganges river dolphins (*Platanista gangetica gangetica*) is 183.3 dB re 1μPa at 1m while the rms source level SLrms is 173.3 dB re 1μPa at 1m [1]. The click centre frequency is approximately 65 kHz, with mean -3dB bandwidth and mean -10dB bandwidth of approximately 44 kHz and 73 kHz respectively. Based on these, the frequency band from 50 kHz to 60 kHz contains the **Dolphin Click Spectrum**, and is, therefore, chosen for measurements of the vessel noise and ambient noise. The underwater sound level measurements for ambient and vessel generated noise are reported as rms values in dB re 1μPa which would allow comparison with Dolphin Sonar SLrms mean value of 173.3 dB.

5.2. Recording Methodology and Instruments used

The sensor and electronics for recording the vessel noise were mounted on small boats different field locations. The underwater acoustic sound pressure was recognized by hydrophone, that converts acoustic energy into electric signal. The electric signal was then amplified in a pre-amplifier and acquired by the data acquisition system (DAQ) controlled by a Laptop and finally recorded and stored in the hard disk for analysis. The monitoring boat was nominally kept 50 m away from the channel. The vessel under investigation for underwater sound was typically made to traverse a maximum of 5 km upstream and 5 km downstream in the channel. A video and photographic record of the measurement process had also been maintained.

The following instruments were used for the field measurements:

a) NI CDAQ 9134 and 9223 Data Acquisition System
b) Benthowave 7001 hydrophone (typical sensitivity -198.5 dB re 1V/μPa)
c) Pre-amplifier box (typical gain 60 dB @50 kHz)
d) 1 TB external hard disk for recording the underwater sound data
e) GPS module using Arduino mega (Ublox neo-6M GPS module)
f) Laser Range Finder (Bushnell Elite 1M 202421)

The sample rate used for recording the sound data is 1 MHz.

The analysis of underwater sound was carried out on sound segments of 1 second duration. The signals vector kept under analysis be *R(t).* In the analysis of underwater noise, first the variation of pre-amplifier gain with frequency and hydrophone sensitivity were then removed to obtain the actual sound level in the water. The gains of the pre-amplifier was denoted by *G(k).* To compensate the effect of the pre-amplifier, the signal *R(t)* after conversion into the frequency domain was multiplied by 1/*G(k)* over the frequency band of interest. The hydrophone response was also compensated by the sensitivity value of -198.5 dB re 1μPa. The underwater signal in frequency domain was denoted by *R(k),* where *k* represents the frequency bins. The effect of hydrophone sensitivity and pre-amplifier gain was removed using the equation (1).

$$S(k) = 10^{\left(198.5/20\right)} R(k)\left(\frac{1}{G(k)}\right) \text{ .... } (1)$$

Here, *S(k)* represents the compensated acoustic pressure signal in the frequency domain at the location of the hydrophone. Next, the rms underwater sound levels were calculated from *S(k)* using equation (2) over full frequency band of interest and presented as root mean square (rms) values in dB re 1µPa.

$$E_{rms} = 10\log_{10}\left(\sum\left(\left|S(k)\right|\right)^2\right) \text{ dB .... } (2)$$

Where E_{rms} represents the rms value of energy in 1 second (rms sound level) over the frequency band. To calculate the rms sound level in the different frequency bands, the equation (2) was used by considering only those values of k which correspond to the frequency bins of interest. rms sound values were computed in the following bands:

a) Full band 100Hz - 100kHz
b) 100 Hz-1 kHz
c) 1 kHz-10 kHz\
d) 10 kHz-20 kHz
e) 20 kHz -30 kHz
f) 30 kHz -40 kHz
g) 40 kHz -50 kHz50 kHz -60 kHz
h) 60 kHz -70 kHz
i) 70 kHz -80 kHz
j) 80 kHz -90 kHz
k) 90 kHz -100 kHz

The visual distance between the target vessel and the observation boat was manually measured by a laser range finder. The distance between their respective GPS receivers can also be calculated from GPS locations of the target vessel and the observation boat/vessel. This is used as an alternative measure of distance. In the observation boat the GPS locations are continuously recorded on the laptop, and in the target vessel the GPS locations from the in-built GPS display is recorded using video recording on a mobile phone. The video recorded by the mobile phone also contains the echo-sounder data about the river depth and the speed of the vessel in knots.

Underwater sound levels are recorded in both directions as the vessel transits downstream-upstream and upstream-downstream. The variation of rms sound level in above frequency bands was plotted for various distances (ranges) of the vessel from the measurement site.

5.3. Measurement of Ambient Noise

The underwater ambient noise was measured at all sites with all machinery switched off and in the absence of navigating vessel. The averaging of noise was done over several seconds to remove the effect of random fluctuations to obtain the average value of underwater ambient noise level.

5.4. Measurement errors

There are three primary sources of error/ uncertainty in determining the underwater acoustic signature of a ship: errors in the data acquisition and processing system; variations in, or improper accounting for source-to-receiver trans-mission issues (bottom and surface effects); and, repeatability of the ship signature itself. In re-porting ship signature levels, attention should be given to providing some quantification, or bounding, of the magnitude of each of these un-certainties or errors. It is noted that many of the earlier recommendations and procedures were made to minimize these types of uncertainties.

5.5. Calculation of Vessel Noise Source Level at 1m and Uncertainty Value

To calculate the vessel noise level at 1 m from the source, a factor of 20log10(R) is to be added in the noise obtained at a vessel distance of R m from the boat using equation (2). However, the point on the vessel used to measure distance R of the vessel from the boat was not the actual location from which noise emanates: it can be up to r meters away from the point on the vessel which is used to measure the distance. The value of r can typically vary from 20 m to 50 m depending on the size of vessel. So, an uncertainty factor of 20log10((R+r)/R) was added in the calculated vessel noise values in various frequency bands at 1 m. The values of rare assumed to be 20 m in case of IWAI survey vessels and 50 m in case of transport vessel M.V. Beki.

5.5.1. Field measurements at Varanasi

Gross tonnage – 92, BHP/KW – 355/264.8

Vessel of 92 tonnage moving upstream has rms band level in the range of 110-120 kHz with 1 km of the vessel (**Figure 5.1**). While the same vessel moving downstream has rms band level in the range of 130-170 kHz (**Figure 5.2**).

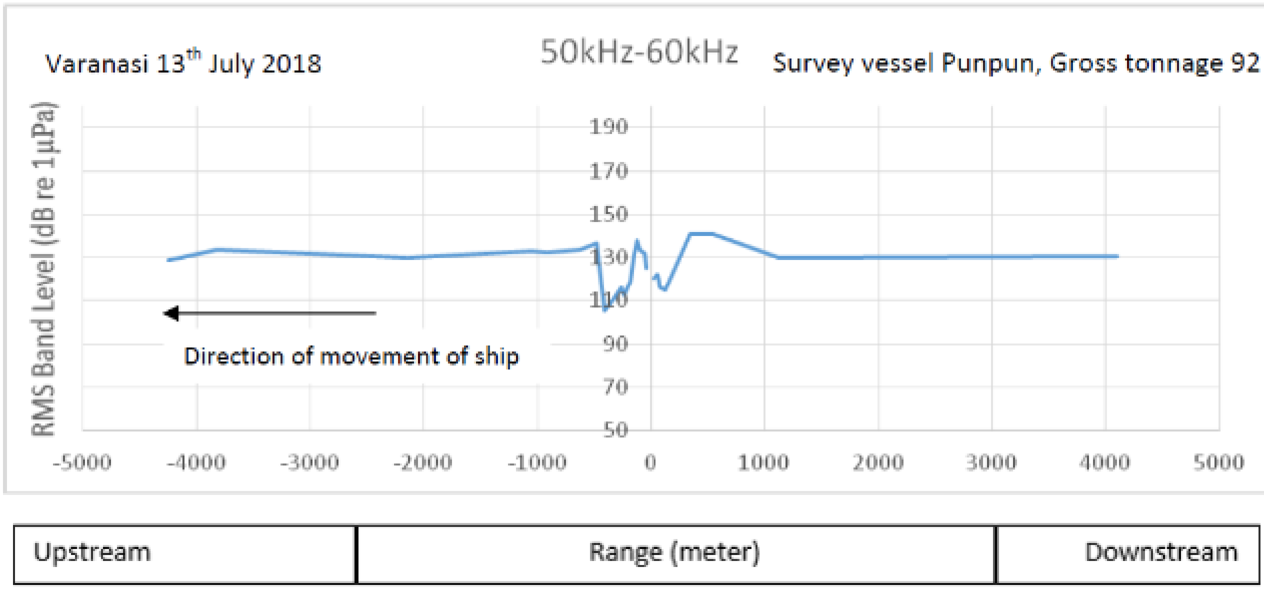

Figure 5.1 : rms Band level vs Range for 50 kHz- 60 kHz at Varanasi with vessel moving upstream

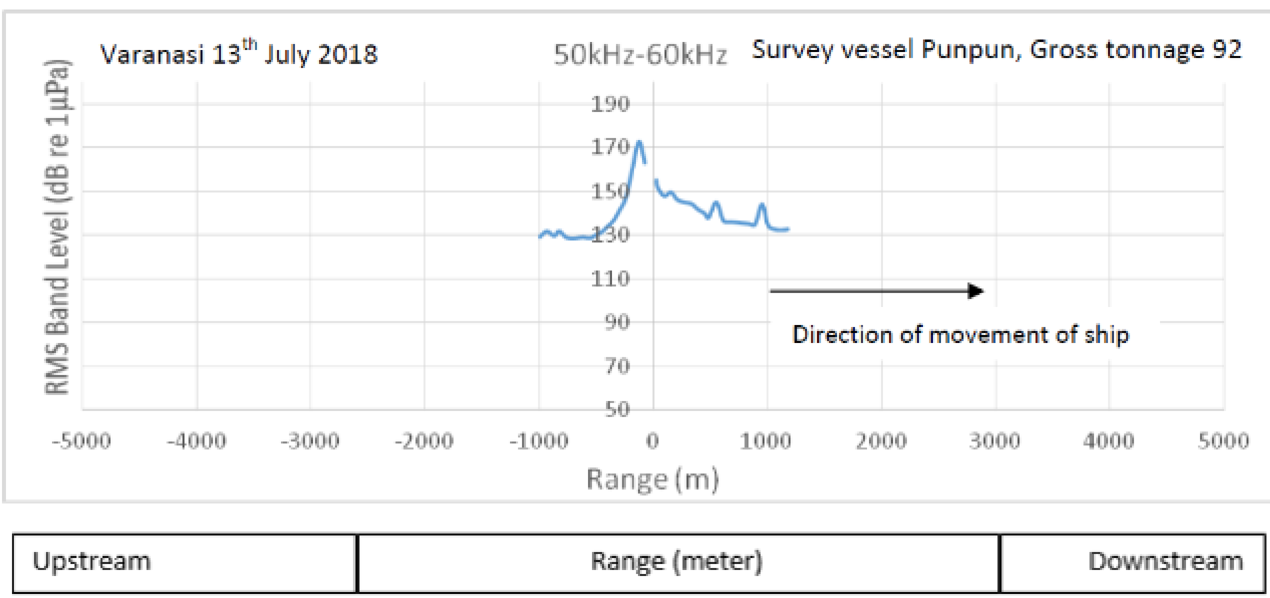

Figure 5.2 : rms Band level vs Range for 50 kHz-60 kHz at Varanasi with vessel moving downstream

The maximum vessel noise was obtained when vessel was at 28 m from the boat. Uncertainty in rms sound level at 1 m due to vessel length is 4.681 dB re 1µPa.

5.5.2. Field Measurements at Patna

Gross tonnage – 78, BHP – 330

Vessel of 78 tonnage moving upstream has rms band level in the range of 135-169 kHz with 1 km (**Fig 5.3)** of the vessel. The same vessel has rms band level in the range of 135-153 kHz moving downstream (**Fig 5.4**).

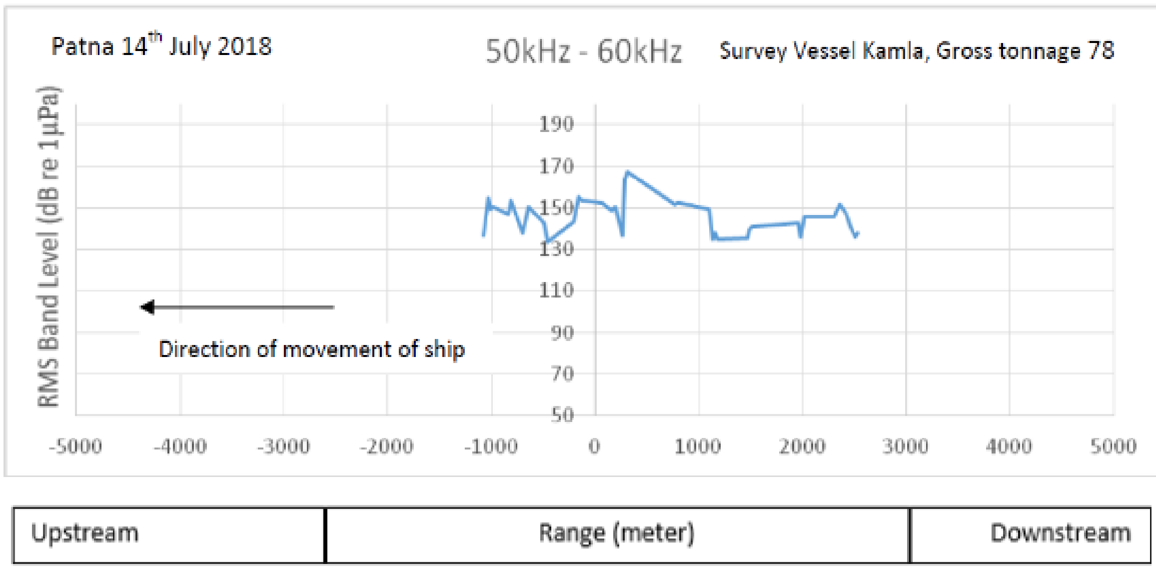

Figure 5.3 : rms Band level vs Range for 50 kHz- 60 kHz at Patna with vessel moving upstream

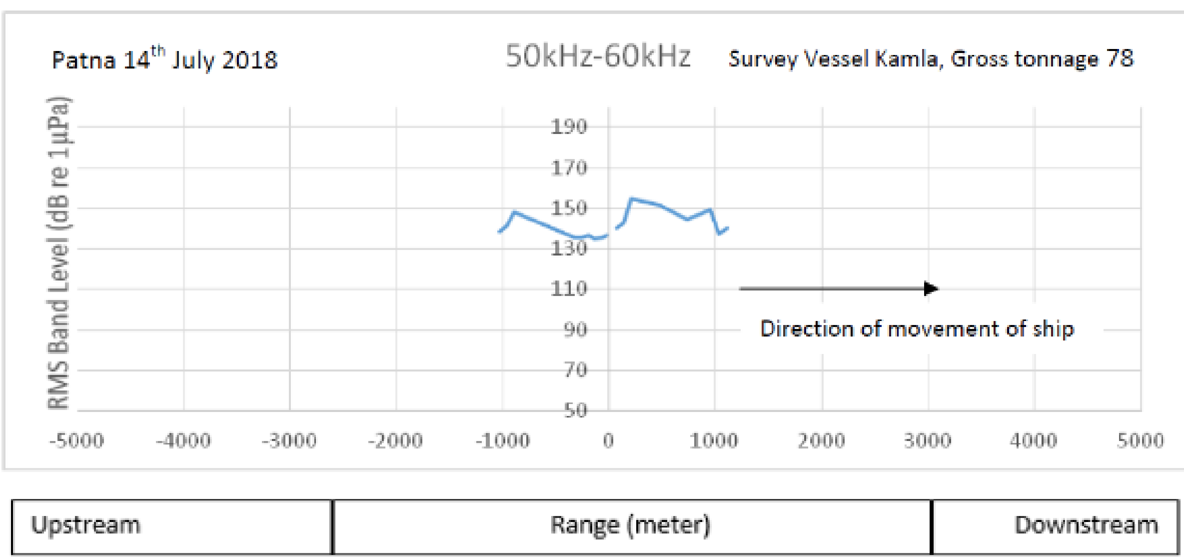

Figure 5.4 : rms Band level vs Range for 50 kHz-60 kHz at Patna with vessel moving downstream

The maximum vessel noise was obtained when the vessel was at 67 meters from the boat. Uncertainty in rms sound level at 1 m due to vessel length is 2.268 dB re 1µPa.

5.5.3. Field Measurements at Sahibganj

Gross tonnage – 92, BHP/KW – 355/264.8

Vessel of 92 tonnage moving upstream has rms band level in the range of 157-169 kHz with 1 km of the vessel. While the same vessel has rms band level in the range of 154-167 kHz moving downstream.

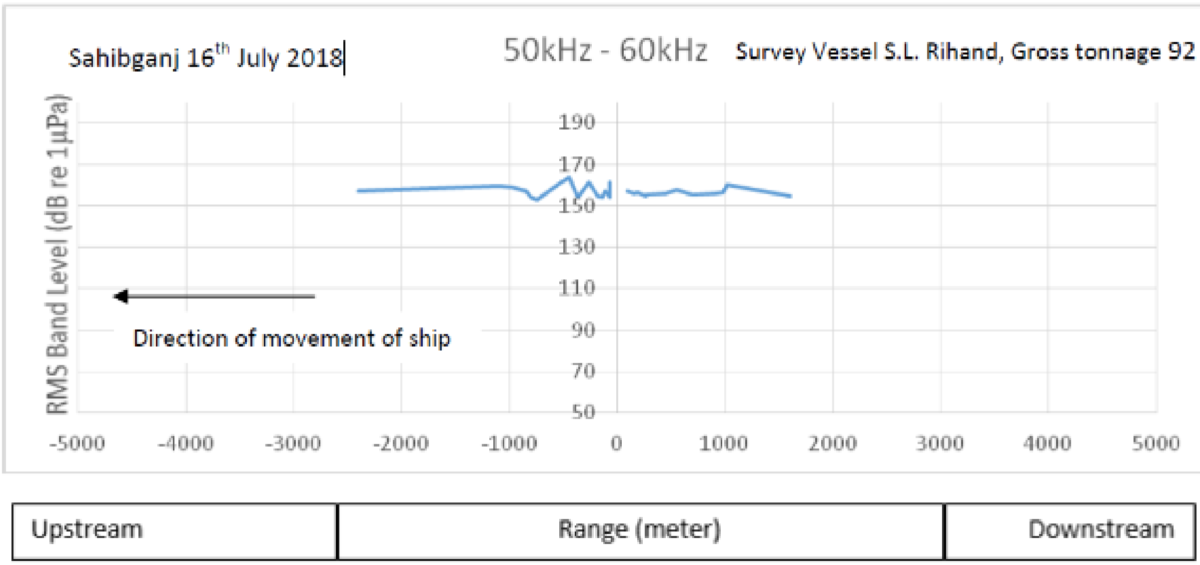

Figure 5.5 : rms Band level vs Range for 50 kHz-60 kHz at Sahibganj with vessel moving upstream

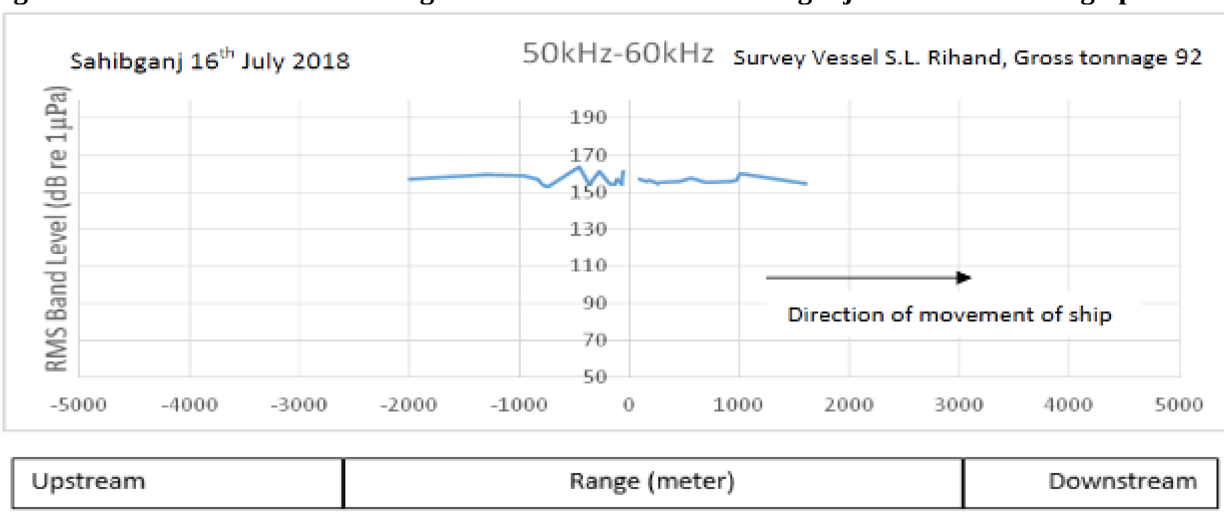

Figure 5.6 : rms Band level vs Range for 50 kHz-60 kHz at Sahibganj with vessel moving downstream

The maximum vessel noise was obtained in Sahib Ganj measurements when vessel was at 63 m from the boat. Uncertainty in rms sound level at 1 m due to vessel length is 2.394 dB re 1µPa.

5.5.4. Field measurements at Rajmahal

Gross tonnage – 2200

Vessel of 2200 tonnage moving upstream has rms band level in the range of 150-175 kHz with 1 km of the vessel. While the same vessel has rms band level in the range of 150-160 kHz moving downstream, the maximum vessel noise was obtained in Rajmahal when vessel was at 192 m from the boat. Uncertainty in rms sound level at 1 m due to vessel length is 2.0102 dB re 1μPa.

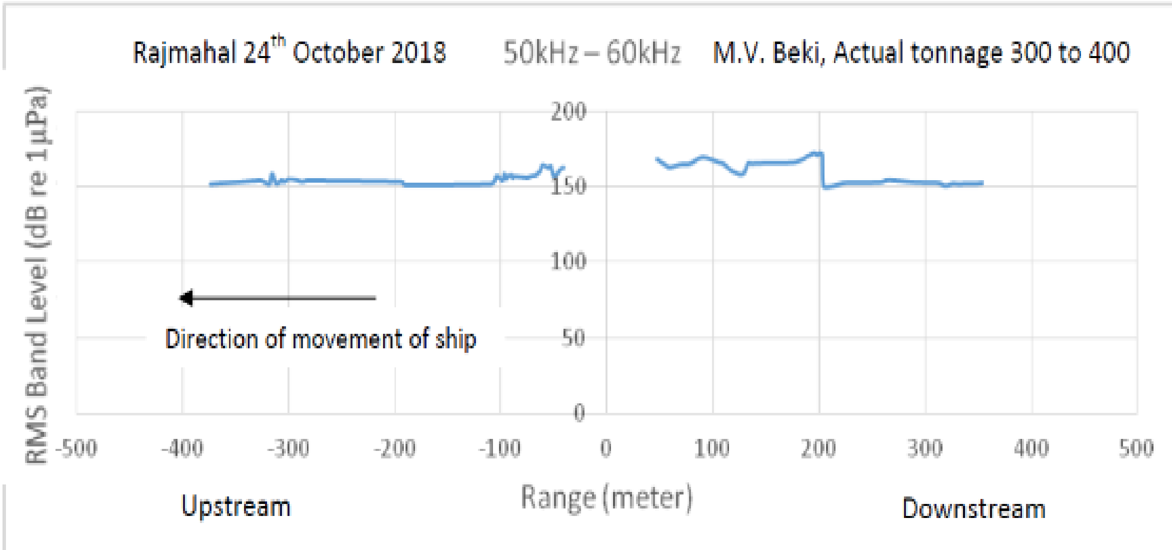

Figure 5.7 : rms Band level vs Range for 50 kHz- 60 kHz at Rajmahal with vessel moving upstream

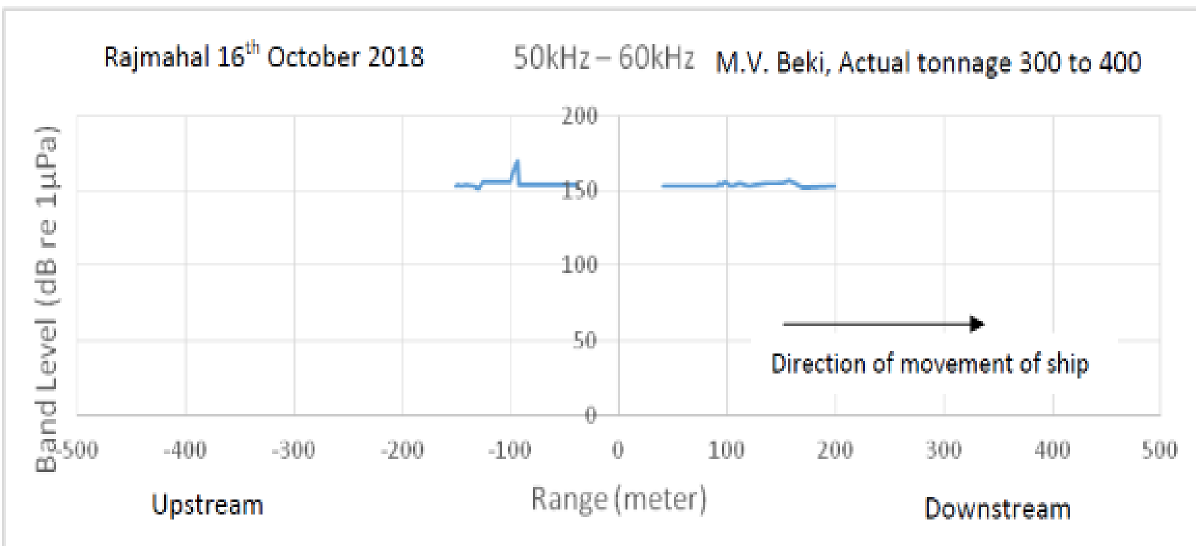

Figure 5.8 : rms Band level vs Range for 50 kHz-60 kHz at Rajmahal with vessel moving downstream

5.6. Summary findings and prevalent underwater noise

The underwater vessel noise measurements have been conducted at four field locations Varanasi, Patna, Sahibganj and Rajmahal during July 2018. Underwater noise generated by bigger vessel (with tonnage of approximately of 300 to 400 tonnes at the time of measurement) was measured at Rajmahal. The rms

Band Level noise was measured in the frequency range of 100Hz to 100kHz considering the click frequency of the Ganges dolphins of 50 kHz to 60 kHz (Fig. 5.9 & 5.10)

Apart from the vessel noise, the underwater ambient noise was also measured at all the field locations after switching off the vessel engine and machinery. The measured underwater noise was analyzed in different frequency bands and rms vessel sound source level at 1m was also calculated for all frequency bands. The comparison charts of vessel rms sound level with average rms ambient noise level in all frequency bands for all field locations have been presented in the report. A comparison of average rms ambient noise level at all locations is shown in **Figure 5.9**. The measured underwater noise was analyzed in different frequency bands and rms vessel sound source level at 1m have also been calculated for all frequency bands. The comparison charts of vessel rms sound level with average rms ambient noise level in all frequency bands for all field locations have been presented in the report.

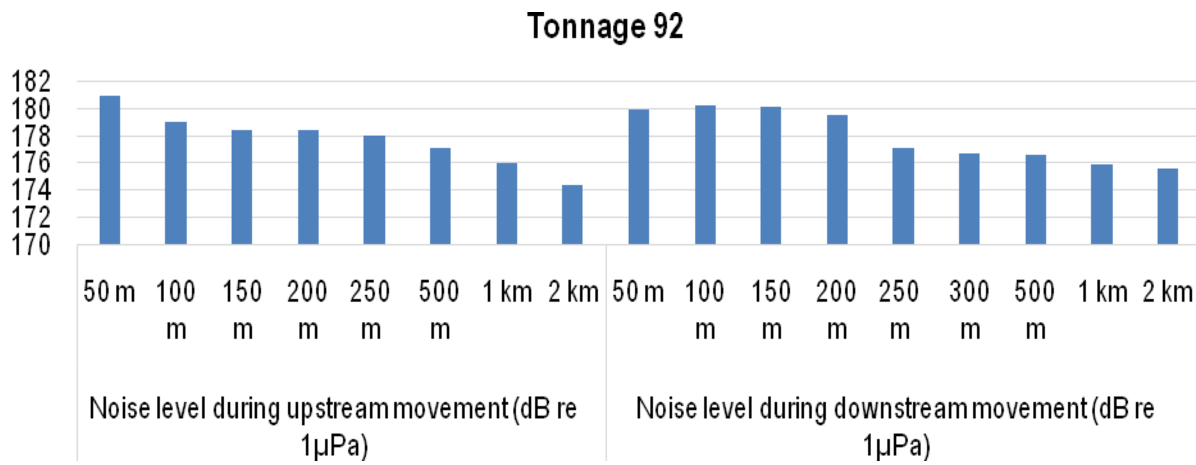

Figure 5.9 : Noise level and distance from source for a 92 tonnage vessel

Attenuation of underwater sound level with distance was due to 2 main reasons: (1) Spreading loss, and (2) Absorption loss.

Absorption loss depends on frequency, water temperature, salinity, depth, and pH. For pure/fresh water, attenuation is much lower than sea water especially up to 100 kHz. For short distances of say less than 1 km, absorption loss can be largely ignored for freshwater conditions. Spreading loss is the significant reason for attenuation at short distances in fresh water at frequencies up to 100 kHz. However, spreading loss is strongly dependent on propagation factors such as underwater channel geometry including reflection and scattering from river water surface, bottom, banks, and other underwater features such as sand banks, rocks etc. Since it is impossible to generalize the complex propagation conditions in a river as they vary from location to location and are also generally unknown at a particular location, we can only use a simplified rule of thumb to estimate spreading loss: say, between 3 to 6 dB (say X dB) for every doubling of distance from the source. So, it may increase by X dB from 1m to 2m, another X dB from 2 to 4m, another X dB from 4-8m, and so on. Thus, the spreading loss is calculated as

$$nX \text{ dB, where } n = \log 2 \text{ (Distance in metres).}$$

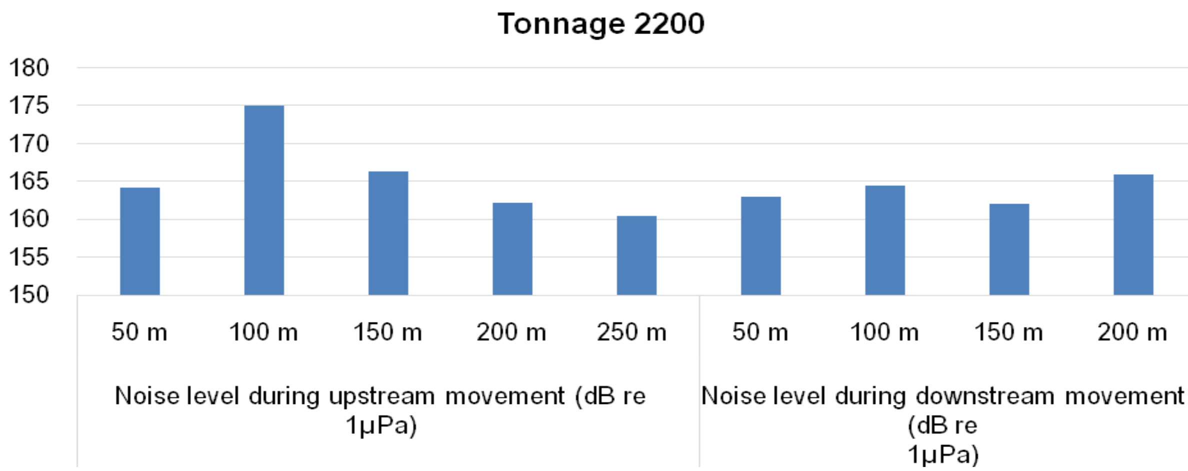

Figure 5.10 : Noise level and distance from source for a 2200 tonnage vessel

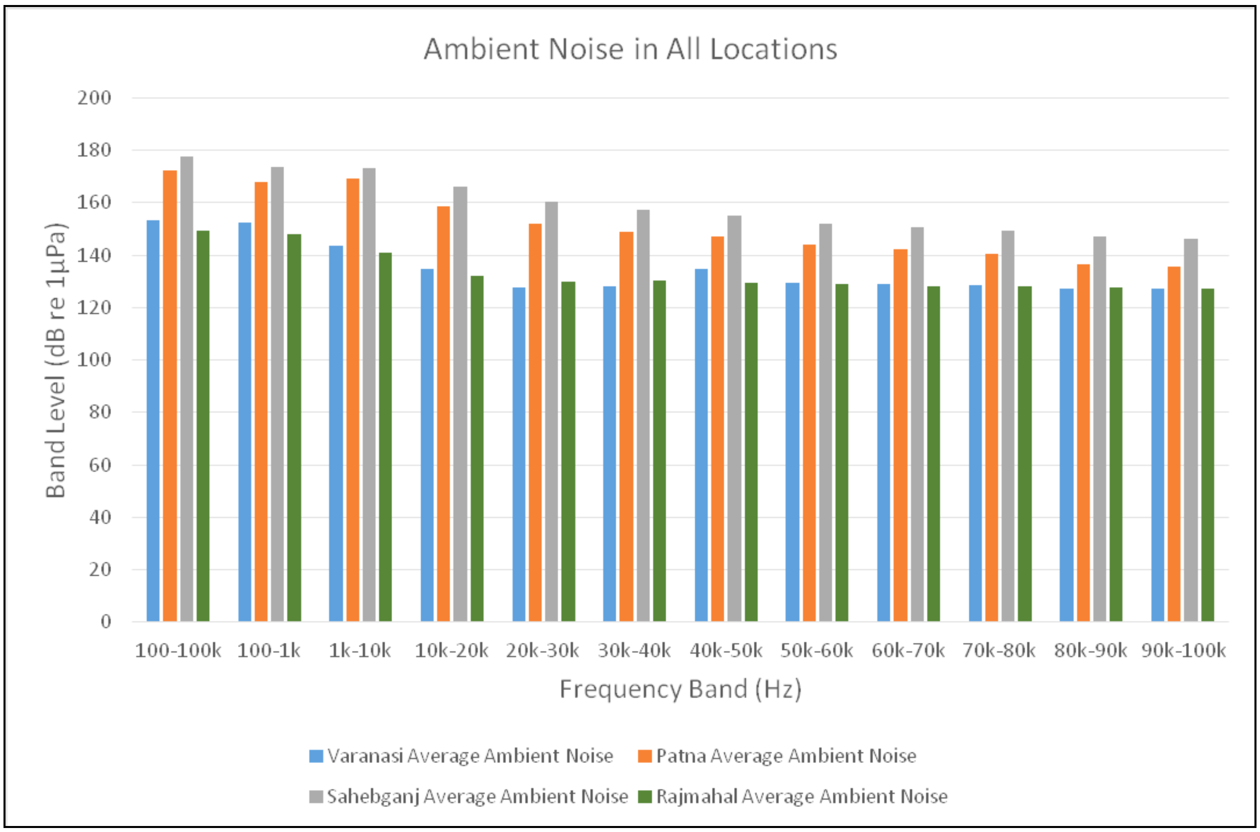

Figure 5.11 : rms Ambient Noise Band level vs Frequency Bands for all four locations

It was observed that underwater noise generated by 92 and 2200 tonnage vessels were almost similar. The smaller vessel when move upstream produced more noise in the 50-200 m range, while when recorded in downstream, the effect of the underwater noise was within 50-250 m range. Example estimates of attenuation due to spreading loss based on the above rule of thumb for specific distances from source have been given below for convenience,

Distance:

- 2m => X dB => 3- 6 dB
- 4m => 2X dB => 6- 12 dB
- 8m => 3X dB => 9- 18 dB
- 128m => 7X dB => 21- 42 dB
- 256m => 8X dB => 24- 48 dB
- 512m => 9X dB => 27- 54 dB

It was also observed that the predominant underwater ambient noise (**Figure 5.11**) at all measured locations varied from 120-160 dB. The movement of the vessels will increase the noise level up to 180 dB.

5.7. Potential effect of vessel noise on Ganges dolphins

Cargo vessels generate substantial broadband underwater noise from their propellers, motors, auxiliary machinery, gear boxes and shafts, plus their hull wake and turbulence. Diesel motors produce more noise than steam or gas turbines, but in most long distances (low frequency) noise is generated by the 'hissing' cavitation of spinning propellers. Noise generation from the vessel movement is a continuous type of noise generation. Noise generation from vessel movement (1500-2000 DWT) varies from 110-140 d(B). This order of noise generation may have an impact on behaviour of various aquatic organisms and may lead to injuries like tissue injury, temporary & permanent hearing loss. However, physical impact on aquatic species is not anticipated as it moves away from source of disturbance (barge) and usually does not come close. However, the level of noise can be responsible for changes in behavioural responses and audiometry of aquatic species, turtles and dolphins particularly. A review of various studies into behavioural disturbance to cetaceans (dolphins, porpoises) to high-frequency noise generated from continuous man-made noise were carried out and the findings of the review have been presented as follows.

- ✓ (*Southall et al., 2007*) proposed that behavioural changes may be relatively minor and/or brief, however have the potential to affect important behaviours such as foraging, breeding and resting. The study concluded that the behavioural changes to levels below 120 dB re 1 μPa were relatively minor or brief in case of harbour porpoise. Significant and sustained avoidance behaviour was recorded when noise levels exceeded 140 dB re 1 μPa in case of harbour porpoise. *For turtles and Dolphin this level is 150 dB and 177 d(B) respectively.*

- ✓ As per *Kelkar (2008)*, it was concluded that number of motorised boats and boat noise were not significantly correlated with dolphin encounter rates. Small boats equipped with outboard engines can produce source levels in the order of 160 dB re 1 μPa at 1 m, with the received levels of over 120 dB re 1 μPa at 1 m up to 500 m. *Although the study results suggest that boat noise is not displacing dolphins, it is not conclusively showing that such noise levels do not impact Dolphin behaviour*.

- ✓ *Jansen et al. (2009)* informed that study sound source levels of various vessel types at different speeds (**Table 5.1**.) The vessels which will be diploid in the NW-1 passing through Sanctuary areas (VGDS) will be 4 stroke engine vessels and propose to move with speed of 5-10 knots within the sanctuary areas. *Thus, as per this study one can conclude that from this source the noise level to be generated from the vessels will be in range of 140-150 d(B) which is slightly higher than the predominant ambient noise.*

Table 5.1 : Vessel noise at different speeds

Engine type, speed	**SL (0.2–40 kHz)**	**SL (2–12.5 kHz)**
	dB re 1 µPaRMS at 1 m	dB re 1 µPaRMS at 1 m
2-stroke, 2.5 knots	112 ± 1.0	108 ± 3.0
4-stroke, 2.5 knots	110 ± 2.6	106 ± 2.2
2-stroke, 5 knots	139 ± 1.0	132 ± 3.0
4-stroke, 5 knots	138 ± 2.6	134 ± 2.2
2-stroke, 10 knots	149 ± 0.6	146 ± 0.6
4-stroke, 10 knots	152 ± 0.3	144 ± 0.5

- ✓ As per findings by *Renilson et al.(2013)*, the relationship of vessel speed vs noise generation from vessel and same is shown at **Figure 5.12**.

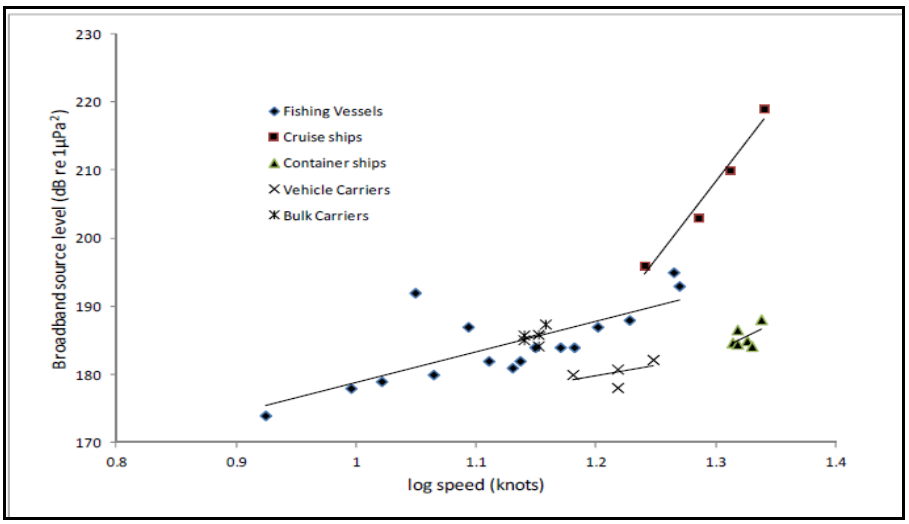

Figure 5.12 : Broadband source levels against log10 (speed in knots) for different vessel types

Vessels being used for material transportation from the NW1 terminal can be considered under category of bulk carriers. Vessel movement speed in the sanctuary areas is to be restricted to 5-10 knots only. As per above graph *it has been established that the noise level generated from bulk carriers moving with speed of 5-10 knots will not be more than 150 d(B)* (arrived based on extrapolation of above graph).However, considering the variation *upper limit of 160 d9B) is also considered as threshold for underwater noise regarding dolphins*.

- ✓ When dolphin's auditory system is exposed to a high level of sound for a specific duration, the sensory hair cells begin to fatigue and do not immediately return to their normal shape (*NRC, 2005*). It causes a reduction in the hearing sensitivity, or increase in hearing threshold. If the noise exposure is below some critical sound energy level, the hair cells will eventually return to their normal shape. This effect is called "**Temporary Threshold Shift (TTS)**" as the hearing loss is temporary. If the noise exposure exceeds the critical sound energy level, the hair cells become permanently damaged and the effect is called "**Permanent Threshold Shift (PTS)"**. **Table 5.2** below summarises the noise exposure criteria adopted for assessing hearing damage (PTS or TTS) and behavioural effects on the Ganges River Dolphin from vessel noise. The noise exposure criteria are based on the review presented by *Southall et al. (2007)* and adopted by NOAA (US National Oceanic and Atmospheric Administration) in 2011 discussed above.

Table 5.2 : Noise exposure criteria for physiological (PTS and TTS)

Impact	**Noise exposure criteria**
Permanent threshold shift	SEL 215 dB(M) re 1$\mu Pa^2 s$
Temporary threshold shift	SEL 195 dB(M) re 1$\mu Pa^2 s$

However, noise generation anticipated from vessel movement in NW-1 (1500-2000 DWT) is between 110-**140 d(B) which is below the noise exposure criteria to cause PTS/TTS in dolphins.** *Thus, impact on auditory systems of dolphins is not anticipated due to noise generation from barge movement***.**

- ✓ An estimation is carried out to assess distance of achieving the safe threshold noise level of 150 d(B) for turtle and 177 d(B) Dolphin from behavioral consideration prospective as per EIA Study of "*Inshore Dolphin Offset Strategy, South of Embley Project, 2015*" sited above. The same has been given at Table 5.3 for scaling factor of 15 and 20 N. It is concluded that noise level of 150 d(B) can be achieved at distance less than 4.6 m from center of the vessel for turtle. However, the maximum beam of vessel which will ply in waterway is 11.4 m. *Dolphins are intelligent animals and would certainly avoid proximity to any disturbance. Although dolphins are sighted near small fishing vessels, the noise disturbance of large vessels may evade dolphins of proximity, thus possibility of occurrence of any aquatic animal like fish, turtle and dolphins at 4.6 is very unlikely*.

Table 5.3 : Distance estimation for achieving 150 d(B) of noise from centre of the vessel

Description	**Scenario 1-considering N Value 15**		**Scenario 2-considering N vale 20**	
	For Turtles	**For Dolphins**	**For Turtles**	**For Dolphins**
Threshold Safe Noise Level -dB	150	177	150	177
Source Sound Level (SL)-dB	160	160	160	160
Safe Distance-R (m)	4.6	Noise level generated are less	3.16	Noise level generated are less

		than the threshold safe level		than the threshold safe level

- ✓ Another impact of high noise level generated from moving barges is masking of biologically important sounds. These sounds may interfere with communication and social interaction and cause changes in behaviour as well. The zone of masking impact will be highly variable and depends on many factors including distance between the listener and sources of the signal and masking noise, the level of the signal and masking noise, and the propagation of noise from the signal and masking source to the listener. It is however important to note that masking of communication and echolocation signals naturally occurs by the ambient noise environment. Man-made noise causes additional masking of a signal only when it is of a higher level than the ambient environment within the species 'critical hearing bandwidth at the signal's dominant frequencies. **Echolocation clicks produced by the Ganges River Dolphin have dominant energy around 65 kHz** (*Sugimatsu et al., 2011*). **This is well above the dominant frequency range of most man-made noise, including pump noise. Masking of echolocation signals is therefore not a significant issue for most man-made sources** (*Richardson et al., 1995*). **Thus, it can be concluded that noise generation due to barge movement is not anticipated to interfere with echolocation ability of Ganges Dolphins**. However, **dolphin may communicate at a higher frequency sound at all time to navigate. This may cause stress in the Dolphins during continuous river traffic.**

- ✓ The Gangetic River Dolphin is likely to produce communication signals, such as whistles, squeals or clicks, based on communication signals produced by other river dolphins. These signals generally have energy at much lower frequencies than the echolocation clicks, i.e. as low as 1-6 kHz. **Communication signals are therefore more likely to be masked by man-made noise than echolocation clicks** (*Richardson et al., 1995*). Noise reduction measures will help in minimizing the noise generation from barge movement and will minimize masking of communication signals generated by dolphins.

- ✓ In the Sundarbans, the Ganges and Irrawaddy dolphins inhabit geo-morphologically complex areas with extremely variable depth, salinity and turbidity in contrast to the more stable characteristics of marine environments. Given the complex acoustic environment and high amount of clutter and reverberation, it may be hypothesized that **Irrawaddy dolphins and Ganges river dolphins employ echolocation signals characterized by low-amplitude, high frequency sonar signals emitted at high repetition rates like small bat species hunting in cluttered habitats** *(Jensen et al., 2013).*

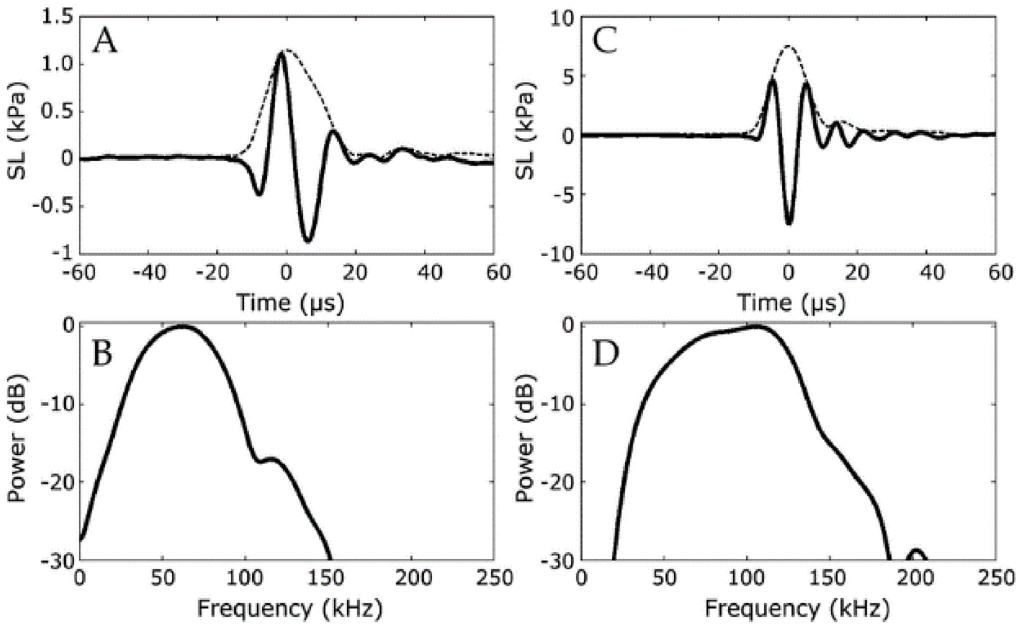

Figure 5.13 : Representative echolocation clicks from Ganges river dolphins and Irrawaddy dolphins. A: Signal waveform (solid line) and envelope (interrupted line) of a Ganges river dolphin echolocation click. B: Normalized power spectrum of a Ganges river dolphin echolocation click.

	Orcaella brevirostris		*Platanista gangetica gangetica*	
	(N = 15)		(N = 29)	
Click parameters *	**Mean ± SD**	**[Min; Max]**	**Mean ± SD**	**[Min; Max]**
SL_{pp} (dB re 1 μPa pp at 1 m)	**194.5±3.6**	**[188.6; 199.5]**	**183.3±3.4**	**[174.8; 188.7]**
SL_{RMS} (dB re 1 μPa RMS at 1 m)	**185.1±3.6**	**[180.1; 191.2]**	**173.3±3.4**	**[164.6; 179.1]**
SL_{EFD} (dB re 1 μPa^2*s at 1 m)	**136.3±3.4**	**[131.1; 142]**	**126.6±3.3**	**[118.4; 132.1]**
D_{-10dB} (μs)	**13.44±3**	**[9.8; 20.8]**	**21.7±2.2**	**[16.6; 26]**
Fc (kHz)	**94.6±9.7**	**[70.2; 109]**	**61.4±4.9**	**[54;72]**
Fp (kHz)	**100.7±19.9**	**[65.2; 125]**	**58.8±6.8**	**[44.7; 73.3]**
BW $-_{3\ dB}$ (kHz)	**64.4±15.8**	**[40.2; 91.4]**	**43.8±7.1**	**[32; 62.3]**
BW $-_{10\ dB}$ (kHz)	**117.9±15.1**	**[83.9; 143.9]**	**73.2±8.7**	**[58; 98]**
BW $_{RMS}$ (kHz)	**29.9±3.7**	**[22.3; 36.5]**	**20±2.4**	**[15.1; 25]**
Q_{RMS}	**3.2±0.3**	**[2.8; 3.7]**	**3.1±0.3**	**[2.5; 3.6]**
ICI (ms)	**44.8±24.6**	**[21; 229]**	**35±18.4**	**[4.6; 125.5]**

*Click parameter abbreviations: SL_{pp} : peak-to-peak source level; SL_{RMS} : RMS source level within a −10 dB energy window; SL_{EFD}: Energy flux density source level within a −10 dB energy window; D_{-10dB}: Click duration (−10 dB energy window); Fc: centroid frequency; Fp: peak frequency; BW: Bandwidth (−3 dB, −10 dB or root-mean-square); Q_{RMS}: Ratio of centroid frequency to RMS bandwidth; ICI: Inter-click interval.
doi:10.1371/journal.pone.0059284.t001

**Adopted from Jensen et al., 2013*

The above studies indicate that the centroid frequency of Ganges dolphins is around 61 dB, with a peak source level of 183.3 dB. The communication system and echolocation of these animals are two vastly different activities and have different frequency and energy signature. **The vessel noise (Table 5.4) generated from different tonnage of vessels represent noise generated at 1 m from the source.**

However, the 1 m proximity is highly unlikely for any animal. *More so, the noise generated by vessels may interfere with the communication of the dolphins, but such evidence is lacking. The vessel noise may not interfere with the echolocation ability of the dolphins*.

Table 5.4 : Summarizes the maximum rms source levels of vessel noise over full band measured at all 4 field locations for the specific vessels.

S. No.	Locations	Maximum rms full band Vessel Source level (dB re 1µPa) at 1 meter
1	Varanasi (13th July 2018)	223.312 to 227.982 ***(IWAI Vessel Punpun)***
2	Patna (14th July 2018)	214.84 to 216.84 ***(IWAI Vessel Kamla)***
3	Sahibganj (16th July 2018)	215.64 to 218.04 ***(IWAI Vessel S.L. Rihand)***
4	Rajmahal (24th October 2018)	236.34 to 237.58 ***(M.V. Beki tonnage 300-400)***

5.7 Conclusion

It was observed that the underwater noise generated by the 92 and 2200 tonnage vessels are almost similar. The smaller vessel when move upstream produce more noise in the 50-200 m range, while moving downstream the effect of the underwater noise was observed in the 50-250 m range. It was also noted that the predominant underwater ambient noise at all measured locations varied from 120-160 dB. The movement of the vessels will increase the noise level upto 180 dB. When the dolphin’s auditory system is exposed to a high level of sound for a specific duration, the sensory hair cells begin to fatigue and do not immediately return to their normal shape. This causes a reduction in the hearing sensitivity, or an increase in hearing threshold. Another impact of high noise level generated from moving barges is masking of biologically important sounds. These sounds may interfere with communication and social interaction and cause changes in behaviour as well. dolphin may communicate at a higher frequency sound at all time to navigate. This may cause stress in the Dolphins during continuous river traffic. Further, long-term study is needed to assess the noise-oriented disturbance to Dolphins when the river will have full traffic load.

CHAPTER 6. IDENTIFICATION OF GANGES DOLPHIN ‘HOT SPOTS’ THROUGH HABITAT MODELLING

6.1. Introduction:

The water quality parameters are essential in determining the planktonic biomass, the fish population and in turn the dolphin sightings. However, the sampling locations in the study are evenly distributed and certain parameters had to be regressed to turn the intermittent data into a temporal continuous data. The data modeling for dolphins and identification of ‘Hot Spots’ were done in a phase-wise manner. The steps are as follows:

- **A.** Correlation assessment and Principal water quality component extraction
- **B.** Regression for assessment of planktonic mass
- **C.** Regression for assessment of fish richness
- **D.** Regression for assessment of fish abundance
- **E.** Principal habitat parameter assessment for dolphin existence
- **F.** Regression modelling for dolphin ‘Hot Spot’ identification

6.2. Correlation assessment and Principal water quality components:

The water quality parameters are often correlated, and the correlation coefficients are pivotal in the regression analysis for any modeling. Thus, the water quality parameters such as pH, Turbidity, TDS, TSS, DO, BOD, O&G, Cl and Nitrate evaluated in the field measurements were taken into consideration for correlation analysis (**Table 6.1**.).

It was found that Turbidity is correlated with O&G and Nitrate. TDS is highly correlated with DO and Cl. The DO is correlated with TDS and BOD. After the assessment of the correlation matrix, it was evident that some parameters change simultaneously and influence each other in the aquatic environment and can be modelled taking the most influencing parameter.

Table 6.1 : Correlation matrix for the water quality parameters to define correlation coefficient for modelling

		pH_G	Tur_G	TDS_G	TSS_G	DO_G	BOD_G	OG_G	Cl_G	Nit_G
Correlation	pH_G	1.000	.338	-.246	.159	.246	-.187	.366	-.276	.102
	Tur_G	.338	1.000	-.144	-.135	.139	-.173	.581	-.033	.647
	TDS_G	-.246	-.144	1.000	.422	-.621	.121	-.243	.896	.077
	TSS_G	.159	-.135	.422	1.000	-.307	.346	-.016	.169	-.236
	DO_G	.246	.139	-.621	-.307	1.000	-.425	-.151	-.379	-.039
	BOD_G	-.187	-.173	.121	.346	-.425	1.000	.280	-.061	-.061
	OG_G	.366	.581	-.243	-.016	-.151	.280	1.000	-.229	.276
	Cl_G	-.276	-.033	.896	.169	-.379	-.061	-.229	1.000	.212
	Nit_G	.102	.647	.077	-.236	-.039	-.061	.276	.212	1.000

To assess the principal influencing factors that describe the overall data variance in the dataset collected from the field observations a Principal Component Analysis (PCA) was carried out. The KMO and Bartlett’s test was carried out to assess the sphericity of the data and whether the data set is appropriate for PCA (**Table 6.2**).

