STRENGTHENING THE MEANING OF A FRESHWATER PROTECTED AREA FOR THE GANGES RIVER DOLPHIN: LOOKING WITHIN AND BEYOND THE VIKRAMSHILA GANGETIC DOLPHIN SANCTUARY, BIHAR, INDIA

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SUBMITTED BY

NACHIKET KELKAR[1, 2, 3]
SUBHASIS DEY[2]
SUNIL K. CHOUDHARY[2]

[1]ASHOKA TRUST FOR RESEARCH IN ECOLOGY AND THE ENVIRONMENT (ATREE), BANGALORE, INDIA
[2]VIKRAMSHILA BIODIVERSITY RESEARCH AND EDUCATION CENTRE (VBREC), BHAGALPUR, INDIA
[3] MEMBER, IUCN CETACEAN SPECIALIST GROUP, GLAND, SWITZERLAND

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Cover picture: A Fisherman hauls out his boat at Bhagalpur, in the Vikramshila Gangetic Dolphin Sanctuary. Photo Credit: © Kadambari Deshpande.

Back picture: A sub-adult Ganges River dolphin lunges out of the water. Photo Credit: © Kadambari Deshpande.

Summary & Highlights

This report is the first detailed assessment of the ecological and social effectiveness of a freshwater protected area, the Vikramshila Gangetic Dolphin Sanctuary, in Bihar, India, with reference to the conservation of the endangered Ganges River dolphin *Platanista gangetica gangetica*. A range of ecological, hydrological, social, political and historical attributes was studied in detail for fisheries settlements and river reaches inside and outside the Vikramshila Sanctuary for this evaluation. Our results show that the Sanctuary might not have had any meaningful impact on either river dolphin conservation or the betterment of poor and marginalized fisher communities that depend on the Ganga and Kosi Rivers for their basic livelihood needs. The report stresses that the root problem of conserving the biodiversity of the Gangetic basin might lie in the socio-political history of the riverscape as much as it is considered a problem of ecological scarcity, risk and resource conflicts in the present day. Using a critical approach throughout the work, the report uses insights from empirical data to identify the limitations of the currently dominant paradigm of adding more and more freshwater protected areas, given larger imminent threats to river biodiversity at the level of entire landscapes. In this attempt we raise many questions about the gaps between concept, design and policy implementation that plague most freshwater protected areas today. Through the example of the Ganges River dolphin, we highlight the complexities inherent in protection, which become apparent when conservationists look beyond their ecological comfort zones, towards wider socio-economic problems.

INTRODUCTION

The recent extinction of the Chinese River dolphin or Baiji from the Yangtze River ecosystem (Turvey et al. 2012) led to considerable and widespread conservation concerns in the case of the endangered Ganges and Indus River dolphins, the oldest lineage among extant river dolphins distributed through the Indo-Gangetic-Brahmaputra drainages of the South Asian region (Smith & Braulik 2012). Indeed, the range of threats faced by the *Platanista* river dolphins are complex and serious: dams and barrages have disconnected populations, river flows have been declining and increasingly irregular, water pollution levels are prohibitive, and mortality risk due to fisheries by-catch and destructive fishing practices (that caused the extinction of the Baiji; Smith & Smith 1998, Turvey et al. 2010, Smith & Reeves 2009, Smith & Braulik 2012). Range decline of river dolphins due to water diversions, leading to downstream attrition, local extinctions and genetic disconnectivity strongly affects the prognosis for their conservation (Choudhary et al. 2012, Braulik et al. 2014). Establishing freshwater protected area networks across river systems to conserve river dolphin populations is therefore a primary objective of conservation plans, which has translated into national policy priorities recently (Kreb et al. 2010; Smith & Braulik 2012). In the case of Ganges river dolphins, national action plans across South Asia consistently identify the declaration of riverine protected areas as a crucial need (Kreb et al. 2010). India declared the Ganges River dolphin as its National Aquatic Animal in 2010 (GoI 2010). As a result, public awareness for river dolphin conservation is growing on similar lines to the much-hyped need for protected areas for the tiger, India's National Animal.

Due to reducing population persistence in upstream reaches, current coverage of freshwater protected areas (FPAs) for river dolphins typically straddles lower river reaches. Dolphin population surveys generally find their occurrence in fairly regular, circumscribed areas or 'hotspots'. In Pakistan, two wildlife sanctuaries, and the Indus Dolphin Preserve have been declared between the Guddu and Sukkur barrages for protecting the Indus River Dolphin (Smith & Braulik 2012, Braulik et al. 2014). In the Sundarbans of Bangladesh, multiple PAs have been designated around river dolphin hotspot areas, with the aim to protect Gangetic dolphins from adverse effects of fishing (Smith et al. 2010). In India, the two major freshwater protected areas that include sizeable river dolphin populations include the National Chambal Sanctuary and the Vikramshila Gangetic Dolphin Sanctuary (the latter especially designated for dolphins; Choudhary et al. 2006, Smith & Braulik 2012, Kelkar & Krishnaswamy 2014). In addition, multiple terrestrial protected areas focused on large mammal or bird conservation, in northern India and Nepal (e.g. Chitwan, Kaziranga, Katerniaghat, Harike) also include river stretches with small river dolphin populations within their boundaries, thus affording incidental protection to the species. In summary, although the overall spatial extent of riverine PAs may still appear wanting, the existing PAs offer some coverage across different river ecosystems in South Asia. However, various conservation assessments have deemed the effectiveness of these FPAs as 'poor' (e.g. Smith & Smith 1998, Choudhary et al. 2006, Smith & Braulik 2012) but the criteria for evaluation and even the definition for effectiveness have seldom been clearly stated. It is therefore interesting as to why such a judgement may be made, and it is likely that the labelling of effectiveness as 'poor' is based simply on the lack of enforcement of rules against dolphin poaching, unregulated and destructive fishing, and the near-absence of river dolphin monitoring by state agencies in charge of the FPAs (Choudhary et al. 2006). In short, the absence of an overbearing authority fuelled by state power is considered a lamentable situation for FPA effectiveness by conservationists, despite their individual 'non-state', i.e. civil society efforts towards conserving river dolphins. Such a criterion for judging effectiveness is problematic and there are multiple reasons why. It appears clear that few empirical data exist for robust, multi-criteria evaluation of ecological and social variables in and around existing FPAs. But we submit here that the lack of data is not the major constraint – rather it is the lack of a deep, honest, critical and conceptual engagement with the issue on the part of conservationists (Choudhary et al. 2015). We identify the need for revisionist and self-critical reassessments of ecological and social