Table 6.2 : The KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.402
Bartlett's Test of Sphericity	Approx. Chi-Square	94.508
	df	36
	Sig.	.000

The PCA has shown that there were 4 PCs, observed from the scree plot (**Figure 6.1.**) that defined the overall data variability. The component loadings were highest for the DO, BOD, TDS, TSS, O&G, Turbidity and Nitrate in PCS 1 and 2 (**Table 5.3**). Those parameters were found to be the most important parameters that defined the overall data variability. These parameters were chosen for further modeling of the planktons, fish abundance and fish richness along the NW-1.

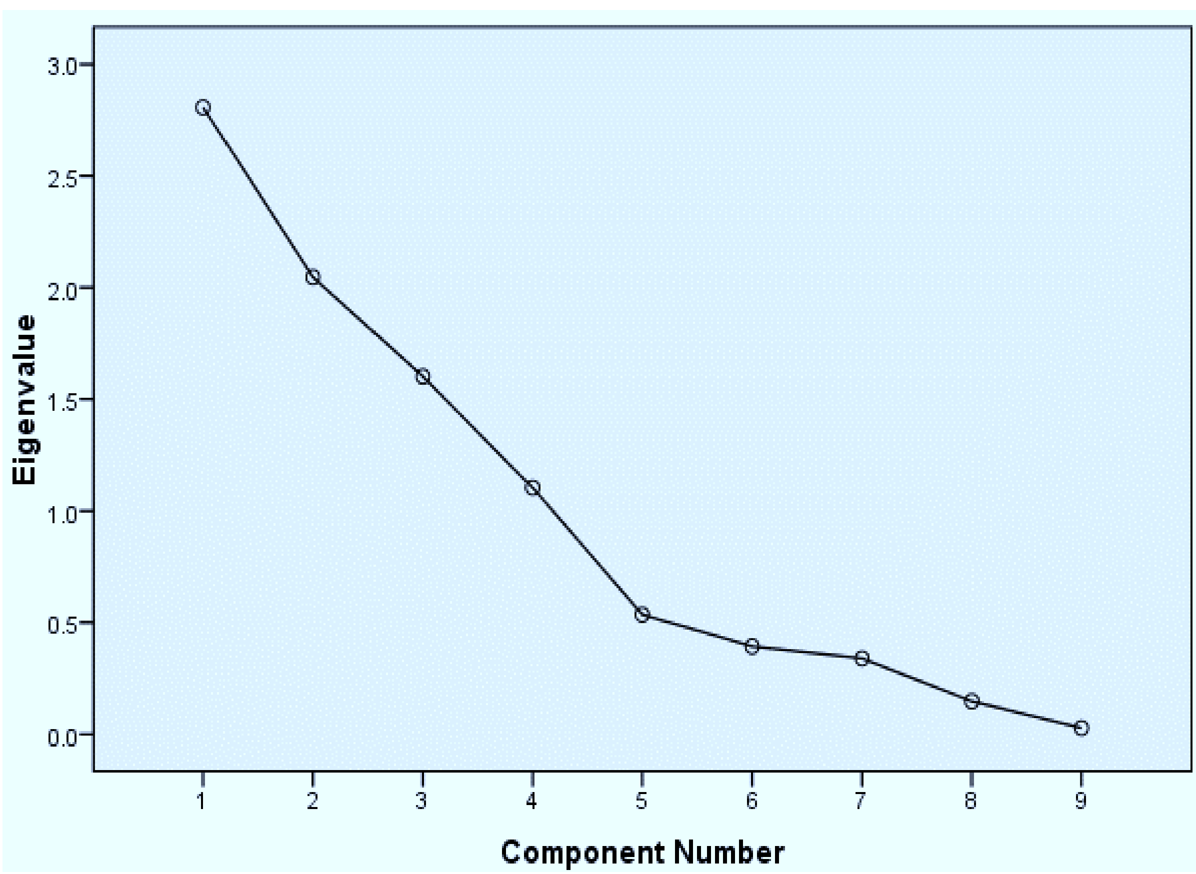

Figure 6.1 : Screen plot for PCs

Table 6.3 : The Component loading matrix and 4 PCs extracted

	Component			
	1	2	3	4
pH_G	-.502	.274	.221	.682
Tur_G	-.499	.754	-.174	.036
TDS_G	.881	.330	-.220	.197
TSS_G	.476	.131	.511	.566
DO_G	-.683	-.389	-.278	.215
BOD_G	.331	.179	.729	-.390
OG_G	-.399	.659	.454	-.141
Cl_G	.726	.343	-.489	.131
Nit_G	-.203	.736	-.398	-.206

Extraction Method: Principal Component Analysis.

a. 4 components extracted.

6.3. Regression for assessment of planktonic mass

The Phytoplankton and zooplankton abundance were dependent on certain water quality parameters. When regression analysis was done it was analyzed that TDS, O&G, TSS, BOD and DO were the principal parameters that were responsible for determining the planktonic mass.

The regression model to predict phytoplankton abundance was highly significant (**Table 6.4**). The coefficients (**Table 6.5**) were taken to build a linear regressing model as **Formula 1**. The data predicted with this formula were then analyzed to model fish abundance and fish richness.

Table 6.4 : The model fit of predicting the Phytoplankton

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.972a	.945	.670	467.51299	3.284

a. Predictors: (Constant), TDS, OG, TSS, BOD, DO

b. Dependent Variable: Phytplank

Table 6.5 : Coefficients to predict phytoplankton abundance

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-38102.723	11280.392		-3.378	.183
	DO	4399.655	1247.936	4.150	3.526	.176
	OG	-795.349	1135.220	-.199	-.701	.611
	TSS	-638.114	216.938	-2.912	-2.941	.209
	BOD	838.417	275.454	2.108	3.044	.202
	TDS	48.778	15.729	3.791	3.101	.199

a. Dependent Variable: Phytplank

Phytoplankton= -38102.7 + 4399.6 x (DO) - 795.3 x (O&G) - 638.1 x (TSS)+ 838.4 x (BOD)+48.8 x (TDS), where R^2=0.945 …………………………………………. Formula 1

The regression model to predict Zooplankton abundance was highly significant (**Table 6.6**.). The coefficients (**Table 6.6**) were taken to build a linear regressing model as **Formula 2**. The data predicted with this formula were then analyzed to model fish abundance and fish richness.

Table 6.6 : The model fit of predicting the Zooplankton

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.999a	.998	.990	3.73687	3.284

a. Predictors: (Constant), TSS, DO, OG, BOD, TDS

b. Dependent Variable: Zooplank

Table 6.7 : Coefficients to predict phytoplankton abundance

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	348.438	90.165		3.864	.161
	DO	-42.210	9.975	-.884	-4.232	.148
	OG	-142.670	9.074	-.792	-15.723	.040
	BOD	-9.285	2.202	-.518	-4.217	.148
	TDS	-.228	.126	-.393	-1.813	.321
	TSS	13.365	1.734	1.354	7.708	.082

a. Dependent Variable: Zooplank

Zooplankton=348.4-42.2 x (DO)-142.7 x (O&G)-9.3 x (BOD)-0.2 x (TDS)+13.4 x (TSS), where R^2=0.99 ……………………………………………………………. Formula 2

6.4. Regression for assessment of Fish Richness

It was evident from the literature that Zoo- and Phytoplankton were important parameters for fish species presence. We also found that planktonic biomass along with DO, TDS, TSS were major determining parameters for Fish Richness.

The regression model to predict Fish Richness was highly significant (Table 6.8.). The coefficients (Table 6.9.) were taken to build a linear regressing model as Formula 3. The data predicted with this formula were then analyzed to model Ganges dolphin abundance.

Table 6.8 : The model fit of predicting the Fish Richness

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.969a	.939	.635	6.15956	3.396

a. Predictors: (Constant), Phytplank, TSS, DO, Zooplank, TDS

b. Dependent Variable: F_rich

Table 6.9 : Coefficients to predict Fish Richness

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	301.264	98.515		3.058	.201
	DO	-30.369	10.523	-2.290	-2.886	.212
	TDS	-.516	.166	-3.206	-3.117	.198
	TSS	4.663	1.458	1.701	3.197	.193
	Zooplank	.192	.105	.690	1.835	.318
	Phytplank	.006	.004	.475	1.530	.369

a. Dependent Variable: F_rich

Fish Richness= 301.3-30.4 x (DO)-0.5 x (TDS)+4.7 x (TSS)+0.2 x (Zooplankton)+0.01 x(Phytoplankton), where R^2=0.94 …………………………………..…………… Formula 3

6.5. Regression for assessment of Fish Abundance

It was evident that planktonic biomass provides the major prey base for fish in aquatic system. On the other hand, the water quality parameters like DO, TDS, TSS were major detrimental parameters for Fish Abundance.

The regression model to predict Fish Abundance was highly significant (Table 6.10.). The coefficients (Table 6.11.) were taken to build a linear regressing model as Formula 4. The data predicted with this formula were then analyzed to model Ganges dolphin abundance.

Table 6.10 : The model fit of predicting the Fish Abundance

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.980a	.960	.761	6.70790E6	3.396

a. Predictors: (Constant), Phytplank, TSS, DO, Zooplank, TDS

b. Dependent Variable: F_ab

Table 6.11 : Coefficients to predict Fish Abundance

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.936E8	1.073E8		-1.804	.322
	DO	1.656E7	1.146E7	.927	1.445	.385
	TDS	509903.085	180299.816	2.353	2.828	.216
	TSS	-1.750E6	1.588E6	-.474	-1.102	.469
	Zooplank	-466202.560	113820.670	-1.247	-4.096	.152
	Phytplank	-2529.574	4233.728	-.150	-.597	.657

a. Dependent Variable: F_ab

Fish Abundance= -1.9 + 1.7 x (DO)+509903 x (TDS) – 1749566 x (TSS) – 466202 x (Zooplankton)-2529.5 x (Phytoplankton), where R^2=0.96 ……………………….. Formula 4

6.6. Principal habitat parameter assessment for dolphin existence

As we have seen earlier that the principal water quality parameters, presence of planktons and fishes are correlated, and the correlation coefficients are pivotal in the regression analysis for modeling. *In a step-by-step manner, the water quality determines the plankton abundance, the plankton abundance determine the fish abundance; and finally, the fish richness and abundance provide prey base for the Ganges dolphins*.

Thus, the water quality parameters such as pH, Turbidity, TDS, TSS, DO, BOD, O&G, Cl and Nitrate were evaluated along with important hydrology parameters like depth and river flow observed during the field measurements and were taken into consideration for correlation analysis (Table 6.12.).

After the assessment of the correlation matrix, it was evident that some parameters change simultaneously and influence each other in the aquatic environment and can be modeled taking the most influencing parameter.

Table 6.12 : Correlation matrix for the dolphin habitat determining parameters to define correlation coefficient for modelling

Correlation Matrix

		WD	WF	pH	Tur	TDS	TSS	DO	BOD	OG	CI	Nit	FRich	FAb	Zoop	PhytP
Correlation	WD	1.000	.368	.046	.472	.446	-.019	-.445	.136	.212	.533	.491	-.121	.374	-.039	-.337
	WF	.368	1.000	-.076	.429	-.038	-.362	-.017	-.562	.048	.377	.278	-.081	.244	-.140	-.135
	pH	.046	-.076	1.000	.323	-.103	.167	.229	-.231	.362	.080	.399	-.239	-.094	.178	.187
	Tur	.472	.429	.323	1.000	-.074	-.219	.083	-.142	.375	.382	.757	-.151	.357	-.262	-.030
	TDS	.446	-.038	-.103	-.074	1.000	.514	-.773	.116	-.164	.669	.171	-.314	.572	-.127	-.110
	TSS	-.019	-.362	.167	-.219	.514	1.000	-.286	.225	.035	.180	-.050	-.004	.203	.238	.047
	DO	-.445	-.017	.229	.083	-.773	-.286	1.000	-.393	-.111	-.388	-.127	.020	-.394	-.115	.131
	BOD	.136	-.562	-.231	-.142	.116	.225	-.393	1.000	.318	-.261	-.037	.392	.086	.163	.024
	OG	.212	.048	.362	.375	-.164	.035	-.111	.318	1.000	-.071	.184	.153	.160	-.048	-.031
	CI	.533	.377	.080	.382	.669	.180	-.388	-.261	-.071	1.000	.478	-.369	.788	-.428	-.267
	Nit	.491	.278	.399	.757	.171	-.050	-.127	-.037	.184	.478	1.000	-.148	.330	-.109	.155
	FRich	-.121	-.081	-.239	-.151	-.314	-.004	.020	.392	.153	-.369	-.148	1.000	-.353	.488	.517
	FAb	.374	.244	-.094	.357	.572	.203	-.394	.086	.160	.788	.330	-.353	1.000	-.619	-.256
	Zoop	-.039	-.140	.178	-.262	-.127	.238	-.115	.163	-.048	-.428	-.109	.488	-.619	1.000	.270
	PhytP	-.337	-.135	.187	-.030	-.110	.047	.131	.024	-.031	-.267	.155	.517	-.256	.270	1.000
Sig. (1-tailed)	WD		.055	.423	.018	.024	.469	.025	.284	.185	.008	.014	.305	.052	.436	.073
	WF	.055		.375	.029	.437	.058	.472	.005	.420	.051	.118	.367	.150	.278	.285
	pH	.423	.375		.082	.332	.241	.166	.163	.058	.369	.041	.155	.346	.226	.216
	Tur	.018	.029	.082		.379	.177	.363	.275	.052	.048	.000	.263	.061	.132	.451
	TDS	.024	.437	.332	.379		.010	.000	.312	.244	.001	.235	.089	.004	.296	.321
	TSS	.469	.058	.241	.177	.010		.110	.170	.441	.223	.417	.494	.196	.156	.422
	DO	.025	.472	.166	.363	.000	.110		.043	.321	.046	.297	.466	.043	.314	.292
	BOD	.284	.005	.163	.275	.312	.170	.043		.086	.133	.439	.044	.360	.246	.460
	OG	.185	.420	.058	.052	.244	.441	.321	.086		.383	.218	.260	.250	.421	.449
	CI	.008	.051	.369	.048	.001	.223	.046	.133	.383		.016	.055	.000	.030	.128
	Nit	.014	.118	.041	.000	.235	.417	.297	.439	.218	.016		.267	.078	.323	.258
	FRich	.305	.367	.155	.263	.089	.494	.466	.044	.260	.055	.267		.063	.014	.010
	FAb	.052	.150	.346	.061	.004	.196	.043	.360	.250	.000	.078	.063		.002	.138
	Zoop	.436	.278	.226	.132	.296	.156	.314	.246	.421	.030	.323	.014	.002		.125
	PhytP	.073	.285	.216	.451	.321	.422	.292	.460	.449	.128	.258	.010	.138	.125	

To assess the principal influencing factors that describe the overall data variance in the dataset and successfully predict dolphin presence which were collected from the field observations; again, a PCA was carried out. The **KMO and Bartlett's test** was carried out to assess the sphericity of the data and whether the data set is appropriate for PCA (**Table 6.13**.).

Table 6.13 : The KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.307
Bartlett's Test of Sphericity	Approx. Chi-Square	200.838
	df	105
	Sig.	.000

The PCA shown that there were 4 PCs, observed from the scree plot (**Figure 6.2**) that defined the overall data variability. The component loadings were highest for the Water depth, Water flow, DO, TDS, Turbidity, Nitrate, TSS, Cl, O&G and Fish Abundance in PCS 1 and 2 (**Table 6.14**). Those parameters were found to be the most important parameters that defined the overall data variability. These parameters were chosen for further modeling of the Ganges dolphin presence along the NW-1.

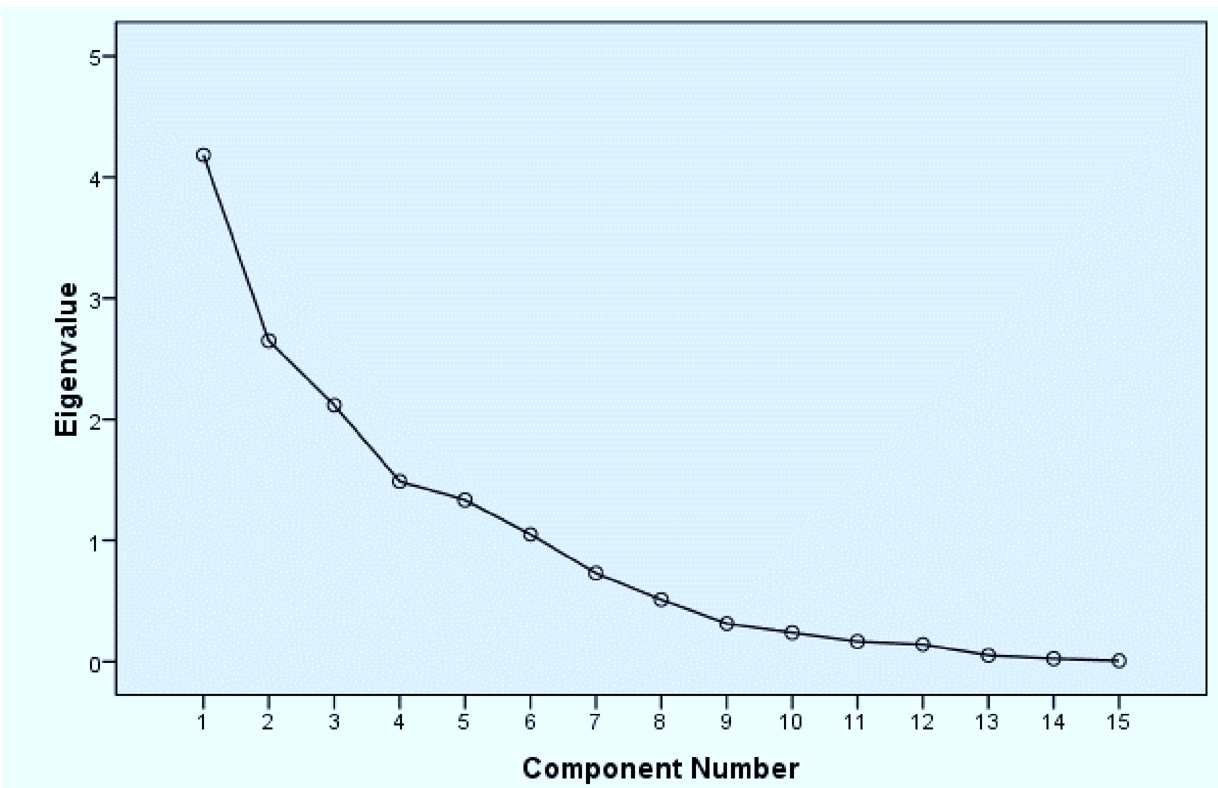

Figure 6.2 : Scree plot for PCs

Table 6.14 : The Component loading matrix and 4 PCs extracted

Rotated Component Matrix[a]

	Component			
	1	2	3	4
WD	.482	.603	.091	-.256
WF	-.123	.504	-.292	-.465
pH	-.122	.435	-.267	.750
Tur	-.039	.899	-.160	-.052
TDS	.938	-.046	-.133	.038
TSS	.590	-.234	.052	.572
DO	-.802	-.042	-.319	.128
BOD	.334	-.064	.792	.009
OG	-.004	.556	.379	.111
Cl	.659	.397	-.475	-.156
Nit	.180	.815	-.125	.189
FRich	-.267	-.016	.786	.046
FAb	.677	.336	-.279	-.283
Zoop	-.148	-.139	.509	.465
PhytP	-.258	.047	.271	.499

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 14 iterations.

6.7. Regression modelling for Ganges dolphin 'Hot Spot' identification

It was evident that prey base along with the water depth, turbidity, TDS, Cl, DO and Nitrate were determining factors for the presence of the Ganges dolphins. The regression model was run with those parameters and the model fit was highly significant (**Table 6.15**). The coefficients (**Table 6.16**) were taken to build a linear regressing model as **Formula 5**. The data predicted from the formula were then analyzed to model Gangetic River Dolphin abundance in the geo-spatial domain. The major congregations, field observations as well as predicted, were then mapped to extract the 'Hot Spots' of dolphin presence.

The model fit was also re-confirmed through residual plot (**Figure 6.3**.). The plot show that the residuals were evenly distributed along the regression line.

Table 6.15 : The model fit of predicting the Dolphin Abundance

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.865[a]	.749	.603	.16344	.749	5.115	7	12	.007	1.050

a. Predictors: (Constant), FAb, Nit, DO, WD, Tur, Cl, TDS

b. Dependent Variable: DEC

Table 6.16 : Coefficients to predict Dolphin Abundance

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.083	2.312		.036	.972
	WD	.027	.338	.017	.080	.937
	Tur	1.168	.444	.744	2.628	.022
	TDS	-.420	.540	-.256	-.778	.452
	DO	1.070	1.601	.169	.668	.517
	Cl	.138	.305	.143	.452	.660
	Nit	-.608	.164	-.914	-3.706	.003
	FAb	-.092	.083	-.288	-1.116	.286

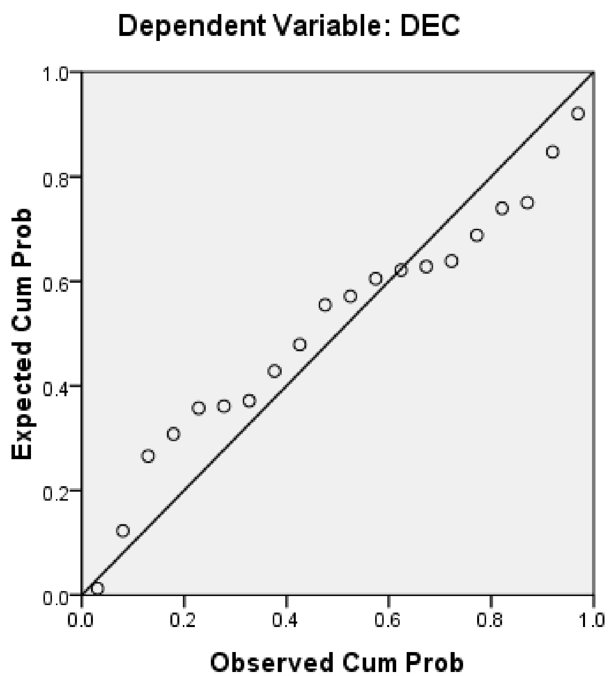

Figure 6.3. Residual plot

Dolphin observation rate = 0.08 + 0.03 x (Water depth) + 1.17 x (Turbidity) – 0.42 x (TDS) + 1.1 x (DO) + 0.14 x (Cl) – 0.61 x(Nitrate) – 0.09 x (Fish abundance) ………… Formula 5

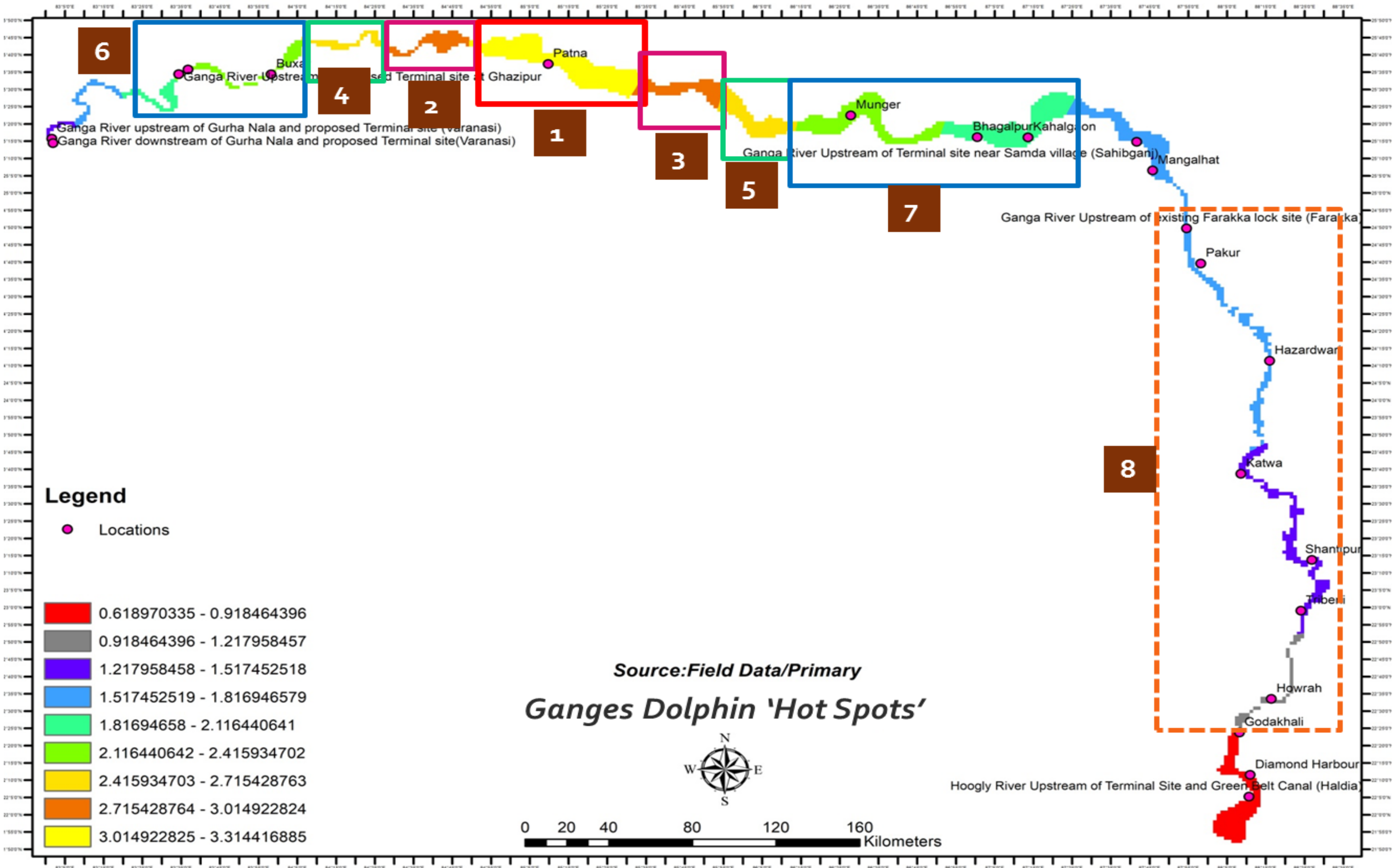

Figure 6.4: The 'Hot Spots' for the Ganges river dolphins

As the data generated from the regression habitat modeling were plotted in the GIS domain, the resulting map distinctively indicated the dolphin abundance in the NW-1 (**Figure 6.3**). The identified '**Hot Spots'** are described in the following table (**Table 6.17**).

Table 6.17 : Description of the Ganges dolphin 'Hot Spots'

Sl. No.	Hot Spots	Description	Dolphin abundance
1	Hot Spot 1	D/d Chhapra to Raghopur, including Patna	Exceptionally good abundance with encounters of more than 3 dolphins in 1 km. Best location in and around Patna.
2	Hot Spot 2	D/s Madhubani to Chhapra	Exceptionally good abundance with encounters of 2-3 dolphins in 1 km.
3	Hot Spot 3	D/s Raghopur to Barh	Incredibly good abundance with encounters of 2-3 dolphins in 1 km.
4	Hot Spot 4	D/s Buxar to Madhubani	Good abundance with encounters of more than 2 dolphins in 1 km.
5	Hot Spot 5	D/s Barh to Begusarai	Good abundance with encounters of more than 2 dolphins in 1 km.
6	Hot Spot 6	D/s Ghazipur to Buxar	Fair abundance with encounters of 1-2 dolphins in 1 km.
7	Hot Spot 7	D/s Begusarai to Barari	Fair abundance with encounters of 1-2 dolphins in 1 km.
8	Hot Spot 8	Farakka to Godkhali	Almost 1 dolphin per km, however this stretch of the river has confined population. Thus, important for the Hooghly river, a major distributary of the Ganga.

A socio-economic assessment of the local fishermen and other community along the NW-1 was also carried to have an overview of the socio-economic status of the community people. It was also found the dependency of the local people on the resources of the river. However, the assessment cannot be correlated with dolphin conservation and any livelihood intervention for the local community is beyond the scope of IWAI. Although the assessment report has been attached as Annexure I. Furthermore, continuous monitoring is required on the economic dependency of the local community on the Ganga and only after 2-3 years of continuous study any correlation with river dolphins may be found out.

CHAPTER 7. LEGISLATIVE BACKGROUND

7.1. Introduction

The **Ganga river**, as lifeline to one-third of the country's population, needs careful and well strategized management and governance. Apart from providing freshwater to its entire basin, approximately 26.3% of India's total area, Ganga also provides livelihood opportunities and economic benefits to the people residing along its banks. Any disturbance in the Ganga owing to anthropogenic impacts and developments will therefore lead to the disruption in the lives and livelihoods for these people. The river also harbors significant populations of aquatic fauna which are of international and national conservation significance, such as the Gangetic river dolphin. Therefore, any development should take into consideration the legislations imposed by the Govt. of India (GOI), for the protection and conservation of the Ganga river and its aquatic wildlife.

7.2. Current Legislation background

The GOI has imposed restrictions on the development of inland & water areas through detailed legislative frameworks for the conservation of these areas. Key legislations include:

1. ***Wildlife (Protection) Act, 1972***
2. ***Environmental Protection Act, 1986***
3. ***Water Act, 1974***

According to the Wildlife (Protection) Act, 1972, several Protected Areas (PAs) have been notified that imposes restrictions or even ban of activities without following a defined clearance process going up to the Supreme Court level. Such areas have been considered as "**No Go Areas"** wherever applicable along the river.

Legislations relevant to the protection and conservation of the Ganga river and for clearance of any development related activity along the river are listed in **Table 7.1.**

Table 7.1 : Key Environmental Legislation at a glance

Legislation	Requirement	Applicability	Controlling Authorities
Environment Protection Act-1986 and Rules 1987-2006 various	To protect and improve overall environment.	Applicable throughout as navigation vessels will disrupt natural environment.	MoEF&CC
Environment Notification, 2006 and amendments	To protect the environment from the impacts of new, modernized and expansion projects listed in schedule 1 of EIA report, 2006	Applicable as modernized vessels will result in the disruption of natural regime, necessitating environment clearances for large vessels.	MoEF&CC/SEIAA

Wildlife (Protection) Act, 1972	To protect wildlife and through the notification of Protected Areas, and buffer areas around these zones 1. National Parks 2. Wildlife Sanctuary 3. Community Reserve 4. Conservation Reserve.	Applicable, as project passes through the Vikramshila Gangetic River Dolphin Sanctuary (VGDS) Bhagalpur, Bihar. VGDS was designated as a PA in 1991 for the protection of Gangetic river dolphins.	Bihar Forest Department and MoEF&CC
Water (Prevention and Control of Pollution) Act, 1974	To control and prevent water pollution.	Applicable as navigation vessels may pollute the river through oil spills, routine shipping, run-offs and dumping. Resulting in destruction of habitats of Gangetic river dolphins and other aquatic fauna.	SPCB
Noise Pollution (Regulation and Control Act) 2000 and amendment till date	Standards for noise for day and night have been promulgated by the MoEF&CC for various land uses.	Applicable as navigation vessels will produce noise which may interfere with the echolocation of Gangetic river dolphins.	SPCB/MoEF&CC
Prevention of Collision on National Waterways Regulations, 2002	Regard to precautions required by the ordinary practice of navigation of large vessels in inland waters.	Applicable as the project is pertaining to the NW-1, where navigation vessels will operate. Collisions in the river will result in large damage to the natural environment and to its aquatic wildlife including Gangetic river dolphins.	IWAI
National Waterways, Safety of Navigation and Shipping Regulations, 2002	Ensuring safety of navigation and shipping on national waterways.	Applicable as the project is pertaining to the NW-1, where navigation vessels will operate.	IWAI
The National Waterway Act, 2016	Provision for regulation and development national waterways for the purpose of shipping and navigation and for the matters connected therewith or incidental thereto.	Applicable for the operationalization of NW-1 on the Ganga river.	IWAI

7.3. Existing Management Status

At present, the stretch of the Ganga river falls within the route of NW-1 and has only one Protected Area, i.e., **Vikramshila Gangetic Dolphin Sanctuary (VGDS**) in Bhagalpur Bihar. This 50 km stretch is strictly protected under the Wildlife (Protection) Act as a Wildlife Sanctuary and also corresponds to **Category IV of the IUCN-WCMC Protected Area**. A part of the **Sundarbans** is also covered within NW-1 which is a **Biosphere Reserve**, protected under the mandate of the **Man and Biosphere (MAB) program of UNESCO**. The rest of the stretch does not come under the jurisdiction of any legislation, although they should be conserved and protected under the mandate of State forest departments, Pollution Control Boards, IWAI and MOEF&CC. The existing legislation, although detailed, has not been implemented critically to reflect the limitations and restrictions imposed by these legislations. In addition, The entire stretch is being managed by the **National Mission For Clean Ganga Under Its *NAMAMI GANGA* Program Of The GOI**, through pollution mitigation and prevention measures such as diversion and source reduction of municipal sewage, management of solid waste and religious offerings through the construction of Sewage Treatment Plants (STPs), skewers and waste segregation.

CHAPTER 8. AQUATIC WILDLIFE PROTECTION PLAN FOR NW-1FOR ACTIVITIES SUCH AS DREDGING AND NAVIGATIONAND RECOMMENDATIONS

8.1. Introduction

Based on our field studies **359** number of dolphins were sighted in between the stretch of Ganga River on Varanasi and Farakka. As there was no continued survey, only sighted quantities can be provided. However, as per the encounter rate it can be said that **1.7 dolphins per km** were sighted. The highest number was observed at **Patna – 81.0** and **no dolphins** were observed at **Hoogly River Upstream of Terminal Site and Green Belt Canal (Haldia)**. However, we take it as a conservative estimate of Dolphins in the Ganga River.

As per appearances of the dolphins, their breeding grounds and their larger groups in the NW-1, **8 hotspots** were identified. These hotspots are crucial habitat for not only the dolphins, but also other aquatic fauna. Since the Gangetic dolphins are indicators of health of rivers, their presence stipulates presence of substantial amount of fishes and other related species too.

After commissioning of the NW-1, large vessels have started to navigate the channel from Varanasi to Haldia. As already discussed, the vessel movement, the produced thereof and dredging activities will have some impact on the aquatic species of the River Ganga. It may also have acute and long-term impacts on the river ecosystem, as well. The aim should focus in reduction of impacts through pre-emptive measures. Thus, action plan has been proposed in the following section, for the aquatic wildlife protection. The action plan consists of **Hotspot-Wise Threat Identification and Mitigation Plan**.

8.2. Aquatic wildlife protection plan for NW-1 for activities such as dredging and navigation

At present, the stretch of the river Ganga falls within the route of NW-1 and has only one Protected Area, i.e., **Vikramshila Gangetic Dolphin Sanctuary (VGDS)** in Bhagalpur Bihar. This 50 km stretch covering the VGDS is strictly protected under the Wildlife (Protection) Act as a Wildlife Sanctuary, which also corresponds to **Category IV of the IUCN-WCMC** Protected Area. The rest of the stretch does not come under the jurisdiction of any legislation. The entire stretch is also being managed by the **National Mission for Clean Ganga under its *NAMAMI GANGE* program of the GOI**, through pollution mitigation and prevention measures. For other hot-spots, WPA will not be applicable. However, **since we are dealing with Schedule 1 species here, precautionary measure shall be followed**. **Speed of the vessels may not be changed as of now, as there is no data support to assess response change in the existing speed**.

Table 8.1 : Aquatic wildlife protection plan for NW-1 for activities such as dredging and navigation

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
Vessel traffic and effect on dolphins	Movement of large vessels in deeper section of the river which is critical for dolphin habitat	Highly likely	All, especially at narrow stretches of the river such as Hot Spots 4, 6 & 8.	• The deeper sections of the river are used by dolphins as their navigation channel for their daily activities. These areas will also be used by vessels. • During lean flow months, if the channel is narrow with a narrower deep-water section, the numbers of vessel movements may be restricted at any point in time. • There should not be to-and-fro traffic in these locations at a time. • In high dolphin sitting areas traffic congestions may be strictly avoided.	• According to vessel movement frequency, the gap between vessels may be calculated and a substantial buffer time may be allotted in between moving vessels. • Sonar-based equipment that can identify locations of dolphin groups may be deployed in the NW-1 at strategic locations as early-warning system. The dolphin locations and their congregations may be communicated only to the Captain of the incoming vessel to get a prior information and act accordingly. The information may also be communicated to the control room where vessel traffic is managed. • The information shall in secrecy to few concerned authorities to avoid poaching of the animals. • Complying with existing rules under the purview of IWPA, 1972 for Wildlife Sanctuary like Vikramshila Gangetic Dolphin Sanctuary. No compromise should be done in the same. Approval is required
	River traffic congestion and interference with dolphin movement	Highly likely, however inference cannot be drawn in terms of available information	Especially at high dolphin abundance stretches of the river such as Hot Spots 1, 2, 3 & 8.		

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
					for dredging and vessel movement.
	River traffic congestion and interference with fish abundance	Likely, however inference cannot be drawn in terms of available information	All	• River traffic shall be controlled in fish breeding and spawning grounds in the Hot Spots like 1, 3, 4, 7 & 8.The river confluences like near Chhapra, Maner, Patna, Kahalgaon areas may be designated as "Sensitive Zones" and vessel traffic may be regulated. • Dredging shall be avoided in such locations.	• Precautionary measures may be adopted like control of any spillage from vessels in such locations. • River training workshops and programmes should be carried out at the bank locations which are prone to erosion to minimize sedimentation & impact on water quality and aquatic organisms. • Support for promoting fish productivity through setting up or supporting existing fish nurseries should be done. Training and awareness programmes through reputed institutes or experts like CIFRI should be given for better fishing practices.

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
	Accidental mortality due to vessel collision	Unknown, however may occur when vessel traffic increases in narrow river stretches during lean flow seasons like summer and winter.	All	• Pinging devices (*Pingers emit pulsed, high frequency signals that alert animals to gear in the water column. Cetaceans may use echolocation to investigate the pinger sound source and avoid the gear, or they may simply be startled by the sound and avoid the area*) that act as deterrent device may be tested in the field. The evasive/repellent devises emitting noise at higher frequency of the dolphin clicks (65 kHz) may be installed in the vessels and responses of dolphins may be observed in various seasons and at different locations through parameters like encounter rate and proximity assessment.	• Sonar-based equipment that can identify locations of dolphin groups may be deployed in the NW-1 at strategic locations as early-warning system. The dolphin locations and their congregations may be communicated only to the Captain of the incoming vessel to get a prior information and act accordingly. The information may also be communicated to the control room where vessel traffic in managed. • Forest Departments may be informed about the schedule of the vessel movement so that response teams may be deployed beforehand. • A detailed study of at least 1 year to determine correlation between vessel speed and proximity of dolphins may be carried out during the full operationalization of NW-1. This will generate information about the speed limit of vessels at Dolphin Hot Spots as well as in Sanctuary area.

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
	Accidental mortality due to propeller collision	Unknown, however may occur when vessel traffic increases and dolphins are confined to certain sections of the river due to lean flow.	All	• In case of any accidental injury/mortality Forest Departments may be informed about the schedule of the vessel movement so that response teams may be deployed beforehand.	• Propeller guards should be installed in all vessels. Their effectiveness may be tested in docked scenario with dummies before active field usage. • Ducted propellers should be tested for their thrust generation power at various RPMs and best design may be adopted. • An enclosed design of propeller that delivers higher thrust and higher thrust efficiency could offer savings in vessel fuel consumption. Vessel owners would also want ease of maintenance and repair should they choose to switch to an enclosed propeller. • A design that includes roller bearings between rotating rim and stationary duct could offer greater structural strength in the stern area, perhaps requiring a lighter weight of drive shaft to transmit power from engine to propeller. The design of the vessel stern area would need to prevent large aquatic fauna like dolphins and turtles in the Ganga from encountering the propeller.

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
Effect of underwater noise generation	Underwater noise generated can interfere with dolphin communication/navigation and incidental collision with vessel may occur	Highly likely	All, especially at narrow stretches of the river such as Hot Spots 4, 6 & 8.	• Noise reduction measures shall be installed to reduce engine noise and other vessel noises, which will help in minimizing the noise generation from barge movement and will minimize masking of communication signals generated by dolphins (Sugimatsu et al., 2011).	• Based on single vessel movement, impact has been found limited and does not warrant speed reduction. However, *2-years continuous monitoring* after the start of full vessel movement of dolphin sighting in the NW-1 route at the dolphin hot-spots along with behavioral study. • The study shall include, monitoring of encounter rate of dolphins at the time of vessel movement, proximity analysis and under-water noise. • Budgetary Provision of supporting foreseeable Studies for conservation of Dolphin and other sensitive studies shall be made.
	Underwater noise generated can interfere with dolphin communication and may have evasive behavior by dolphins and they may leave such areas	Unknown, however incidental evidences suggest likeliness.	In dolphin-rich Hot Spots		• A detailed study of dolphin behavior changes due to vessel movement, noise and other factors should be done for at least 2 years at various seasons to attain predictive models on dolphin behavior. The detailed study will help in national level policy formulation on the regulation and restriction of vessel.

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
					movement in waterways throughout India. • Modern vessel- better technology vessels or with retrofits with quieting techniques to reduce further the noise generation (specifically cavitation's noise).
	Underwater noise generated can interfere with other aquatic species such as turtles and fish	Likely, however detailed study is needed.	Especially at high dolphin abundance stretches of the river such as Hot Spots 1, 2, 3 & 8.	• Weekly fish abundance data (Catch per unit effort, CPUE) may be collected at heavy traffic sites for at least three months in pre-monsoon to assess the effects on fish population and disturbance in breeding sites.	• A year-round study on the sitting of turtles, during their breeding season from February-June and again during October to January should be be carried out. • This information with respect to vessel traffic, frequency and noise level can be modelled to deduce behavioral change if any. • The information will also help in generating guidelines for vessel movement in rivers with high biodiversity.
Pollution from vessel movement	Oil spill from vessel may pollute water.	Highly likely	All	• For major spillage, in order to avoid oil pollution and crew loss, SOPEP/SMPEP	• Crew of the vessel carrying especially oil should be competent and experienced so as they can prevent the

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
				procedures are to be followed and mainly: • Stop cargo, bunkering, all cargo/fuel transfer operations and internal transfer. • Advice immediately berth operators and terminal authorities. • For minor oil spread during regular operations of vessels, Leakage source must be identified and mitigation and repair actions to be implemented immediately.	accidents to happen as much as possible • Regular maintenance of vessels engine and Propellers. • River training works should be carried out at the bank locations which are prone to erosion to minimize sedimentation & impact on water quality and aquatic organisms.
	Oil spill can effect phyto- and zoo-plankton community and fish abundance	Likely	All	• Immediate/quick clean-up of oil/other spills to prevent damage on aquatic organisms shall be undertaken and vessel owners should be liable for the same.	• Facilities should be made to ensure quick rescue and clean-up operations in case of accidents
	Discharge of solid or liquid waste from vessels	Likely	All	• Development of Waste Management Plans to minimize the chance of accidentally losing items overboard. • Compliance with Inland Vessels (Prevention and Control of Pollution and Protection of Inland Water) Rules,	• All vessels should follow Inland Vessels (Prevention and Control of Pollution and Protection of Inland Water) Rules, 2016/MARPOL for managing their liquid and solid waste. • No vessel should discharge the liquid and solid waste in the river.

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
				2016/MARPOL prohibitions on dumping trash and debris in the ocean. • Black Water: Compliance with MARPOL. Treat to achieve no floating solids, no discoloration of surrounding water and no residual chlorine content prior to discharge. • Material having potential to generate the dust like coal, sandstone aggregates should be transported under covered conditions to minimize dust generation and its settlement on river surface.	• All waste shall be discharged at vessel repair facility only. • IWAI should develop the stringent norms to be followed by vessel operators and shall develop the system of penalizing based on polluters pay principle in case the standards are not met or violated.
	Discharge of Deck drainage and Bilge water and change in water quality	Highly likely	All	• Compliance with The Environmental (Protection) Act, 1986, Schedule VI - 'General standards for discharge of environmental pollutants: Part A: Effluents' to treat oily water and discharge limit is 10 mg/l max.	• Oily deck drainage should be treated with absorbents or collected by a pollution pan for recycling and/or disposal.
	Discharge of Produced water and change in water quality	Highly likely	All	• Compliance with The Environmental (Protection) Act, 1986, Schedule VI - 'General standards for discharge of	• Three stage produced water treatment system on FPSO (Floating Production Storage and Offloading) with

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
				environmental pollutants: Part A: Effluents' to treat oily water and discharge limit is 10 mg/l max.	continuous monitoring of oil-in-water levels and alarm/re-routing system to an off-spec tank with 24-hour storage capacity for re-treatment if required.
	Leaching of paint materials from vessels and toxicity in water	Likely	All	• --	• Usage of non-toxic and non-TBT containing anti-fouling paints for painting vessel
	Impacts on the quality of the local physical environment in the vicinity of onshore bases.	Likely	Especially at high dolphin abundance stretches of the river such as Hot Spots and Sanctuary like 1, 2, 3, 7& 8.	• Chemical and Fuels Storage • Provide appropriate secondary containment, and procedures for managing the secondary containment for chemical and fuel storage areas. • Impervious concrete surfaces will be in place at all areas of potential chemical and fuel leaks and spills, including below gauges, pumps, sumps and loading /unloading areas. • Fuelling and loading and unloading activities will be conducted by properly trained personnel according to pre-established formal procedures. • Air Quality Mitigation for	• Storage tanks and components should meet international standards, such as those of the American Petroleum Institute for structural design and integrity. • Storage tanks and components should undergo periodic inspection for corrosion and integrity and be subject to regular maintenance. • Spill control and response plans should be developed in consultation with concerned authority. • Minimization of VOC emissions from fuel storage and transfer activities by means of equipment selection and adoption of management practices (eg. tank and piping leak detection and repair programs) should be done. • Regular patrol and inspections

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
				Combustion Sources • Support vessels will shut down main engines when docked in Terminal.	should be carried out to monitor the activities in waterway. Regular monitoring of environmental attributes as proposed in environment planning plan should be carried out for the waterway to keep track of the condition of the environmental attributes.
Dredging and environmental impact	Dredging can have long-term effect on the alteration of river course where large tributaries like Gomti, Gandak, Ghaghra, Kosi, Sone joins.	Highly likely	Especially at high dolphin abundance stretches of the river such as Hot Spots 1, 2, 3, 4 & 6.	• The spill limit has to be assessed before the start of dredging works. • Monitoring of overflow to calculate the spill. • Hindcast modeling of all dredging operations based on actual dredging records. • Daily water sampling at fixed stations. • Online measurements at two locations to derive TSS levels and current flow conditions. • Current and TSS transects at three stages of the project to produce details of the spatial extent of the sediment plume for model calibration. • Meetings shall be organized regularly to discuss the evolution of	• Design measures like bandalling and design of groin should be considered that can reduce the dredging requirement and help in meeting depth, width and steerage needs and reduces dredging requirement. • The disposal of dredging material should be managed to reduce siltation in rainy season. It should also be considered that, the dredge material shall not affect the bank characteristics and the existing soil chemistry of the adjoining area. • Complying with existing rules under the purview of IWPA, 1972 for Wildlife Sanctuary like Vikramshila Gangetic Dolphin Sanctuary should be followed. No compromise should be done that regard. Approval is required for
	Dredging can have acute effect on water quality in the downstream	Highly likely	Especially at high dolphin abundance stretches of the river such as Hot Spots 1, 2, 3, 4 & 6.		
	Dredging activity can intensely change fish community structure and reoccurrence may take time.	Likely, however detailed study is needed.	All		
	Disposal of dredging materials on the shore may increase siltation during rainy season.	Highly likely	Especially at river confluence and high dolphin abundance stretches of the		

	Threats	Incidence likeliness	Specific Hot Spot	Mitigation measures	Precautionary measures
			river such as Hot Spots 1, 2, 3, 4 & 6.	the project and also visits to the dredger, these visits included different stakeholders as the Department of Environment, The Department of Irrigation and Department of Forest and others. The main idea of the reports and meetings was to present a clear status of the situation and the approach.	dredging and vessel movement. • A detailed study is needed in the pre-monsoon season, which is also the fish breeding season, for assessing the effects of the dredging activities on the fish fauna.

Apart from the specific steps that can be adopted, here are some general precautionary measures (suggested by researchers). They have suggested following recommendations for the conservation of Gangetic Dolphins in Brahmaputra river region.

Dolphin monitoring units within the IWAI fraternity should be formed in association with local communities and management authorities in the identified important dolphin habitats. The units should be encouraged to closely monitor the dolphins and their habitats. All these units need to work together as a single dolphin conservation network through information dissemination and simultaneous actions.

A detailed study should be undertaken on the dolphin mortality due to increase in vessel movement. In areas where this problem is prevalent, proper identification of the precautionary measures such pinging devices, propeller guards are necessary.

During the rainy season, dolphins usually migrate through the tributaries of Brahmaputra River (as well as in various other tributaries of river Ganga in Indo Gangetic Plain). Steps should be taken to protect these seasonally migrating dolphins. All the tributary mouths be treated as important dolphin habitats and fishing controlled in these tributary mouths. Close monitoring of these river mouths, especially during rainy season, should be made with the help of a local dolphin monitoring groups.

Table 8.2 : Monitoring programme/Protocol to adaptively manage existing EMP by use of appropriate performance indicators

Activities	Precautionary measures	Performance indicator		
		Monitoring parameters	Timeline /responsibility	Indicators
Movement of large vessels in deeper section of the river which is critical for dolphin habitat	• According to vessel movement frequency, the gap between vessels should be calculated and a substantial buffer time may be allotted in between moving vessels. • Sonar-based equipment that can identify locations of dolphin groups may be deployed in the NW-1 at strategic locations as early-warning system. The dolphin locations and their congregations should be communicated only to the Captain of the incoming vessel to get a prior information and act accordingly. The information can also be communicated to the control room where vessel traffic in managed. • The information should be kept secret to few concerned authorities to avoid poaching of the animals. • Compliance with existing rules under the purview of IWPA, 1972 for Wildlife Sanctuary like Vikramshila Gangetic Dolphin Sanctuar should be followed. No compromise should be done in that regard. Approval will be required for dredging and vessel movement.	➢ Vessel speed ➢ Distance between two vessels ➢ Monitoring of Dolphin movement at strategic locations ➢ Dredging plan to be developed by IWAI	➢ Regular / Vessel & dredger operator / IWAI	➢ Dolphin collusion with large vessels reduced
River traffic congestion and interference with dolphin movement				
River traffic congestion and interference with fish abundance	• Precautionary measures may be adopted like control of any spillage from vessels in such locations. • River training works should be carried out at the bank locations which are prone to erosion to minimize sedimentation & impact on water quality and aquatic organisms.	➢ Monitoring of fish abundance in the identified sensitive zones ➢ Awareness module to be developed and implemented for	➢ Seasonal / independent agency/ IWAI ➢ Monthly / IWAI	➢ Prey fish abundance increased in sensitive zones ➢ Increased awareness among fishers

Activities	Precautionary measures	Performance indicator		
		Monitoring parameters	Timeline /responsibility	Indicators
	• Support for promoting fish productivity through setting up or supporting existing fish nurseries. Also providing training and awareness support through reputed institutes or experts like CIFRI for better fishing techniques	the fishers and vessel operators		and vessels operators
Accidental mortality due to vessel collision	• Sonar-based equipment that can identify locations of dolphin groups may be deployed in the NW-1 at strategic locations as early-warning system. The dolphin locations and their congregations may be communicated only to the Captain of the incoming vessel to get a prior information and act accordingly. The information may also be communicated to the control room where vessel traffic in managed. • Forest Departments may be informed about the schedule of the vessel movement so that response teams may be deployed beforehand. • A detailed study of at least 1 year to determine correlation between vessel speed and proximity of dolphins may be carried out during the full operationalization of NW-1. This will generate information about the speed limit of vessels at Dolphin Hot Spots as well as in Sanctuary area.	➢ Rescue protocol developed ➢ Rescue and rehabilitation of aquatic animal by trained experts ➢ Monitoring of the safety equipments pinging devices and sonar etc. ➢ Determine correlation between vessel speed and proximity of dolphins	➢ During accidents/ IWAI/ Forest dept. Regular/ Vessel operator/ IWAI ➢ Regular/ Vessel operator/ IWAI	➢ Decrease in accidental mortality of aquatic animals
Accidental mortality due to propeller collision	• Propeller guards shall be installed in all vessels. Their effectiveness may be tested in docked scenario with dummies before active field usage. • Ducted propellers may be tested for their thrust generation power at various RPMs and best design may be adopted. • An enclosed design of propeller that delivers	➢ Propeller guard installed and maintained	➢ Regular/ Vessel operator/ IWAI	➢ Reduced mortality rate of dolphins and increase in the area of occupancy of aquatic animal

Activities	Precautionary measures	Performance indicator		
		Monitoring parameters	Timeline /responsibility	Indicators
	higher thrust and higher thrust efficiency could offer savings in vessel fuel consumption. Vessel owners would also want ease of maintenance and repair should they choose to switch to an enclosed propeller. • A design that includes roller bearings between rotating rim and stationary duct could offer greater structural strength in the stern area, perhaps requiring a lighter weight of drive shaft to transmit power from engine to propeller. The design of the vessel stern area would need to prevent large aquatic fauna like dolphins and turtles in the Ganga from coming into contact with the propeller.			
Underwater noise generated can interfere with dolphin communication/navigation and incidental collision with vessel may occur	• Based on single vessel movement, impact is found limited and does not warrant speed reduction. However, 2-years continuous monitoring after start of full vessel movement of dolphin sighting in the NW-1 route at the dolphin hot-spots along with behavioural study. • The study shall include, monitoring of encounter rate of dolphins at the time of vessel movement, proximity analysis and under-water noise. • Budgetary Provision of supporting foreseeable Studies for conservation of Dolphin and other sensitive studies shall be made.	➢ Monitoring of vessel movement in dolphin hot spot areas ➢ Detail dolphin conservation proposal to be developed as per the action plan	➢ Regular/ Vessel operator/ IWAI ➢ One Year / IWAI/ Independent agency	➢ Dispersal of dolphins during vessel movement ➢ Detailed proposal for conservation of dolphin is developed for implementation to understand the migration pattern and lateral movement of dolphin

Activities	Precautionary measures	Performance indicator		
		Monitoring parameters	Timeline /responsibility	Indicators
Underwater noise generated can interfere with dolphin communication and may have evasive behavior by dolphins and they may leave such areas	• A detailed study of dolphin behaviour change due to vessel movement, noise and other factors may be done for at least 2 years at various seasons to attain predictive models on dolphin behavior. The detailed study will help in national level policy formulation on the regulation and restriction of vessel movement in waterways throughout India. • Modern vessel- better technology vessels or with retrofits with quieting techniques to reduce further the noise generation (specifically cavitation's noise).	Detail dolphin conservation proposal to be developed as per the action plan	➢ One Year / IWAI/ Independent agency	➢ Detailed proposal for conservation of dolphin is developed for implementation to understand the effect of change in underwater aquatic environment
Underwater noise generated can interfere with other aquatic species such as turtles and fish	• A year-round study on the sitting of turtles, during their breeding season from February-June and again during October to January may be carried out. • This information with respect to vessel traffic, frequency and noise level can be modelled to deduce behavioral change if any. • The information will also help in generating guidelines for vessel movement in rivers with high biodiversity.	Detail dolphin conservation proposal to be developed highlighting the other aquatic species also.	➢ One Year / IWAI/ Independent agency	➢ Detailed proposal for conservation of dolphin is developed for implementation
Oil spill from vessel may pollute water.	• Crew of the vessel carrying especially oil should be competent and experienced so as they can prevent the accidents to happen as much as possible	Training and awareness programmes for crew members	➢ Regular/ Vessel operator/ IWAI	➢ Increased awareness among fishers and vessels operators

Activities	Precautionary measures	Performance indicator		
		Monitoring parameters	Timeline /responsibility	Indicators
	• Regular maintenance of vessels engine and Propellers. • River training works should be carried out at the bank locations which are prone to erosion to minimize sedimentation & impact on water quality and aquatic organisms.			
Oil spill can effect phyto- and zoo-plankton community and fish abundance	• Facilities should be made to ensure quick rescue and clean-up operations in case of accidents	➢ Rescue and rehabilitation of aquatic animals ➢ Monitoring of water quality	➢ During accidents/ IWAI/ Forest dept. ➢ Regular/ Vessel operator/ IWAI ➢ Regular/ Vessel operator/ IWAI	➢ Reduced the effect on phyto- and zoo-plankton community and fish abundance for increase availability of prey base for the dolphins
Discharge of solid or liquid waste from vessels	• All vessels should follow Inland Vessels (Prevention and Control of Pollution and Protection of Inland Water) Rules, 2016 for managing their liquid and solid waste. • No vessel should discharge the liquid and solid waste in the river. • All waste shall be discharged at vessel repair facility only. • IWAI should develop the stringent norms to be followed by vessel operators and shall develop	Training and awareness programmes for crew members	➢ Regular/ Vessel operator/ IWAI	➢ Increased awareness among fishers and vessels operators

Activities	Precautionary measures	Performance indicator		
		Monitoring parameters	Timeline /responsibility	Indicators
	the system of penalizing based on polluters pay principle in case the standards are not met or violated. • Every inland vessel above 1000 Gross Tonnes shall be equipped with oily mixture treatment equipment. • Every' inland vessel shall be equipped with a holding tank or equivalent arrangement of capacity as specified in Part II of Schedule III. • Every inland port shall provide reception facilities, based on the nature of' operation taking place			
Discharge of Deck drainage and Bilge water and change in water quality	• Oily deck drainage should be treated with absorbents or collected by a pollution pan for recycling and/or disposal.	Training and awareness programmes for crew members	➢ Regular/ Vessel operator/ IWAI	➢ Increased awareness among fishers and vessels operators
Discharge of Produced water and change in water quality	• Three stage produced water treatment system on FPSO with continuous monitoring of oil-in-water levels and alarm/re-routing system to an off-spec tank with 24-hour storage capacity for re-treatment if required.	Training and awareness programmes for crew members Monitoring of water quality	➢ Regular/ Vessel operator/ IWAI	➢ Increased awareness among fishers and vessels operators
Leaching of paint materials from vessels and toxicity in water	• Usage of non-toxic and non-TBT containing anti-fouling paints for painting vessel	Monitoring of water quality	➢ Monthly /Independent agency/ IWAI	➢ Improve water quality
Impacts on the quality of the local physical environment in the vicinity of onshore bases.	• Storage tanks and components will meet international standards, such as those of the American Petroleum Institute for structural design and integrity. • Storage tanks and components will undergo	Monitoring of physical environment	➢ Monthly /Independent agency/ IWAI	➢ The quality of the local physical environment improved

Activities	Precautionary measures	Performance indicator		
		Monitoring parameters	Timeline /responsibility	Indicators
	periodic inspection for corrosion and integrity and be subject to regular maintenance. • Spill control and response plans will be developed in consultation with concerned authority. • Minimization of VOC emissions from fuel storage and transfer activities by means of equipment selection and adoption of management practices (eg. tank and piping leak detection and repair programs) should be done. • Regular patrol and inspections should be carried out to monitor the activities in waterway. Also regular monitoring of environmental attributes as proposed in environment planning plan of this should be carried out for the waterway to keep track of the condition of the environmental attributes.			
Dredging can have long-term effect on the alteration of river course where large tributaries like Gomti, Gandak, Ghaghra, Kosi, Sone joins.	• Design measures like bandalling and design of groin should be considered which can reduce the dredging requirement and help in meeting depth, width and steerage needs and reduces dredging requirement. • The disposal of dredging material should be managed to reduce siltation in rainy season. It shall also be considered that the dredge material shall not affect the bank characteristics and the existing soil chemistry of the adjoining area. • Compliance with existing rules under the purview of IWPA, 1972 for Wildlife Sanctuary like Vikramshila Gangetic Dolphin Sanctuar	Monitoring of dredged channel in the identified hot spots	➢ Monthly /Independent agency/ IWAI	➢ Improve water quality
Dredging can have acute effect on water quality in the downstream		Monitoring of water quality in dredged channel	➢ Monthly /Independent agency/ IWAI	➢ Improve water quality
Dredging activity can intensely change fish community structure and reoccurrence may				

Activities	Precautionary measures	Performance indicator		
		Monitoring parameters	Timeline /responsibility	Indicators
take time.	should be followed. No compromise should be done in that regard. Approval will be required for dredging and vessel movement. • A detailed study is required in the pre-monsoon season, which is also the fish breeding season, for assessing the effects of the dredging activities on the fish fauna.			
Disposal of dredging materials on the shore may increase siltation during rainy season.		Monitoring of dredge material	➢ Monthly /Independent agency/ IWAI	➢ Improve water quality

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ANNEXURE-I:
REPORT ON UNDERWATER SOUND LEVEL MEASUREMENT IN NW-1

PROJECT REPORT

On

UNDERWATER SOUND LEVEL MEASUREMENT IN NATIONAL WATERWAY-I

Submitted by

FITT, Indian Institute of Technology, Delhi

in collaboration with

M/s DELSIG Systems Pvt. Limited

Project Investigators

Prof. R. Bahl and Prof. Arun Kumar (CARE, IIT Delhi)

Submitted to

EQMS India Pvt. Ltd.

November, 2018

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Prof. R. Bahl Prof. Arun Kumar

CARE, IIT Delhi

CONTENTS

1. BACKGROUND

The Inland Waterways Authority of India (IWAI) have retained M/s EQMS to conduct various studies in Ganges river, declared as National Waterway-1 (NW-1). An earmarked navigation channel is proposed to be maintained as a waterway for passage of various types of shipping craft. The Ganges river is also home to India's National Aquatic Mammal the Ganges River Dolphin (*Platanista gangetica gangetica*). Underwater sound level measurements have been sought to be conducted over the band of frequencies used by the Ganges River Dolphin. In this context, EQMS have approached M/s DELSIG Systems Pvt. Ltd. and through them their collaborators at FITT, IIT Delhi who together have the specialized equipment and domain knowledge to conduct these measurements. The specific deliverables in the report are listed in the Appendix.

A team constituted by FITT, IIT Delhi and assisted by M/s DELSIG has conducted the field measurements during July and October 2018. The underwater sound level measurements have been conducted in two rounds at four field locations. In the first round, underwater sound emanating from small craft represented by an IWAI survey vessel were conducted from 13th July 2018 to 16th July 2018 at Varanasi, Patna and Sahibganj locations as indicated in the Fig. 1.

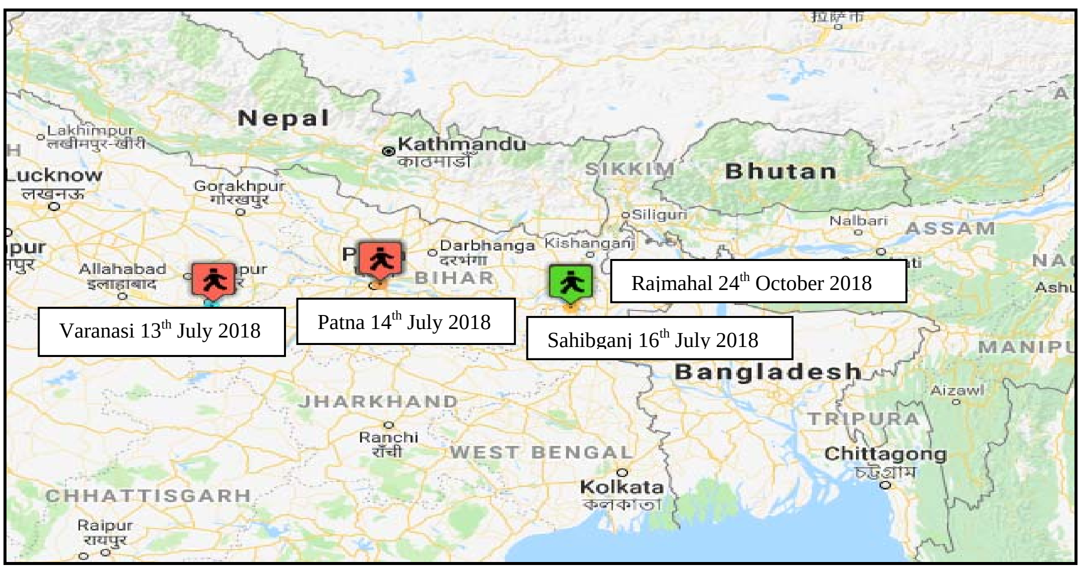


Figure 1: Ship noise estimation from 13th July to 16th July 2018 and on 24th October 2018

In the second round, the underwater noise generated by a bigger transportation vessel (with capacity of 2200 tonnes, but a lower actual tonnage of approximately of 300 to 400 tonnes at the time of measurement) has been measured at Rajmahal on 24 October 2018. The underwater noise measurement is done in the frequency range from 100Hz to 100 kHz. The underwater ambient noise in absence of navigating craft is also measured at all the above field locations.

2. UNDERWATER NOISE MEASUREMENTS AND DOLPHIN SONAR

2.1 Dolphin Source Level and Spectrum from the Literature:

The mean reported peak-to-peak source level SL_{pp} of Ganges river dolphins (*Platanista gangetica gangetica*) is 183.3 dB re 1µPa at 1m while the rms source level SL_{rms} is 173.3 dB re 1µPa at 1m [1]. The click centre frequency is approximately is 65 kHz [2], with mean -3dB bandwidth and mean -10dB bandwidth of approximately 44 kHz and 73 kHz respectively [1]. Based on these values from the literature, the frequency band from 100 Hz to 100 kHz contains the dolphin click spectrum, and is, therefore, chosen for measurements of the ship noise and ambient noise. The underwater sound level measurements for ambient and ship-generated noise are reported as rms values in dB re 1µPa which would allow comparison with Dolphin Sonar SL_{rms} mean value of 173.3 dB.

2.2 Recording Methodology and Instruments Used:

The sensor and electronics for recording the ship noise were mounted on small boats for Varanasi, Patna and Sahibganj field locations. The underwater noise recording system set-up is shown in Fig. 2. The underwater acoustic sound pressure is sensed by the hydrophone, which converts the acoustic energy into electric signal. The electric signal is then amplified in a pre-amplifier and is acquired by the data acquisition system cDAQ controlled by a Laptop and finally recorded and stored in the hard-disk for analysis. In the fourth site at Rajmahal, the IWAI survey ship was used to mount the measurement equipment to permit monitoring of the much larger transiting target ship. The monitoring boat is nominally kept 50 meters away from the channel. The ship under investigation for underwater sound is typically made to traverse a maximum of 5 km upstream and 5 km downstream in the channel. A video and photographic record of the measurement process has also been maintained.

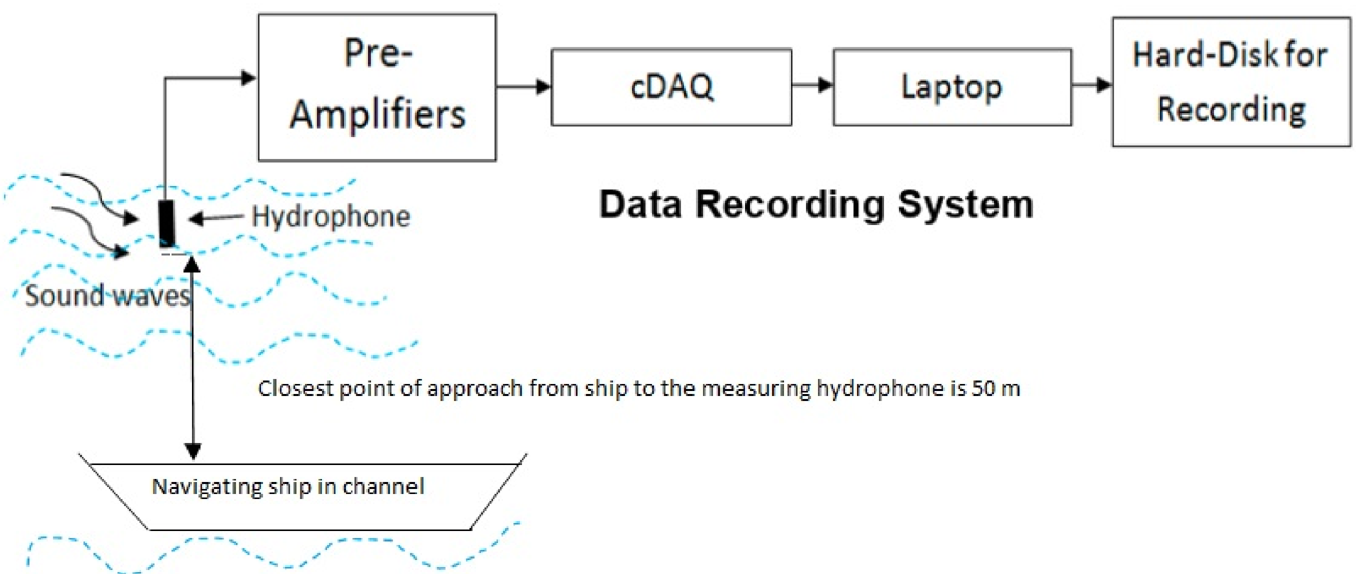


Figure 2: Underwater sound recording system (the depth of hydrophone is kept between 0.5 m to 0.7 m).

The following instruments are used for the field measurements:

a. NI CDAQ 9134 and 9223 Data Acquisition System
b. Benthowave 7001 hydrophone (typical sensitivity -198.5 dB re 1V/µPa)
c. Pre-amplifier box (typical gain 60 dB @50 kHz)
d. 1 TB external hard disk for recording the underwater sound data
e. GPS module using Arduino mega (Ublox neo-6M GPS module)
f. Laser Range Finder (Bushnell Elite 1M 202421)

The sample rate used for recording the sound data is 1 MHz.

The analysis of underwater sound is carried out on sound segments of 1 second duration. Let the signal vector under analysis be *R(t)*. In the analysis of underwater noise, first the variation of pre-amplifier gain with frequency and hydrophone sensitivity are removed in order to obtain the actual sound level in the water. Let the gain of the pre-amplifier be denoted by *G(ω)*. To compensate the effect of the pre-amplifier, the signal *R(t)* after conversion into the frequency domain is multiplied by 1/*G(ω)* over the frequency band of interest. The hydrophone response is also compensated by the sensitivity value of -198.5 dB re 1µPa. Let the underwater signal in frequency domain be denoted by *R(k),* where *k* represents the frequency bins. The effect of hydrophone sensitivity and pre-amplifier gain is removed using the equation (1).

$$S(k) = 10^{\left(198.5/20\right)} R(k)\left(\frac{1}{G(k)}\right) \quad \text{.......} \quad (1)$$

Here, *S(k)* represents the compensated acoustic pressure signal in the frequency domain at the location of the hydrophone. Next, the rms underwater sound levels are calculated from *S(k)* using equation (2) over full frequency band of interest and presented as root mean square (rms) values in dB re 1µPa.

$$E_{rms} = 10\log_{10}\left(\sum \left(\left|S(k)\right|\right)^2\right) \text{ dB} \quad \text{.......} \quad (2)$$

Where E_{rms} represents the rms value of energy in 1 second (rms sound level) over the frequency band. To calculate the rms sound level in the different frequency bands, the equation (2) is used by considering only those values of *k* which correspond to the frequency bins of interest. We have computed the rms sound levels in the following bands:

a) Full band 100Hz - 100kHz

b) 100 Hz-1 kHz

c) 1 kHz-10 kHz

d) 10 kHz-20 kHz

e) 20 kHz -30 kHz

f) 30 kHz -40 kHz

g) 40 kHz -50 kHz

h) 50 kHz -60 kHz

i) 60 kHz -70 kHz

j) 70 kHz -80 kHz

k) 80 kHz -90 kHz

l) 90 kHz -100 kHz

We manually measure the visual distance between the target ship and the observation boat by a laser range finder. The distance between their respective GPS receivers can also be calculated from GPS locations of the target ship and the observation boat/ship. This is used as an alternative measure of distance. In the observation boat the GPS locations are continuously recorded on the laptop, and in the target ship the GPS locations from the in-built GPS display is recorded using video recording on a mobile phone. The video recorded by the mobile phone also contains the echo-sounder data about the river depth and the speed of the ship in knots.

Underwater sound levels are recorded in both directions as the ship transits downstream-upstream and upstream-downstream. The variation of rms sound level in above frequency bands is plotted for various distances (ranges) of the ship from the measurement site.

2.3 Measurement of Ambient Noise:

The underwater ambient noise in absence of navigating ship is measured at all sites with all machinery switched off. The averaging of noise is done over several seconds to remove the effect of random fluctuations in order to obtain the average value of underwater ambient noise level.

2.4 Calculation of Ship Noise Source Level at 1m and Uncertainty Value:

To calculate the ship noise level at 1 meter from source, a factor of 20log10(R) is to be added in the noise obtained at a ship distance of R meters from the boat using equation (2). However, the point on the ship used to measure distance R of the ship from the boat is not the actual location from which noise emanates: it can be up to r meters away from the point on the ship which is used to measure the distance. The value of r can typically vary from 20 meters to 50 meters depending on the size of ship. So, we have added an uncertainty factor of 20log10((R+r)/R) in the calculated ship noise values in various frequency bands at 1 meter. The values of r are assumed to be 20 m in case of IWAI survey ships and 50 m in case of transport ship M.V. Beki.

3. VARANASI FIELD MEASUREMENTS (13TH JULY 2018)

3.1. Vessel Details

Name of the ship – PUNPUN
Length – 25 meters
Breadth – 5.8 meters
Depth – 2.8 meters
Gross tonnage – 92
Registered tonnage – 28
Number of Decks – 1
Number of Bulkheads – 5

Specifications of Engine

BHP/KW – 355/264.8
Number of sets of engine – 2
Number of Shafts – 2
Maximum Estimated Speed – 9.78 Knots
Number and diameter of cylinder of each set – 6 nos and 120.0 mm

3.2. Varanasi Field Measurement Photos (Scenario and Ship Movement):

The photos of scenario at Varanasi are shown in Fig. 3. The cabin of ship is shown in Fig. 4. Assembly of equipment for measurements at Varanasi is shown in Fig. 5. Figure 6 shows the actual path obtained from GPS locator and Fig. 7 shows the GPS location of the observation boat.

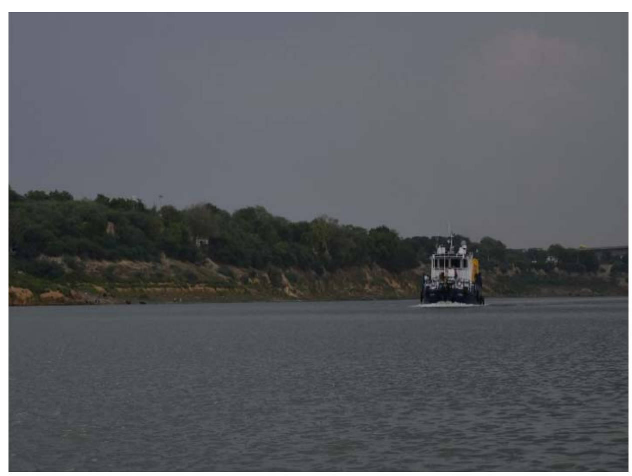


Figure 3: Scenario of field and ship travelling through its channel at Varanasi

Figure 3 (continued): Scenario of field and ship travelling through its channel at Varanasi

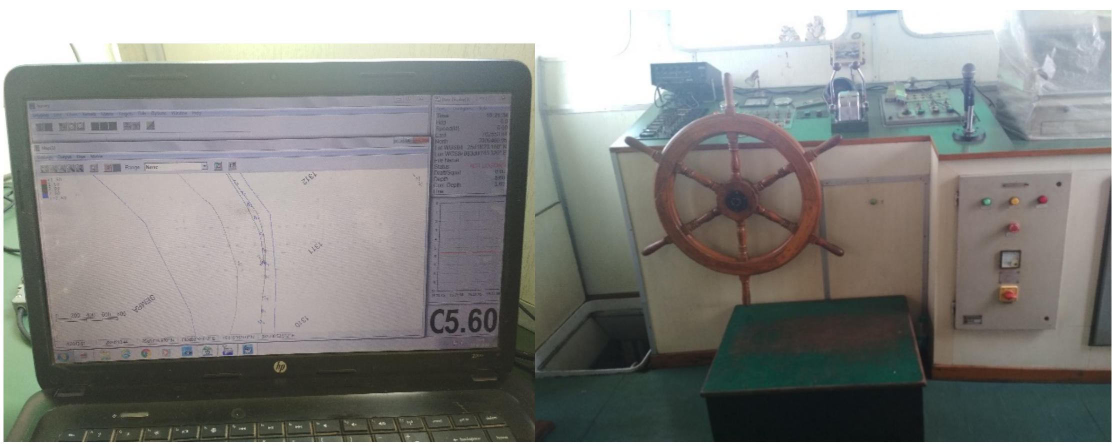


Figure 4: GPS location available on screen inside the ship cabin.

Figure 5: Assembly of equipment for measurements at Varanasi

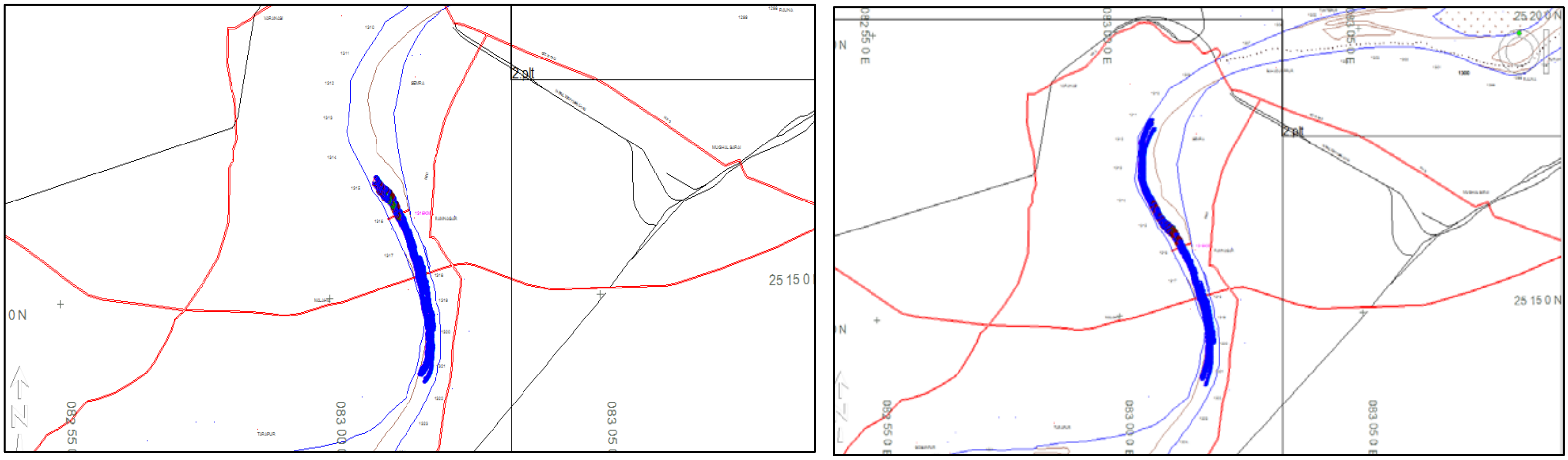


Figure 6: Ship traversing 5 kms downstream and the 5 kms upstream in the river at Varanasi

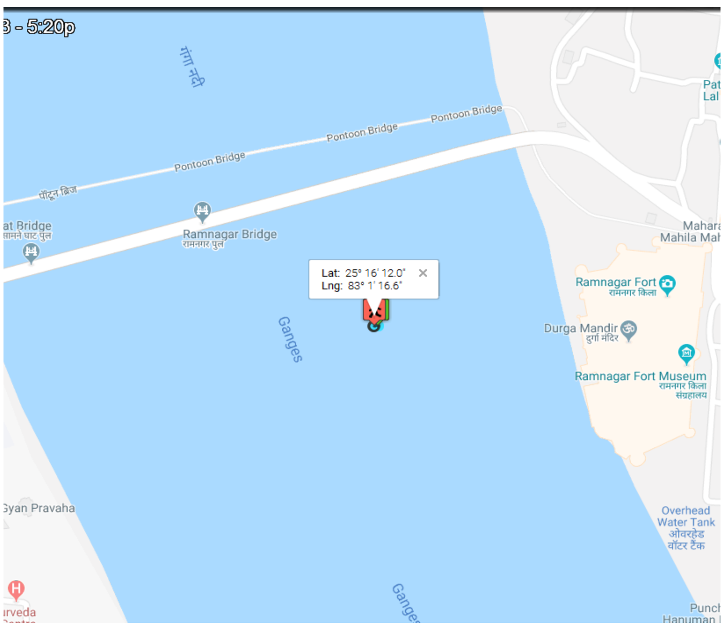


Figure 7: Location of the Receiver Boat at Varanasi

3.3. Observations and Results from Varanasi Measurements:

The measurements were done both for upstream and downstream i.e. ship moving opposite to the direction of river flow and ship moving in the direction of river flow respectively. Also the graphs are plotted. Figs. 8 to 19 are plots of noise levels in dB re 1µPa.

3.3.1. Upstream- When ship was moving opposite to the direction of river flow.

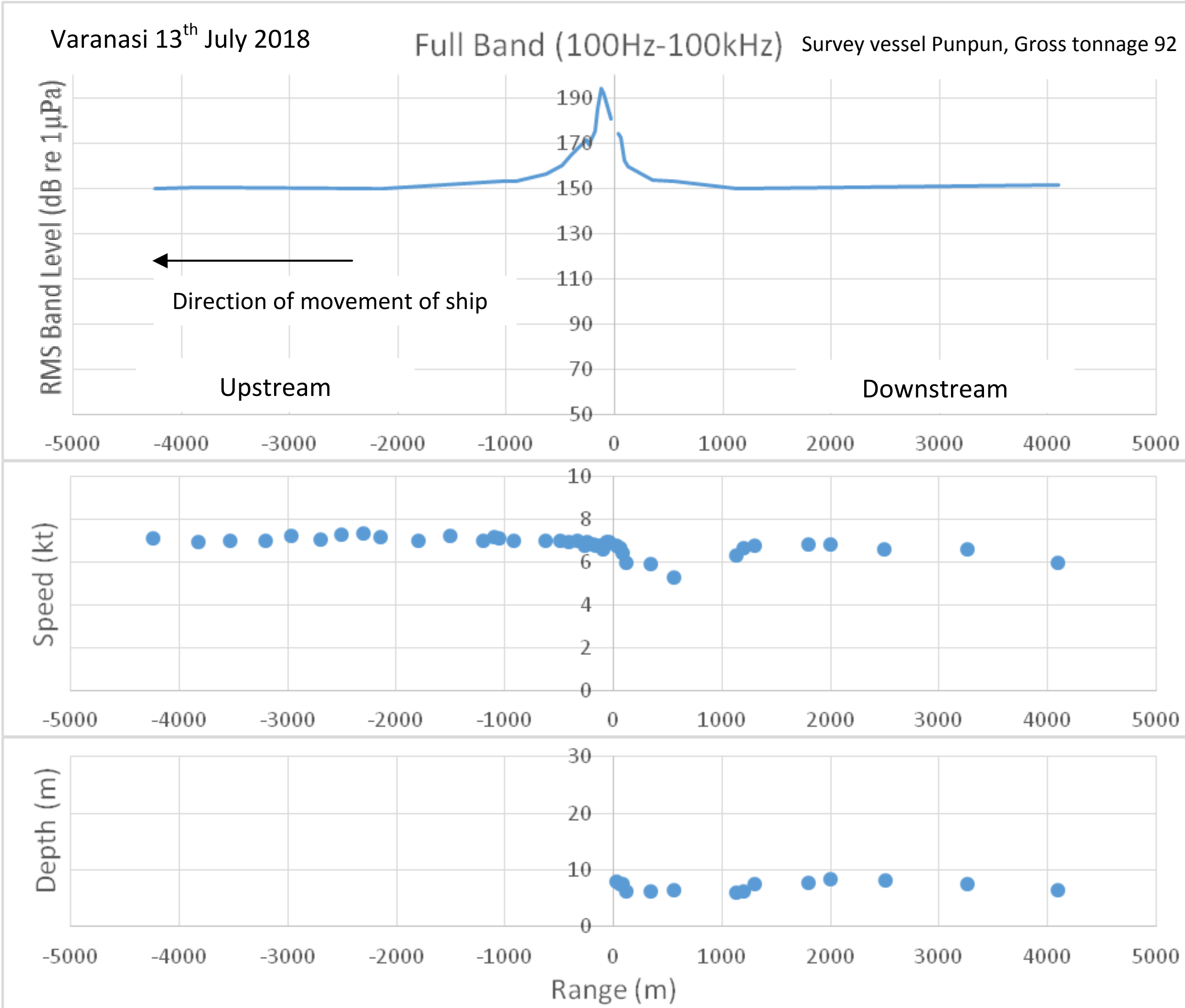
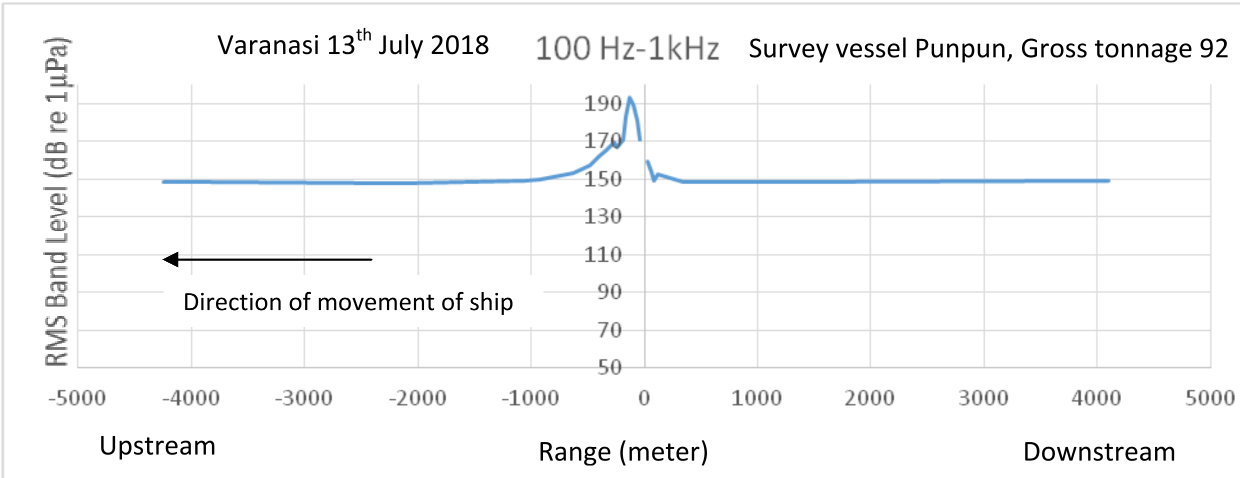
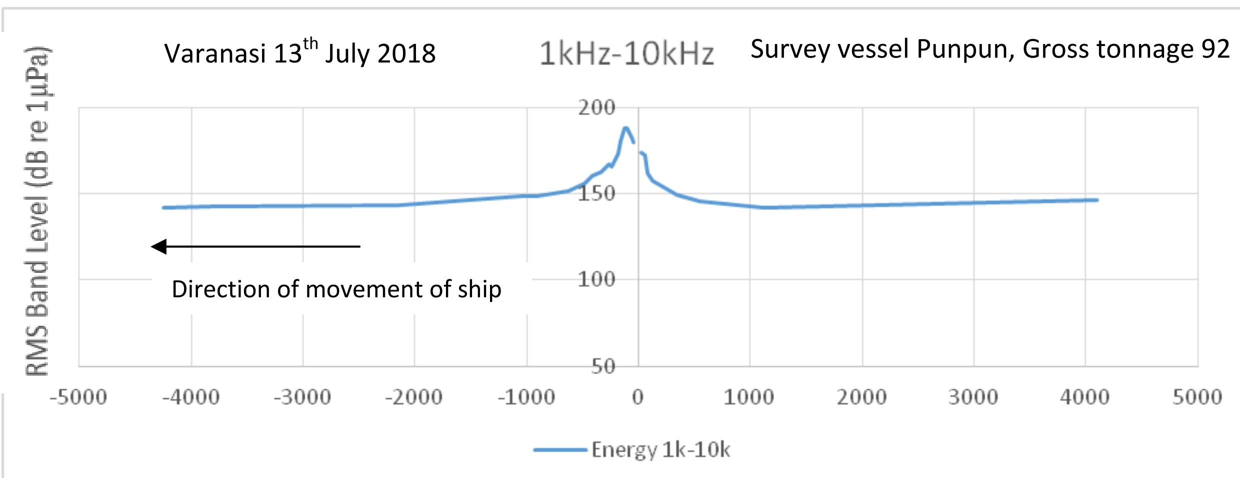


Figure 8: Upper most plot is rms Full Band Sound Level vs Range, Middle plot is Speed (in knots) vs Range and Bottom plot is Depth (in meters) vs Range at Varanasi dated 13th July 2018 with ship moving upstream



Upstream	Range (meter)	Downstream

Figure 9: rms Band level vs Range for 100 Hz-1 kHz at Varanasi dated 13th July 2018 with ship moving upstream



Upstream	Range (meter)	Downstream

Figure 10: rms Band level vs Range for 1 kHz-10 kHz at Varanasi dated 13th July 2018 with ship moving upstream

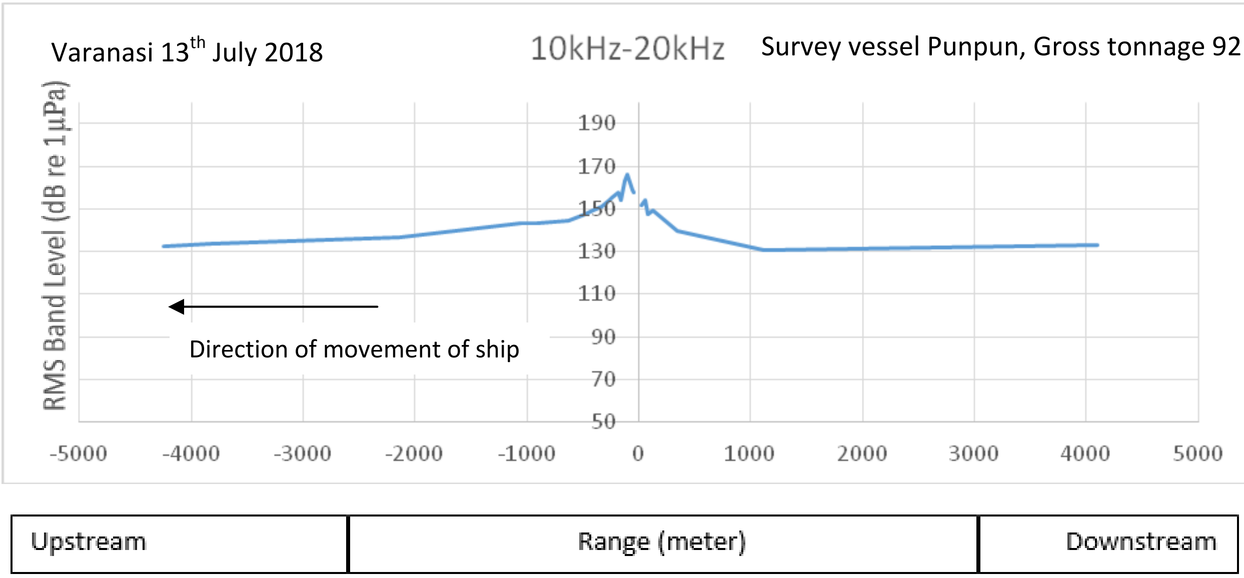


Figure 11: rms Band level vs Range for 10 kHz-20 kHz at Varanasi dated 13th July 2018 with ship moving upstream

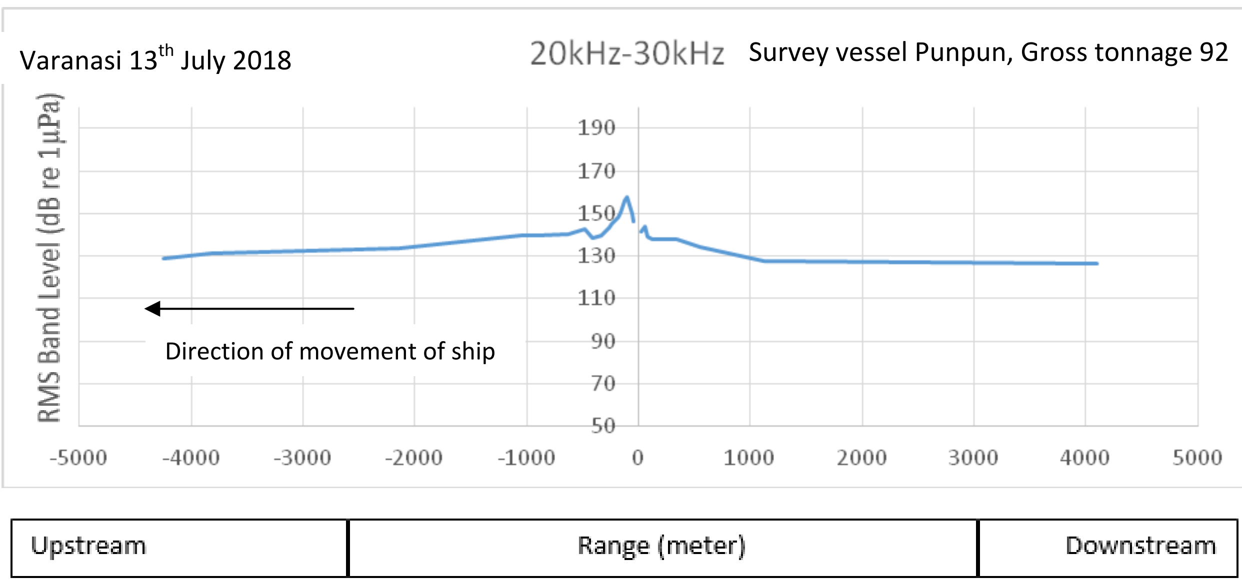
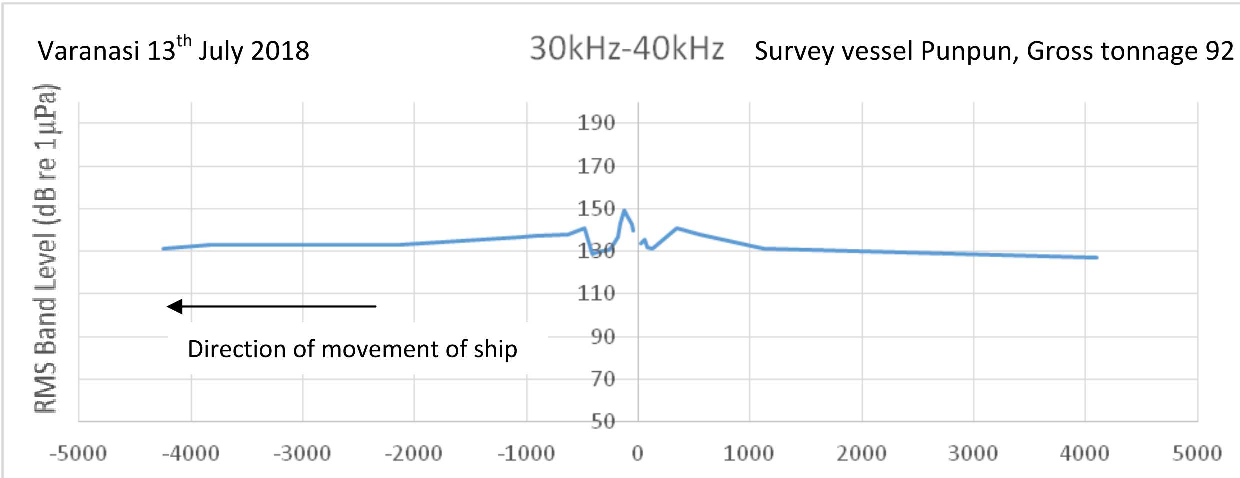
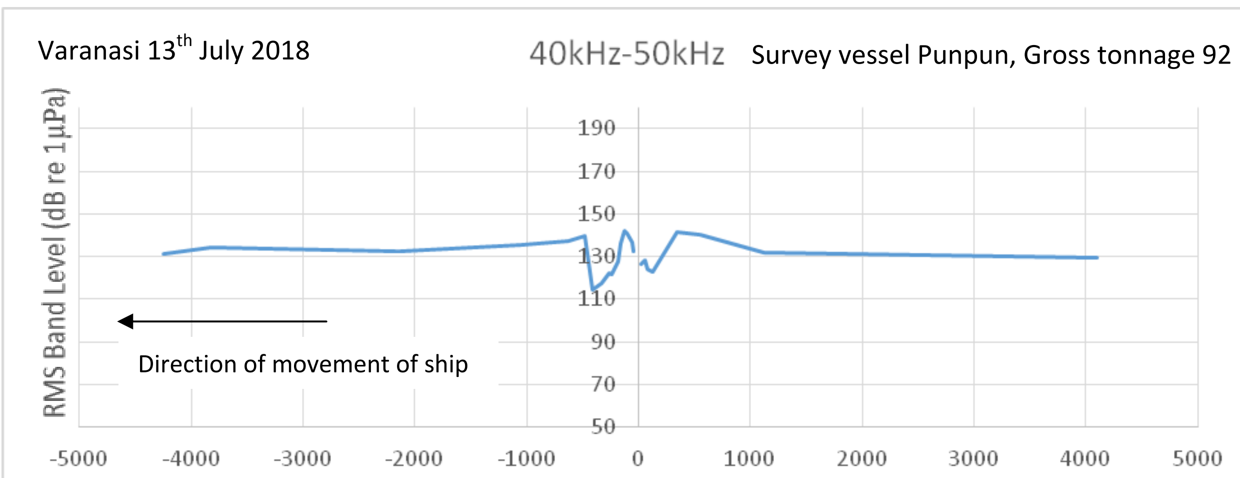


Figure 12: rms Band level vs Range for 20 kHz-30 kHz at Varanasi dated 13th July 2018 with ship moving upstream



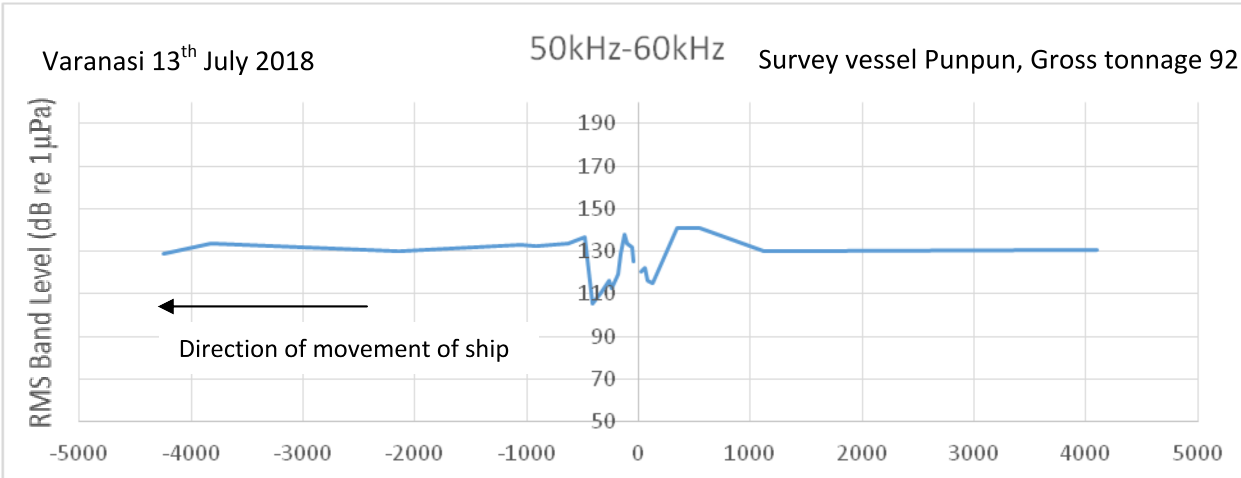
Upstream	Range (meter)	Downstream

Figure 13: rms Band level vs Range for 30 kHz-40 kHz at Varanasi dated 13th July 2018 with ship moving upstream



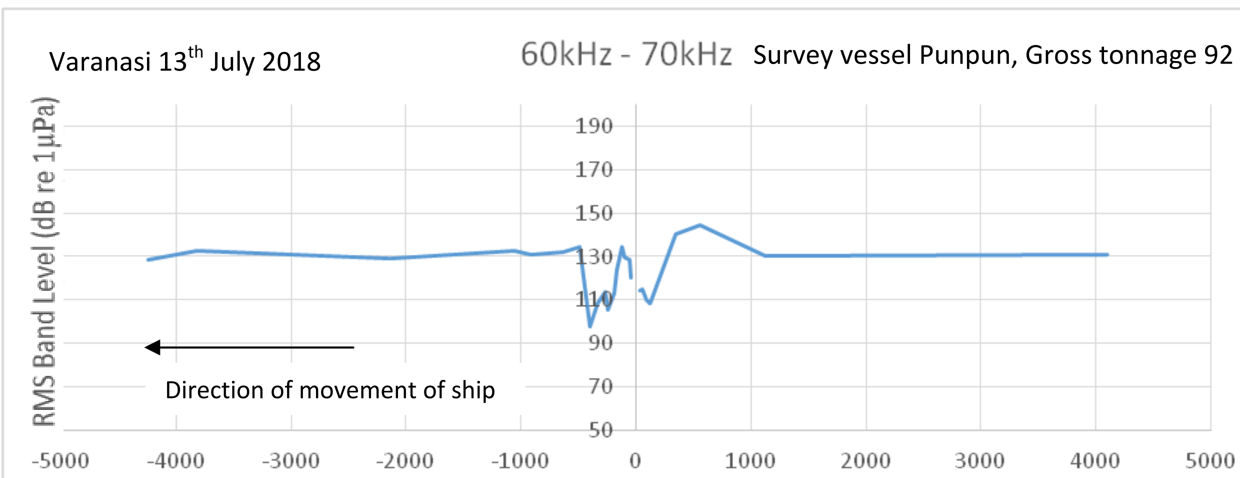
Upstream	Range (meter)	Downstream

Figure 14: rms Band level vs Range for 40 kHz-50 kHz at Varanasi dated 13th July 2018 with ship moving upstream



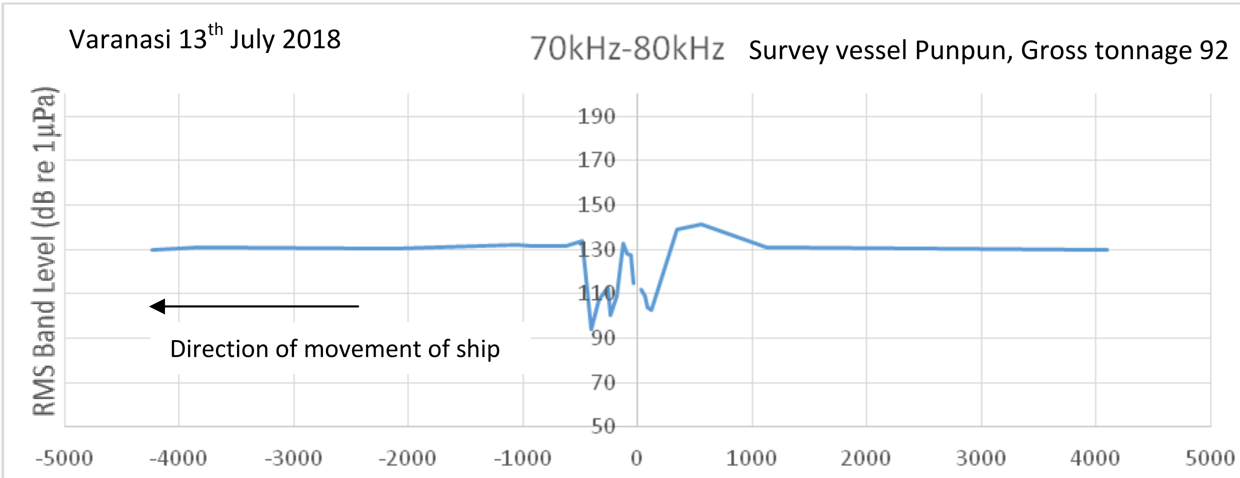
Upstream	Range (meter)	Downstream

Figure 15: rms Band level vs Range for 50 kHz-60 kHz at Varanasi dated 13th July 2018 with ship moving upstream



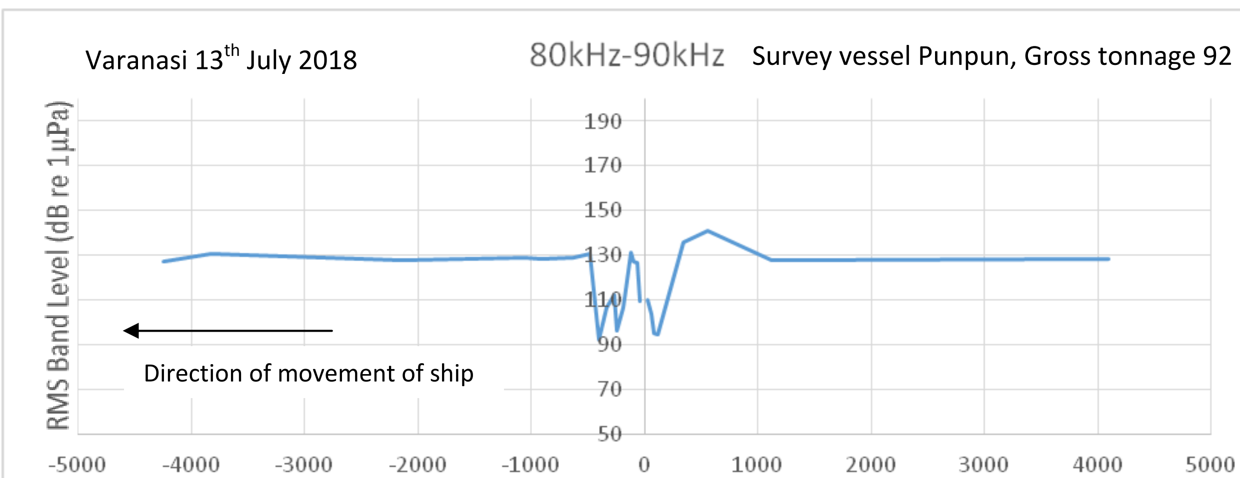
Upstream	Range (meter)	Downstream

Figure 16: rms Band level vs Range for 60 kHz-70 kHz at Varanasi dated 13th July 2018 with ship moving upstream



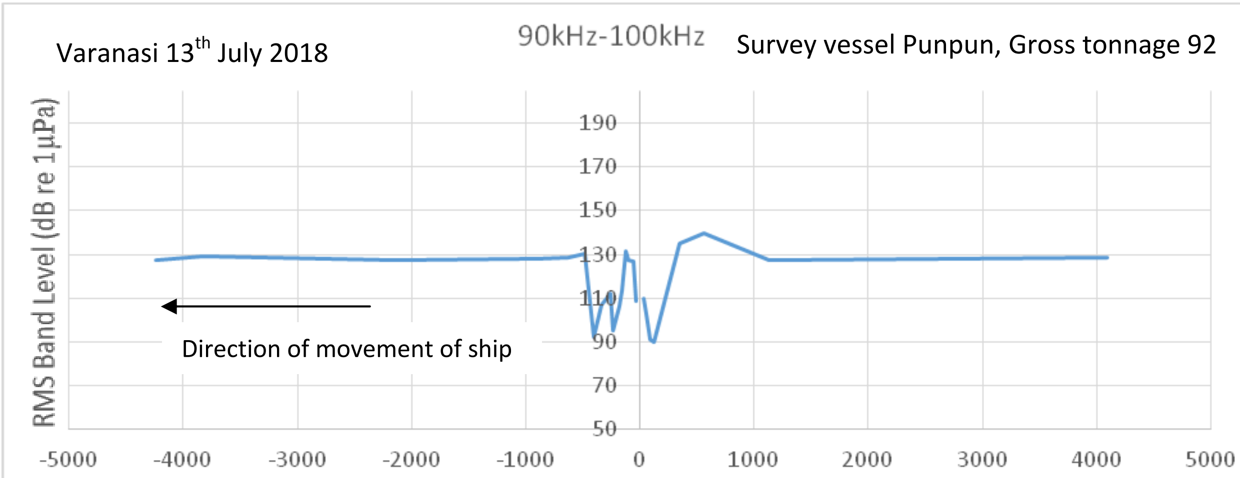
Upstream	Range (meter)	Downstream

Figure 17: rms Band level vs Range for 70 kHz-80 kHz at Varanasi dated 13th July 2018 with ship moving upstream



Upstream	Range (meter)	Downstream

Figure 18: rms Band level vs Range for 80 kHz-90 kHz at Varanasi dated 13th July 2018 with ship moving upstream.

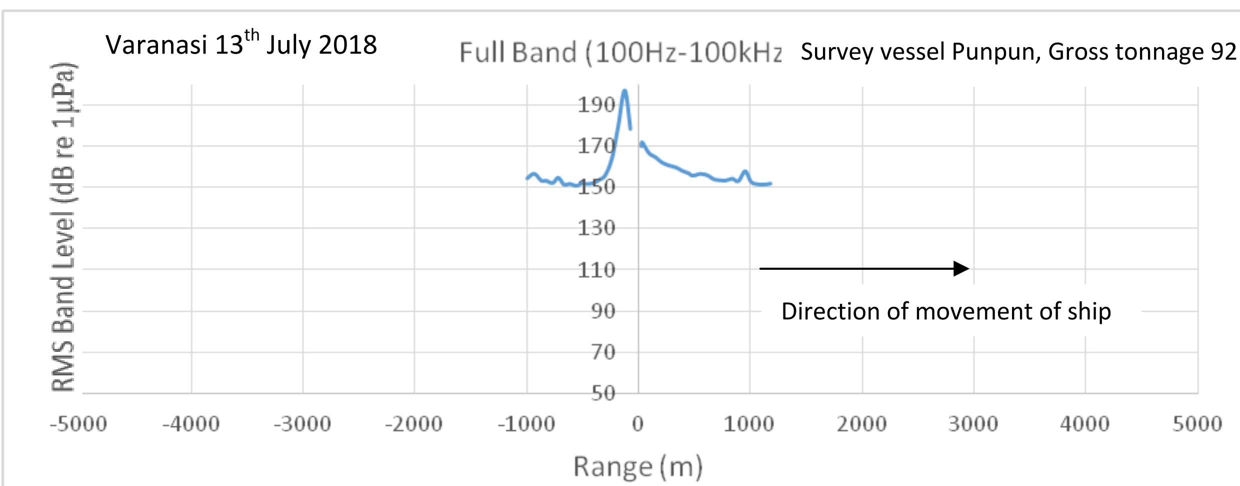


Upstream	Range (meter)	Downstream

Figure 19: rms Band level vs Range for 90 kHz-100 kHz at Varanasi dated 13th July 2018 with ship moving upstream

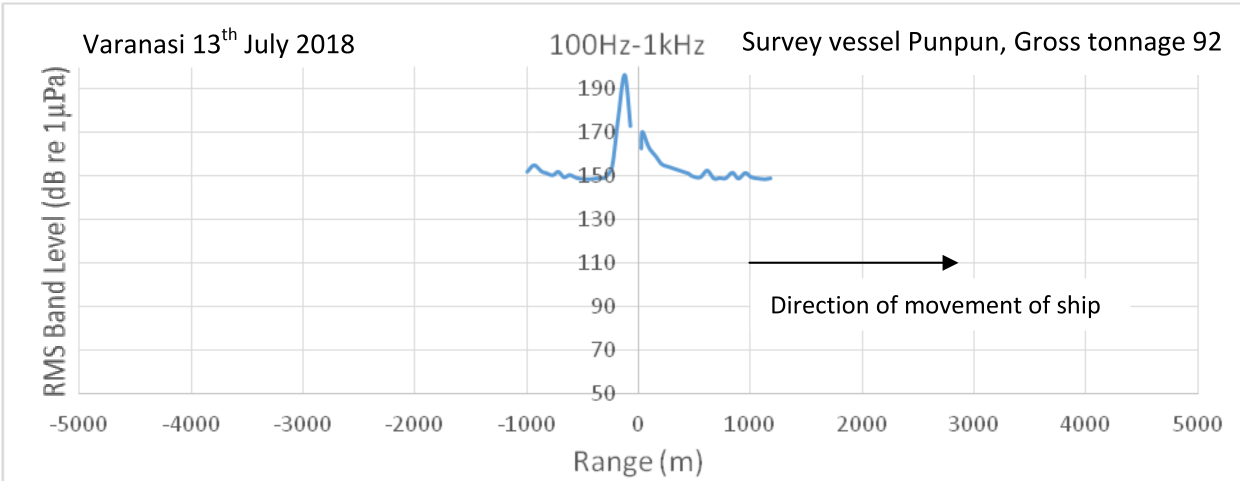
From Figure 8 we observe that depth is varying from 8-10 meters for upstream and speed is varying from 5 knots to 7 knots.

3.3.2. Downstream: The plots below are depicting the rms Band level at different ranges for various frequency bands when ship was moving in the direction of flow of river at Varanasi dated 13th July 2018.



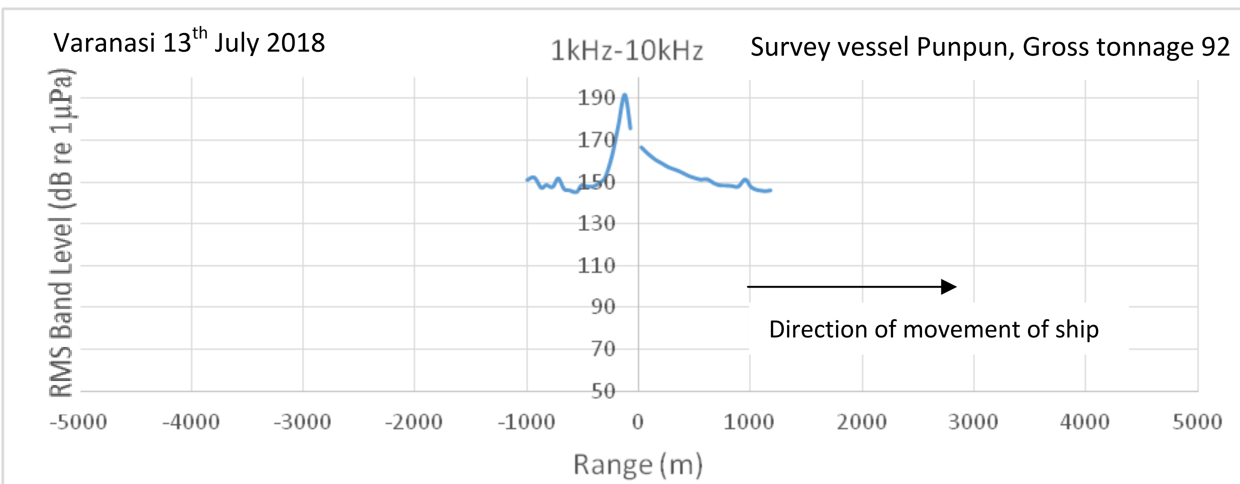
Upstream	Range (meter)	Downstream

Figure 20: rms Band level vs Range (in meters) for Full Band (100Hz-100kHz) at Varanasi dated 13th July 2018 with ship moving downstream



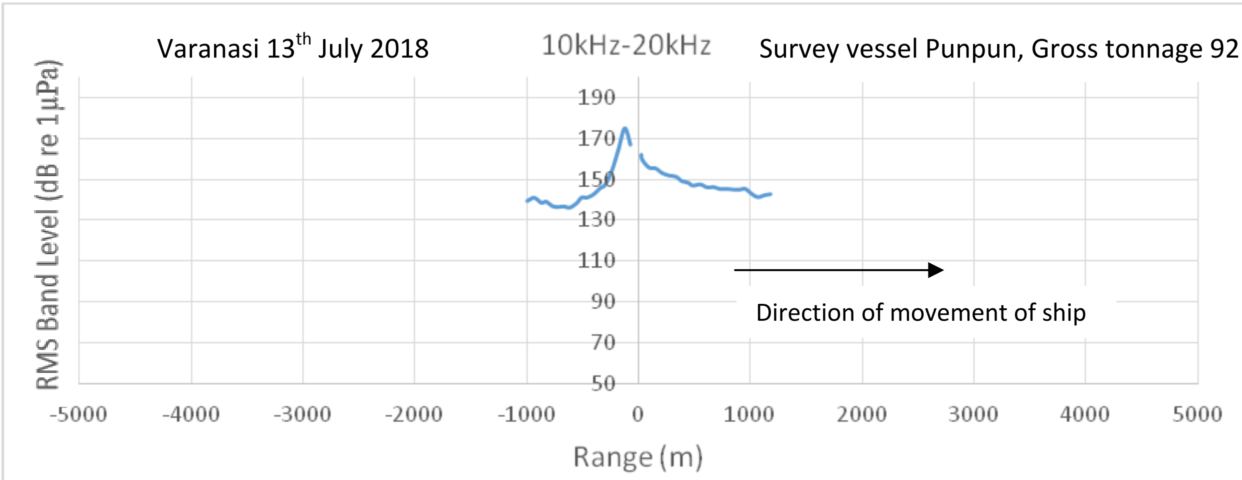
Upstream	Range (meter)	Downstream

Figure 21: rms Band level vs Range (in meters) for 100Hz-1kHz at Varanasi dated 13th July 2018 with ship moving downstream



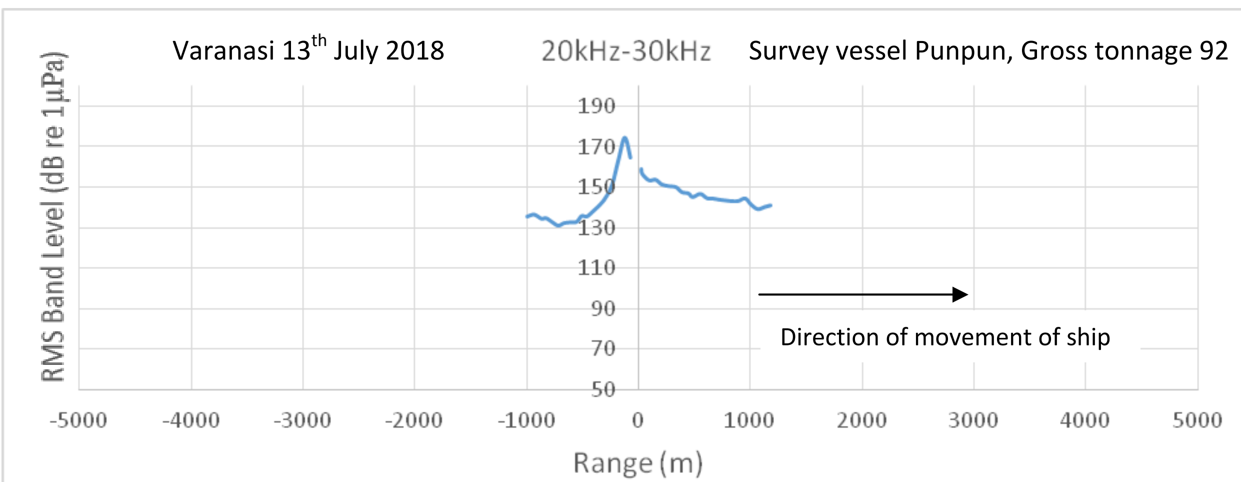
Upstream	Range (meter)	Downstream

Figure 22: rms Band level vs Range (in meters) for 1kHz-10kHz at Varanasi dated 13th July 2018 with ship moving downstream



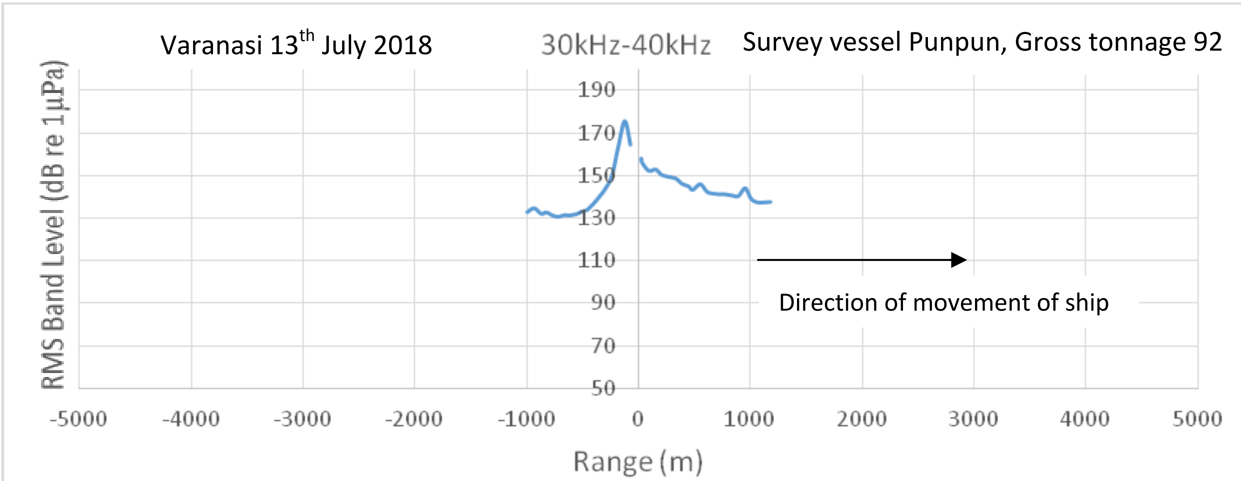
Upstream	Range (meter)	Downstream

Figure 23: rms Band level vs Range (in meters) for 10 kHz-20 kHz at Varanasi dated 13th July 2018 with ship moving downstream



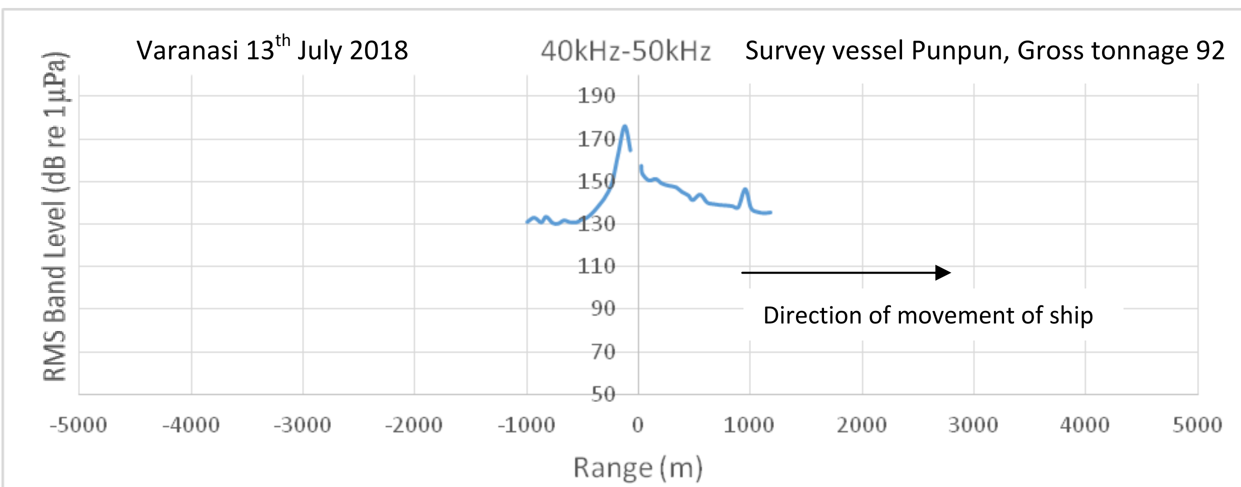
Upstream	Range (meter)	Downstream

Figure 24: rms Band level vs Range (in meters) for 20 kHz-30 kHz at Varanasi dated 13th July 2018 with ship moving downstream



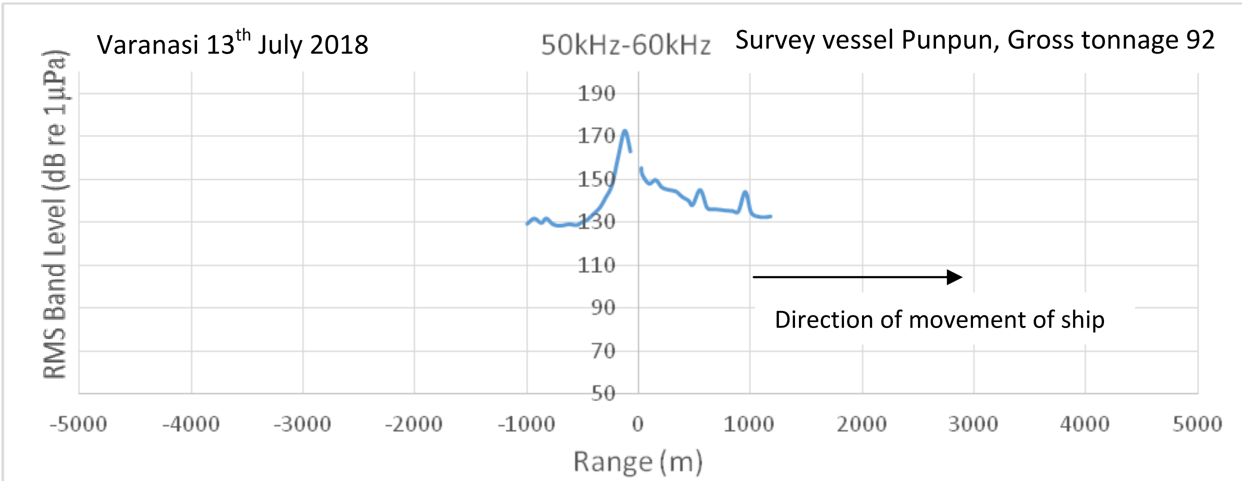
Upstream	Range (meter)	Downstream

Figure 25: rms Band level vs Range (in meters) for 30 kHz-40 kHz at Varanasi dated 13th July 2018 with ship moving downstream



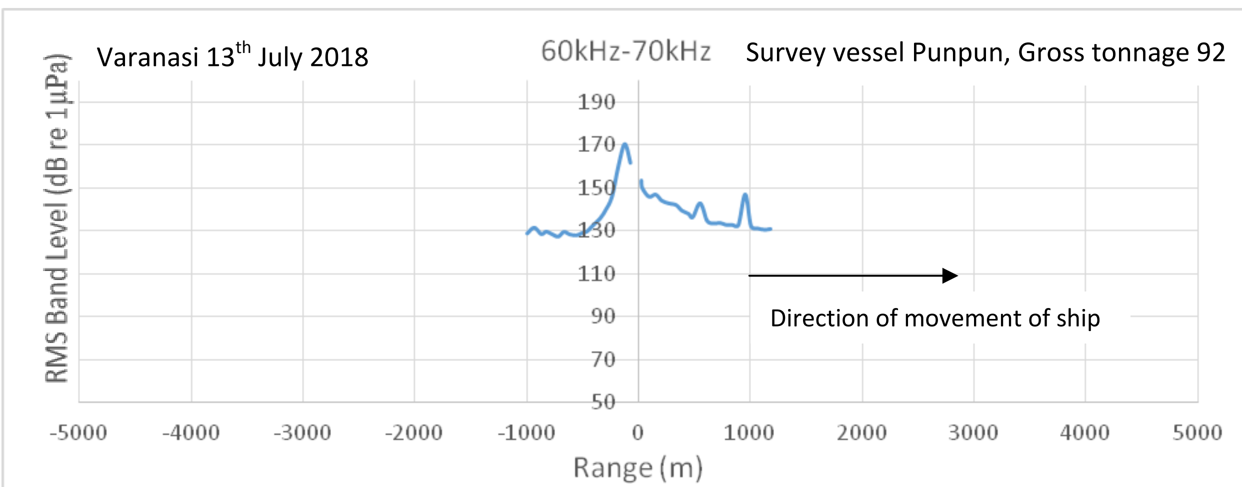
Upstream	Range (meter)	Downstream

Figure 26: rms Band level vs Range (in meters) for 40 kHz-50 kHz at Varanasi dated 13th July 2018 with ship moving downstream



Upstream	Range (meter)	Downstream

Figure 27: rms Band level vs Range (in meters) for 50 kHz-60 kHz at Varanasi dated 13th July 2018 with ship moving downstream



Upstream	Range (meter)	Downstream

Figure 28: rms Band level vs Range (in meters) for 60 kHz-70 kHz at Varanasi dated 13th July 2018 with ship moving downstream

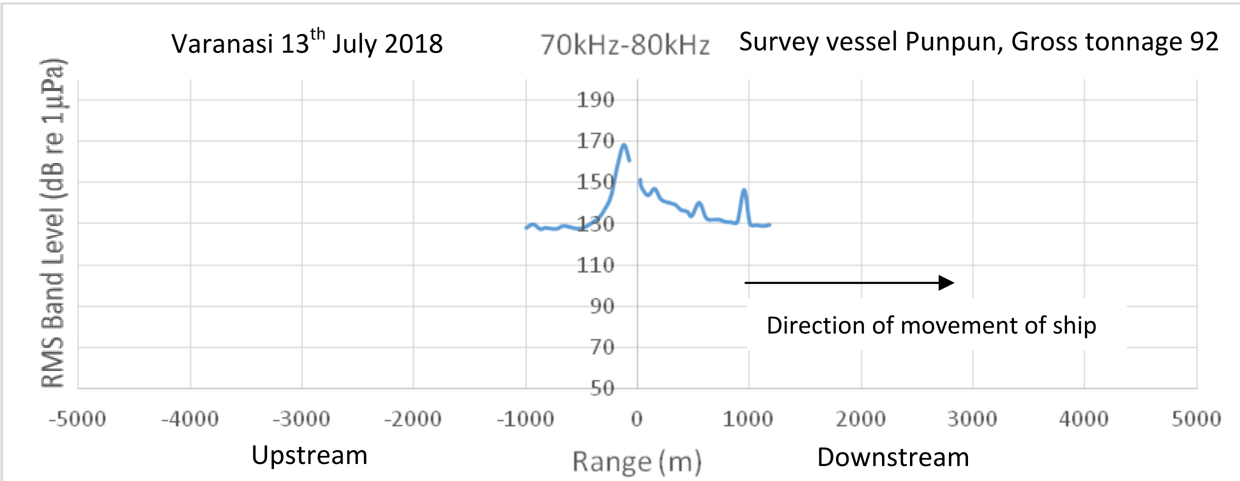


Figure 29: rms Band level vs Range (in meters) for 70 kHz-80 kHz at Varanasi dated 13th July 2018 with ship moving downstream

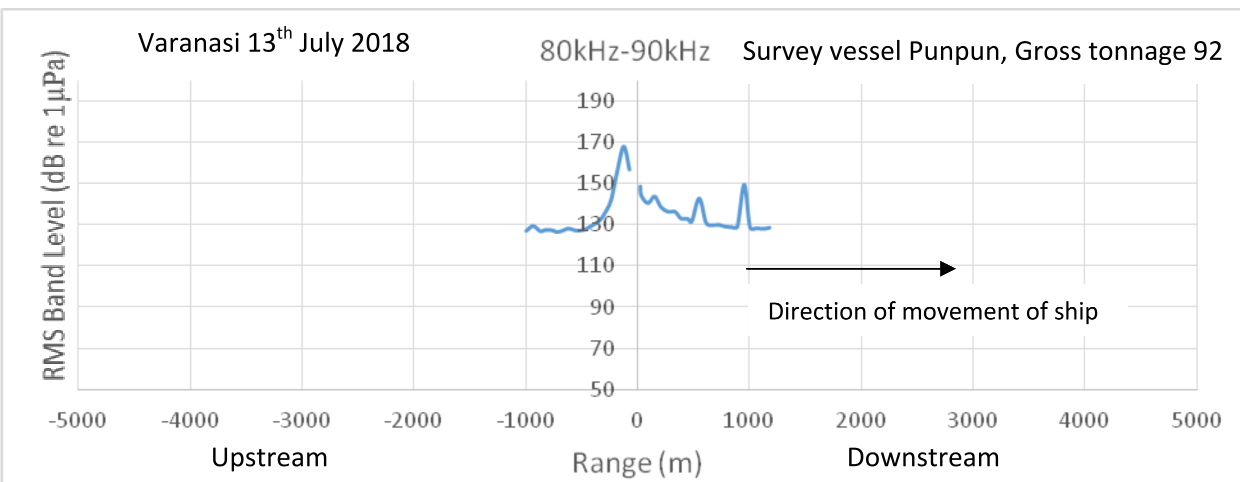


Figure 30: rms Band level vs Range (in meters) for 80 kHz-90 kHz at Varanasi dated 13th July 2018 with ship moving downstream

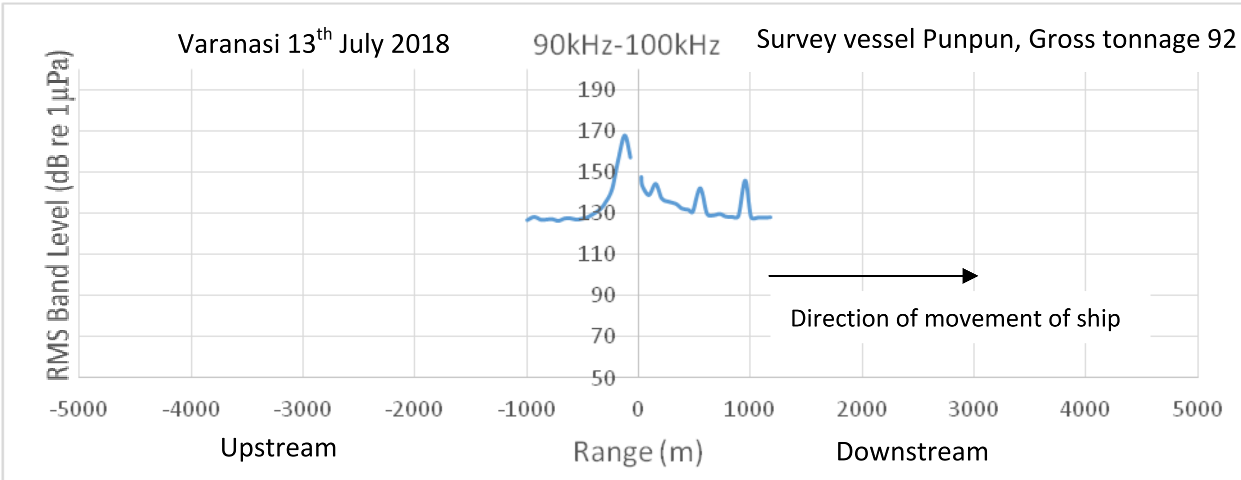


Figure 31: rms Band level vs Range (in meters) for 90 kHz-100 kHz at Varanasi dated 13th July 2018 with ship moving downstream

3.3.3. Maximum ship noise in different bands: The maximum ship noise is obtained in Varanasi when ship was at a distance of 28 meters from the boat. The rms ambient noise and the calculated maximum rms ship sound level at 1 meter in various frequency bands are shown in figure 32.

Shortest Ship distance from boat = 28 meters

Survey vessel Punpun, Gross tonnage 92

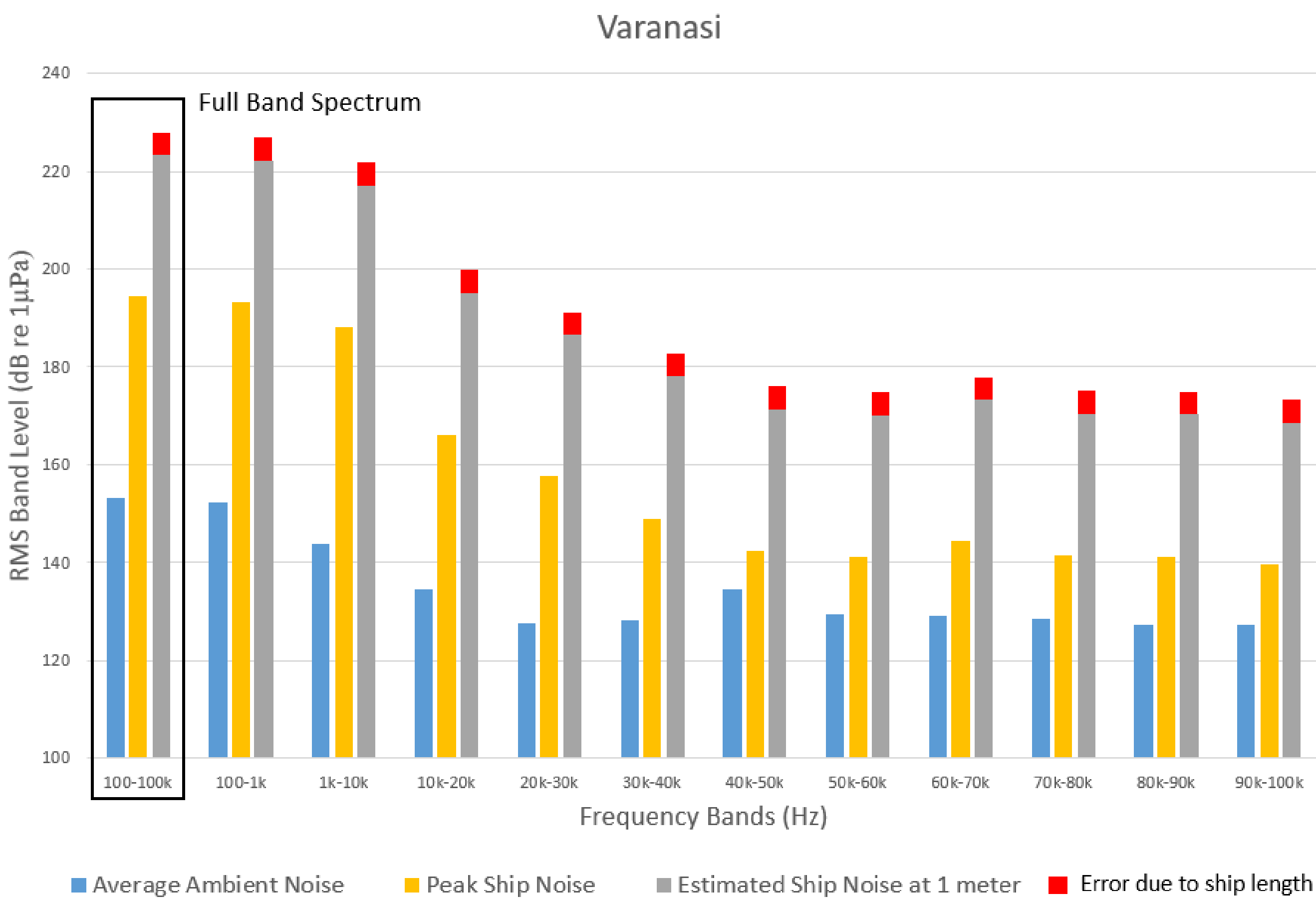


Figure 32: RMS Band level vs Frequency Bands for Varanasi (13th July 2018) for Upstream

Uncertainty in rms sound level at 1 m due to ship length is 4.681 dB re 1µPa.

4. PATNA FIELD MEASUREMENTS (14TH JULY 2018)

4.1 Specifications of Vessel

Name of the ship – KAMLA
Length – 24.55 meters
Breadth – 5.50 meters
Depth – 2.6 meters
Gross tonnage – 78
Registered tonnage – 23
Number of Decks – 1
Number of Bulkheads – 5

Specifications of Engine

BHP – 330
Number of sets of engine – 2
Number of Shafts – 2
Estimated Speed – 9.52 Knots
Number and diameter of cylinder of each set – 6 nos and 130.0 mm

4.2 Arrangements During Measurements and GPS Location

Figure 33: Assembly of equipment for the measurements at Patna

Figure 33 (continued) : Assembly of equipment for the measurements at Patna

Figure 34: Ship and other boats at Patna

Figure 34 (Continued): Ship and other boats at Patna

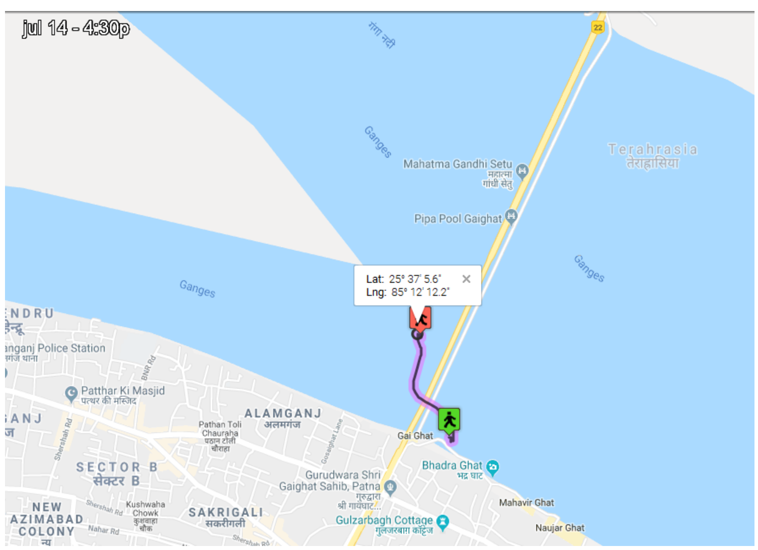


Figure 35: GPS location of Receiver Boat approx 50 meters away from the channel at Patna

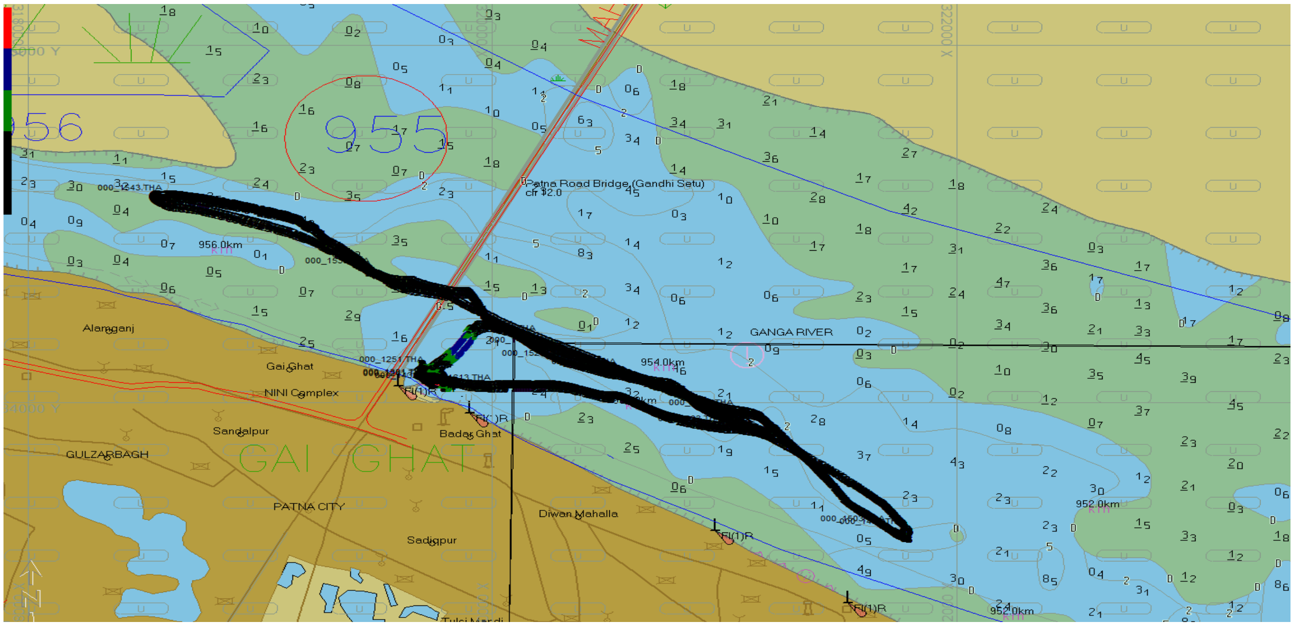


Figure 36: Ship traversal through the channel at Patna

4.3 Observations and Results from Patna Measurements

4.3.1 Upstream: Measurement of ship sound level in Patna on 14th July 2018 with ship moving opposite to the direction of flow of river. Plots of the noise versus range are given in the following figures for various frequency bands.

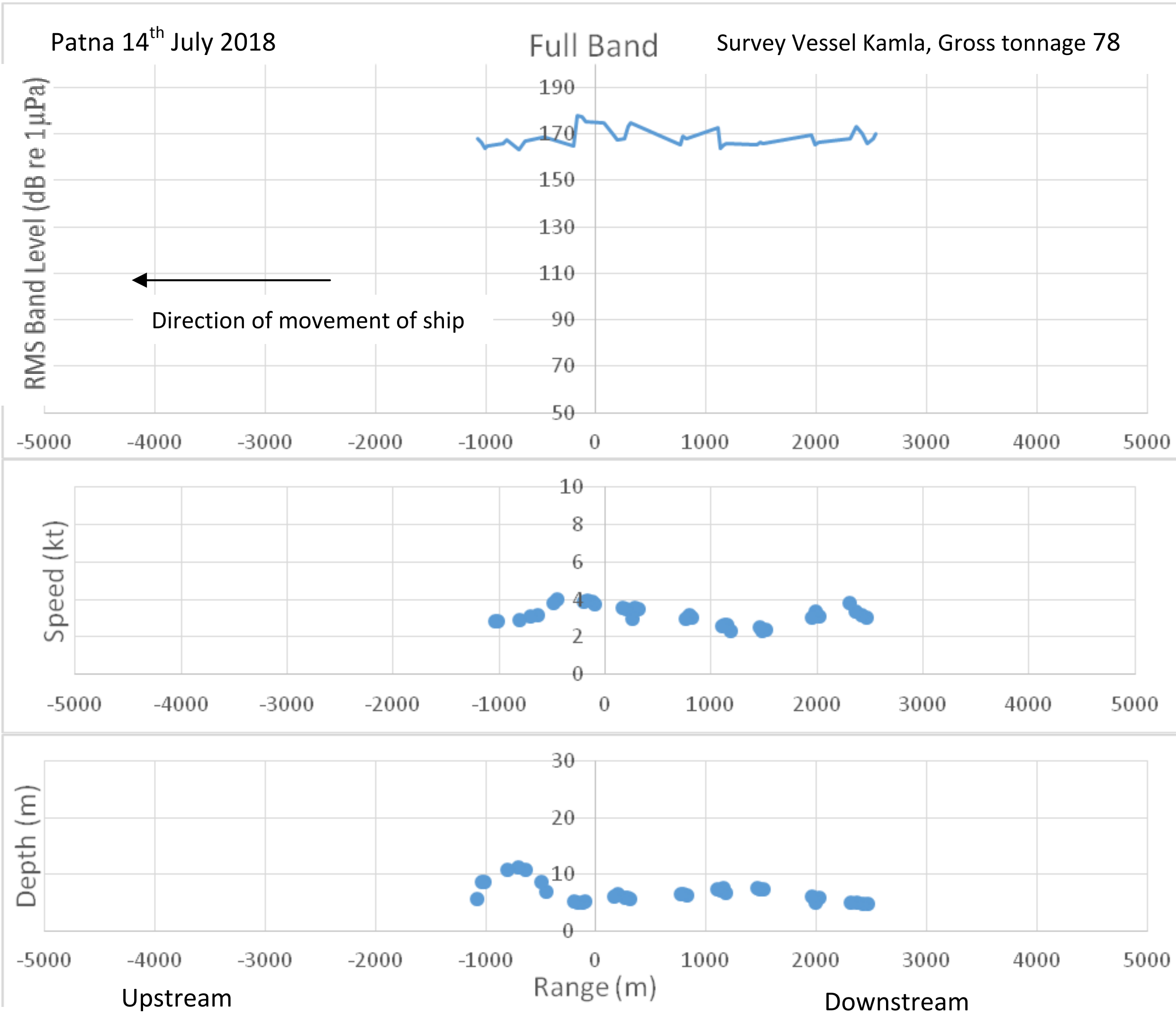


Figure 37: Upper most plot is rms Band level vs Range, Middle plot is Speed (in knots) vs Range and Bottom plot is Depth (in meters) vs Range for Full Band (100Hz-100kHz) at Patna on 14th July 2018 with ship moving upstream

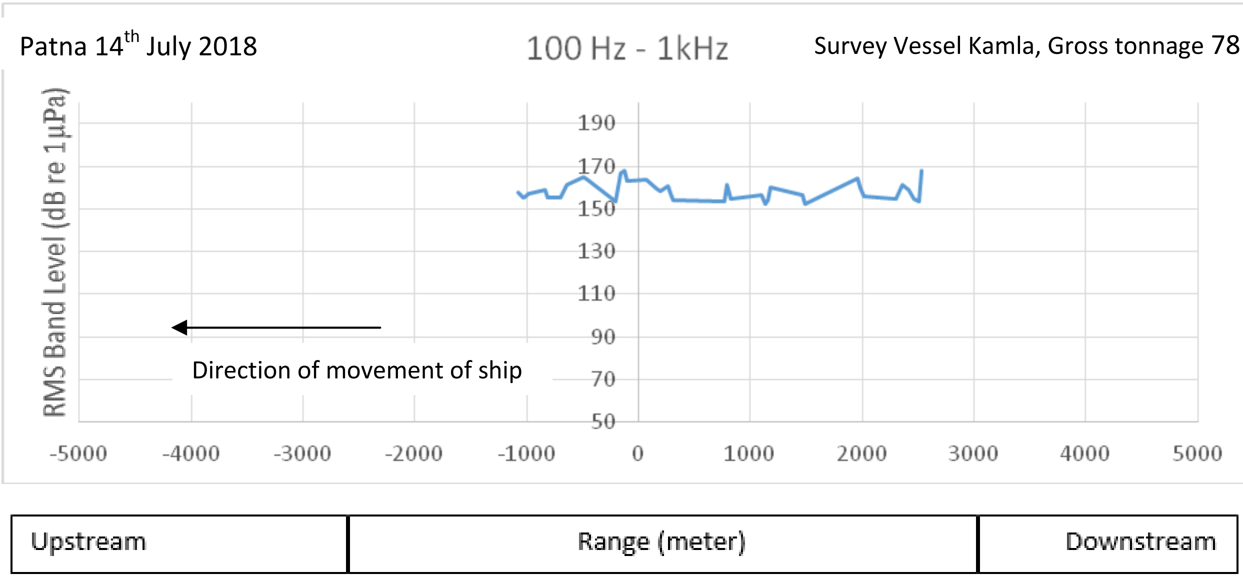


Figure 38: rms Band level vs Range for 100 Hz-1 kHz at Patna on 14th July 2018 with ship moving upstream

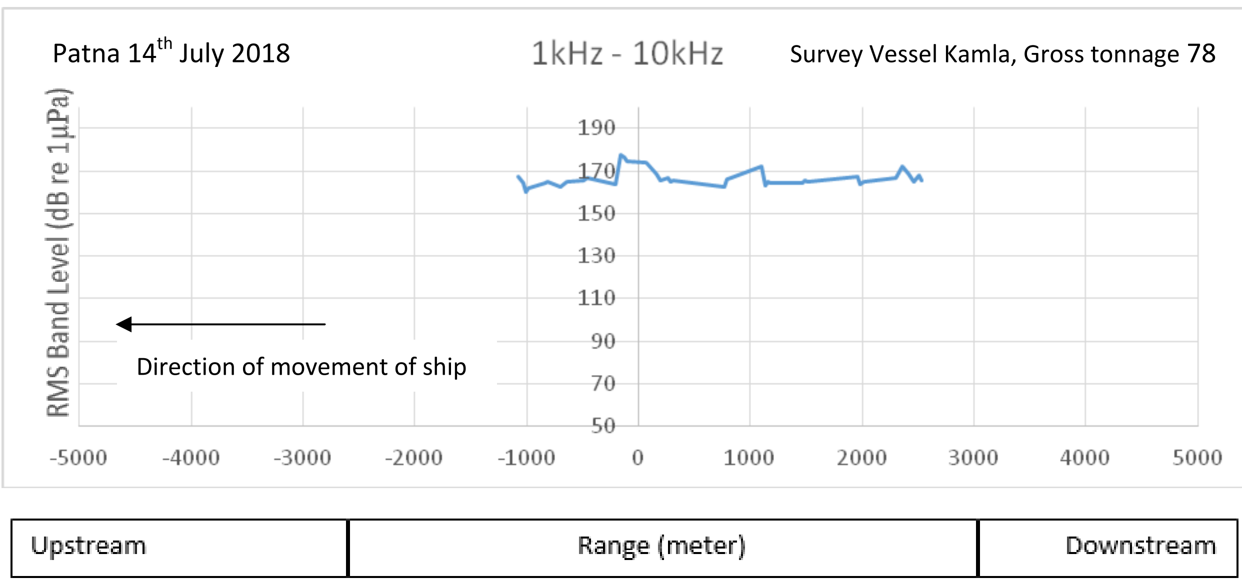


Figure 39: rms Band level vs Range for 1 kHz-10 kHz at Patna on 14th July 2018 with ship moving upstream

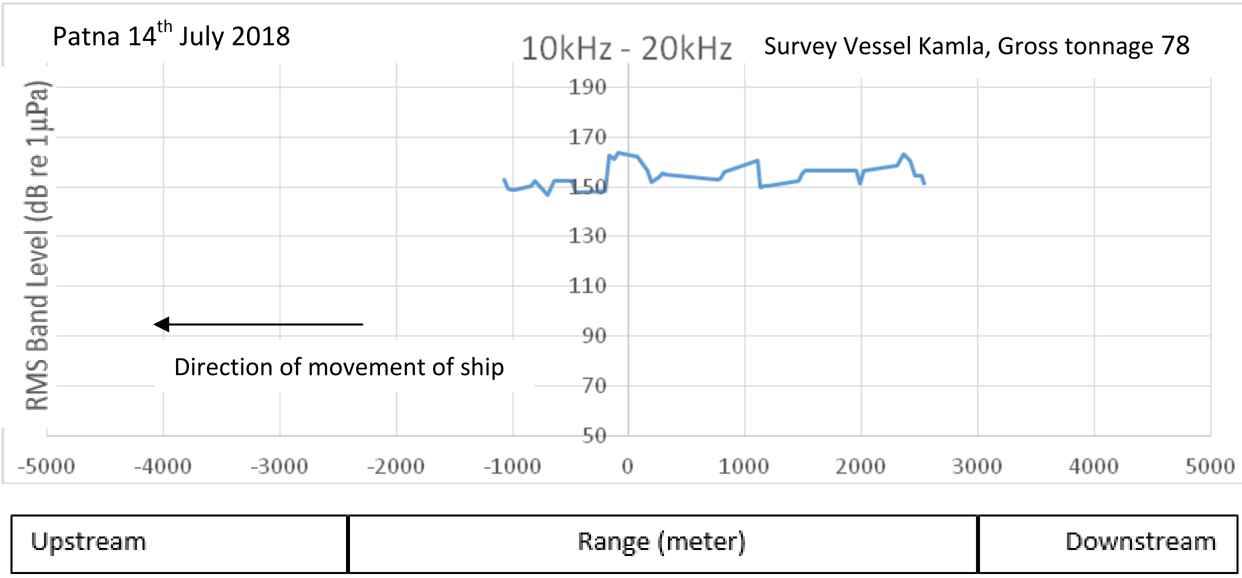


Figure 40: rms Band level vs Range for 10 kHz-20 kHz at Patna on 14th July 2018 with ship moving upstream

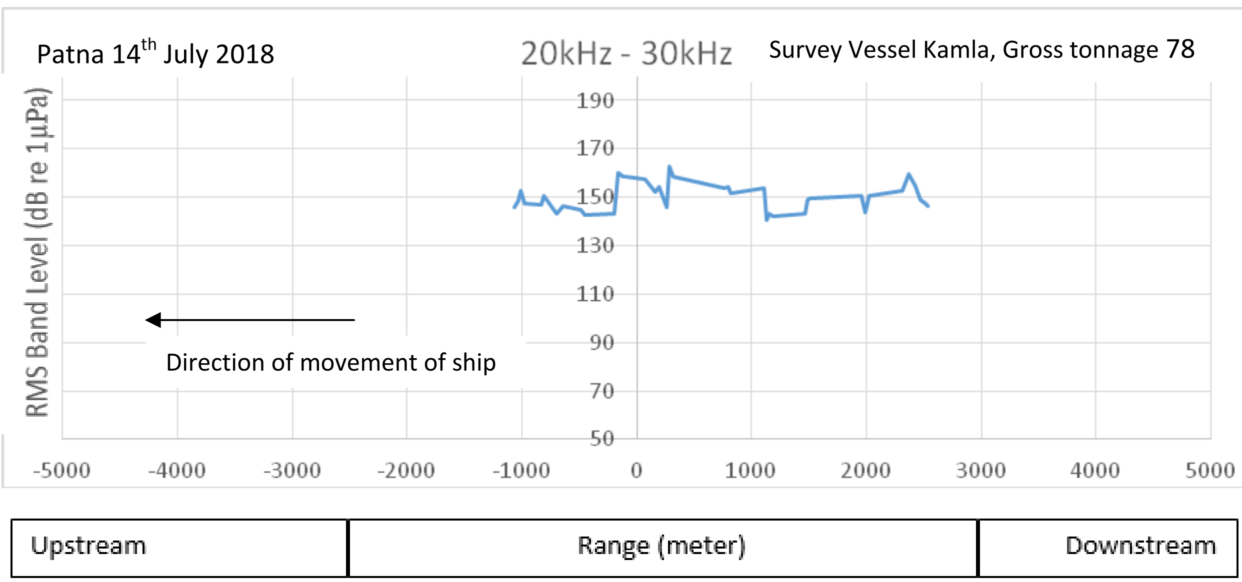


Figure 41: rms Band level vs Range for 20 kHz-30 kHz at Patna on 14th July 2018 with ship moving upstream

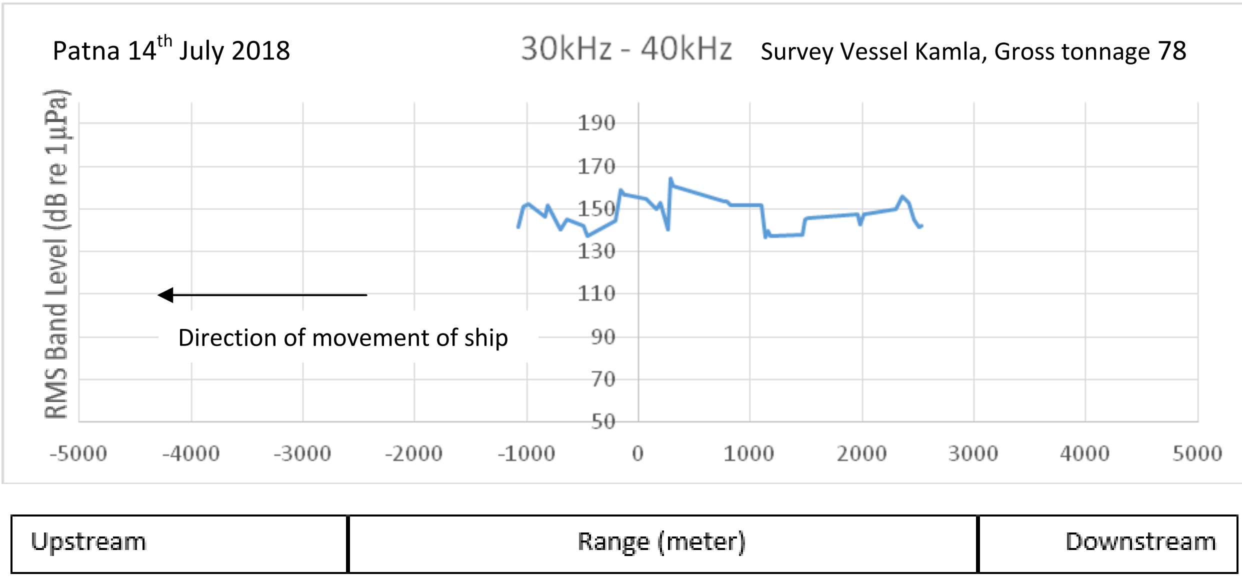


Figure 42: rms Band level vs Range for 30 kHz-40 kHz at Patna on 14th July 2018 with ship moving upstream

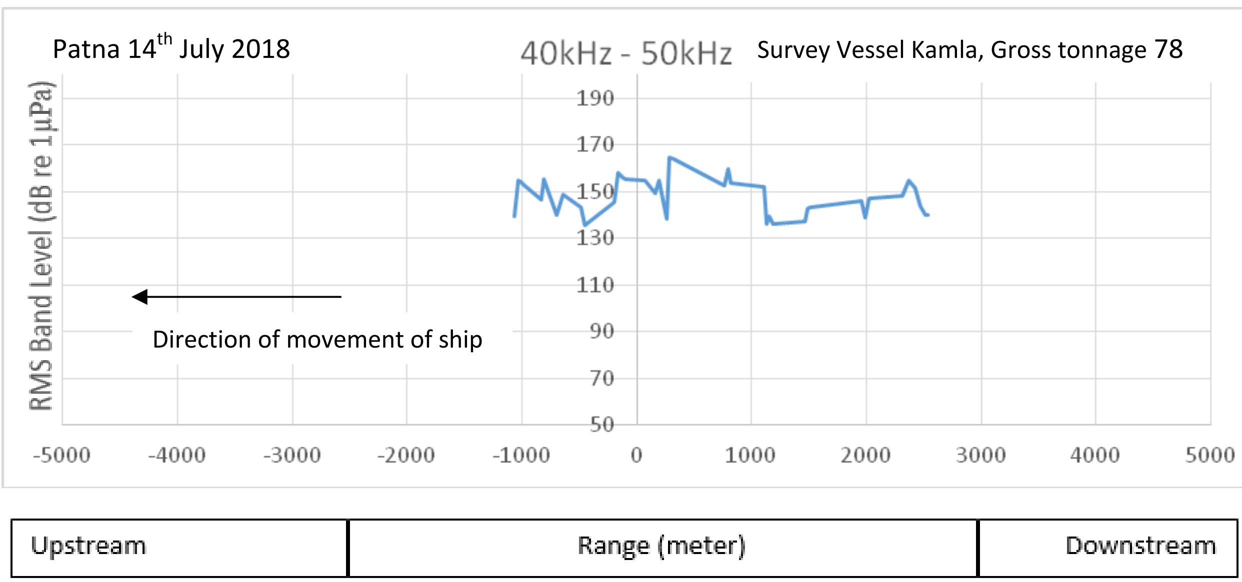


Figure 43: rms Band level vs Range for 40 kHz-50 kHz at Patna on 14th July 2018 with ship moving upstream

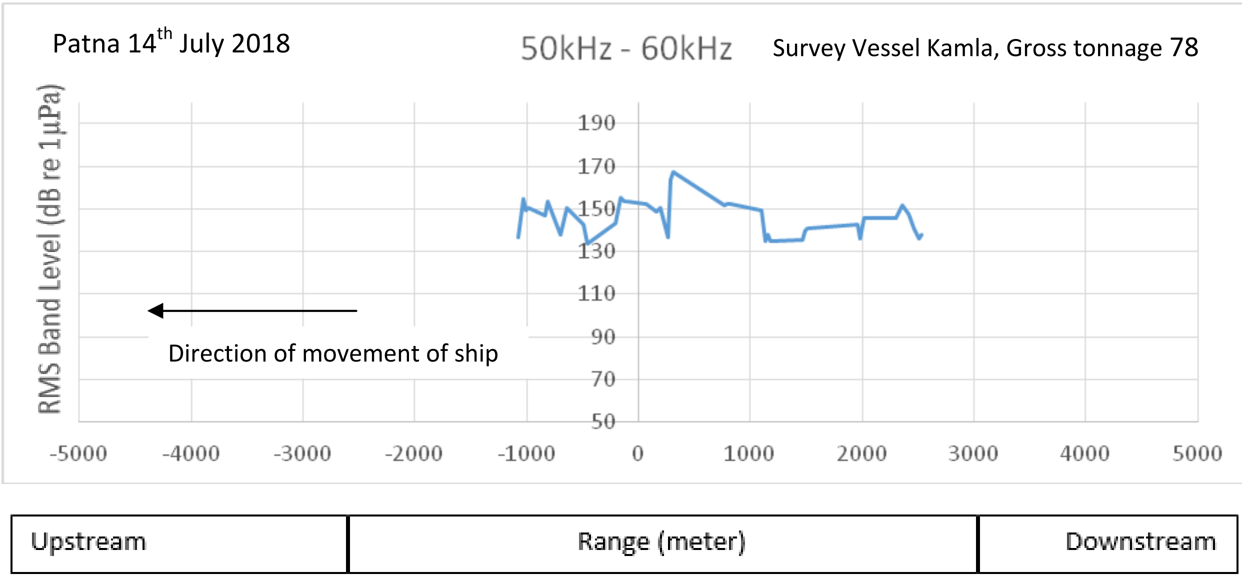


Figure 44: rms Band level vs Range for 50 kHz-60 kHz at Patna on 14th July 2018 with ship moving upstream

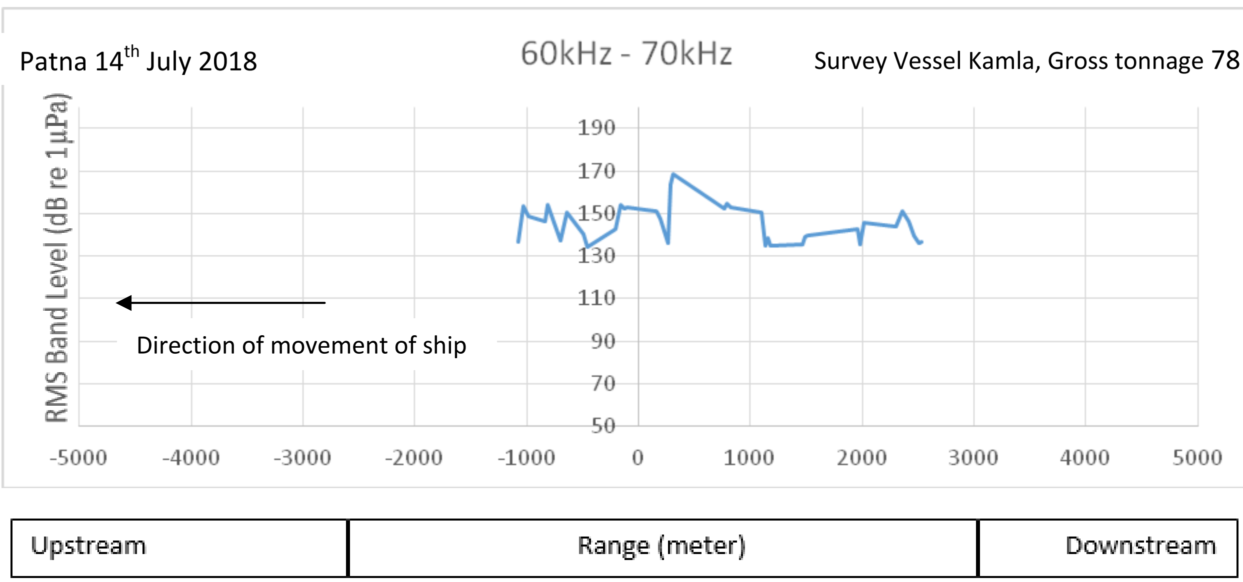
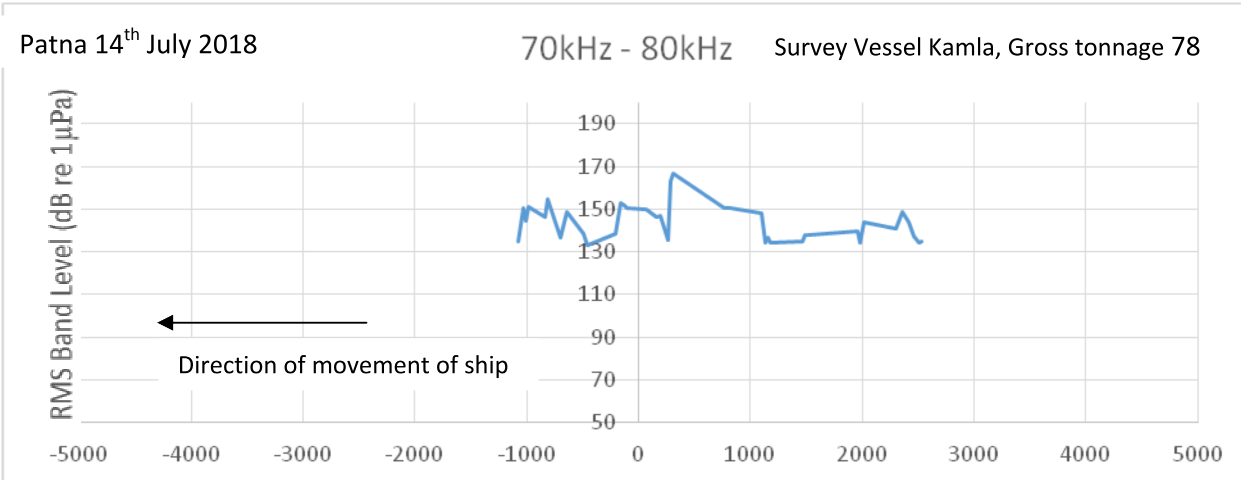
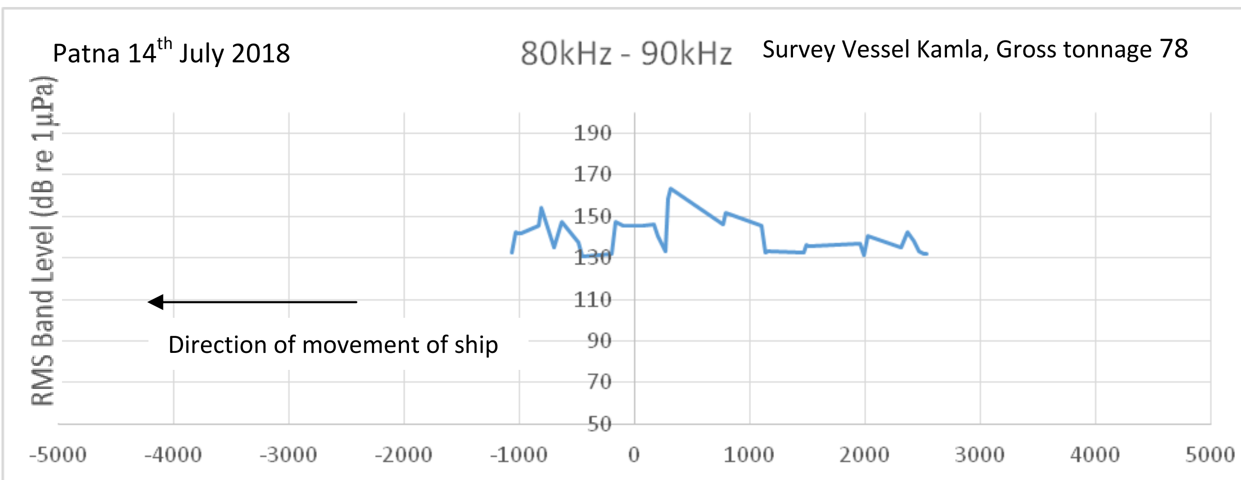


Figure 45: rms Band level vs Range for 60 kHz-70 kHz at Patna on 14th July 2018 with ship moving upstream



Upstream	Range (meter)	Downstream

Figure 46: rms Band level vs Range for 70 kHz-80 kHz at Patna on 14th July 2018 with ship moving upstream



Upstream	Range (meter)	Downstream

Figure 47: rms Band level vs Range for 80 kHz-90 kHz at Patna on 14th July 2018 with ship moving upstream

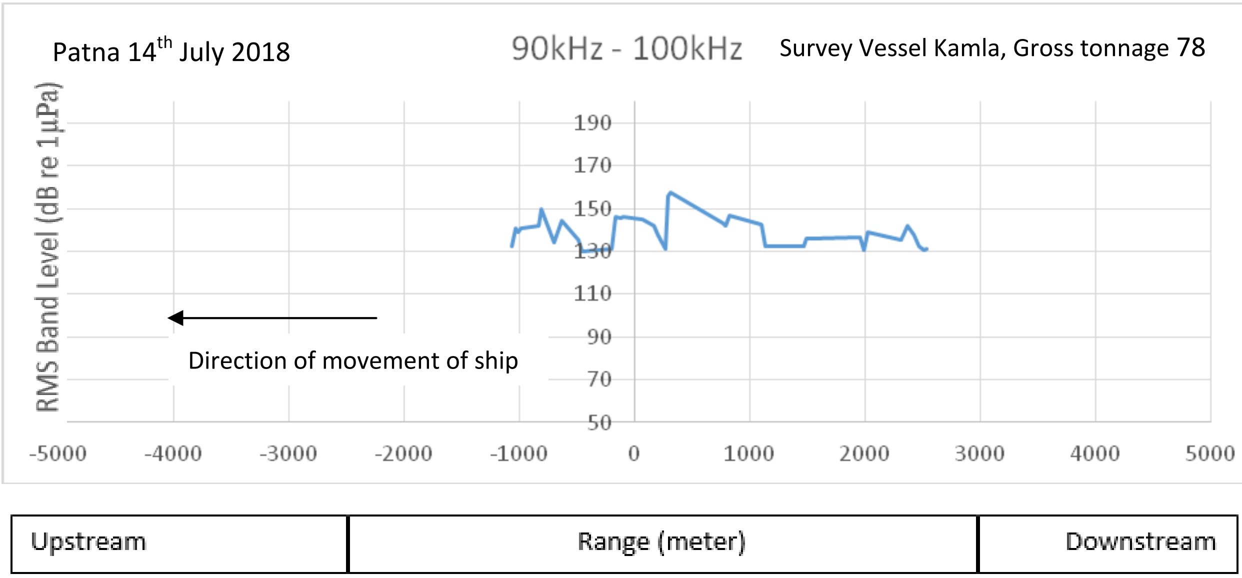


Figure 48: rms Band level vs Range for 90 kHz-100 kHz at Patna on 14th July 2018 with ship moving upstream

From Figure 37 we observe that speed of the vessel is varying from 3 knots to 4 knots and depth is varying from 8 meters to 12 meters.

4.3.2 Downstream: Measurement of Ship noise in Patna on 14th July 2018 with ship moving in the direction of flow of river. Plots of the noise versus range are given in the following figures for various frequency bands.

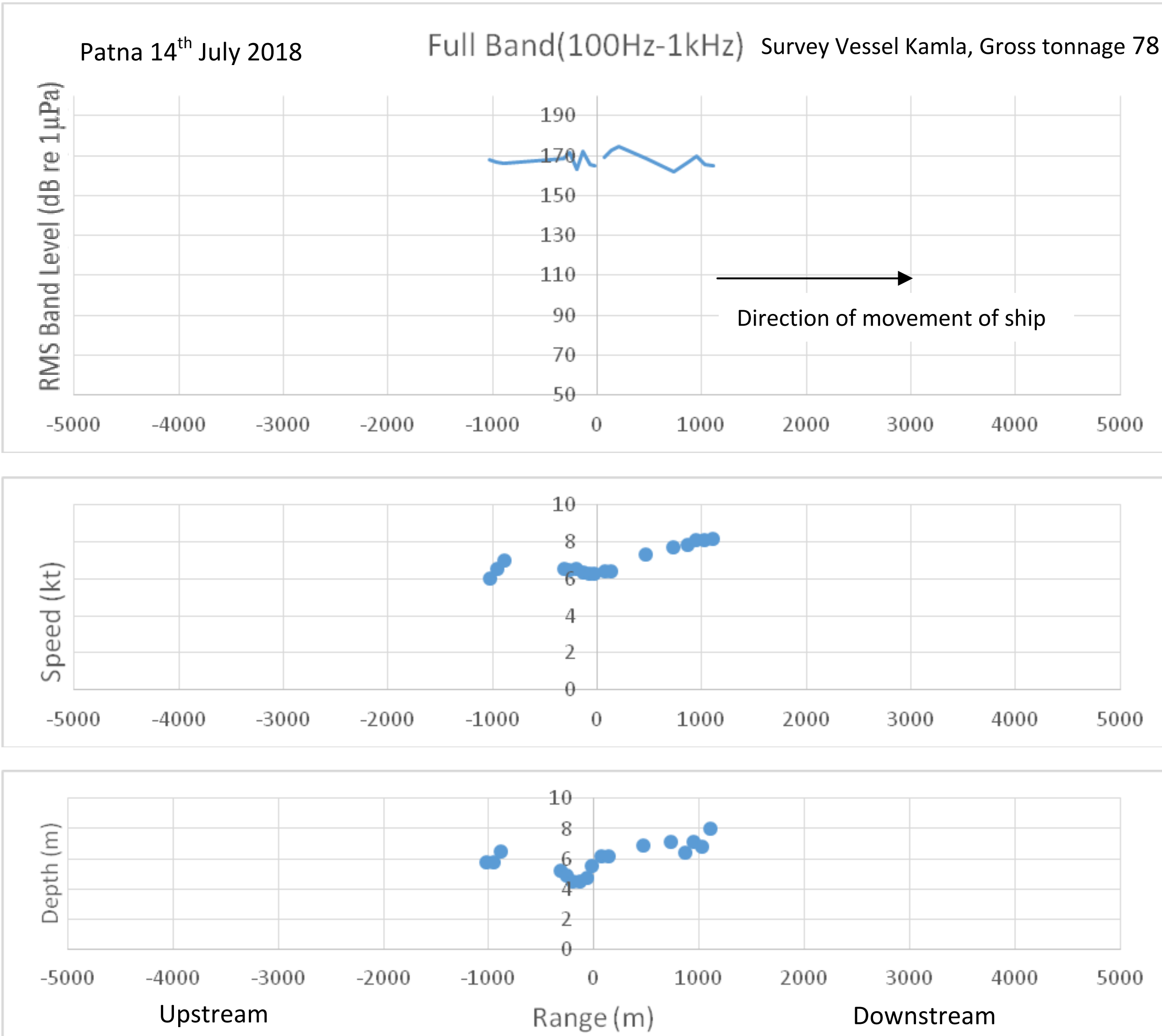


Figure 49: Upper most plot is rms Band level vs Range, Middle plot is Speed (in knots) vs Range and Bottom plot is Depth (in meters) vs Range for Full Band (100Hz-100kHz) at Patna on 14th July 2018 with ship moving downstream

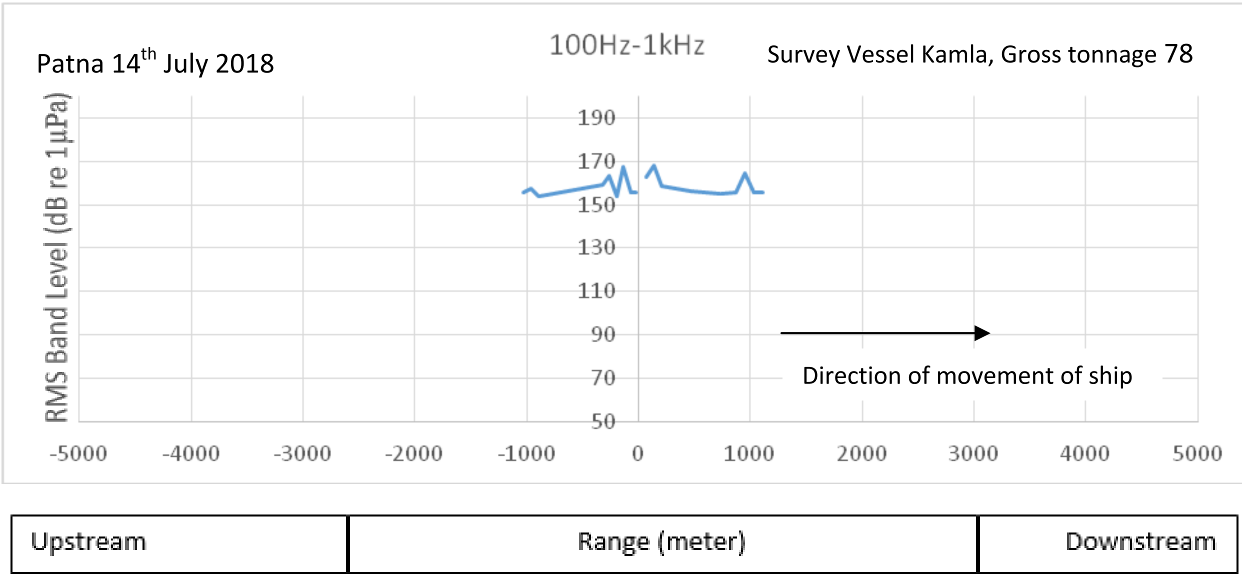


Figure 50: rms Band level vs Range for 100 Hz-1 kHz at Patna on 14th July 2018 with ship moving downstream

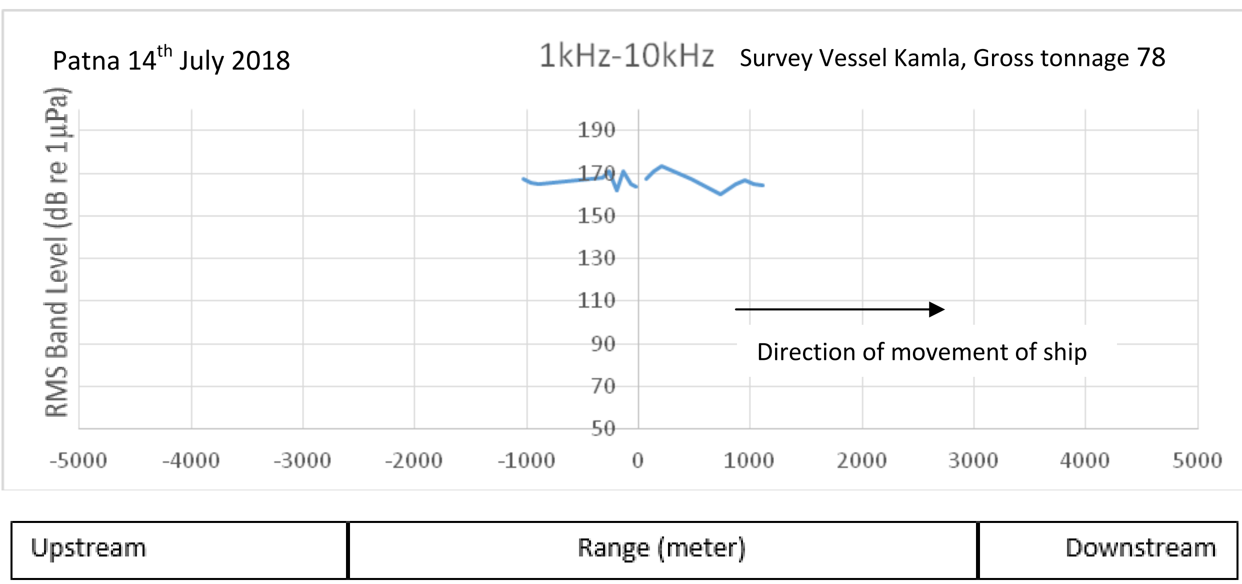


Figure 51: rms Band level vs Range for 1 kHz-10 kHz at Patna on 14th July 2018 with ship moving downstream

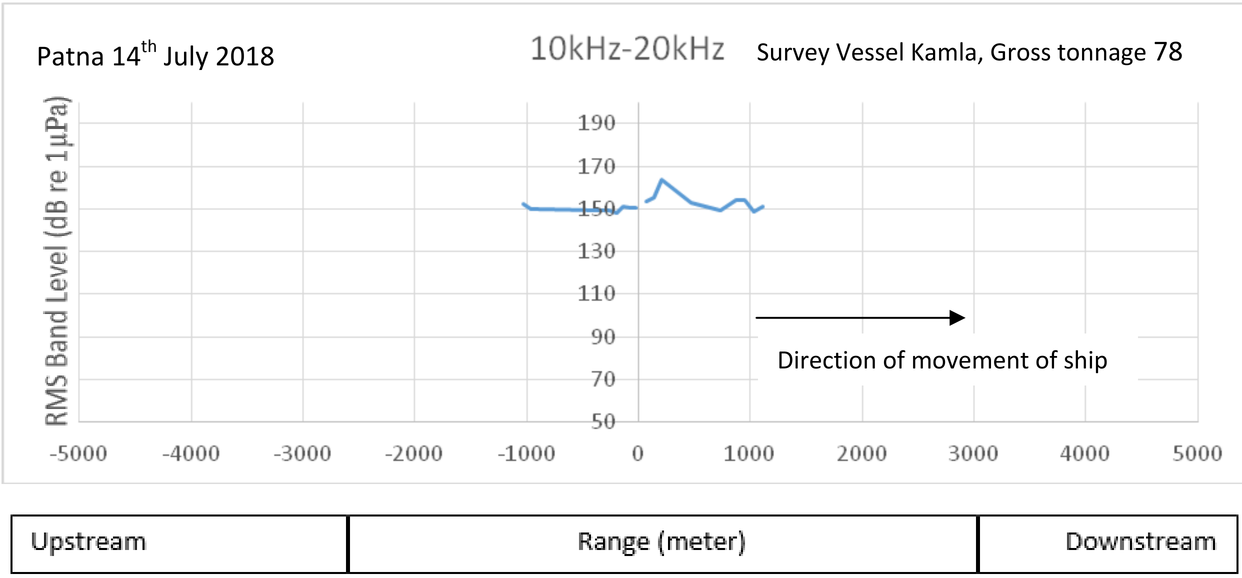


Figure 52: rms Band level vs Range for 10 kHz-20 kHz at Patna on 14th July 2018 with ship moving downstream

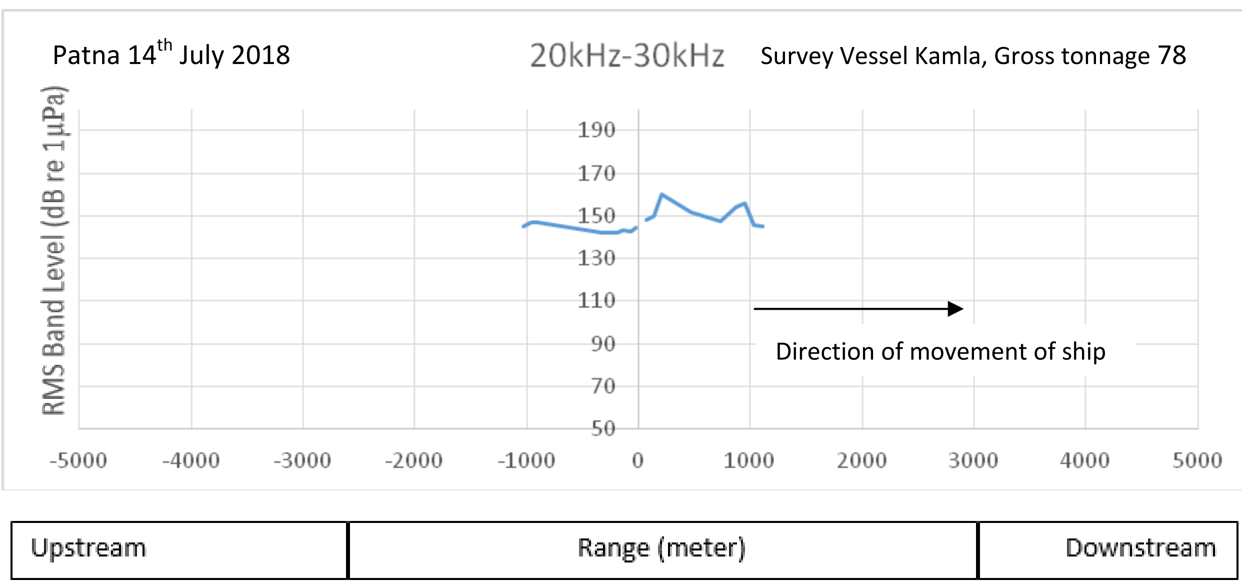


Figure 53: rms Band level vs Range for 20 kHz-30 kHz at Patna on 14th July 2018 with ship moving downstream

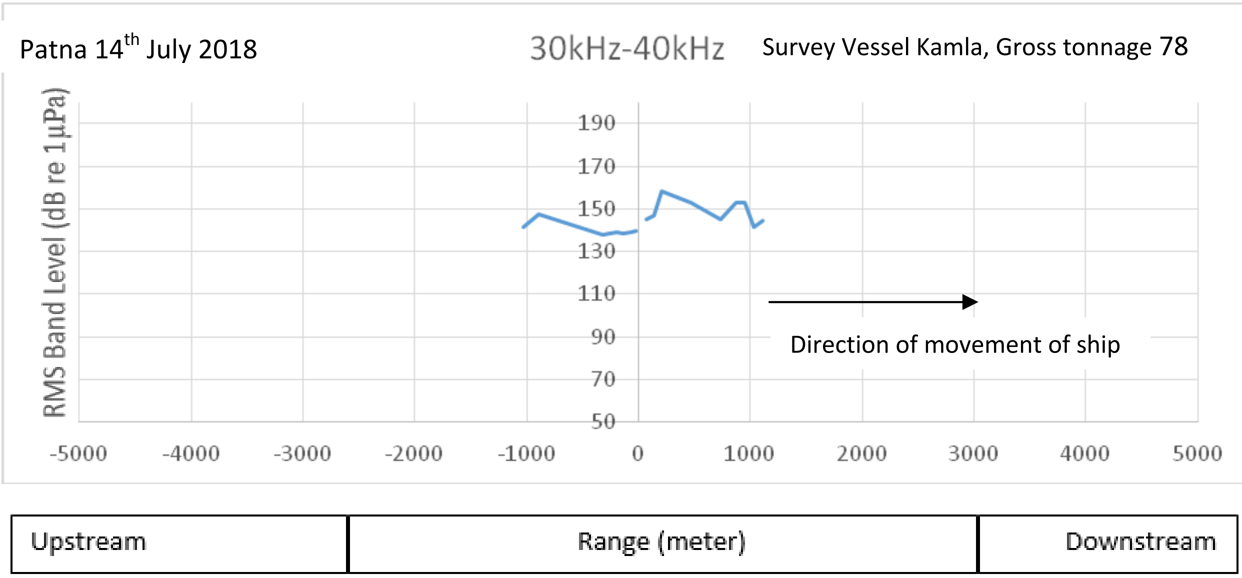


Figure 54: rms Band level vs Range for 30 kHz-40 kHz at Patna on 14th July 2018 with ship moving downstream

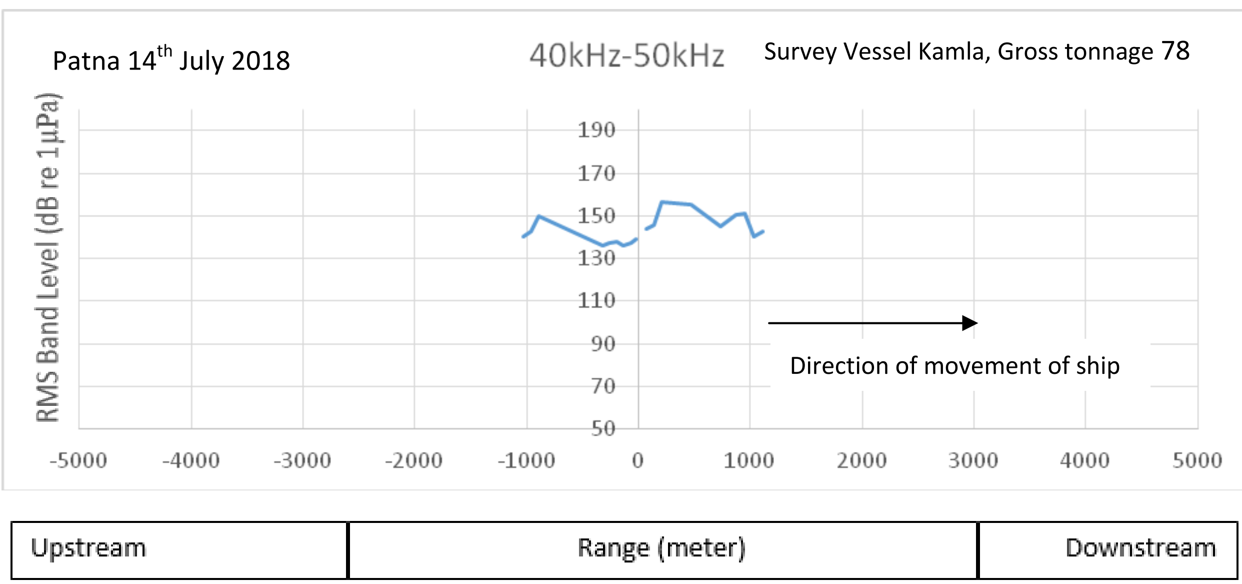


Figure 55: rms Band level vs Range for 40 kHz-50 kHz at Patna on 14th July 2018 with ship moving downstream

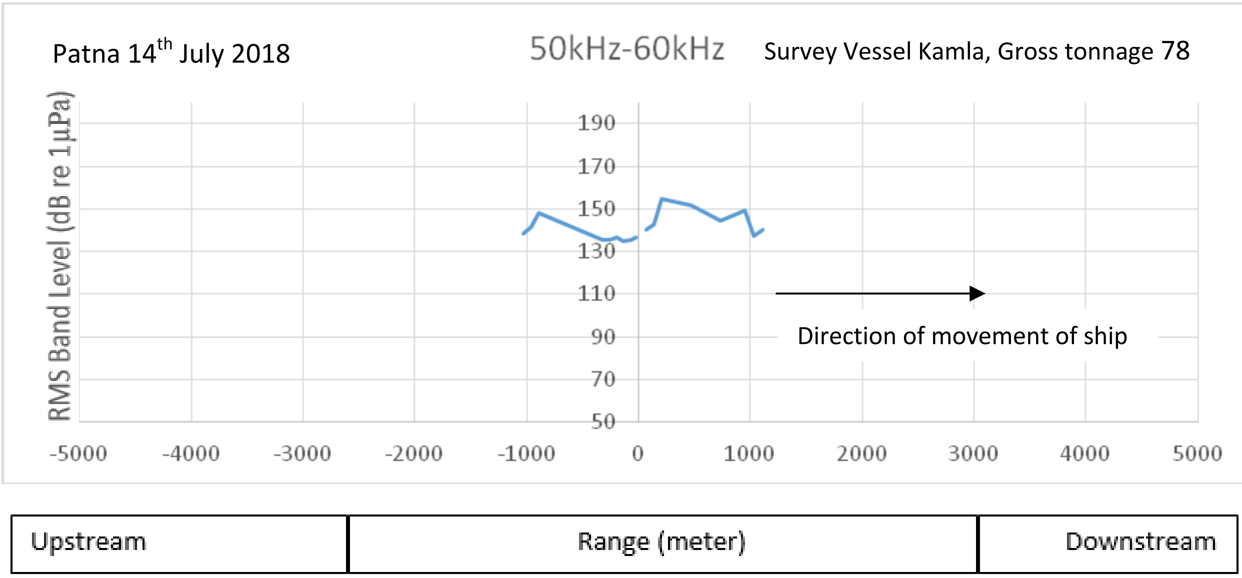


Figure 56: rms Band level vs Range for 50 kHz-60 kHz at Patna on 14th July 2018 with ship moving downstream

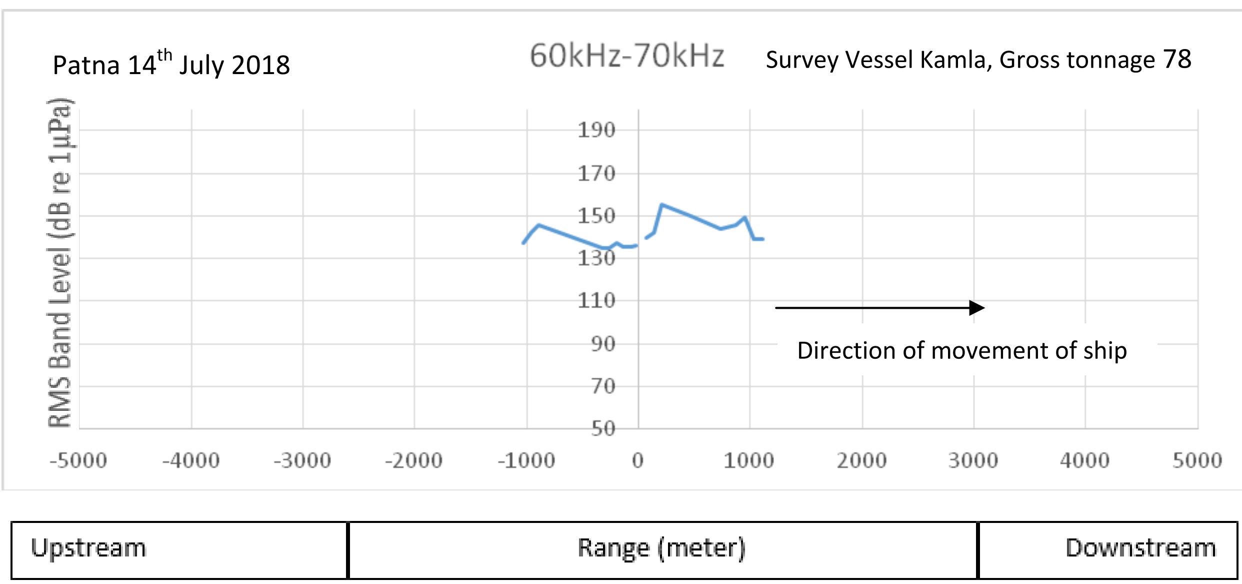


Figure 57: rms Band level vs Range for 60 kHz-70 kHz at Patna on 14th July 2018 with ship moving downstream

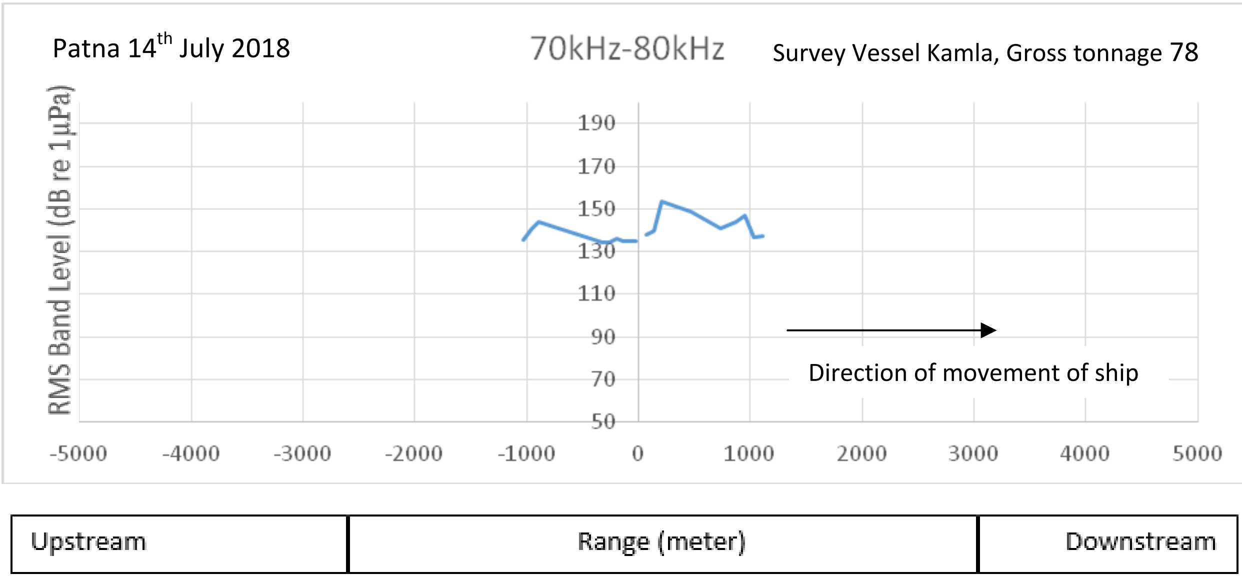


Figure 58: rms Band level vs Range for 70 kHz-80 kHz at Patna on 14th July 2018 with ship moving downstream

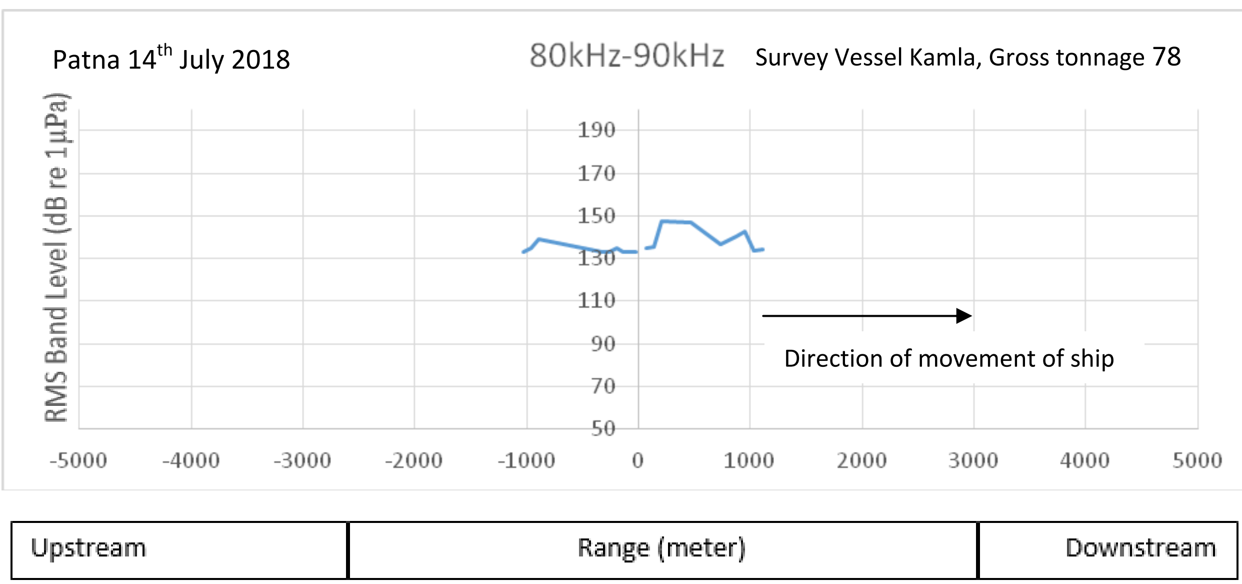


Figure 59: rms Band level vs Range for 80 kHz-90 kHz at Patna on 14th July 2018 with ship moving downstream

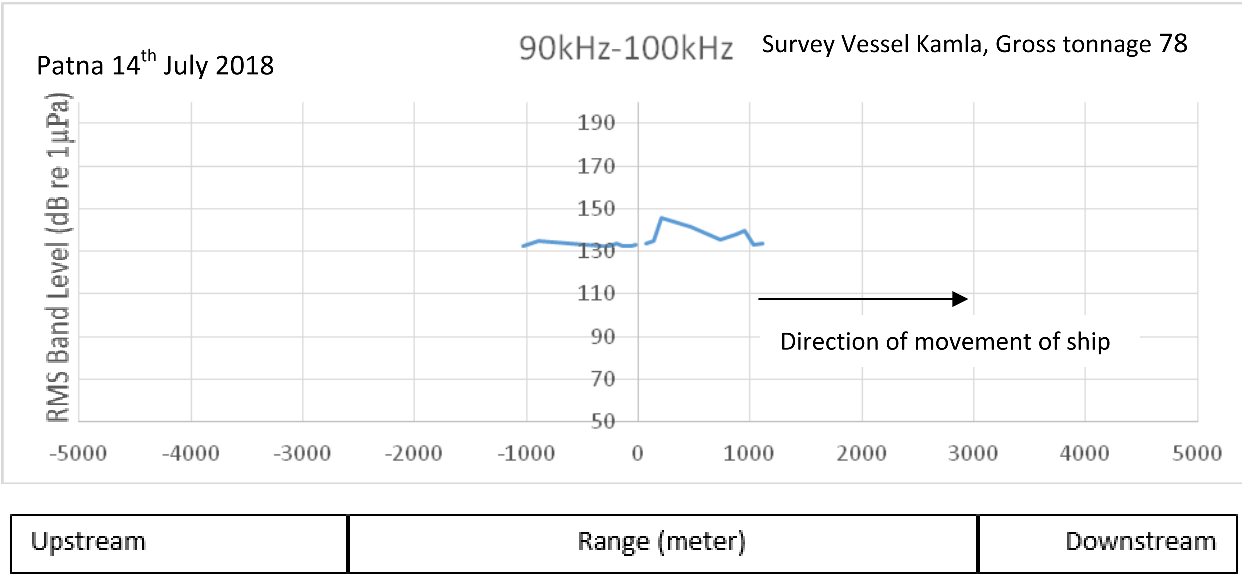


Figure 60: rms Band level vs Range for 90 kHz-100 kHz at Patna on 14th July 2018 with ship moving downstream

From Figure 49 we observe that speed is varying from 5 knots to 8 knots and depth from 5 meters to 8 meters approximately.

4.4.3 Maximum ship noise in different bands: The maximum ship noise is obtained in Patna measurements when it was at a distance of 67 meters from the boat. The ship noise in various frequency bands are shown in figure 61. The rms ambient noise and the calculated maximum ship rms sound level at 1 meter are also shown in figure 61.

Shortest Ship distance from boat = 67 meters

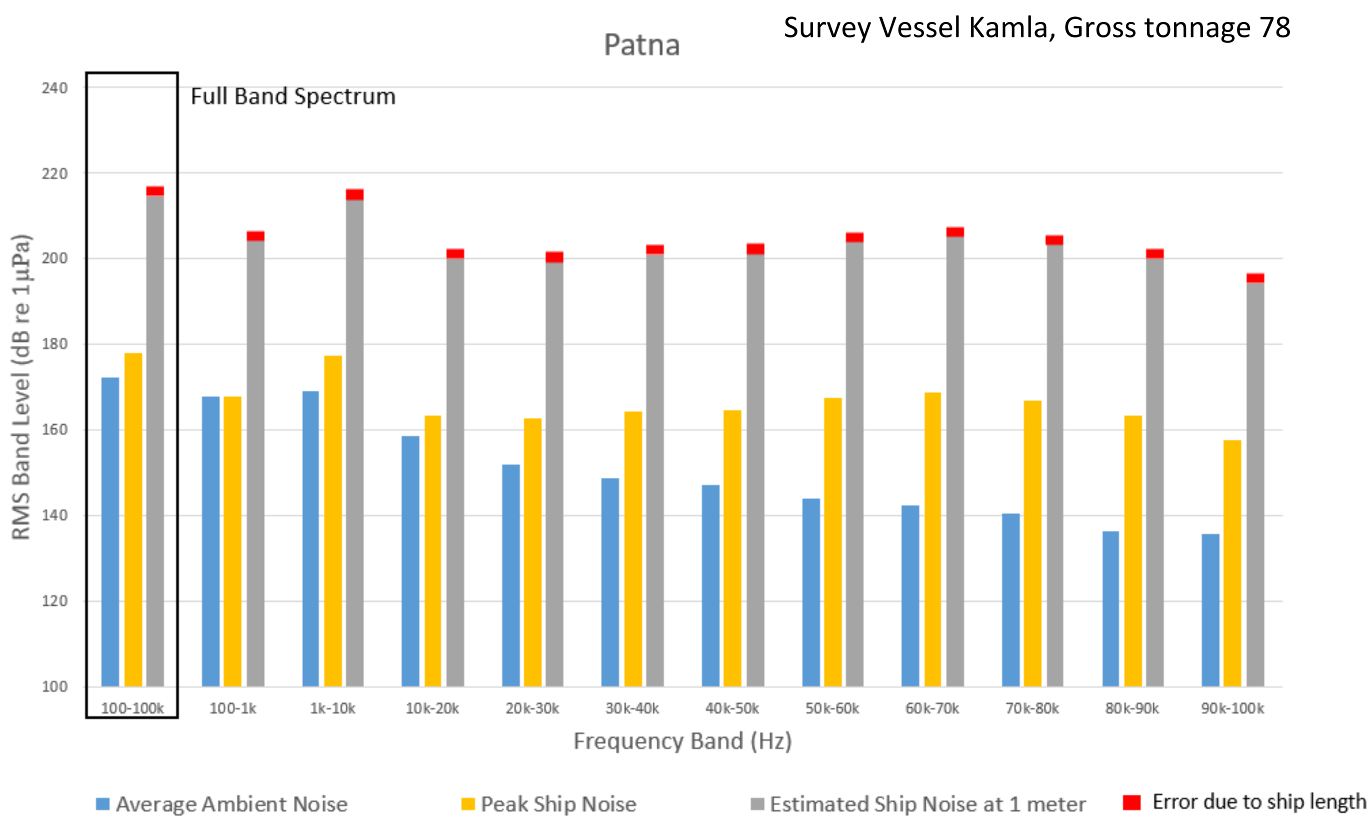


Figure 61: rms Band level vs Frequency Bands for Patna (14th July 2018) for upstream

Uncertainty in rms sound level at 1 m due to ship length is 2.268 dB re 1µPa.

5. SAHIBGANJ FIELD MEASUREMENTS (16TH JULY 2018)

5.1 Specifications of Vessel

Name of the ship – S.L. Rihand
Length – 25 meters
Breadth – 5.8 meters
Depth – 2.8 meters
Gross tonnage – 92
Registered tonnage – 28
Number of Decks – 1
Number of Bulkheads – 5

Specifications of Engine

BHP/KW – 355/264.8
Number of sets of engine – 2
Number of Shafts – 2
Estimated Speed – 9.78 Knots
Number and diameter of cylinder of each set – 6 nos and 120.0 mm
Arrangements During Measurements and GPS Location

5.2 Arrangements During Measurements and GPS Location

Figure 62: Assembly of equipment for the measurements at Sahibganj

Figure 63: Surroundings and Ship travelling through its channel at Sahibganj

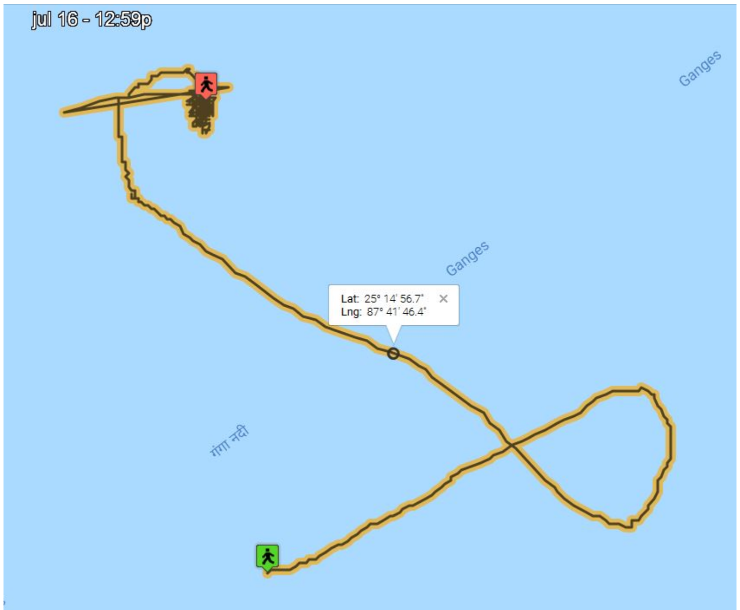


Figure 64: GPS location of Receiver Boat approx 50 meters away from the channel at Sahibganj

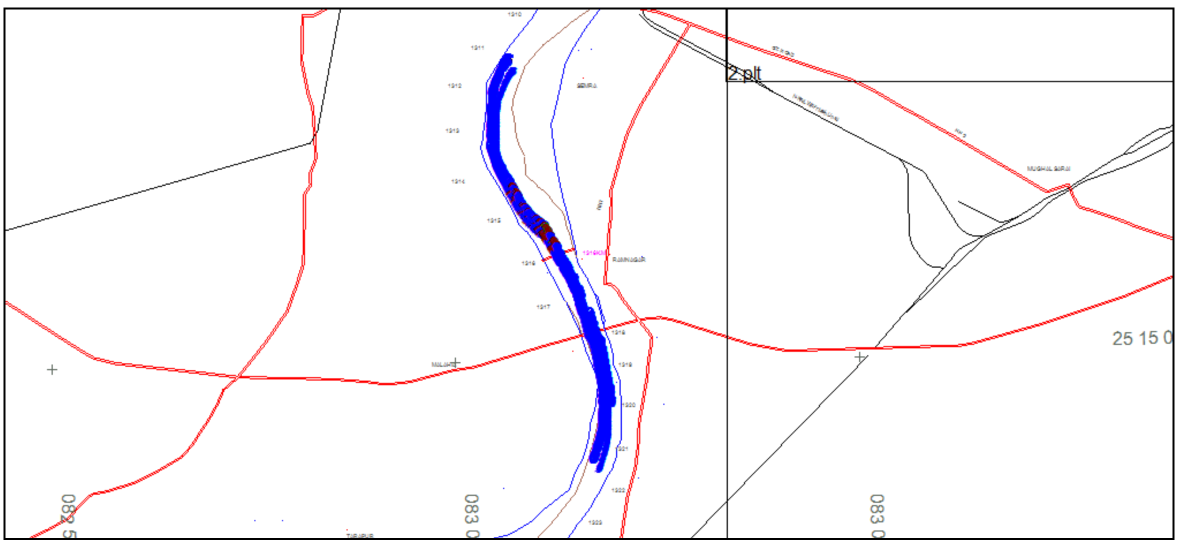


Figure 65: Ship traversal through the channel at Sahibganj

5.3 Observations and Results from Sahibganj Measurements:

5.3.1 Upstream: Measurement of Ship noise in Sahibganj on 16th July 2018 with ship moving opposite to the direction of flow of river. Plots of the noise versus range are given in the following figures for various frequency bands.

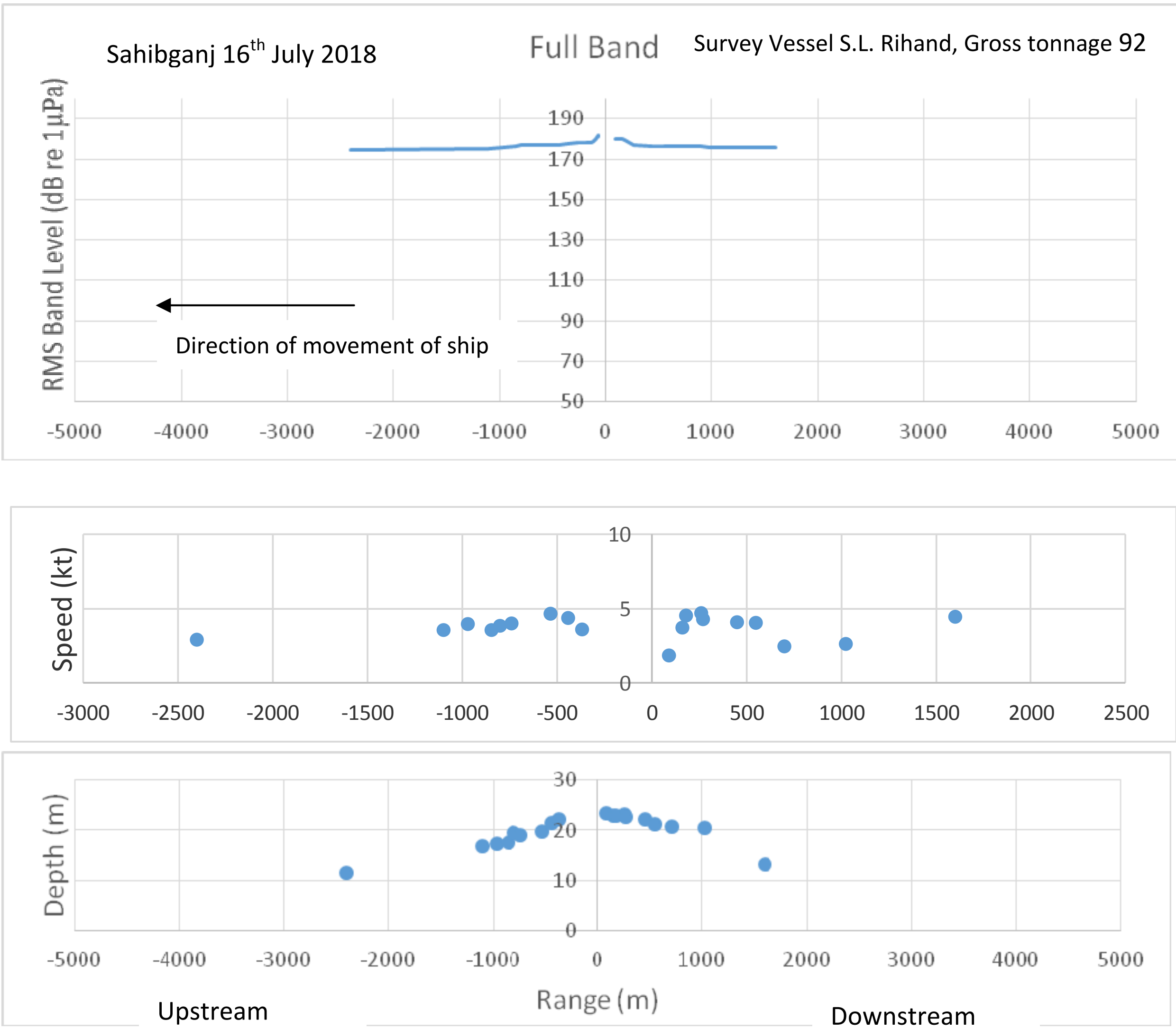


Figure 66: Upper most plot is rms Band level vs Range, Middle plot is Speed (in knots) vs Range and Bottom plot is Depth (in meters) vs Range for Full Band (100Hz-100kHz) at Sahibganj on 16th July 2018 ship moving upstream

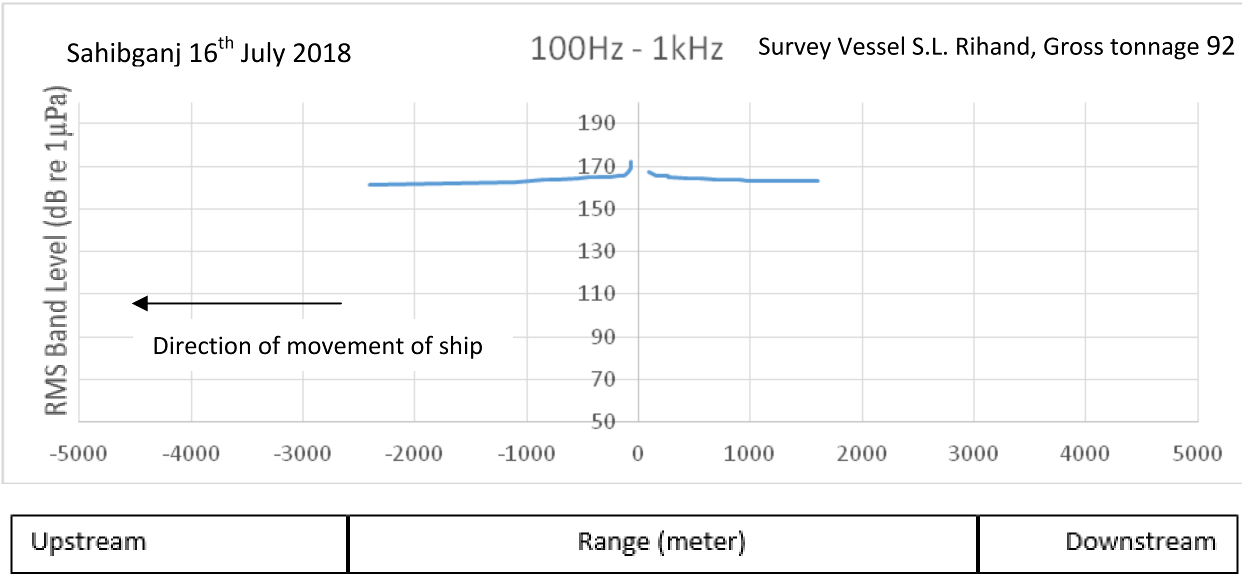


Figure 67: rms Band level vs Range for 100 Hz-1 kHz at Sahibganj on 16th July 2018 ship moving upstream

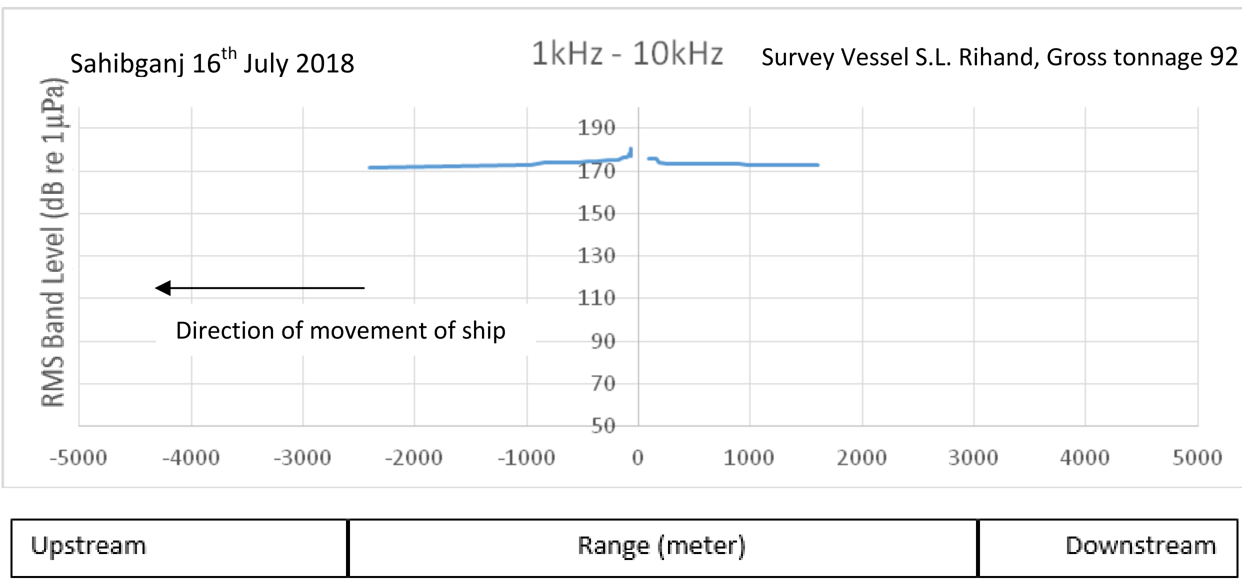
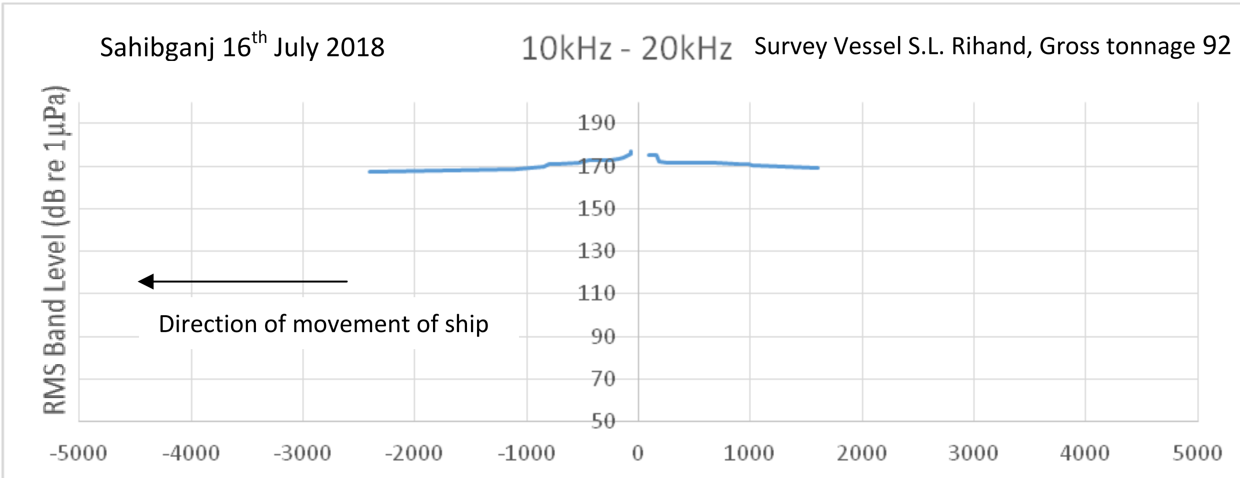
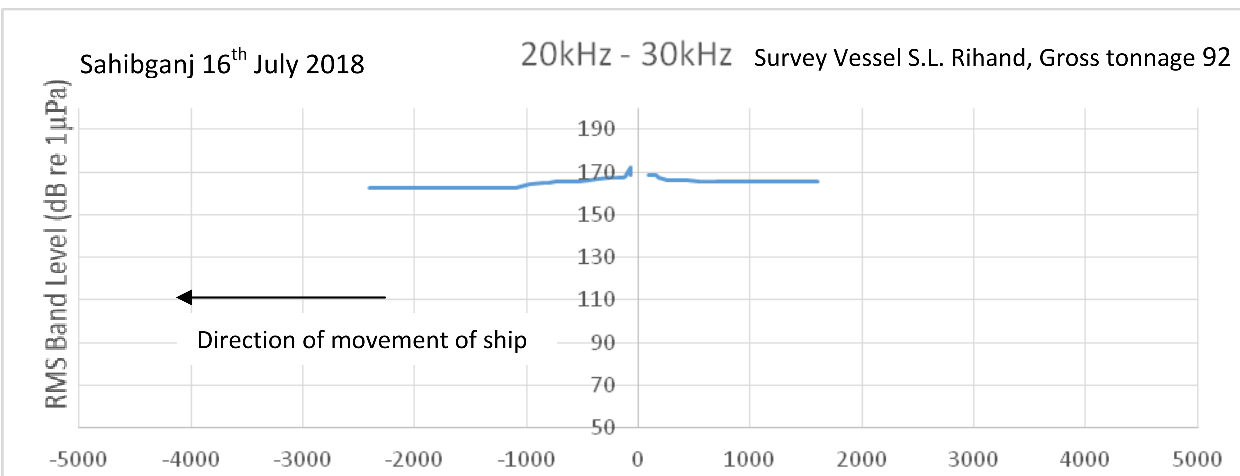


Figure 68: rms Band level vs Range for 1 kHz-10 kHz at Sahibganj on 16th July 2018 ship moving upstream



Upstream	Range (meter)	Downstream

Figure 69: rms Band level vs Range for Full Band 10 kHz-20 kHz at Sahibganj on 16th July 2018 ship moving upstream



Upstream	Range (meter)	Downstream

Figure 70: rms Band level vs Range for 20 kHz-30 kHz at Sahibganj on 16th July 2018 ship moving upstream

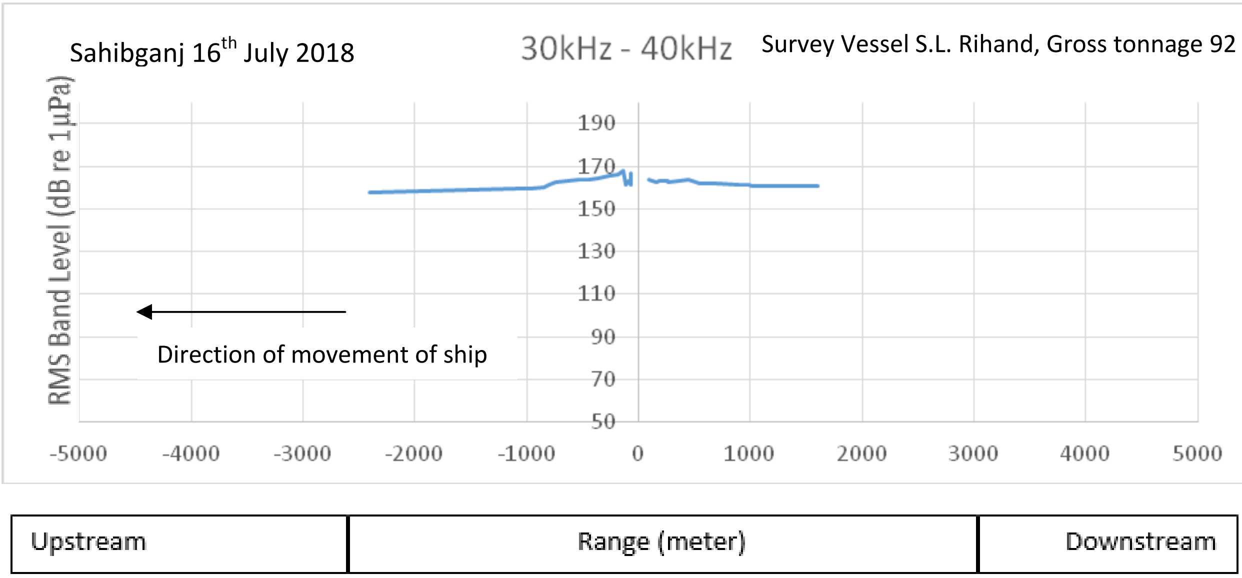


Figure 71: rms Band level vs Range for 30 kHz-40 kHz at Sahibganj on 16th July 2018 ship moving upstream

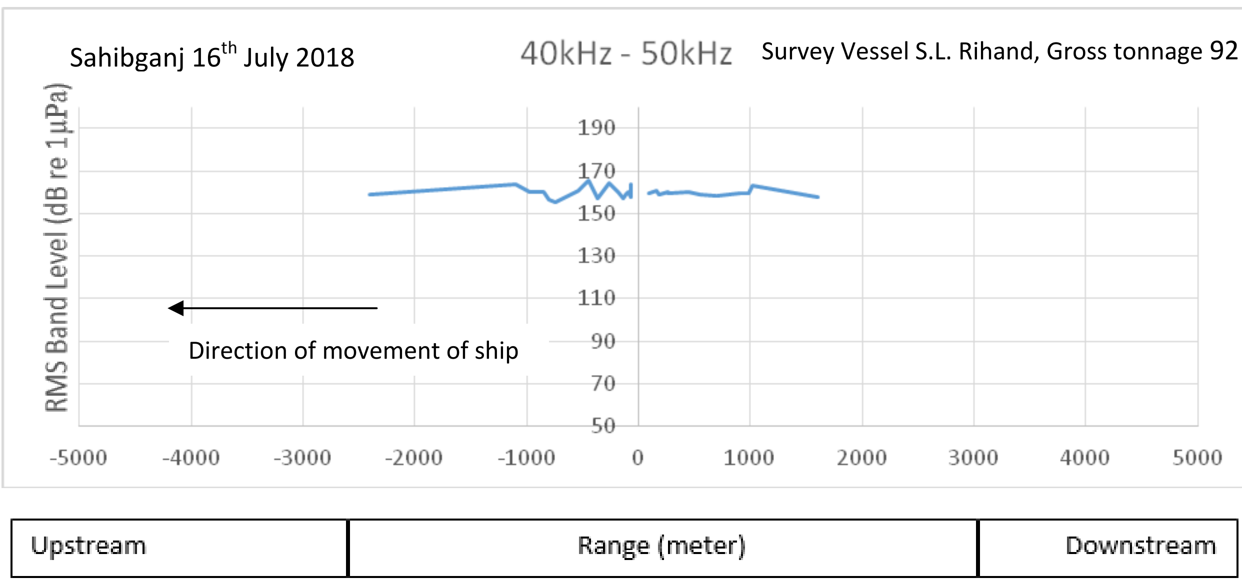


Figure 72: rms Band level vs Range for 40kHz-50kHz at Sahibganj on 16th July 2018 ship moving upstream

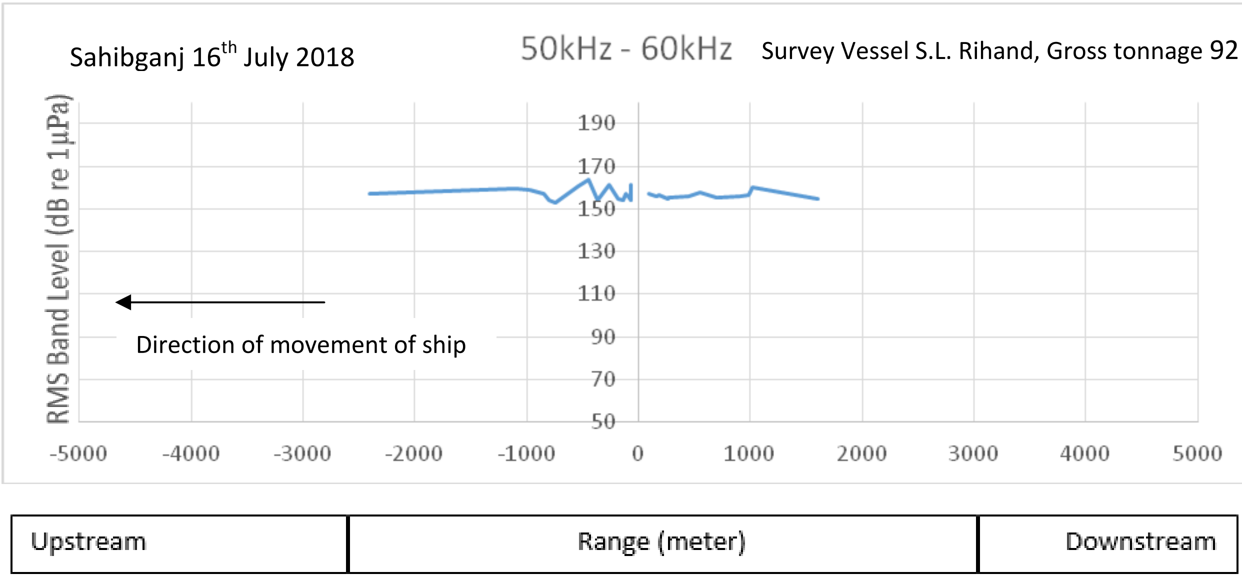


Figure 73: rms Band level vs Range for 50kHz-60kHz at Sahibganj on 16th July 2018 ship moving upstream

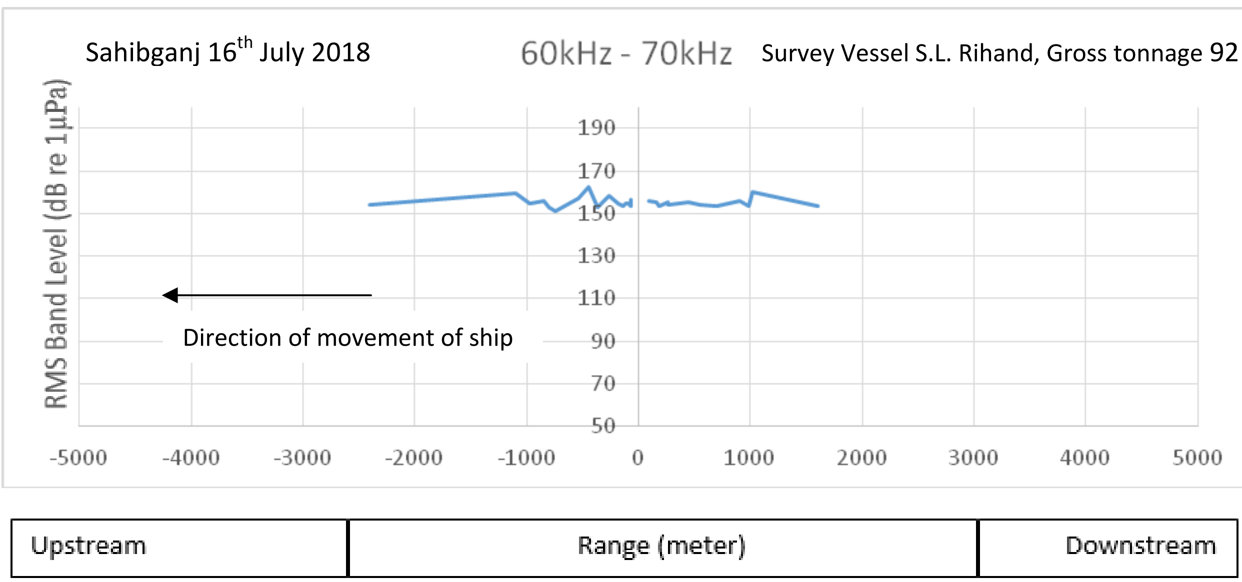


Figure 74: rms Band level vs Range for 60kHz-70kHz at Sahibganj on 16th July 2018 ship moving upstream

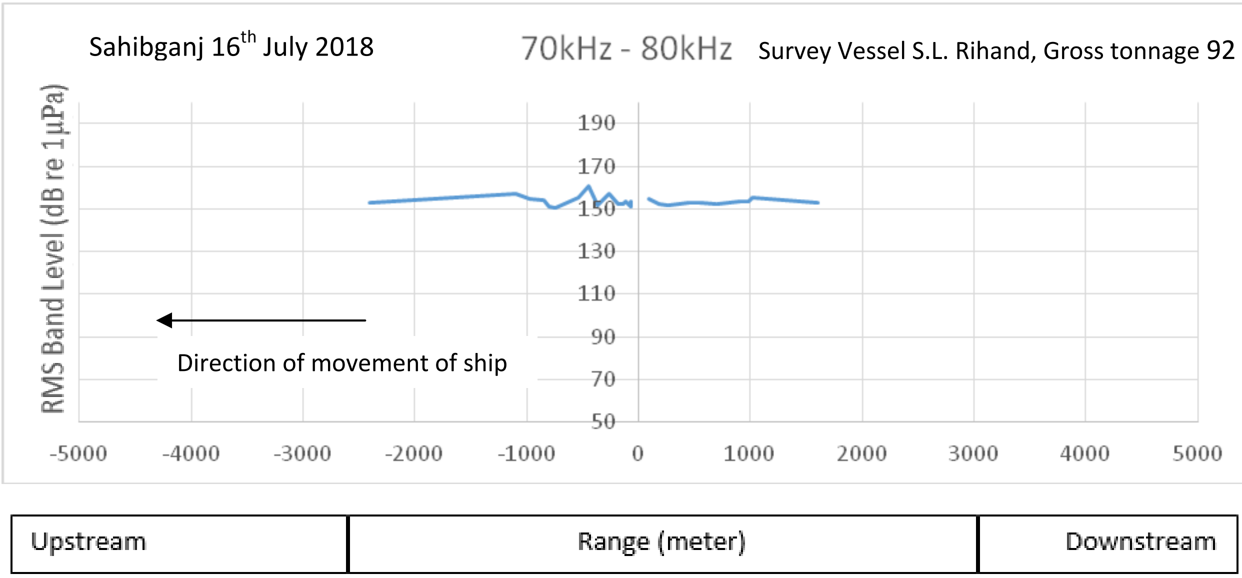


Figure 75: rms Band level vs Range for 70kHz-80kHz at Sahibganj on 16th July 2018 ship moving upstream

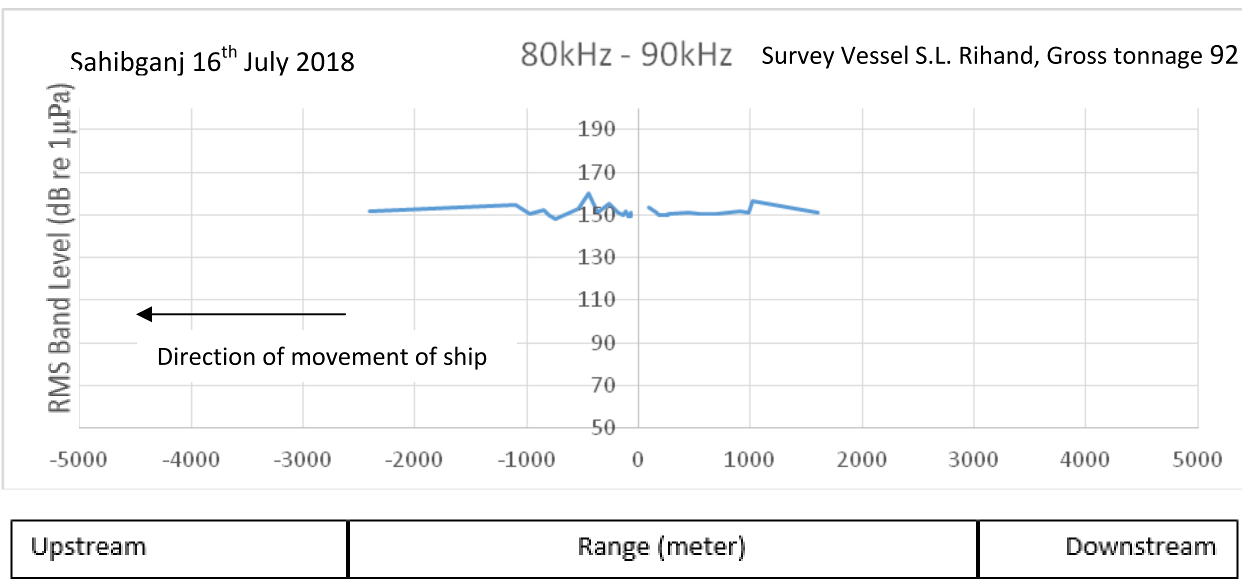


Figure 76: rms Band level vs Range for 80kHz-90kHz at Sahibganj on 16th July 2018 ship moving upstream

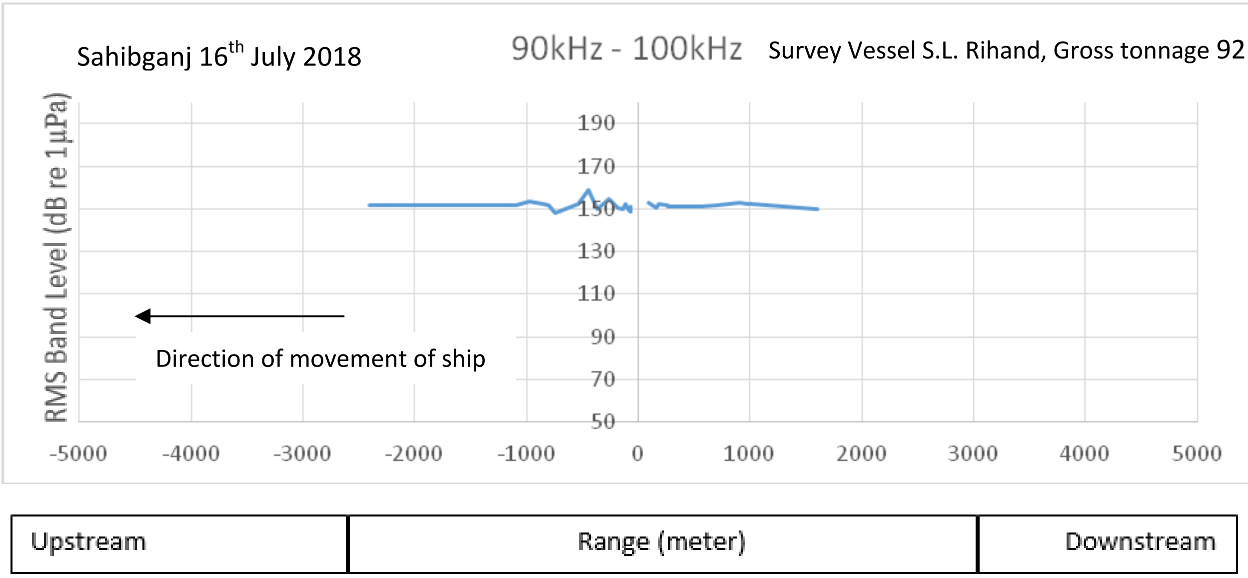


Figure 77: rms Band level vs Range for 90kHz-100kHz at Sahibganj on 16th July 2018 ship moving upstream

From Figure 66 we observe that speed of the vessel varied from 2 to 5 knots and depth from 10 meters to 24 meters approximately.

5.3.2 Downstream: Measurement of Ship noise in Sahibganj on 16th July 2018 with ship moving in the direction of flow of river. Plots of the noise versus range are given in the following figures for various frequency bands.

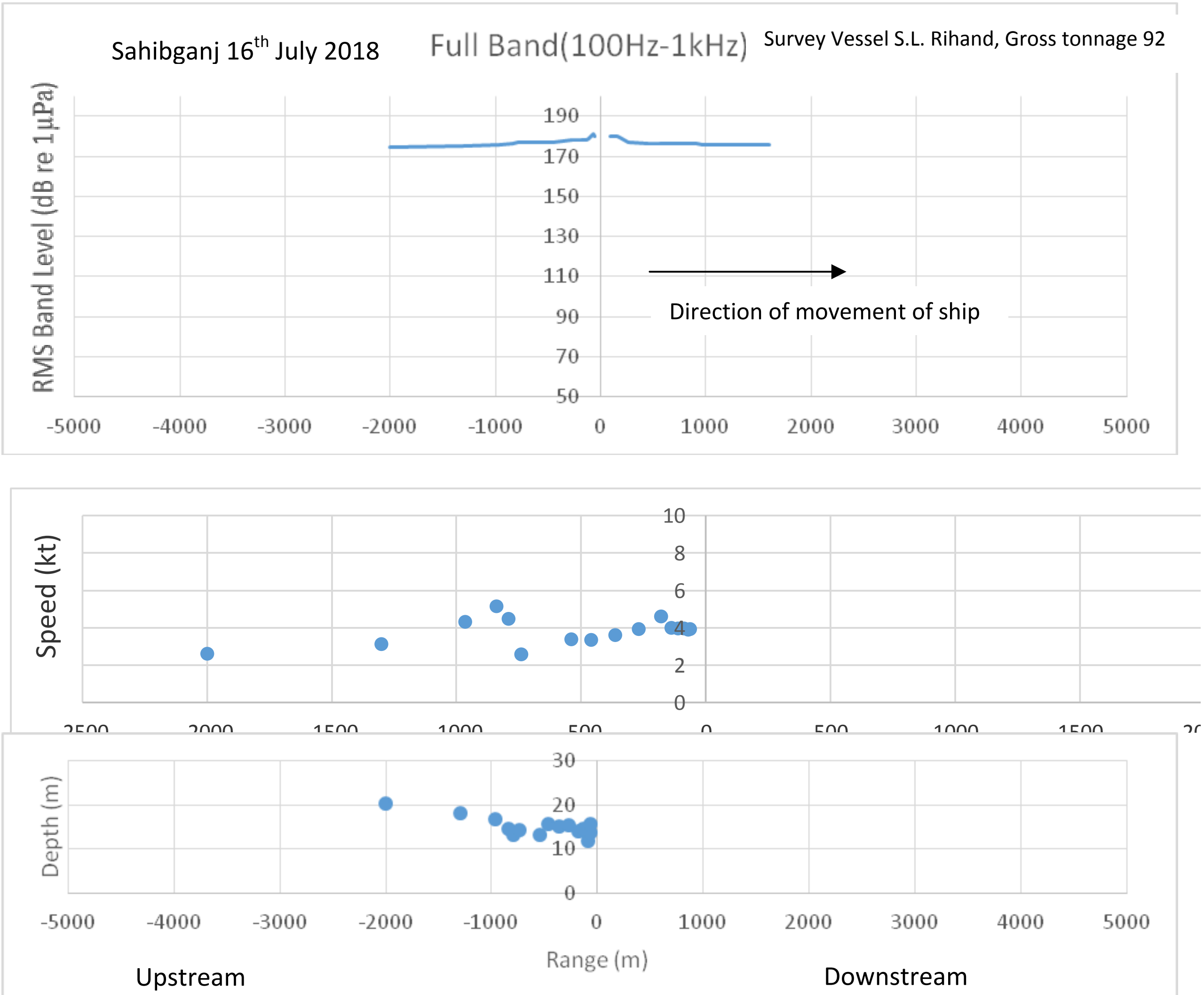


Figure 78: Upper most plot is rms Band level vs Range, Middle plot is Speed (in knots) vs Range and Bottom plot is Depth (in meters) vs Range for Full Band (100 Hz-100 kHz) at Sahibganj on 16th July 2018 ship moving downstream

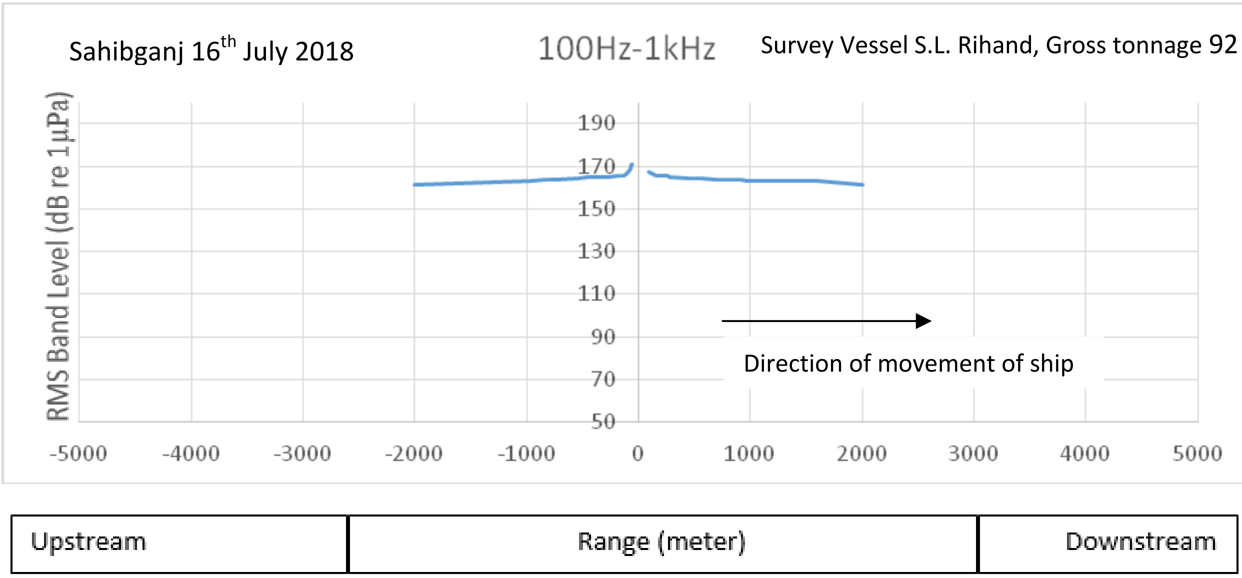


Figure 79: rms Band level vs Range for 100 Hz-1 kHz at Sahibganj on 16th July 2018 ship moving downstream

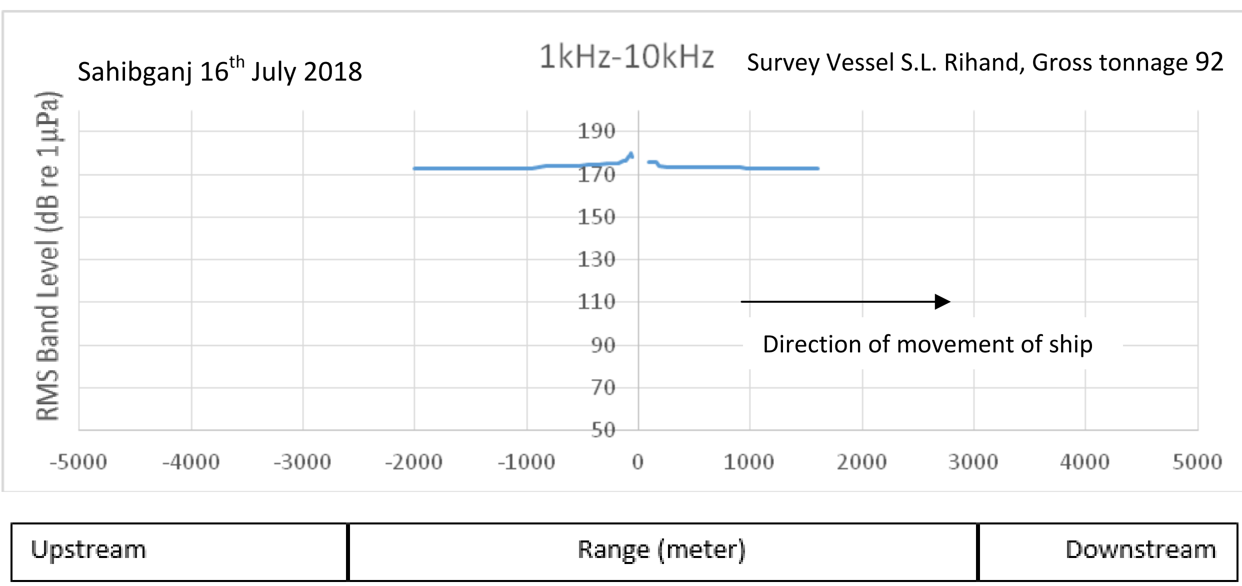


Figure 80: rms Band level vs Range for 1 kHz-10 kHz at Sahibganj on 16th July 2018 ship moving downstream

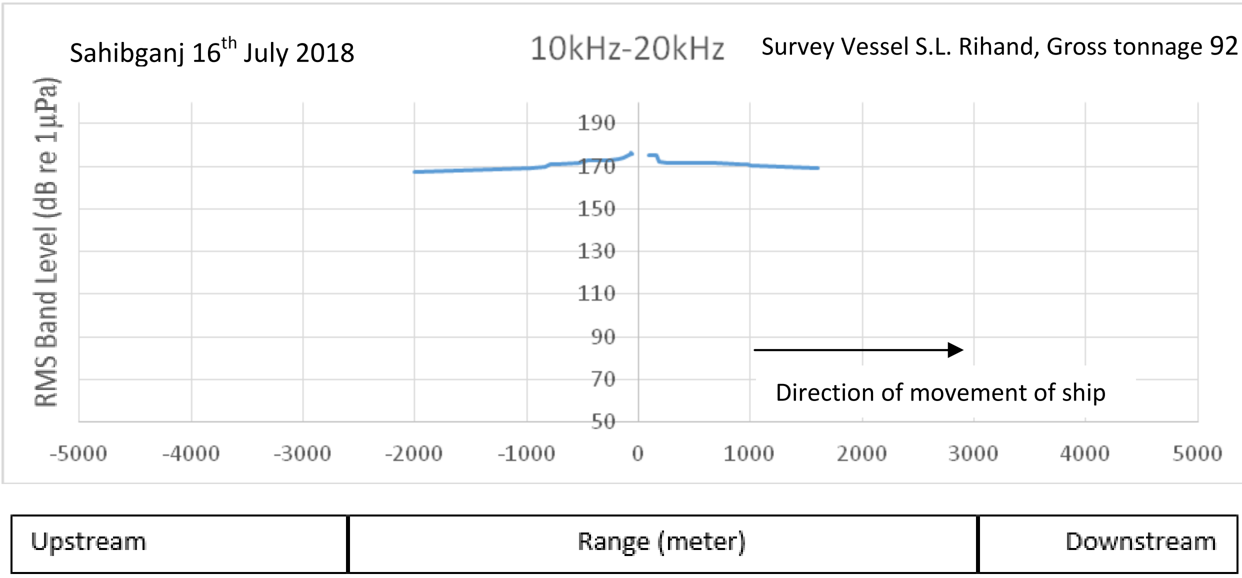


Figure 81: rms Band level vs Range for 10 kHz-20 kHz at Sahibganj on 16th July 2018 ship moving downstream

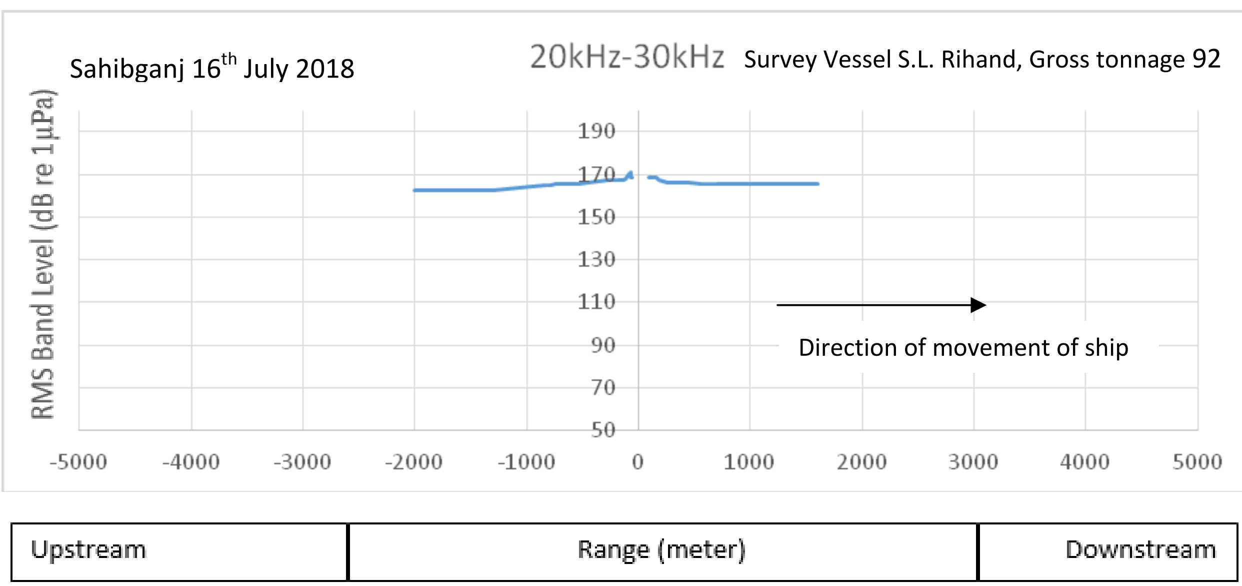


Figure 82: rms Band level vs Range for 20 kHz-30 kHz at Sahibganj on 16th July 2018 ship moving downstream

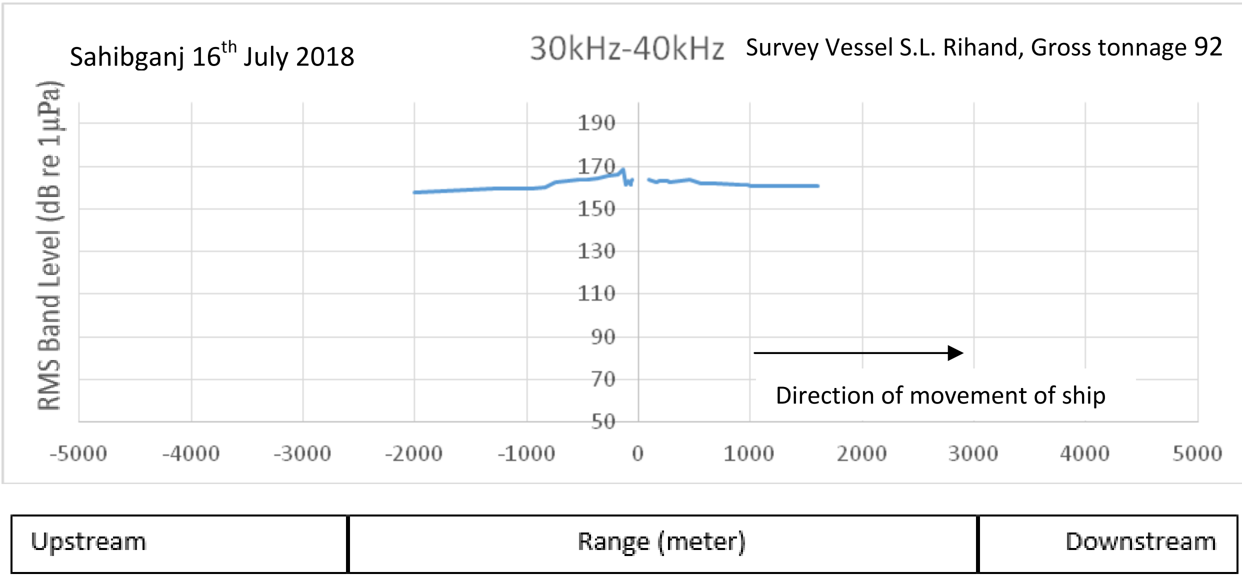


Figure 83: rms Band level vs Range for for 30 kHz-40 kHz at Sahibganj on 16th July 2018 ship moving downstream

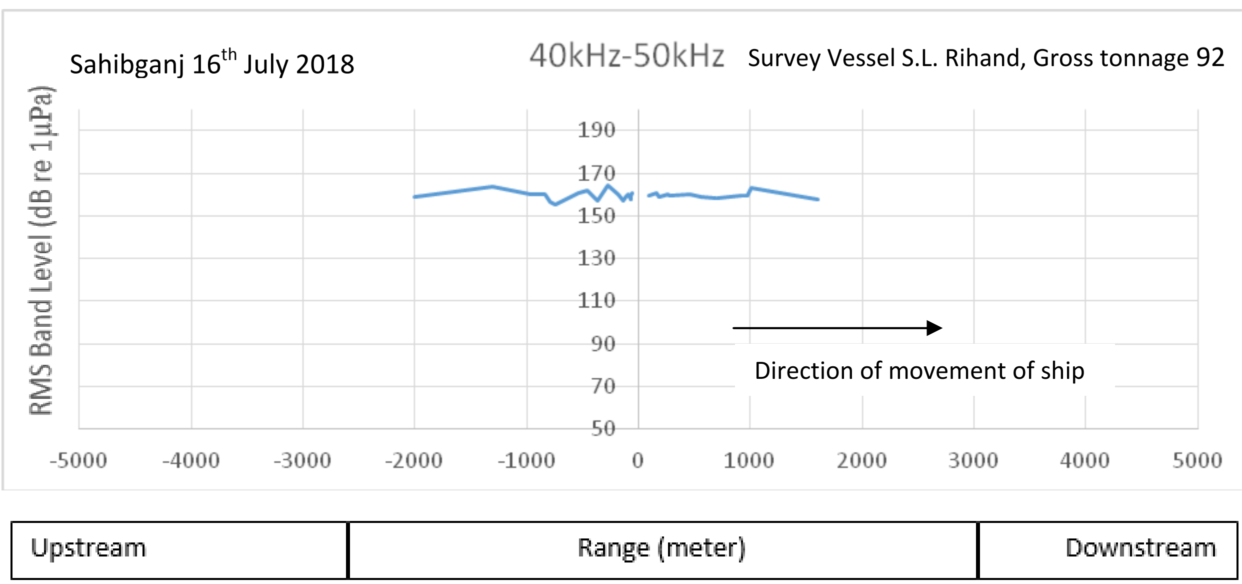


Figure 84: rms Band level vs Range for 40 kHz-50 kHz at Sahibganj on 16th July 2018 ship moving downstream

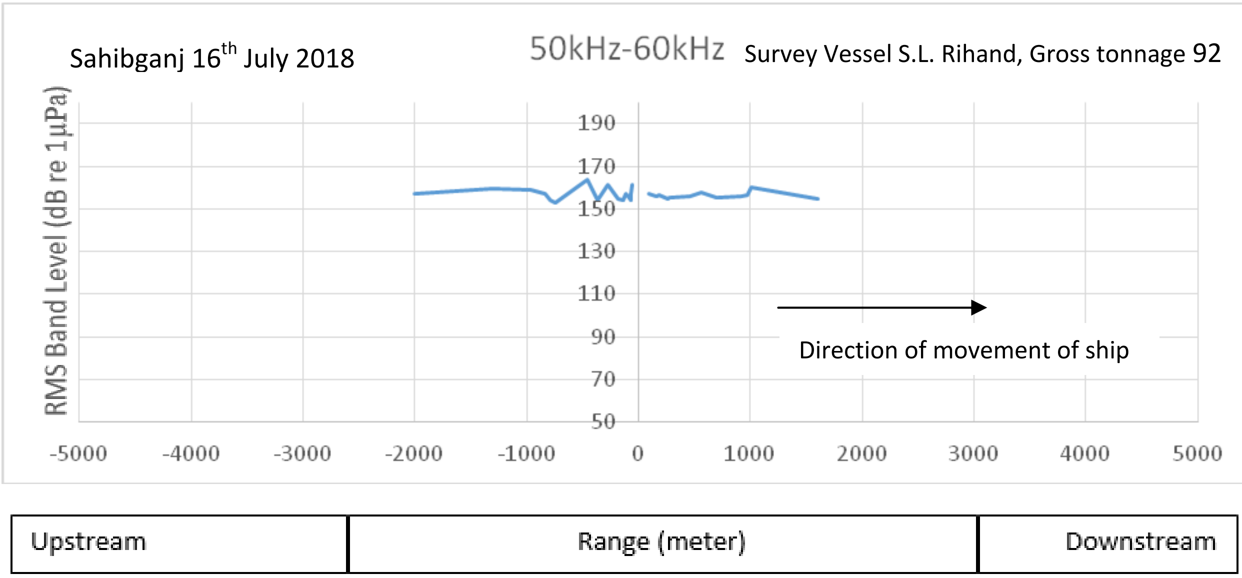


Figure 85: rms Band level vs Range for 50 kHz-60 kHz at Sahibganj on 16th July 2018 ship moving downstream

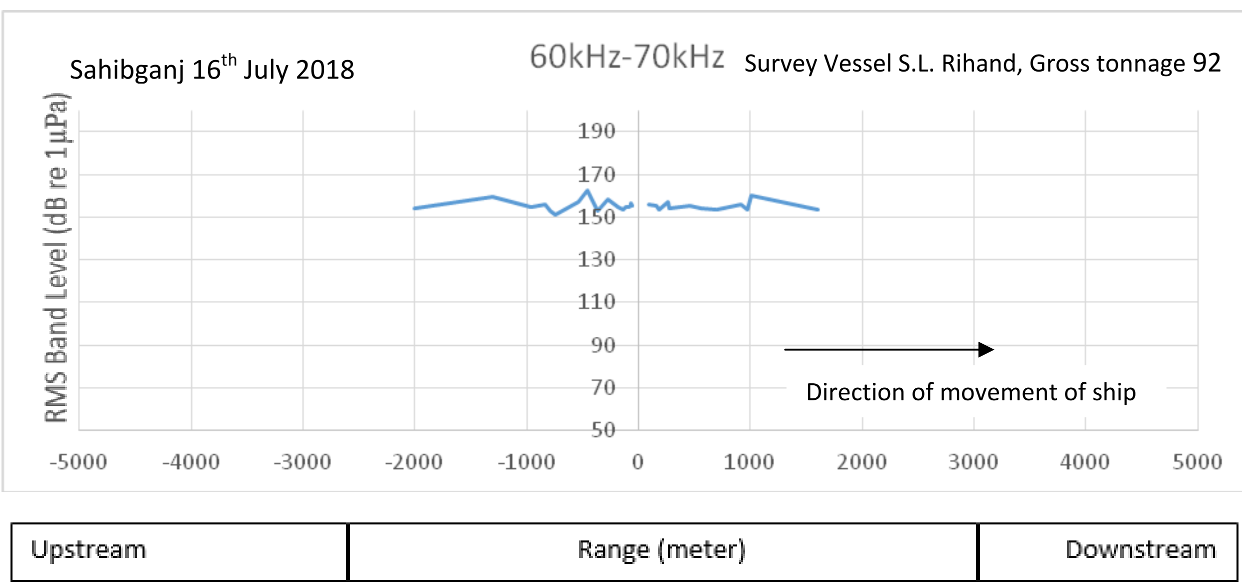


Figure 86: rms Band level vs Range for 60 kHz-70 kHz at Sahibganj on 16th July 2018 ship moving downstream

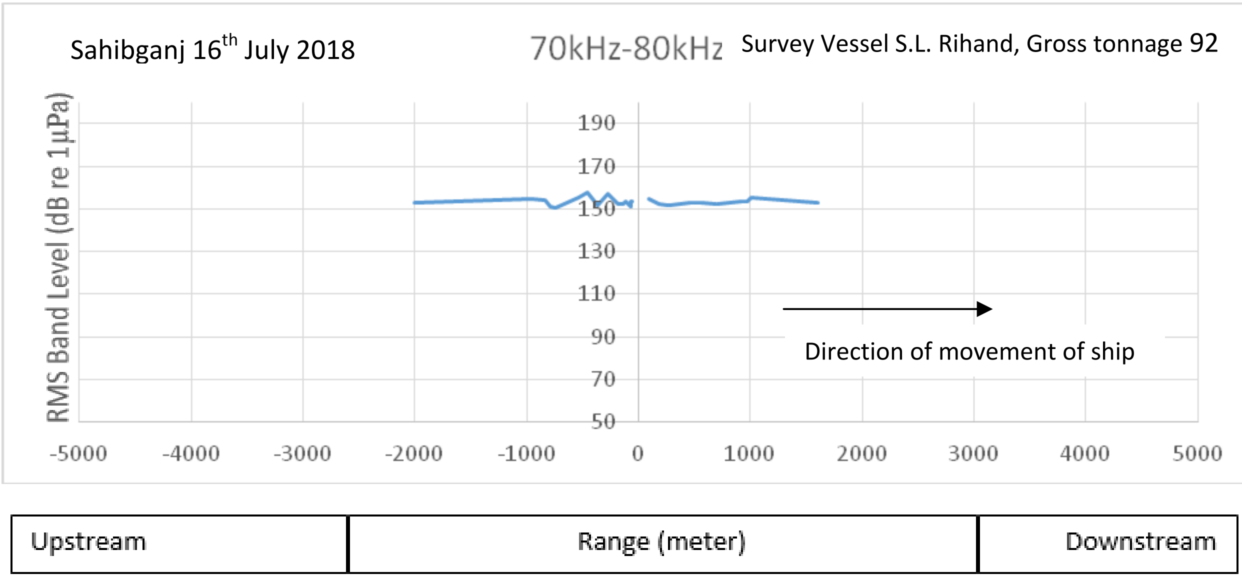


Figure 87: rms Band level vs Range for 70 kHz-80 kHz at Sahibganj on 16th July 2018 ship moving downstream

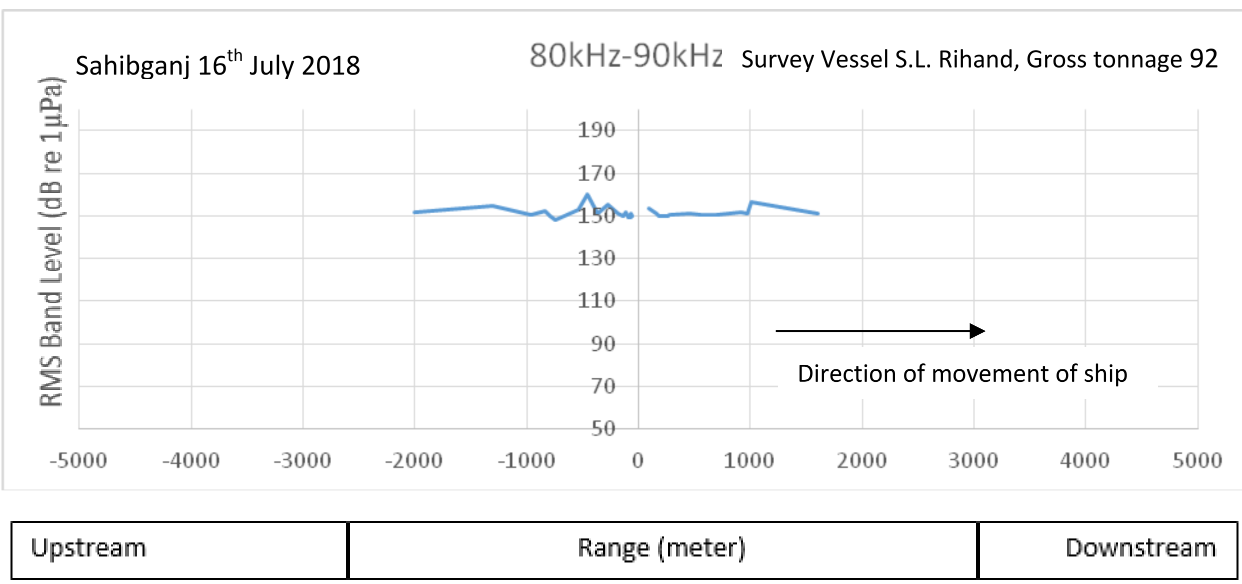


Figure 88: rms Band level vs Range for 80 kHz-90 kHz at Sahibganj on 16th July 2018 ship moving downstream

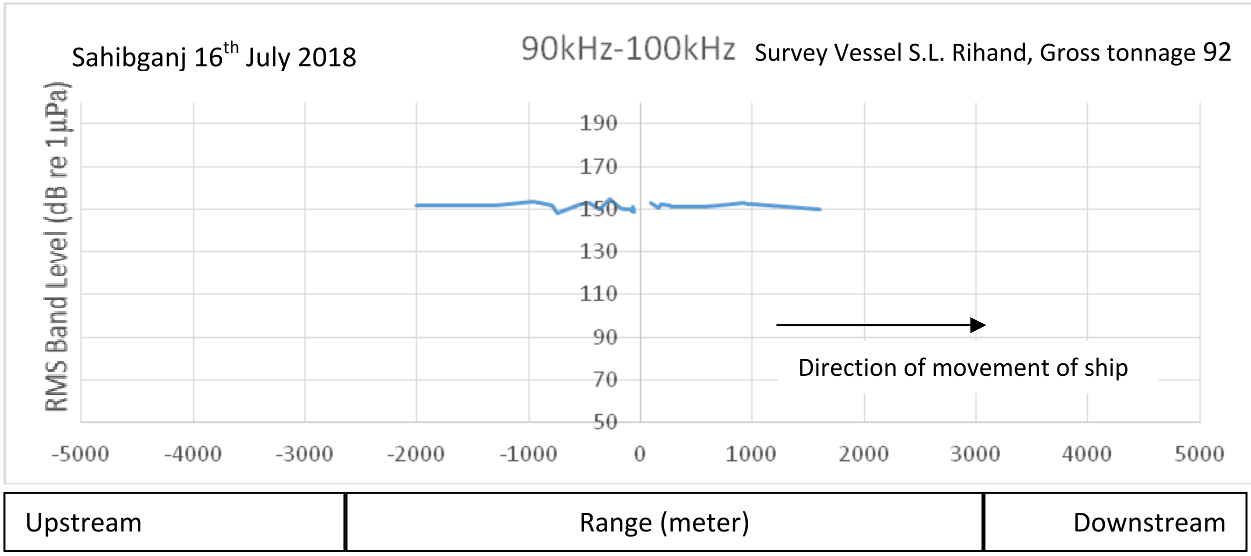


Figure 89: rms Band level vs Range for 90 kHz-100 kHz at Sahibganj on 16th July 2018 ship moving downstream

From Figure 78 we observe that speed varied from 2.5 knots to 5 knots and depth varies from 12 meters to 22 meters approximately.

5.3.3: Maximum ship noise in different bands: The maximum ship noise is obtained in Sahibganj measurements, when ship was at a distance of 63 meters from the boat. The ship noise in various frequency bands are shown in figure 90. The rms ambient noise level and the calculated maximum rms ship sound level at 1 meter are also shown in figure 90.

Shortest Ship distance from boat = 63 meters

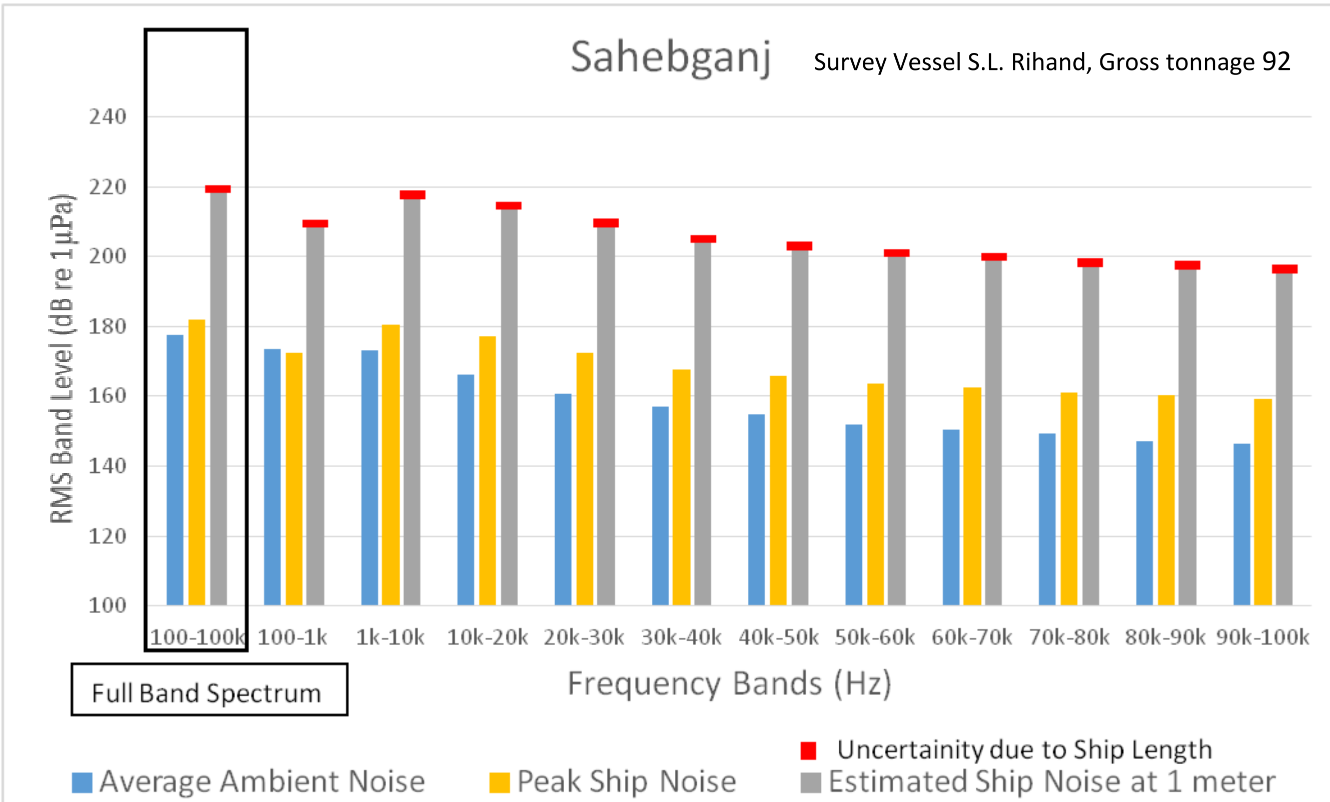


Figure 90: rms Band level vs Frequency Bands at Sahibganj (16th July 2018) upstream

Uncertainty in rms sound level at 1 m due to ship length is 2.394 dB re 1µPa.

6. RAJMAHAL FIELD MEASUREMENTS (24TH OCTOBER 2018)

6.1 Ship Details

Name of the ship – M.V. BEKI
Length – 77.37 meters
Breadth – 15 meters
Depth – 5 meters
Gross tonnage – 2200, Actual tonnage 300 – 400 (As per IWAI engineer)

6.2 Arrangements During Measurements

Figure 91: Assembly of equipment for the measurements at Rajmahal on 24th October 2018

Figure 91 (continued): Assembly of equipment for the measurements at Rajmahal on 24th October 2018

6.3 Observations and Results from Measurements

6.3.1 Upstream: Measurement of Ship sound level in Rajmahal on 24th October 2018 with 300 to 400 actual tonnage ship moving opposite to the direction of flow of river at maximum recorded ship speed of 5.6 knots. Plots of the noise versus range are given in the following figures for various frequency bands.

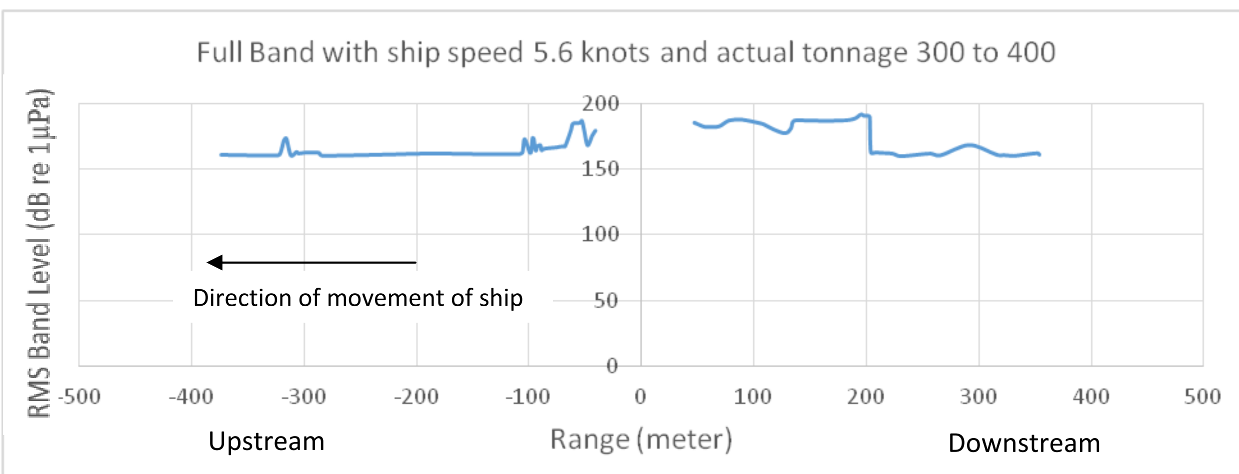


Figure 92: rms Band level vs Range for Full Band (100Hz-100kHz) at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

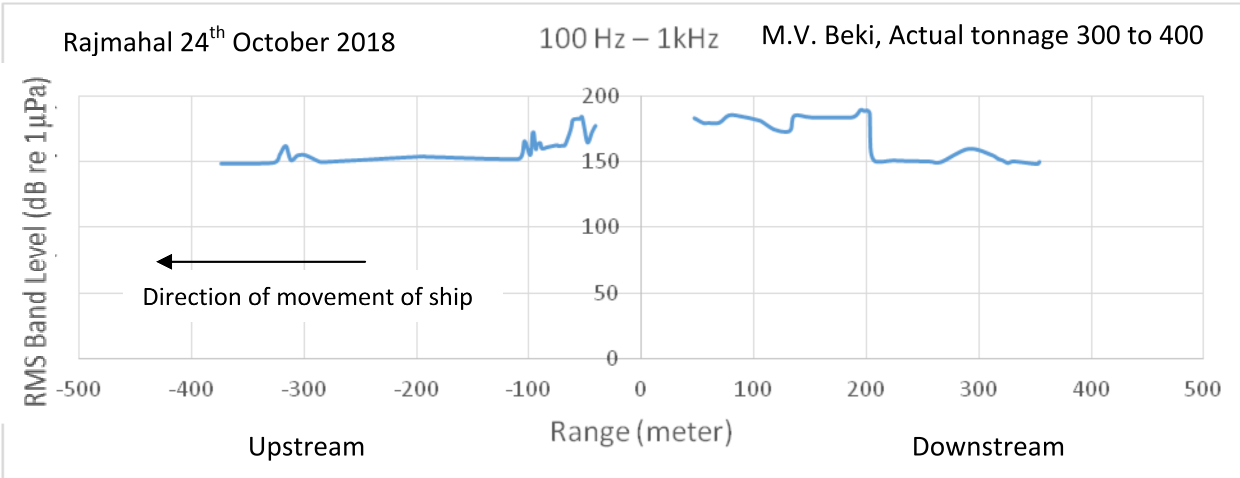


Figure 93: rms Band level vs Range for 100 Hz-1 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

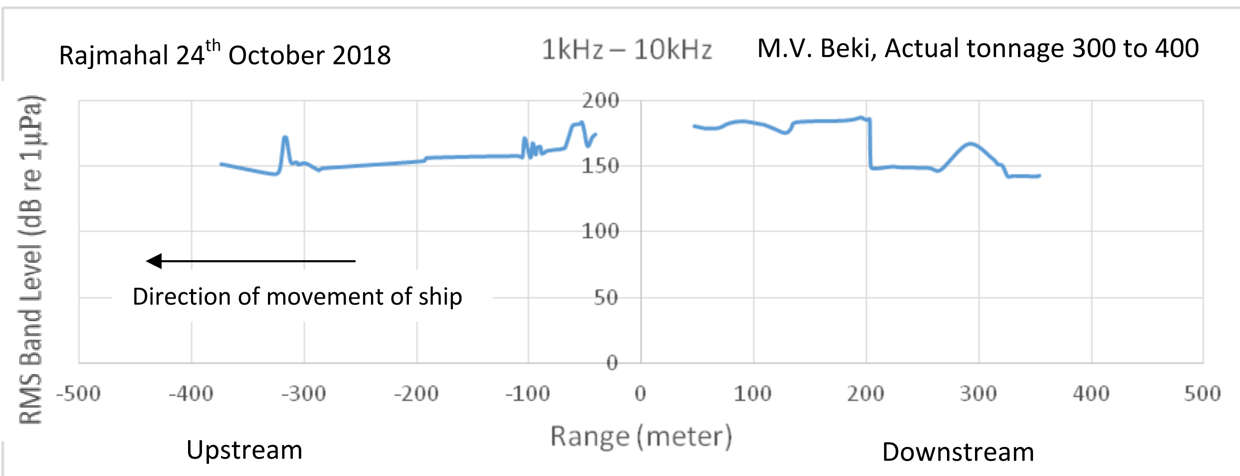


Figure 94: rms Band level vs Range for 1 kHz-10 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

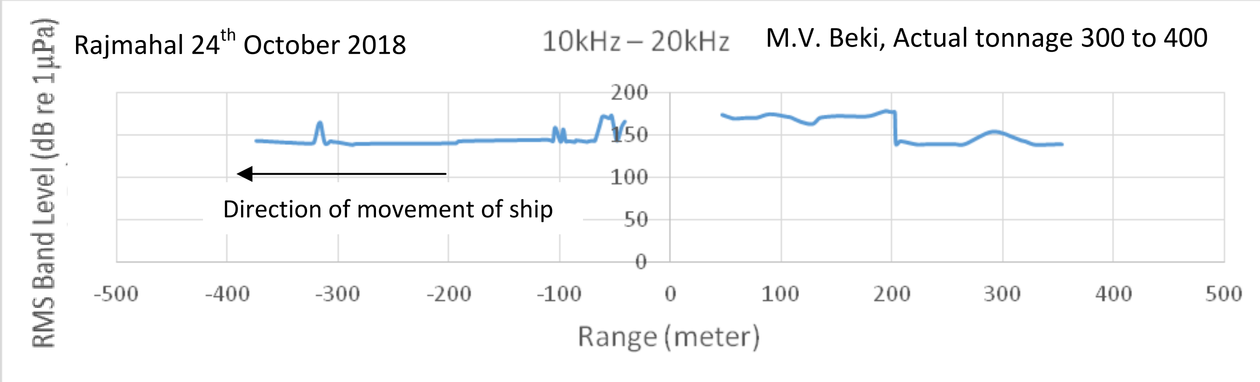


Figure 95: rms Band level vs Range for 10 kHz-20 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

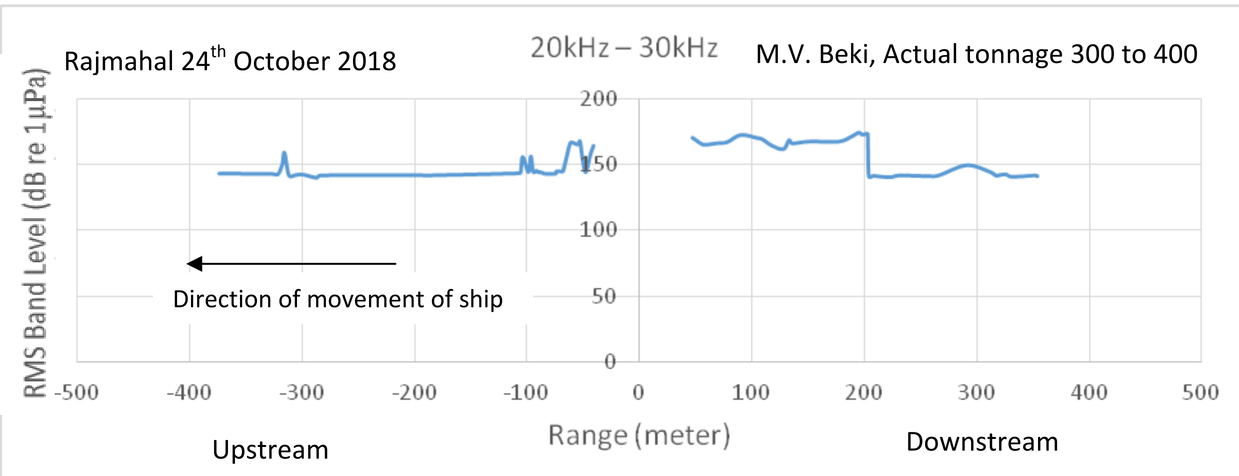


Figure 96: rms Band level vs Range for 20 kHz-30 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

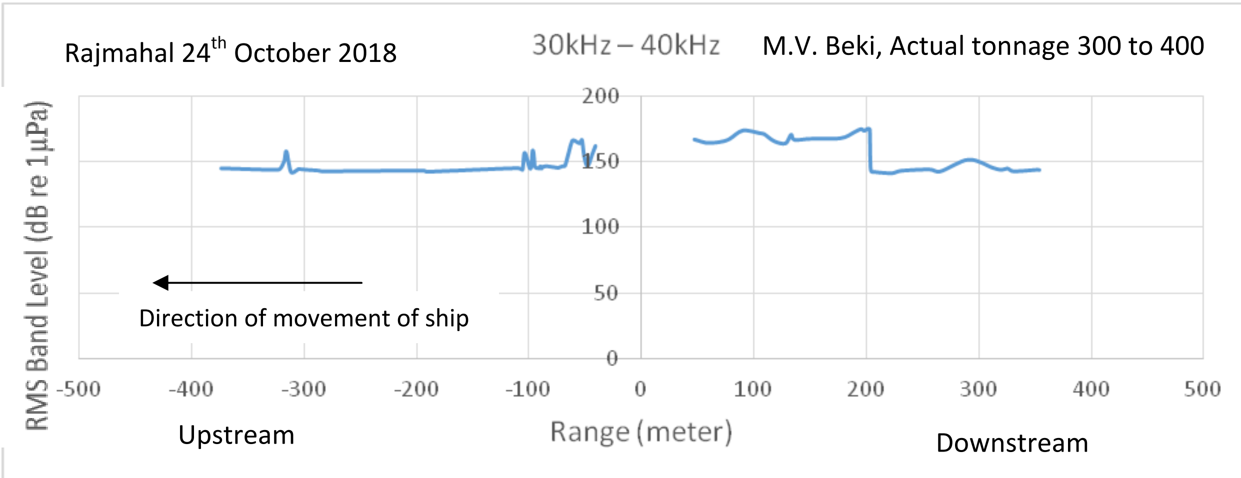


Figure 97: rms Band level vs Range for 30 kHz-40 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

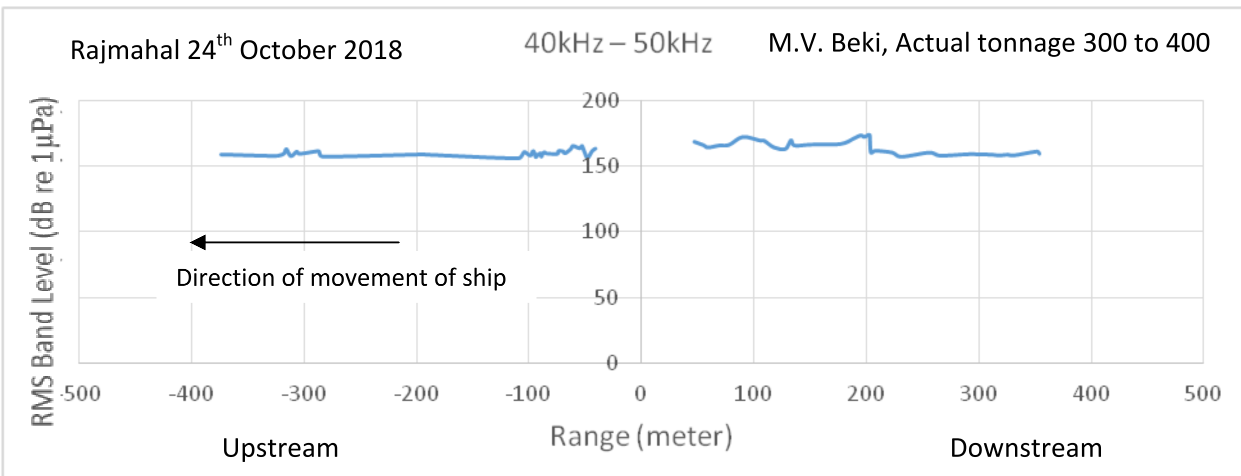


Figure 98: rms Band level vs Range for 40 kHz-50 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

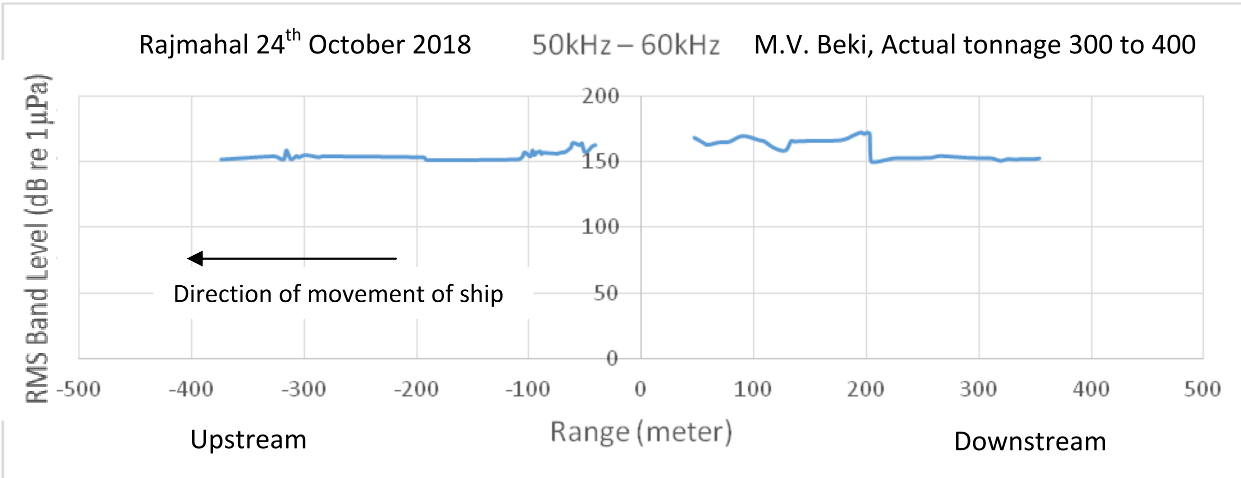


Figure 99: rms Band level vs Range for 50 kHz-60 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

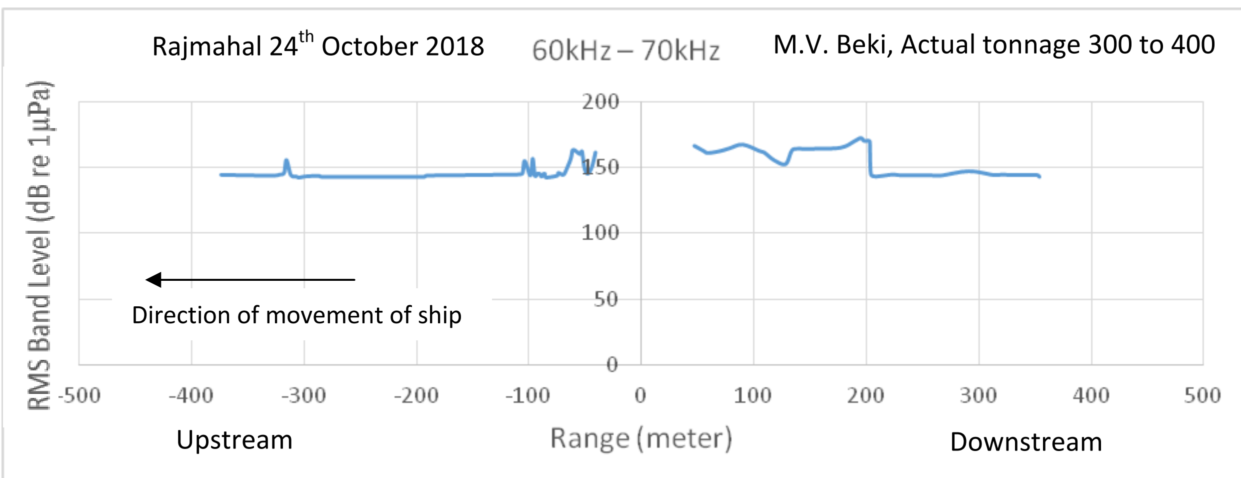


Figure 100: rms Band level vs Range for 60 kHz-70 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

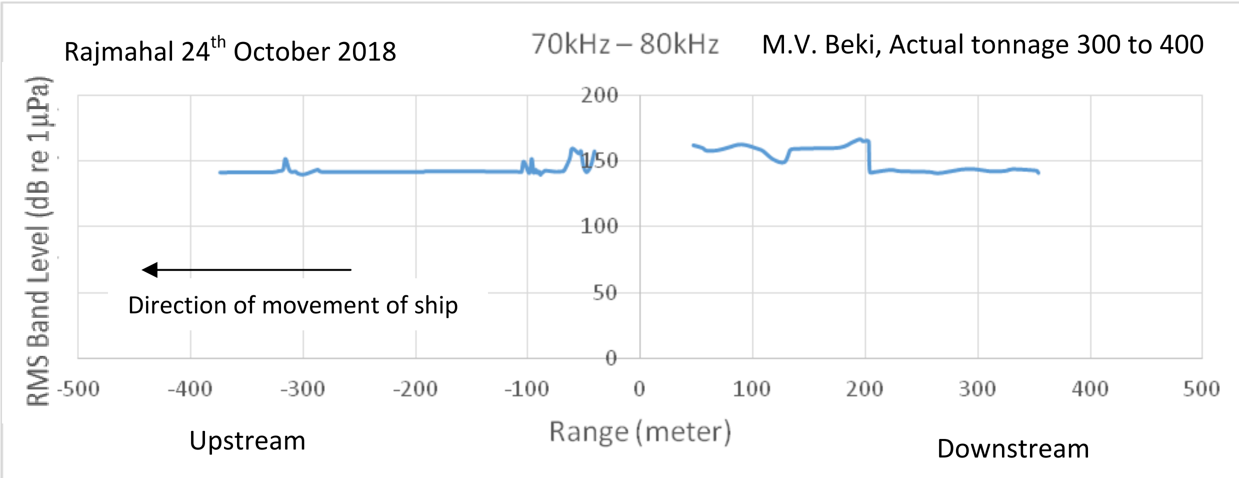


Figure 101: rms Band level vs Range for 70 kHz-80 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

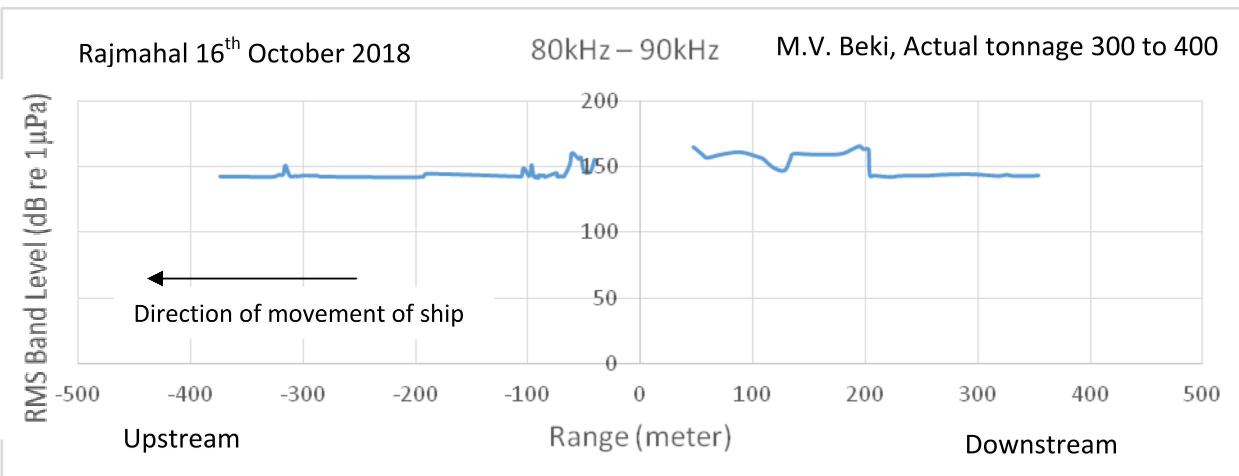


Figure 102: rms Band level vs Range for 80 kHz-90 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

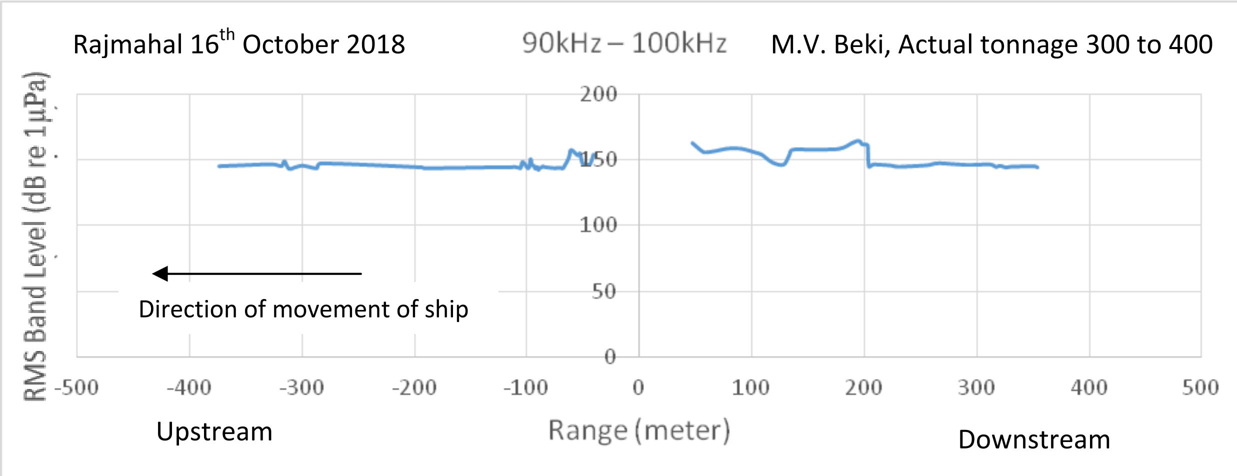


Figure 103: rms Band level vs Range for 90 kHz-100 kHz at Rajmahal on 24th October 2018 ship moving upstream with speed of 5.6 knots and 300 to 400 actual tonnage

6.3.2 Downstream: Measurement of Ship noise in Rajmahal on 24th October 2018 with 300 to 400 actual tonnage ship moving in the same direction of flow of river at maximum recorded ship speed of 5.6 knots. Plots of the noise versus range are given in the following figures for various frequency bands.

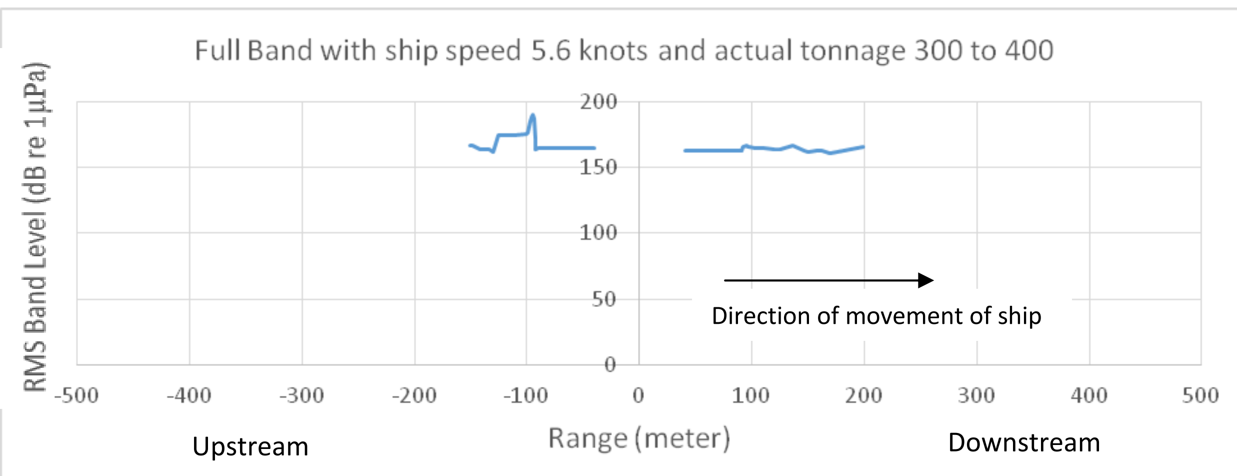


Figure 104: rms Band level vs Range for Full Band (100Hz-100kHz) at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

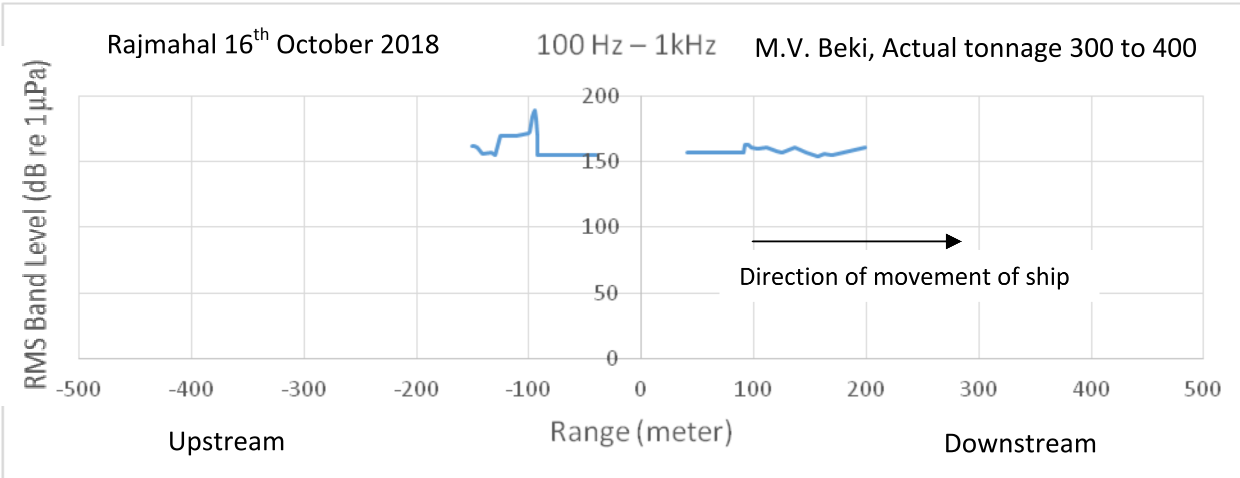


Figure 105: rms Band level vs Range for 100 Hz-1 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

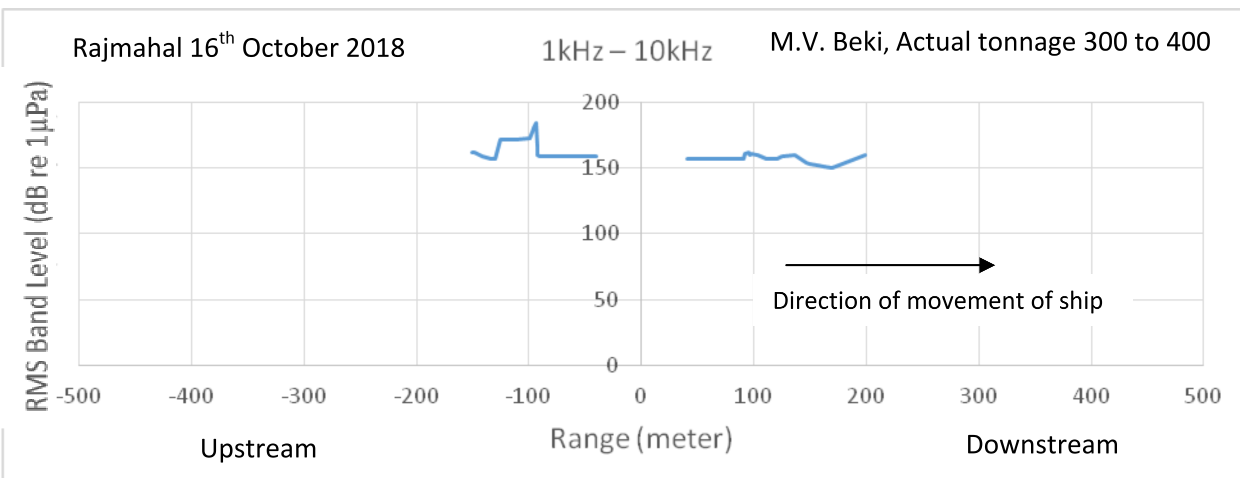


Figure 106: rms Band level vs Range for 1 kHz-10 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

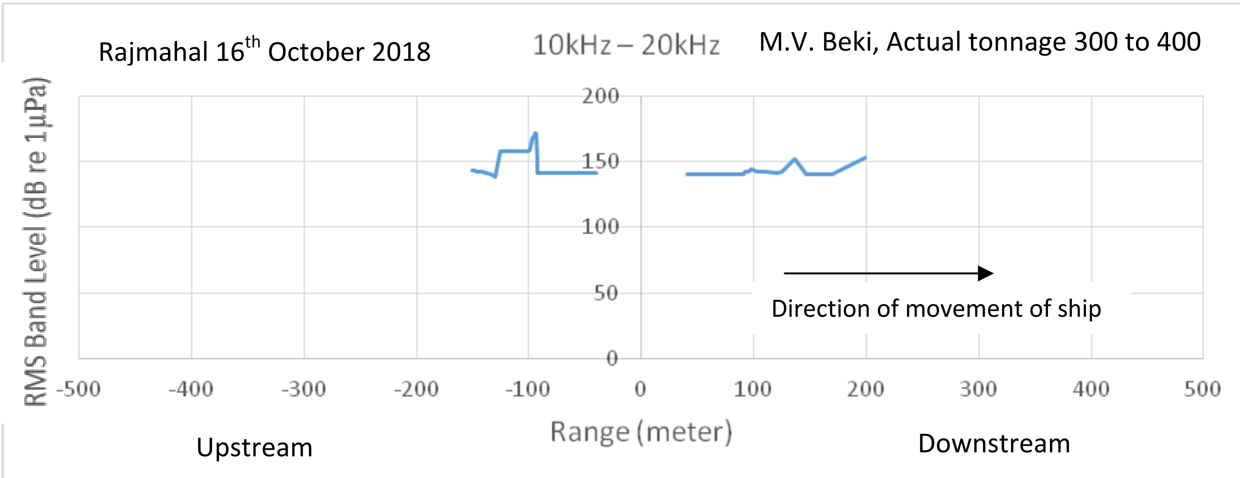


Figure 107: rms Band level vs Range for 10 kHz-20 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

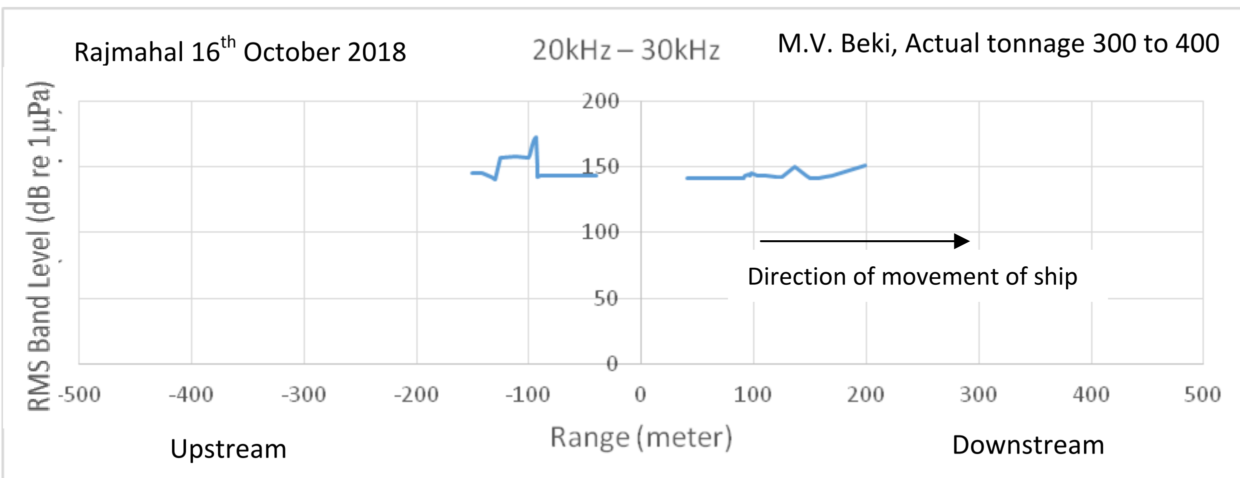


Figure 108: rms Band level vs Range for 20 kHz-30 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

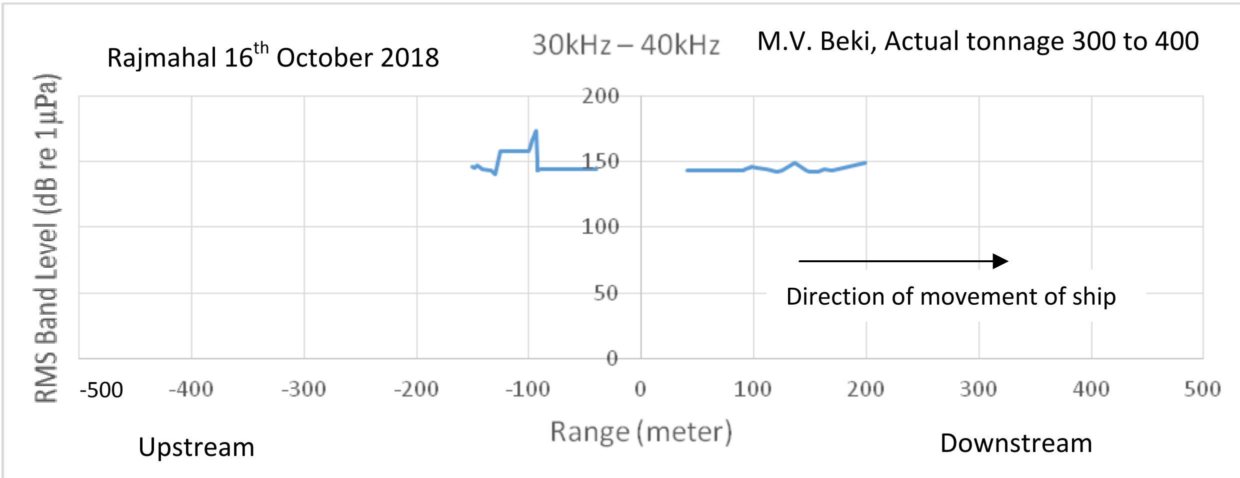


Figure 109: rms Band level vs Range for 30 kHz-40 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

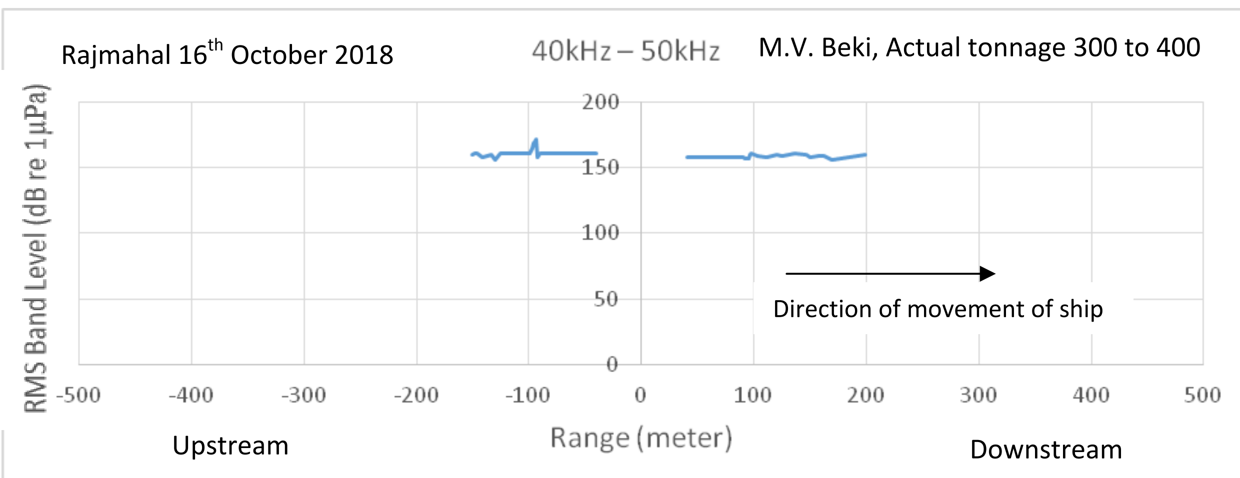


Figure 110: rms Band level vs Range for 40 kHz-50 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

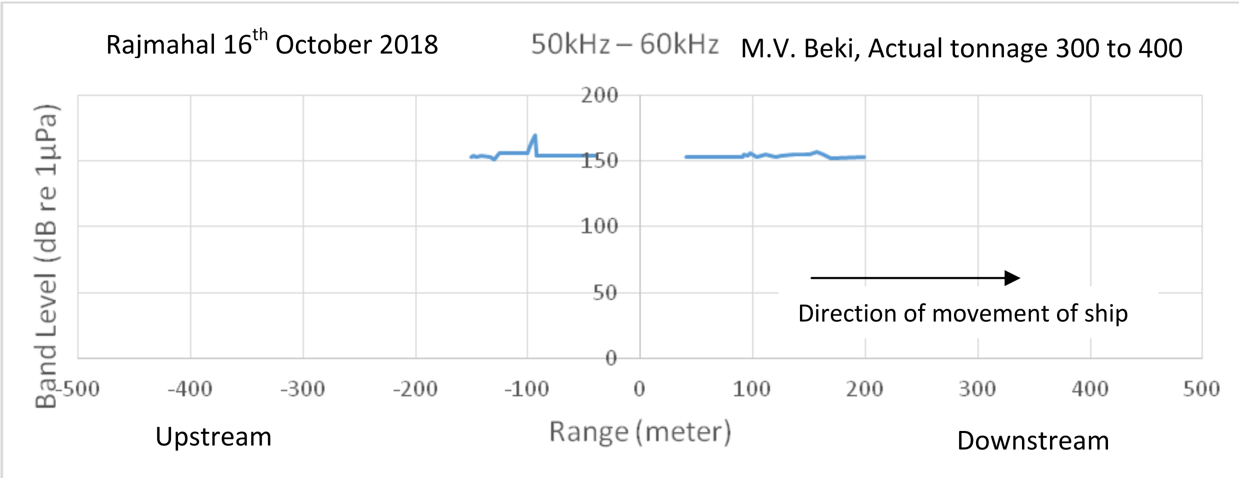


Figure 111: rms Band level vs Range for 50 kHz-60 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

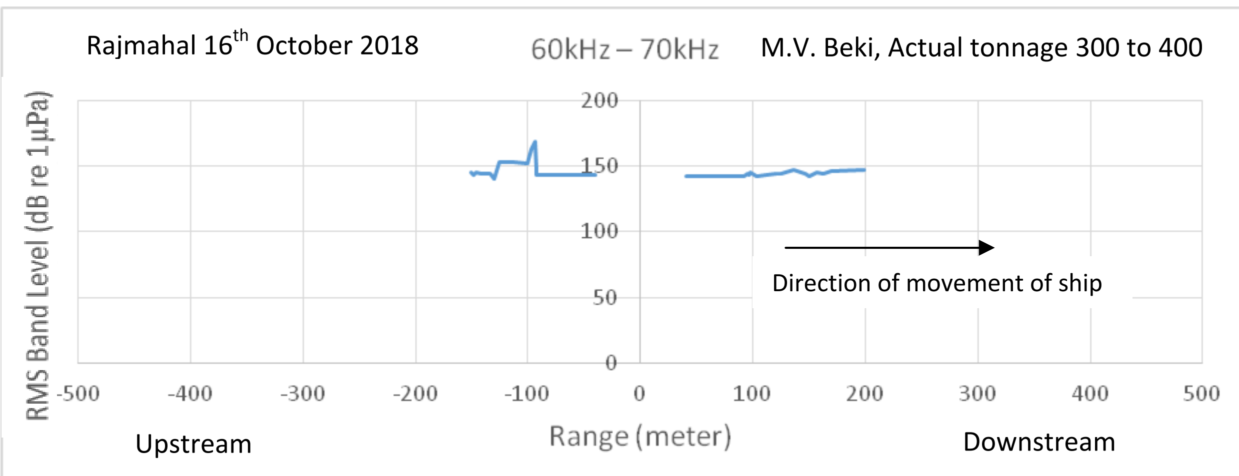


Figure 112: rms Band level vs Range for 60 kHz-70 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

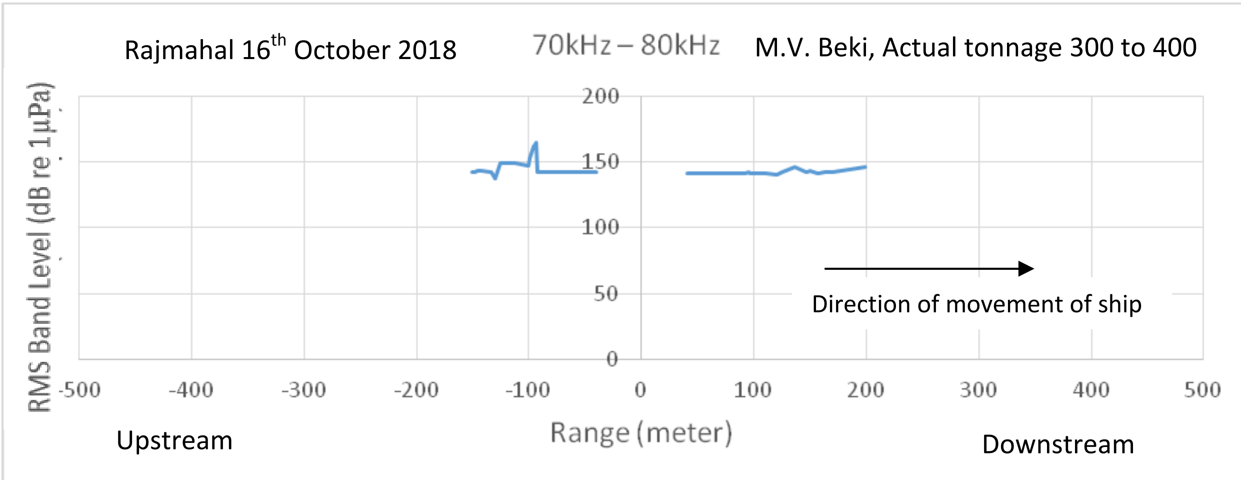


Figure 113: rms Band level vs Range for 70 kHz-80 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

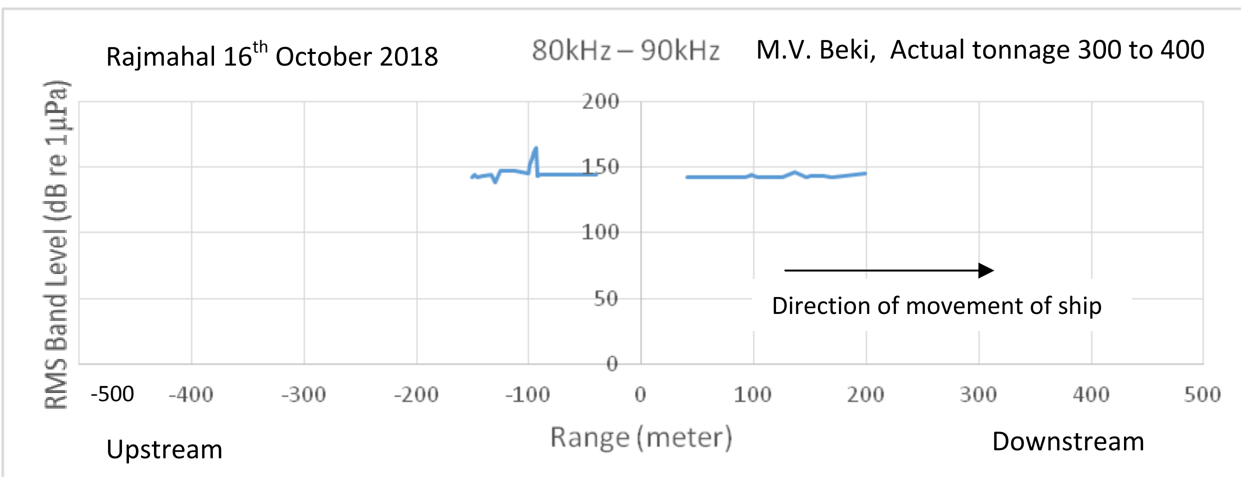


Figure 114: rms Band level vs Range for 80 kHz-90 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

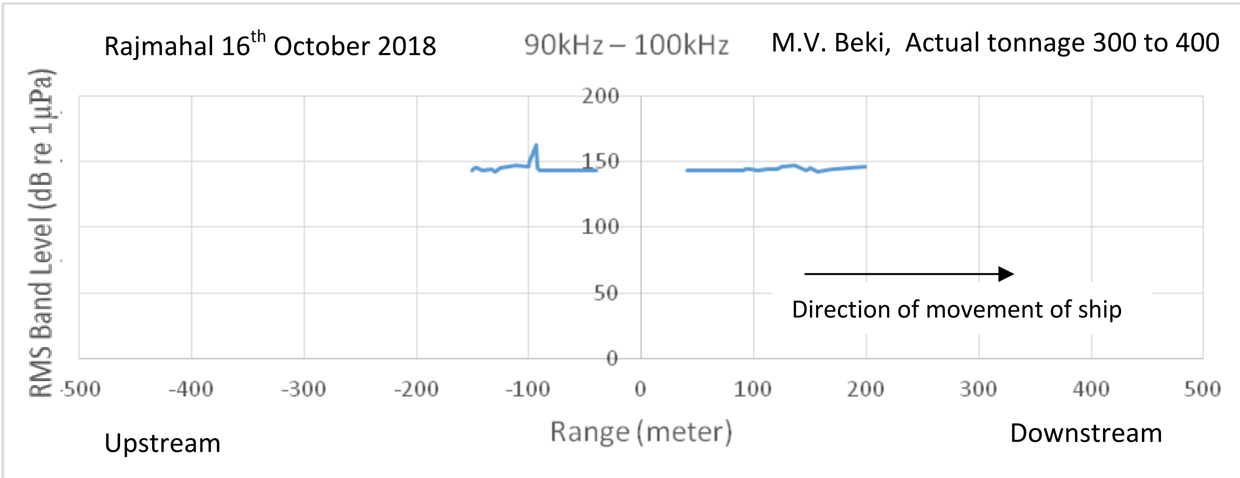


Figure 115: rms Band level vs Range for 90 kHz-100 kHz at Rajmahal on 24th October 2018 ship moving downstream with speed of 5.6 knots and 300 to 400 actual tonnage

6.3.3: Maximum ship noise in different bands: The maximum ship noise is obtained in Rajmahal measurements when ship was at a distance of 192 meters from the boat even though the nearest distance recorded was 41 meters. The reason is that the Master of the ship pumped maximum power for accelerating the ship when it was at a distance of 192 meters. The ship noise in various frequency bands are shown in figure 116. The rms ambient noise level and the calculated maximum rms ship sound level at 1 meter are also shown in figure 116.

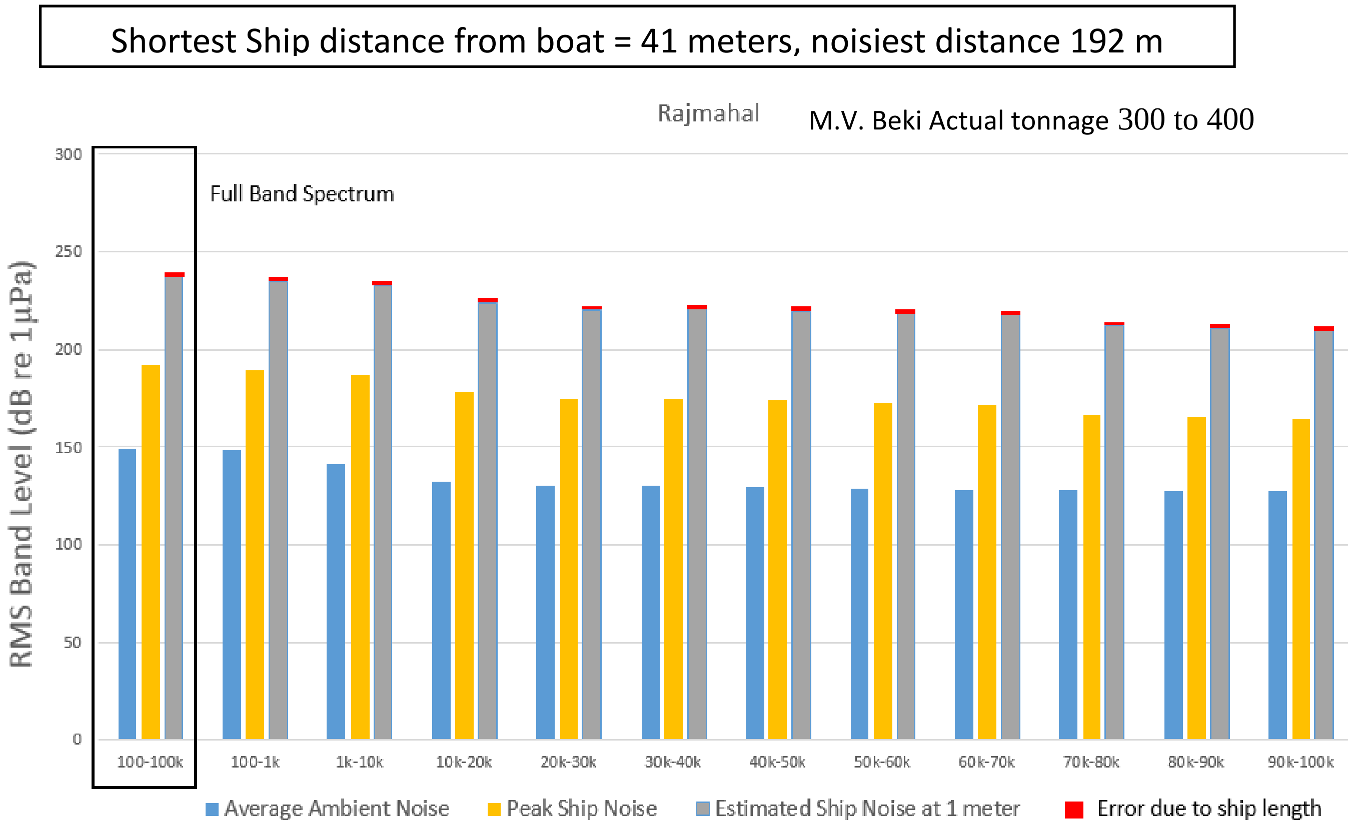


Figure 116: rms Band level vs Frequency Bands at Rajmahal on 24th October 2018 with speed of 5.6 knots and 300 to 400 actual tonnage for upstream

Uncertainty in rms sound level at 1 m due to ship length is 2.0102 dB re 1µPa.

7. SUMMARY

The underwater ship noise measurements have been conducted at four field locations in two rounds. In the first round, the underwater noise of IWAI survey ships were measured at three field locations Varanasi, Patna and Sahibganj during on 13th July 2018 to 16th July 2018. In the second round, the underwater noise generated by bigger vessel (with tonnage of approximately of 300 to 400 tonnes at the time of measurement) has been measured at Rajmahal on 24 October 2018. The rms Band Level noise is measured in the frequency range 100Hz to 100kHz. Apart from the ship noise, the underwater ambient noise is also measured at all the field locations after switching off the ship engine and machinery. The measured underwater noise is analyzed in different frequency bands and rms ship sound source level at 1m is also calculated for all frequency bands. The comparison charts of ship rms sound level with average rms ambient noise level in all frequency bands for all field locations are presented in this report. A comparison of average rms ambient noise level at all locations is shown in Fig. 117.

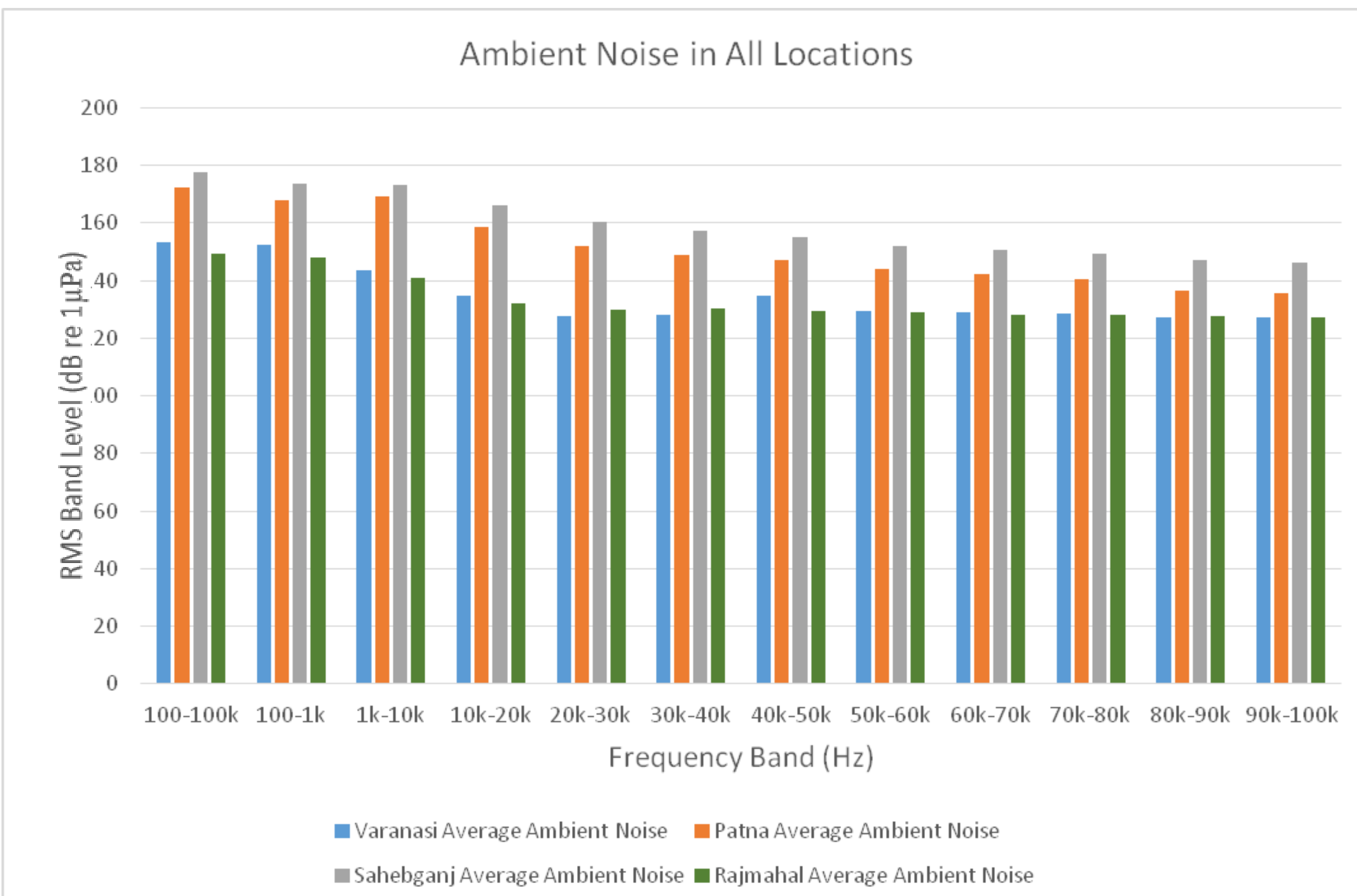


Figure 117: rms Ambient Noise Band level vs Frequency Bands for all four locations

Table 1 summarizes the maximum rms source levels of ship noise over full band measured at all 4 field locations for the specific ships.

S. No.	Locations	Maximum rms full band Ship Source level (dB re 1µPa) at 1 meter
1	Varanasi (13th July 2018)	223.312 to 227.982 ***(IWAI Vessel Punpun)***
2	Patna (14th July 2018)	214.84 to 216.84 ***(IWAI Vessel Kamla)***
3	Sahibganj (16th July 2018)	215.64 to 218.04 ***(IWAI Vessel S.L. Rihand)***
4	Rajmahal (24th October 2018)	236.34 to 237.58 ***(M.V. Beki tonnage 300-400)***

Table1: Comparison of Maximum rms full band ship sound source level at 1 meter

Attenuation of underwater sound level with distance is due to 2 reasons: (1) spreading loss, and (2) absorption loss. Absorption loss depends on frequency, water temperature, salinity, depth and pH. For pure/fresh water, attenuation is much lower than in sea water especially upto 100 kHz. For short distances of say less than 1 km, absorption loss can, therefore, be largely ignored for fresh water conditions. Spreading loss is the significant reason for attenuation at short distances in fresh water at frequencies upto 100 kHz. *However, spreading loss is strongly dependent on propagation factors such as underwater channel geometry including reflection and scattering from river water surface, bottom, banks and other underwater features such as sand banks, rocks etc.* **Since it is impossible to generalise the complex propagation conditions in a river as they vary from location to location and are also generally unknown at a particular location, we can only use a simplified rule of thumb to estimate spreading loss: say, between 3 to 6 dB (say X dB) for every doubling of distance from the source.** So, it may increase by X dB from 1m to 2m, another X dB from 2 to 4m, another X dB from 4-8m, and so on. Thus, the spreading loss is calculated as nX dB, where n = $\log_2$ (Distance in metres). Example estimates of attenuation due to spreading loss based on the above rule of thumb for specific distances from source are given below for convenience.

Distance: 2m => X dB => 3-6 dB
4m => 2X dB => 6-12 dB
8m => 3X dB => 9-18 dB
.
.
128m => 7X dB => 21-42 dB
256m => 8X dB => 24-48 dB
512m => 9X dB => 27-54 dB
etc.

Please note that these values are an average expectation of the spreading loss as there could be other variations due to local conditions as pointed out above.

--------------------- End of Report ----------------------

References

[1] Frants H. Jensen, Alice Rocco, Rubaiyat M. Mansur, Brian D. Smith, Vincent M. Janik, Peter T. Madsen, "Clicking in Shallow Rivers: Short-Range Echolocation of Irrawaddy and Ganges River Dolphins in a Shallow, Acoustically Complex Habitat", *PLoS ONE*, April 2013.

[2] T. Ura, R. Bahl, H. Sugimatsu, J. Kojima, T. Inoue, T. Fukuchi, S. Behera, A. Pattnaik, M. Khan, S. Kar, C.S. Kar, D. Swain, "Estimated beam pattern and echolocation characteristics of clicks recorded from a free-ranging Ganges river dolphin", *Proc. Of Intl Symp on Underwater Technology 2007,* Tokyo, Japan, 17-20 April, 2007, pages 527-534.

Appendix

Terms of Reference from EQMS

Appendix I (Deliverables)

A report containing the following results would be delivered:

1. Underwater sound levels in dB rel 1 microPascal in various frequency bands at various positions of the transiting navigating vessel.
2. Underwater sound levels in dB rel 1 microPascal in various frequency bands of the background sounds (due to any boats and craft in the vicinity of the observation boat).

3. You will also participate in the presentation at IWAI as and when required, and also answer any query raised by IWAI with respect to your report.

Your report will also provide Level of noise propagation from source (vessels) & its attenuation level at different distances from the source at different frequencies including & frequencies on which Dolphin works.

Monitoring will include minimum the following areas: underwater noise measurement for 2500 to 3000 ton vessel already plying between Farakka to Haldia. Between Varanasi to Patna and Patna to Farakka at least one set each based on survey vessel of IWAI (Including reading in sanctuary area).

ANNEXURE II

SOCIO-ECONOMIC STUDY OF FISHERMEN COMMUNITY IN THE MIDDLE AND LOWER STRETCH OF THE RIVER GANGA

ANNEXURE II

SOCIOECONOMIC STUDY OF FISHERMEN COMMUNITY IN THE MIDDLE AND LOWER STRETCH OF THE RIVER GANGA

A survey was conducted for the fishermen community in and around river Ganga for livelihood study. The area selected for the study were Buxar, Patna, Bhagalpur, Farakka, Godakhali and Diamond harbour. The river stretch of study area was divided into two strata i.g., middle stretch (first strata) and lower stretch (second strata) of the river Ganga based on the fishing practices and the water quality parameters. Middle stretch consisting Bauxar, Patna, Bhagalpur area and the lower stretch having the Farakka, Godakhali, Balagarh and Diamond harbour area. Survey was conducted based on the questionnaire with the following characters. Name of the study area (place), name of fisherman, age (years), education level (below matriculation), above matriculation, only read and write, family members (male, female and children), earning members per family (numbers), occupation (full or part time), experience in fishing occupation (years), monthly income (in rupees), average catch (kg/month), type of catch (indian major carps(IMC), exotic, catfishes and miscellaneous), fish selling price (rupees/kg), fishing net use for fish catch, net hired or owned, income from IMC (rupees/month), boat used (self or hired), catching practices for important commercial fish species, income from the commercial fish catch. A total number of 200 fishermen population were interviewed during the survey. Out of total fishermen (200), 30% fishermen were participated from Farakka area, 25% from the Buxar area and rest 45 % fishermen participated from the remaining study area. The total fishermen were divided into two strata in which middle stretch covered 40% (80 fishermen) and lower stretch 60% (120 fishermen). The comparative study in both the middle and lower stretch of the river is presented in Table 7.1 and 7.2. Socio-economic survey details are given at Table 7.3 to 7.10. Photographs of the socio-economic survey are given at Photograph 7.1 to 7.14. The copy of socio-economic survey schedule is given in at **Annexure – III**. Copy of filled survey sheet is given at **Annexure – IV**.

In the middle stretch of the river the average fishermen age was 46 years with minimum age of 23 years to maximum 68 years. The education level of the 90% fishermen were below matriculation (10th standard) and 10% above the matriculation level. The average family members in the fishermen community were 6 with the minimum one to maximum 22. The total family members having the average 2 male and female per family and 3 children. Two earning members per fisherman family. 95% of the fishermen population main occupation is fishing however besides fishing 5% fishermen also spent some time for spawn collection, labour and others. Average fisherman fishing experience was 27 years with a minimum 5 years and maximum 50 years. The monthly income was around Rs. 9500 per month with a range Rs. 4500 to Rs. 1600 per month. The major fish catch species in this stretch is IMC, exotic, catfishes and miscellaneous. The average ± std. catch per month per fisherman family was observed to be IMC (8.5±4.40 kg), exotic (13±7.98 kg), catfishes (18±7.98 kg) and miscellaneous (20±10 kg), the rate (Rs./kg) of fishes depends on the size and the average rate was observed as IMC (227±60), exotic (178±60) , catfishes (292±60) and miscellaneous (20±10). Generally, fishermen use gillnet for fishing however some were also use dragnet, hook net, scine net, traps etc. The nets of all the fishermen having their own. The average major income from the IMC per month is around Rs. 2413.04±1700. 99% fishermen were having their own boat. There was negligible amount of commercial fishing were done in the middle stretch of the river by the fishermen.

In the lower stretch of the river the average fishermen age was 44 years with minimum age of 22 years to maximum 75 years. The education level of the 10% fishermen was above matriculation (10th standard) and 90% below the matriculation level. The average family members in the fishermen community were 8 and the minimum 1 to maximum 20. The total family members contains the average 2 male and female per family and 2 children. Two earning members per fisherman family. 96% of the fishermen population main occupation is fishing however beside fishing 4% fishermen also spent some time for net preparation, labour, rickshaw pulling, vegetable selling. Average fisherman fishing experience was 25 years with a minimum 4 years and maximum 63 years. The monthly income was around Rs. 6658 per month per family with a minimum Rs. 3000 to Rs. 15000. The fish catch species IMC, exotic, catfishes and miscellaneous was also observed in lesser quantity. The average ± std. catch per month per fisherman family was observed to be, IMC (1.63±2.24 kg), exotic (0.175±0.81 kg) , catfishes (6.09±18.45 kg) and miscellaneous (32.20±90.90 kg), the rate (Rs./kg) of fishes depends on the size and the average rate was observed as IMC (220.6±135), exotic (178±60), catfishes (292±150) and miscellaneous (230±80). Generally fishermen use gillnet for fishing however some were also use dragnet, hook net, scine net, traps etc. The nets of all the fishermen having its own. The average major income from the IMC per month is around Rs. 1129.04±700. 99% fishermen were having their own boat. Tenualosa ilisha (Hilsa) was the major commercial fishing in the lower stretch of the river. The average monthly income from the commercial fishing was found to be Rs. 4952± 4030 in the lower stretch of the river Ganga.

The study reveals that the socioeconomic status of the fishermen community in both the middle stretch and the lower stretch of the river Ganga is similar except the major fish catch practice (IMC, exotic, catfishes and miscellaneous) which is found higher in middle stretch than the lower stretch (Figure. 7.1). However, the commercial fishing (Tenualosa ilisha) is found to be the major fishing practice in the lower stretch which is not practiced in the middle stretch and it provide fishermen a handsome amount of income (Figure. 7.2). Due to commercial fishing practices the average income in the lower stretch fishermen is higher than the middle stretch. The average monthly income of the fishermen in the middle stretch is comparatively higher than the lower stretch because in lower stretch fishermen focuses on the commercial fishing like Tenualosa ilisha which is not practiced yearly (Figure. 7.3).

As the socioeconomic analysis showed the fish catch in the middle stretch of IMC, exotic, catfishes and miscellaneous is higher than the lower stretch in the river Ganga. So, fish availability may be one of the factors for dolphin habitat preference in the middle zone. Fish catch and average monthly income of fishermen also higher in the middle stretch of river Ganga. As reported by Sinha, R.K. 2013 that almost 50% of the total population of the Ganges River dolphin (total population over 3000) is surviving in rivers of Bihar. However less number was observed in the lower stretch of river Ganga. This may be due to the construction of Dam at Farakka, water quality, low fish catch of IMC, exotic, catfishes and miscellaneous as observed through the survey study.

Table 8.2 : The socioeconomic status of the fishermen in the lower and middle stretch of the river Ganga

Sl. No.	Study variables	Middle stretch	Lower Stretch
1	Age (years)	46	44
2	Education level (%)	90	90

	below matriculations		
3	Family member in numbers (no.)	6	8
4	Earning members per family (no.)	2	2
5	Fishing occupation	95%	98%
6	Year in fishing experience (average ± std.)	27±11.12 years	25±11.10 years
7	Monthly income per family	Rs. 9500±2872	Rs. 6658±2223
8	Type of fish catch/ month (average ± std.)	IMC (8.5±4.40 kg), exotic (13±7.98 kg) , catfishes (18±7.98 kg) and miscellaneous (20±10 kg),	IMC (1.63±2.24 kg), exotic (0.175±0.81 kg) , catfishes (6.09±18.45 kg) and miscellaneous (32.20±90.90 kg),
9	Rate of fish catch (average ± std.)	IMC (227±60 Rs./kg), exotic (178±60 Rs./kg) , catfishes (292±60 Rs./kg) and miscellaneous (20±10 Rs./kg)	IMC (220.6±135), exotic (178±60) ,catfishes (292±150) and miscellaneous (230±80)
10	IMC income per month	Rs. 2413.04±1700	1129.04±700
11	Commercially fish practices	Nill	*Tenualosa ilisha* (Hilsa)
12	Income from commercial fishing per month per family	Nill	Rs. 4952± 4030

Table 8.3 : Fishermen participated from the different part of the river stretch Ganga

River Ganga stretch	Places	Fishermen participation (no.)
Middle stretch	Bauxar	47
	Patna	25
	Bhagalpur	8
Lower stretch	Farakka	62
	Godakhali	33

	Balagarh	19
	Diamond harbour	6
Total		**200**

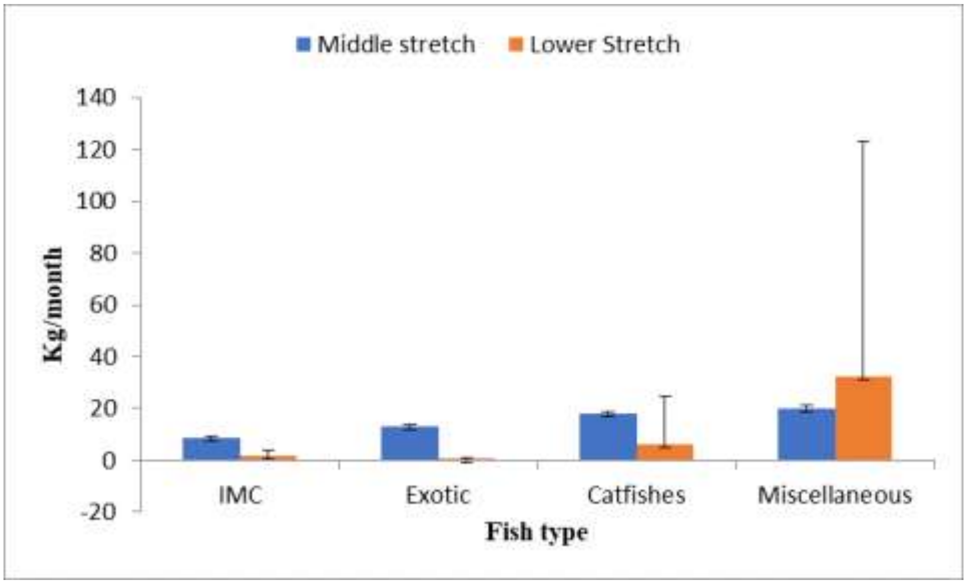


Figure 8.1 : Indian major carps (IMC), exotic, catfishes and miscellaneous fish catch per month per fisherman family in the middle and upper stretch of the river Ganga.

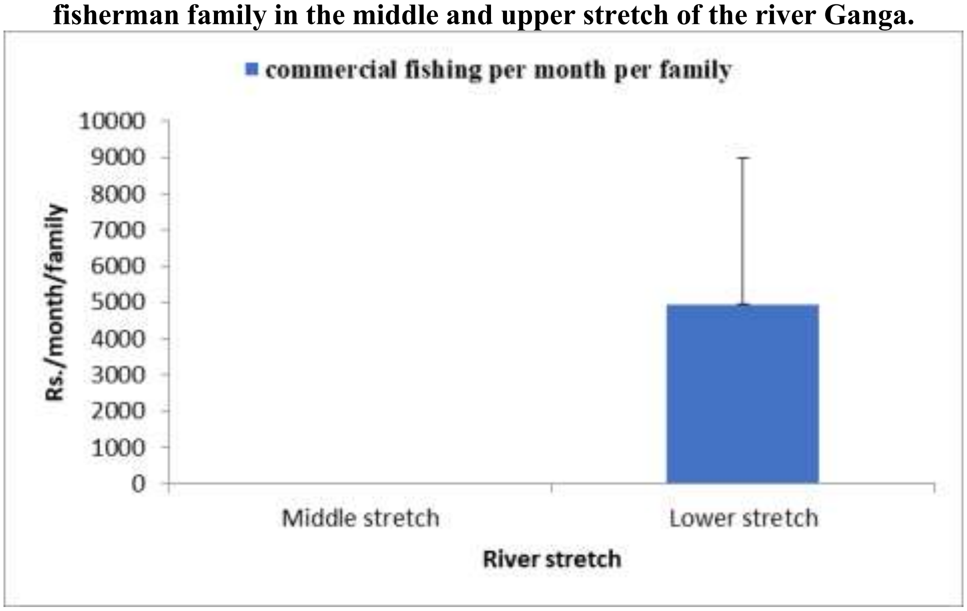


Figure 8.2 : Commercial fish catch income in the two stretches of river Gangaper month per fisherman family members

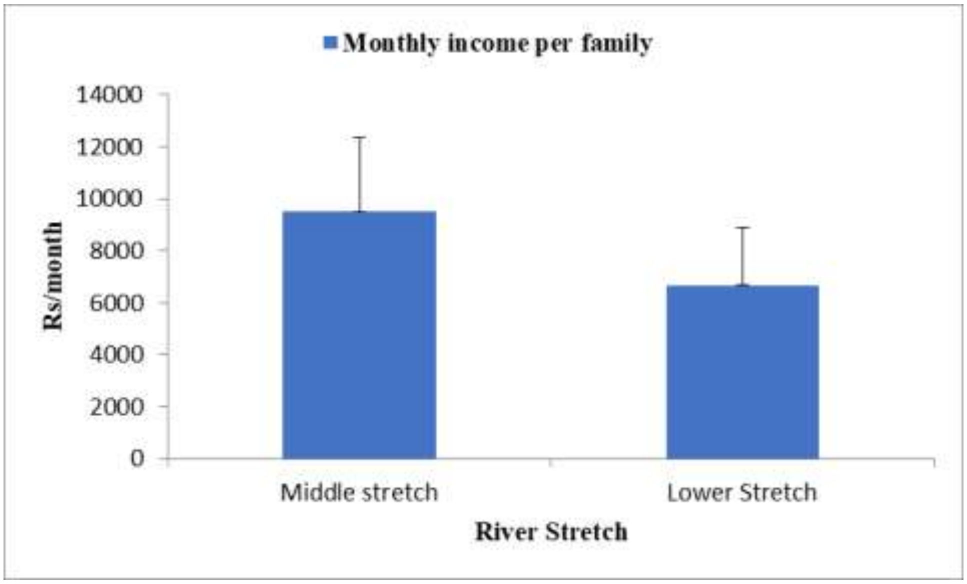


Figure 8.3 : Monthly income per family of fishermen community in the middle and lower stretch of river Ganga

Photographs of Socio Economic Survey Conducted

Photograph 1 : Socioeconomic survey conducted at Buxar, Bihar

Photograph 2: Socioeconomic survey conducted at Buxar, Bihar

Photograph 3 : Socioeconomic survey conducted at Buxar, Bihar

Photograph 4 : Socioeconomic survey conducted at Mokama, Bihar

Photograph 5 : Socioeconomic survey conducted at Gaighat, Patna

Photograph 6 : Socioeconomic survey conducted at, Patna

Photograph 7 : Socioeconomic survey conducted at, Bhagalpur

Photograph 8 : Socioeconomic survey conducted at, Bhagalpur

Photograph 9 : Socioeconomic survey conducted at, Bhagalpur

Photograph 10 : Socioeconomic survey conducted at, Balagarh

Photograph 11 : Socioeconomic survey conducted at, Godakhali

Photograph 12 : Socioeconomic survey conducted at, Farakka

Photograph 13 : Socioeconomic survey conducted at, Diamond harbour

Photograph 14 : Socioeconomic survey conducted at, Diamond harbour

Table 8.4 : Combined Socio-Economic NMCG (Patna)

Sl no.	Place	Name	Age	Education	family membars			Total members	Earning members	Occupation (full time)	Occupation (Part time)	Year in fishing occupation	Monyhly income
					male	female	children						
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Patna	Rajesh Prasad	40	10	4	1	5	10	7	fisherman	0	12	6000
2	Patna	Saroj Chowdhury	35	8	2	2	1	5	2	fisherman	0	25	7000
3	Patna	H. Khan	31	8	3	2	1	6	1	fisherman	0	12	10000
4	Patna	Ajay Sahani	48	0	4	3	2	9	5	fisherman	0	20	7500
5	Patna	Brijesh Sahani	42	1	2	2	5	9	2	fisherman	fish selling, labour	22	12000
6	Gaighat, Patna	Mithai Sahani	50	0	3	2	4	1	9	fisherman	livestock farming	40	10000
7	Gaighat, Patna	Musafir Sahani	60	0	5	6	4	15	11	fisherman	labour	48	12000
8	Gaighat, Patna	Sautlal Sahani	55	0	6	4	3	13	5	fisherman	0	42	13000
9	Gaighat, Patna	Kumar Sahani	45	read & write	2	1	0	3	1	fisherman	labour	30	8000
10	Gaighat, Patna	Lagandeb Sahani	50	0	2	1	0	3	1	fisherman	0	35	8000
11	Gaighat, Patna	Sabir Sahani	50	0	4	2	2	8	3	fisherman	labour	35	10000
12	Gaighat, Patna	Raghuvir Sahani	60	read & write	8	4	3	15	5	fisherman	0	39	12000
13	Gaighat, Patna	Harindar Sahani	26	5	6	3	3	12	4	fisherman	fish selling, labour	14	12000
14	Gaighat, Patna	Manoj Sahani	42	0	3	2	1	6	2	fisherman	0	30	10000
15	Gaighat, Patna	Rajdeb Sahani	50	0	3	4	3	10	3	fisherman	labour	38	12000

Avg. catch (kg)/month				rate of fishes (Rs./Kg)				Fishing net used to catch	Fishing net whether self owned or hired	Income from IMC (Rs.)/month	Boat used is whether self owned or hired	Catch another commercially imp. sp.	Income from those species (Rs.)/month
IMC	Exotic	Catfishes	Miscellaneous	IMC	Exotic	Catfishes	Miscellaneous						
15	16	17	18	19	20	21	22	23	24	25	26	27	28
15	25	20	20	160	80	250	30	gill net, hook and line	selfowned	1000	self owned	0	0
4	20	20	50	200	350	300	50	gill net	selfowned	500	self owned	0	0
10	22	25	30	200	0	350	150	scine net, gill net, hook & line	selfowned	3000	selfowned	0	0
7	10	30	20	250	150	300	150	Scine net, gill net, traps	selfowned	5000	selfowned	0	0
2	12	25	15	250	200	350	100	gill net, hook & line	selfowned	500	self owned	0	0
0	20	25	30	250	200	350	100	gill net	selfowned	0	selfowned	0	0
10	12	20	15	200	200	200	80	gill net	selfowned	2000	selfowned	0	0
12	10	22	15	250	200	200	100	gill net	selfowned	1500	selfowned	0	0
10	5	22	20	250	200	200	100	gill net	selfowned	1500	selfowned	0	0
10	12	15	20	300	200	350	150	gill net	selfowned	1000	selfowned	*Sperata* sp	1500
0	30	25	15	300	200	350	150	gill net	selfowned	1500	selfowned	0	0
12	15	15	30	350	250	350	100	gill net	selfowned	4000	selfowned	0	0
10	10	15	25	350	250	350	100	gill net	selfowned	2500	selfowned	0	0
12	10	20	35	350	250	350	100	gill net, hook & line	selfowned	3000	selfowned	0	0
8	12	10	25	300	200	350	150	gill net, trap	selfowned	3000	selfowned	0	0

Table 8.5 : Combined Socio-Economic NMCG (Bhagalpur)

Sl no.	Place	Name	Age	Education	family membars male	female	children	Total members	Earning members	Occupation (full time)	Occupation (Part time)	Year in fishing occupation	Monyhly income
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Bhagalpur	Haridev Salmi	23	0	4	3	1	8	3	fisherman	0	10	16000
2	Bhagalpur	Babulal Nishad	48	0	4	2	2	8	3	vegetable seller	fisherman	8	4500
3	Bhagalpur	Bapi Biswas	52	4	3	2	0	5	2	fisherman	0	24	12000
4	Bhagalpur	Jitu Chowdhury	24	12	3	4	2	9	1	fisherman	labour	8	8000
5	Bhagalpur	Nikhil Chowdhury	38	10	9	5	7	21	4	fisherman	Agriculture	12	8000
6	Bhagalpur	Jipu Ram	52	3	1	1	5	7	2	fisherman	Agriculture	20	10000
7	Bhagalpur	Rayan Majhi	39	Graduate	2	2	1	5	2	fisherman	labour	12	10000

Avg. catch (kg)/month IMC	Exotic	Cat fishes	Miscellaneous	rate of fishes (Rs./Kg) IMC	Exotic	Catfishes	Miscellaneous	Fishing net used to catch	Fishing net whether self owned or hired	Income from IMC (Rs.)/month	Boat used is whether self owned or hired	Catch another commercially important species	Income from those species (Rs.)/month
15	16	17	18	19	20	21	22	23	24	25	26	27	28
12	50	20	10	250	0	550	200	gill net	self owned	3000	self owned	no	0
7	3	10	8	200	100	200	150	gill net	self owned	1400	Hired	yes	1500
16	2	22	21	200	150	225	150	gill net, drag net and hook and line	self owned	1200	self owned	no	0
4	15	5	10	200	200	300	100	gill net, hook &	self owned	1000	self owned	no	0

								line					
2	12	4	10	200	200	250	150	gill net, hook & line	self owned	400	self owned	no	0
2	0	5	15	350	0	300	100	gill net, Hook & line, trap	self owned	2000	self owned	no	0
2	10	5	5	250	200	300	100	gill net, hook & line	self owned	10000	self owned	no	0

Table 8.6 : Combined Socio-Economic NMCG (Buxar)

Sl no.	Place	Name	Age	Education	family membars			Total members	Earning members	Occupation(full time)	Occupation(Part time)	Year in fishing occupation	Monyhly income
					male	female	children						
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Buxar	Ram Jiban	52	4	3	2	0	5	1	fisherman	labour	21	12000
2	Buxar	Jiten Ram	42	5	4	3	2	9	4	fisherman	0	12	16000
3	Buxar	Lakshman Mallah	48	7	4	3	1	8	3	fisherman	0	20	10000
4	Buxar	Govind Sankar	45	8	3	2	2	7	3	fihserman	0	10	15000
5	Buxar	Dinesh Kumar	29	Graduate	4	3	5	12	2	fisherman	Agriculture	5	10000
6	Buxar	Anil Chowdhury	45	0	4	3	1	8	3	fisherman	Agriculture	30	10000
7	Buxar	Ramesh Prasad	40	10	3	2	2	7	2	fisherman	Agriculture	20	6000
8	Buxar	Bhutan Chowdhury	40	4	2	2	0	4	2	fisherman	0	22	8000
9	Buxar	Subhas Chowdhury	68	1	2	4	2	8	2	fisherman	company job	20	12000
10	Buxar	Lalji Chowdhury	35	0	4	2	4	10	3	fisherman	labour	20	10000
11	Buxar	Santlal Chowdhury	40	0	4	2	4	10	2	fisherman	0	20	6000
12	Buxar	Dinanath Chaowdhury	60	0	4	3	2	9	2	fisherman	0	40	6000
13	Buxar	Gajadhar Chowdhury	50	0	5	4	1	10	3	fisherman	0	35	12000
14	Buxar	Rajesh Chowdhury	32	0	4	10	8	22	5	fisherman	company job	10	8000
15	Buxar	Karridy Chowdhury	48	5	5	3	3	11	3	fisherman	0	30	8000
16	Bu	Arun Kumar	58	4	4	3	1	8	2	fisherman	Fish vending	32	9000

	xar												
17	Bu xar	Rabindar Chowdhury	42	2	3	4	4	11	2	fisherman	labour	10	12000
18	Bu xar	Birbal Chowdhury	58	4	5	3	0	8	2	fisherman	labour	30	15000
19	Bu xar	Ram Iqbal Chowdhury	65	5	8	6	4	18	3	fisherman	labour	50	14000
20	Bu xar	Ram Avatar Chowdhury	55	Read & write	4	5	2	11	2	fisherman	labour	25	13000

Avg. catch (kg)/month				**rate of fishes (Rs./Kg)**				**Fishing net used to catch**	**Fishing net whether self owned or hired**	**Income from IMC (Rs.)/month**	**Boat used is whether self owned or hired**	**Catch another commercially important species**	**Income from those species (Rs.)/month**
I M C	**E xo tic**	**Ca tfis hes**	**Misc ellan eous**	**I M C**	**E xo tic**	**Ca tfis hes**	**Misc ellan eous**						
1 5	**16**	**17**	**18**	**1 9**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
1 2	20	30	25	2 0 0	12 5	200	150	gill net, drag net and hook and line	self owned	2400	self owned	0	0
1 0	25	25	20	2 5 0	15 0	200	150	gill net, hook and line	self owned	9500	self owned	0	0
1 5	30	20	12	2 0 0	15 0	200	150	gill net, cast net and hook and line	self owned	8000	self owned	0	0
1 2	25	20	18	2 5 0	10 0	250	150	scine net, trap, hook & line	selfowned	5000	selfowned	0	0
4	25	2	10	2 5 0	20 0	350	150	gill net, hook & line	self owned	500	self owned	0	0
5	10	5	25	2 5 0	20 0	300	100	gill net	self owned	1500	self owned	0	0
3	10	5	20	2 5	20 0	300	100	gillnet, scine net, hook &	self owned	1200	self owned	0	0

				0				line					
12	15	20	30	250	200	300	100	gill net	self owned	2000	self owned	0	0
10	12	30	35	300	250	350	100	gil net	self owned	2500	self owned	0	0
5	15	20	20	250	200	300	80	gill net	self owned	1000	self owned	0	0
12	10	25	30	250	200	300	100	gill net, hook and line	self owned	1200	self owned	0	0
0	5	8	5	0	150	150	100	hook & line	self owned	0	self owned	0	0
4	15	12	10	200	150	250	100	gill net	self owned	1000	self owned	0	0
5	12	20	25	250	200	300	100	gill net	self owned	1000	self owned	0	0
6	20	25	30	200	250	300	100	gill net	self owned	2000	self owned	0	0
5	10	20	30	200	200	350	100	gill net	self owned	1500	self owned	0	0
5	12	25	35	200	250	350	100	gill net	self owned	1000	self owned	0	0
8	12	30	35	250	200	300	100	gill net	self owned	1000	self owned	0	0
5	10	20	30	250	200	300	100	gill net	self owned	1200	self owned	0	0
8	10	15	25	200	250	300	100	gill net	self owned	1000	self owned	0	0

Table 8.7 : Combined Socio-Economic NMCG (Farakka)

Sl no.	Place	Name	Age	Education	family membars			Total members	Earning members	Occupation(full time)	Occupation(Part time)	Year in fishing occupation	Monyhly income
					male	female	children						
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Farakka	Prabhat Halder	45	0	2	2	1	5	1	fisherman	0	10	6000
2	Farakka	Bablu Chowdhury	42	5	2	1	1	4	1	fisherman	0	15	5000
3	Farakka	Ranjit Chowdhury	45	6	2	3	0	5	1	fisherman	boat rent	12	5000
4	Farakka	Bhasa Halder	30	10	2	2	2	6	2	fisherman	toto driver	14	7000
5	Farakka	Chitta Halder	39	4	1	4	0	5	1	fisherman	0	20	6500
6	Farakka	Manik Halder	35	8	3	2	3	8	2	fisherman	0	18	5000
7	Farakka	Ratan Halder	33	5	5	4	6	15	3	fisherman	labour	13	7000
8	Farakka	Sunil Halder	39	3	2	1	3	6	1	fisherman	0	20	4000
9	Farakka	Ajit Halder	40	2	1	2	2	5	1	fisherman	labour	22	5500
10	Farakka	Basu Halder	55	0	4	4	5	13	3	fisherman	0	37	5000
11	Farakka	Heera Halder	32	12	3	2	0	5	2	fisherman	0	16	7500
12	Farakka	Nikhil Halder	22	4	4	4	5	13	3	fisherman	fish selling	7	3000
13	Farakka	Jhantu Halder	39	6	2	4	0	6	1	fisherman	0	19	6000
14	Farakka	Prabal Halder	33	8	3	4	0	7	2	fisherman	fish selling, labour	18	10000
15	Farakka	Jagai Halder	38	8	2	3	0	5	1	fisherman	0	20	4500
16	Fara	Haradhan	43	2	5	6	1	12	3	fisherman	0	25	5000

	kka	Halder											
17	Farakka	Madhai Halder	36	5	2	2	3	7	1	fisherman	0	20	4000
18	Farakka	Suku Chowdhury	46	3	3	2	4	9	2	fisherman	fish selling	30	6000
19	Farakka	Foring Chowdhury	52	4	3	4	2	9	3	fisherman	0	30	8000
20	Farakka	Sanjay Chowdhury	40	5	2	4	0	6	1	fisherman	0	22	5000

Avg. catch (kg)/month				**rate of fishes (Rs./Kg)**				**Fishing net used to catch**	**Fishing net whether self owned or hired**	**Income from IMC (Rs.)/month**	**Boat used is whether self owned or hired**	**Catch another commercially important species**	**Income from those species (Rs.)/month**
IMC	**Exotic**	**Catfishes**	**Miscellaneous**	**IMC**	**Exotic**	**Catfishes**	**Miscellaneous**						
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
5	0	200	100	150	0	250	150	gill net	self owned	800	self owned	Ilish	4000
10	6	20	80	200	150	250	100	gill net, seine net	self owned	1000	self owned	Ilish	2000
4	0	12	50	150	0	250	100	gill net	self owned	1000	self owned	Ilish	5000
3	0	8	30	200	0	200	100	gill net	self owned	1200	self owned	Ilish	3000
0	0	15	30	0	0	250	100	gill net	self owned	0	self owned	Ilish	4000
0	0	12	50	0	0	200	150	gill net	self owned	0	self owned	Ilish	5000
2	0	10	20	250	0	200	150	gill net	self owned	200	self owned	Ilish	4000
0	0	10	25	0	0	200	110	gill net	self owned	0	self owned	Ilish	5000
5	0	6	12	2	0	250	100	gill net,	self owned	500	self owned	Ilish	3000

				00				seine net					
0	0	15	15	0	0	220	150	gill net	self owned	0	self owned	Ilish	6000
4	0	12	22	200	0	200	120	gill net	self owned	1000	self owned	Ilish	4000
0	0	6	10	0	0	200	110	gill net, seine net, hook & line	self owned	0	self owned	Ilish	5000
0	0	10	15	0	0	180	120	gill net, hook & line	self owned	0	self owned	Ilish	5000
5	0	10	20	250	0	200	100	gill net	self owned	1000	self owned	Ilish	10000
0	0	5	10	0	0	200	150	gill net	self owned	0	self owned	Ilish	4000
3	0	6	12	250	0	180	120	gill net	self owned	600	self owned	Ilish	5000
0	0	6	10	0	0	150	120	gill net, hook & line	self owned	0	self owned	Ilish	4000
3	0	8	15	220	0	200	150	gill net, hook & line	self owned	400	self owned	Ilish	4000
4	0	10	50	250	0	200	120	gill net, hook & line	self owned	600	self owned	Ilish	6000
4	0	15	25	200	0	200	150	gill net	self owned	500	self owned	Ilish	5000

Table 8.8 : Combined Socio-Economic NMCG (Balagarh)

Sl no.	Place	Name	Age	Education	family members			Total members	Earning members	Occupation(full time)	Occupation(Part time)	Year in fishing occupation	Monyhly income
					male	female	children						
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Bala garh	Animesh Biswas	36	0	1	3	2	6	1	fisherman	0	17	3500
2	Bala garh	Srikanta Biswas	40	4	1	2	0	3	1	fisherman	0	30	10000
3	Bala garh	Shyam Halder	51	3	3	2	2	7	3	fisherman	0	30	4000
4	Bala garh	Nagendra Halder	59	0	4	2	2	8	3	fisherman	0	32	5000
5	Bala garh	Sankar Biswas	45	10	3	3	5	11	2	fisherman	0	20	4000
6	Bala garh	Ranjit Halder	38	8	2	2	4	8	2	fisherman	paddy culture	15	4000
7	Bala garh	Nikhil Halder	50	6	4	4	1	9	3	fisherman	driver	22	6000
8	Bala garh	Raghunath Biswas	42	12	2	2	3	7	1	fisherman	fish selling	20	5000
9	Bala garh	Himalaya Halder	48	0	1	1	3	5	1	fisherman	fish selling	30	8000
10	Bala garh	Kumar Sarkar	52	0	2	1	0	3	1	fisherman	fish selling	30	5000
11	Bala garh	Bhola Halder	26	6	3	2	0	5	2	fisherman	0	16	8000
12	Bala garh	Paritosh Halder	51	0	1	2	2	5	1	fisherman	0	35	6000
13	Bala garh	Bablu Halder	55	0	5	2	0	7	3	fisherman	0	43	5000
14	Bala garh	Thandaram Sarker	71	0	2	5	0	7	2	fisherman	net making	60	5000
15	Bala garh	Akanta Sarkar	40	2	1	1	1	3	1	fisherman	fish selling	30	5500
16	Bala	Sushil	38	2	1	1	0	2	1	fisherman	0	22	5000

	garh	Barman											
17	Bala garh	Govinda Barman	32	4	2	1	1	4	1	fisherman	0	22	6000
18	Bala garh	Tapas Halder	38	2	1	2	2	5	1	fisherman	0	20	5000
19	Bala garh	Dulal Halder	70	10	2	3	2	7	2	fisherman	0	55	5000

Avg. catch (kg)/month				**rate of fishes (Rs./Kg)**				**Fishing net used to catch**	**Fishing net whether self owned or hired**	**Income from IMC (Rs.)/month**	**Boat used is whether self owned or hired**	**Catch another commercially important species**	**Income from those species (Rs.)/month**
IMC	**Exotic**	**Cat fishes**	**Miscellaneous**	**IMC**	**Exotic**	**Cat fishes**	**Miscellaneous**						
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
0	0	0	15	0	0	0	250	gill net, hook and line	self owned	0	Hired	0	0
4	2	5	10	500	350	400	200	gill net	self owned	180	self owned	0	0
4	0	5	12	250	0	300	100	gill net, hook & line	self owned	2000	self owned	hilsa	1000
5	0	6	14	250	0	300	150	scine net	self owned	800	self owned	hilsa	1500
7	0	0	10	250	0	0	100	scine net, gill net,	self owned	1000	self owned	0	0
2	0	5	10	250	0	300	80	scine net	self owned	500	self owned	0	0
4	0	5	10	200	0	300	80	scine net, gill net	self owned	2000	self owned	0	0
3	0	7	20	2	0	350	100	scine net,	self owned	1000	self owned	0	0

				00				trap					
5	2	0	10	300	200	0	200	gill net, hook & line	self owned	2000	self owned	ilish	5000
5	3	0	0	250	150	0	0	gill net, hook & line	self owned	1000	self owned	ilish,chital,sol	2000
3	0	0	12	450	0	0	500	gill net	self owned	2000	self owned	0	0
3	0	0	0	200	0	0	0	gill net, hook & line	self owned	6000	self owned	0	0
3	2	0	8	300	150	0	100	gill net	self owned	1000	self owned	0	0
0	0	0	12	0	0	0	80	gill net	self owned	0	self owned	0	0
0	0	0	10	0	0	0	100	gill net	self owned	0	self owned	0	0
0	0	0	15	0	0	0	150	gill net	self owned	0	self owned	0	0
0	0	0	12	0	0	0	120	gill net	self owned	0	self owned	0	0
0	0	0	10	0	0	0	100	gill net	self owned	0	self owned	0	0
0	0	0	15	0	0	0	100	gill net	self owned	0	self owned	0	0

Table 8.9 : Combined Socio-Economic NMCG (Godakhali)

Sl no.	Place	Name	Age	Education	family members: male	female	children	Total members	Earning members	Occupation(full time)	Occupation(Part time)	Year in fishing occupation	Monthly income
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Godakhali	kanai patra	55	0	3	2	0	5	2	fisherman	sand mining	35	6000
2	Godakhali	Ratan Patra	52	3	2	3	3	8	2	fisherman	Mason	20	7000
3	Godakhali	Purna Patra	40	4	1	1	2	4	1	fisherman	0	25	5000
4	Godakhali	Halo Majhi	37	5	2	1	2	5	1	fisherman	0	22	4500
5	Godakhali	Prahallad Patra	32	4	1	1	1	3	1	fisherman	0	16	5000
6	Godakhali	Rajkumar Patra	45	8	2	2	2	6	1	fisherman	0	30	6000
7	Godakhali	Velu Patra	70	0	1	3	4	8	1	fisherman	0	55	5500
8	Godakhali	Khoka Patra	60	0	2	2	1	5	2	fisherman	fish selling	44	7500
9	Godakhali	Gopal Biswas	28	7	4	2	1	7	2	fisherman	fish selling	12	8000
10	Godakhali	Dhiren Biswas	40	10	5	2	4	11	3	fisherman	0	24	10000
11	Godakhali	Subol Biswas	45	9	3	2	0	5	2	fisherman	0	30	8500
12	Godakhali	Prasanta Biswas	30	8	2	2	4	8	2	fisherman	fish selling	16	8000
13	Godakhali	Tapan Dheki	52	10	2	4	3	9	1	fisherman	0	38	5000
14	Godakhali	Gopal Das	55	2	3	5	0	8	2	fisherman	0	41	7000
15	Godakhali	Jayanta Pakhira	45	6	4	1	2	7	2	fisherman	0	31	6000
16	Godak	Sukdeb	55	5	3	5	1	9	2	fisherman	0	34	5000

	hali	Barik											
17	Godak hali	Dhula Nepu	35	4	1	2	1	4	1	fisherman	0	19	5000
18	Godak hali	Madan Nepu	60	0	2	2	1	5	1	fisherman	0	45	5000
19	Godak hali	Jhantu Patra	30	7	1	2	2	5	1	fisherman	0	17	5000
20	Godak hali	Birendra Sasmal	36	8	4	2	2	8	3	fisherman	0	20	10000

Avg. catch (kg)/month				**rate of fishes (Rs./Kg)**				**Fishing net used to catch**	**Fishing net whether self owned or hired**	**Income from IMC (Rs.)/month**	**Boat used is whether self owned or hired**	**Catch another commercially important species**	**Income from those species (Rs.)/month**
IMC	**Exotic**	**Cat fishes**	**Miscellaneous**	**IMC**	**Exotic**	**Cat fishes**	**Miscellaneous**						
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
0	0	0	55	0	0	0	150	gill net	self owned	0	Hired	ilish	10000
0	0	5	80	0	0	200	100	bag net, gill net	self owned	0	self owned	ilish	12000
0	0	0	50	0	0	0	150	bag net, gill net	self owned	0	self owned	ilish	4000
0	0	0	15	0	0	0	120	gill net	self owned	0	self owned	ilish	5000
0	0	0	20	0	0	0	100	gill net, bag net	self owned	0	self owned	ilish	9000
0	0	0	22	0	0	0	80	gill net	self owned	0	self owned	ilish	12000
0	0	0	12	0	0	0	120	gill net, bag net, hook & line	self owned	0	self owned	ilish	15000
0	0	0	30	0	0	0	150	gill net	self owned	0	self owned	ilish	10000
0	0	0	35	0	0	0	150	gill net	self owned	0	self owned	ilish	10000
0	0	0	40	0	0	0	120	gill net	self owned	0	self owned	ilish	12000
0	0	0	40	0	0	0	125	gill net	self owned	0	self owned	ilish	8000
0	0	0	45	0	0	0	125	gill net	self owned	0	self owned	ilish	15000

0	0	0	25	0	0	0	130	gill net	self owned	0	self owned	ilish	8000
0	0	0	35	0	0	0	155	gill net	self owned	0	self owned	ilish	12000
0	0	0	35	0	0	0	150	gill net	self owned	0	self owned	ilish	12000
0	0	0	25	0	0	0	150	gill net, hook &line, bag net	self owned	0	self owned	ilish	5000
0	0	0	12	0	0	0	120	gill net, bag net	self owned	0	self owned	ilish	10000
0	0	0	15	0	0	0	120	gill net	self owned	0	self owned	ilish	5000
0	0	0	20	0	0	0	125	gill net	self owned	0	self owned	ilish	8000
0	0	0	30	0	0	0	150	gill net	self owned	0	self owned	ilish	5000

Table 8.10 : Combined Socio-Economic NMCG (D.Harbour)

Sl no.	Place	Name	Age	Education	family members			Total members	Earning members	Occupation(full time)	Occupation(Part time)	Year in fishing occupation	Monyhly income
					male	female	children						
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	D. Harbour	Chandan Bag	47	8	3	2	1	6	2	fisherman	driver	15	6000
2	D. Harbour	Kishore Bag	24	9	2	4	0	6	2	fisherman	Mason	10	6000
3	D. Harbour	Amrit Bag	44	4	2	4	0	6	2	fisherman	0	24	5000
4	D. Harbour	Rama Naskar	44	4	4	2	3	9	2	fisherman	0	22	6000
5	D. Harbour	Sudip Pramanik	56	4	2	3	1	6	2	fisherman	Horticulture	30	12000
6	D. Harbour	Buddhadeb Naskar	52	6	4	2	1	7	3	fisherman	labour	32	15000

Avg. catch (kg)/month				rate of fishes (Rs./Kg)				Fishing net used to catch	Fishing net whether self owned or hired	Income from IMC (Rs.)/month	Boat used is whether self owned or hired	Catch another commercially important species	Income from those species (Rs.)/month
IMC	Exotic	Cat fishes	Miscellaneous	IMC	Exotic	Cat fishes	Miscellaneous						
15	16	17	18	19	20	21	22	23	24	25	26	27	28
0	0	0	40	0	0	0	120	bag net, gill net, hook & line	self owned	0	self owned	hilsa, topse	2000

0	0	0	30	0	0	0	120	Scine net, gill net	self owned	0	self owned	hilsa	
0	0	0	25	0	0	0	120	scine net, gill net	self owned	0	self owned	hilsa	
0	0	0	40	0	0	0	100	meen jal, bag net	self owned	0	self owned	hilsa	
0	0	0	1000	0	0	0	150	bag net, gill net	self owned	0	self owned	0	0
0	0	0	200	0	0	0	150	gill net	self owned	0	self owned	0	0

Table 8.11 : Combined Socio-Economic NMCG (Varanasi)

Sl no.	Place	Name	Age	Education	family membars			Total members	Occupation(full time)	Year in fishing occupation	Monyhly income	Fishing net used to catch	Boat used is whether self owned or hired
					child	adult	old						
1	Varanasi	Raju Sahani	58	Illiterate	3	2	1	6	fishimg	6	37200	chaar Angur	self owned
2	Varanasi	Gopal Nishad	51	Illiterate	0	6	2	8	fishimg	40	9000	2-8 angul	self owned
3	Varanasi	Lala Nishad	76	Illiterate	2	3	2	7	fishimg	66	6000	-	No boat
4	Varanasi	Ramnath Shani/Jawahir	60	Primary school	-	6	2	8	fishimg	48	9250	2-8 angul	self owned
5	Varanasi	Sopal Sahani	42	Primary school	8	10	4	22	fishimg	30	8250	2-3 angur/Maha Jaal	self owned
6	Varanasi	Ramakant Nishad	72	Middle school	3	7	5	15	fishimg	43	33600	2-12 angur	self owned
7	Varanasi	Haridhan Nishad	60	Illiterate	11	5	2	18	fishimg	47	27000	Maha Jaal	self owned
8	Varanasi	Rambalak Nishad	50	Middle school	2	7	2	9	fishimg	38	8750	Saroul Jaal	self owned
9	Varanasi	Rajendra Prasad Nishad	40	Illiterate	2	5	4	11	fishimg	28	12750	Chote jaal	self owned
10	Varanasi	Ramji Nisad	54	Illiterate	-	5	-	5	fishimg	40	23500	Mosquito Net	self owned
11	Varanasi	Akas Lal Nishad	60	Illiterate	2	2	3	7	fishimg	46	14250	4 angul	self owned
12	Varanasi	Laxman Nishad	60	Illiterate	8	6	2	16	fishimg	50	22000	6-12 Angul	self owned
13	Varanasi	Tershu Nishad	50	Illiterate	2	2	-	4	fishimg	38	12000	6-12 Angul	self owned
14	Varanasi	Ram kishan Nishad	62	Illiterate	1	3	2	6	fishimg	50	9750	-	No boat
15	Varanasi	Vijendra Nishad	40	Illiterate	4	2	-	6	fishimg	28	12375	-	No boat

16	Vara nasi	Chandrika Nisad	50	Illiterate	2	3	2	7	fishimg	2	14900	-	No boat
17	Vara nasi	Ramji Nishad	60	Illiterate	1	2	-	3	fishimg		8250	2 angul	No boat
18	Vara nasi	Punvasi Kumar	22	Higher secondary	5	3	-	8	fishimg	8	11500	1-9 Angul	self owned
19	Vara nasi	Rambali Nishad	65	Illiterate	1	9	2	12	fishimg	50	9750	3-5 angul	self owned
20	Vara nasi	Biyas Nishad	40	Illiterate	6	12	2	20	fishimg	28	9400	-	self owned

ANNEXURE III

SOCIO-ECONOMIC STUDY SCHEDULE

Annexure-III : Socio Economic Schedule

SOCIO ECONOMIC SCHEDULE

1. Date:
2. Place/Station (NAME): Longitude: Latitude:
3. Age and education:
4. Number of family members / No. of earning members:

Male	Female	Adult	Child

5. Occupation (whether full time fishermen, if not any other occupation?):
Main:
Subsidiary:

5. Years in the fishing occupation:

6. Average IMC/ Snow trout/ Golden mahseer catch per day/month (Kg):

IMC	Exotic	Catfishes	Golden mahaseer	Snow trout	Miscellaneous

7. Rate of fishes Rupees/Kg.

IMC	Exotic	Catfishes	Golden mahaseer	Snow trout	Miscellaneous

8. Fishing net used to catch IMC/ Snow trout/ Golden mahseer whether self-owned or hired? (If hired then amount per month):
9. Income from IMC/ Snow trout/ Golden mahseer in a day/month:
10. Average monthly income:
11. Fishing boat used is whether self-owned or hired? (If hired then amount per month):
12. Average amount of other commercially important species in the catch and income from those fish :
13. Name, address and phone no. of the fisherman:
    - Name:
    - Address:
    - Ph. No.:

Data collected by............................

ANNEXURE IV

FILLED SOCIO-ECONOMIC STUDY SCHEDULE

Annexure-IV : Filled Socio Economic Schedule

ANNEXURE

SOCIO ECONOMIC SCHEDULE

1. Date: 1.3.19
2. Place/Station (NAME): Farakka . Longitude: Latitude:
3. Age and education: 48 yrs. 8th class
4. Number of family members / No. of earning members:

Male	Female	Adult	Child
3	2	4	1

5. Occupation (whether full time fishermen, if not any other occupation?):
   Main: Fishing
   Subsidiary: Small trading
5. Years in the fishing occupation: 22 yrs.
6. Average IMC/ Snow trout/ Golden mahseer catch per day/month (Kg):

IMC	Exotic	Catfishes	Golden mahaseer	Snow trout Hilsa	Miscellaneous
3-4 kg	–	4-5 kg	–	6-7 kg	4-5 kg

7. Rate of fishes Rupees/Kg.

IMC	Exotic	Catfishes	Golden mahaseer	Snow trout Hilsa.	Miscellaneous
300/-	–	250/-	–	600-700/-	200-250/-

8. Fishing net used to catch IMC/ Snow trout/ Golden mahseer whether self-owned or hired? (If hired then amount per month): owned
9. Income from IMC/ Snow trout/ Golden mahseer in a day/month: 1200-1500/-
10. Average monthly income: 7000-8000/-
11. Fishing boat used is whether self-owned or hired? (If hired then amount per month): Self owned
12. Average amount of other commercially important species in the catch and income from those fish : 3000-4000/-
13. Name, address and phone no. of the fisherman:
    - Name: Kanu Halder
    - Address: 012 Rly. Colony, Ambika nagar
    - Ph. No.:

ANNEXURE

SOCIO ECONOMIC SCHEDULE

1. Date: 26/2/19
2. Place/Station (NAME): Gaighat, Patna Longitude: Latitude:
3. Age and education: 34, Illeterate
4. Number of family members / No. of earning members: 5

Male	Female	Adult	Child
2	3		2

5. Occupation (whether full time fishermen, if not any other occupation?): Fishers
   Main:
   Subsidiary:
5. Years in the fishing occupation: 15 yrs.
6. Average IMC/ Snow trout/ Golden mahseer catch per day/month (Kg): 1 - 1.5 kg

IMC	Exotic	Catfishes	Golden mahseer	Snow trout	Miscellaneous

7. Rate of fishes Rupees/Kg. 200 - 250/-

IMC	Exotic	Catfishes	Golden mahseer	Snow trout	Miscellaneous

8. Fishing net used to catch IMC/ Snow trout/ Golden mahseer whether self-owned or hired? (If hired then amount per month): Gill net (22 - 24 mm)
9. Income from IMC/ Snow trout/ Golden mahseer in a day/month:
10. Average monthly income: 8000/-
11. Fishing boat used is whether self-owned or hired? (If hired then amount per month): Self
12. Average amount of other commercially important species in the catch and income from those fish :
13. Name, address and phone no. of the fisherman:
    - Name: Lagendar Sahani
    - Address: Sonepur, Meenabazar.
    - Ph. No.: 62035 58606.

ANNEXURE

SOCIO ECONOMIC SCHEDULE

1. Date: 27/2/19
2. Place/Station (NAME): Buxar Longitude: Latitude:
3. Age and education: 38, Literate
4. Number of family members / No. of earning members: 5

Male	Female	Adult	Child
2	3	2	3

5. Occupation (whether full time fishermen, if not any other occupation?): Fishers
   Main:
   Subsidiary: Labour
5. Years in the fishing occupation: 25 yrs .
6. Average IMC/ Snow trout/ Golden mahseer catch per day/month (Kg): 1 - 3 kg

IMC	Exotic	Catfishes	Golden mahseer	Snow trout	Miscellaneous

7. Rate of fishes Rupees/Kg. 150 ₹

IMC	Exotic	Catfishes	Golden mahseer	Snow trout	Miscellaneous

8. Fishing net used to catch IMC/ Snow trout/ Golden mahseer whether self-owned or hired? (If hired then amount per month): Grill net (2/3/4 inch)
9. Income from IMC/ Snow trout/ Golden mahseer in a day/month:
10. Average monthly income: 7000 ₹
11. Fishing boat used is whether self-owned or hired? (If hired then amount per month): Self
12. Average amount of other commercially important species in the catch and income from those fish :
13. Name, address and phone no. of the fisherman:
    - Name: Shivdular Chowdhury
    - Address: Sarhai, Kotwa
    - Ph. No.: 9670812762

ANNEXURE

SOCIO ECONOMIC SCHEDULE

1. Date: 2/3/19
2. Place/Station (NAME): Jangipur Longitude: Latitude:
3. Age and education: 51 yr class 2
4. Number of family members / No. of earning members:

Male	Female	Adult	Child
03	02	–	–

5. Occupation (whether full time fishermen, if not any other occupation?):
   Main: Fishing.
   Subsidiary: –
5. Years in the fishing occupation: 28 yr.
6. Average IMC/ Snow trout/ Golden mahseer catch per day/month (Kg):

IMC	Exotic	Catfishes	Golden mahaseer	~~Snow~~ trout Hiba	Miscellaneous
2-3 kg.	–	1-2.5 kg	–	2-3 kg.	3-4 kg.

7. Rate of fishes Rupees/Kg.

IMC	Exotic	Catfishes	Golden mahaseer	Snow trout Hiba	Miscellaneous
300/-	–	200/-	–	500-600/-	250/-

8. Fishing net used to catch IMC/ Snow trout/ Golden mahseer whether self-owned or hired? (If hired then amount per month): Owned
9. Income from IMC/ Snow trout/ Golden mahseer in a day/month: 800 – 900/-
10. Average monthly income: 10,000
11. Fishing boat used is whether self-owned or hired? (If hired then amount per month): owned.
12. Average amount of other commercially important species in the catch and income from those fish : 6000-7000/-
13. Name, address and phone no. of the fisherman:
    - Name: Biswanath Halder
    - Address: Sonatikri colony, Jangipur.
    - Ph. No.: 8348868948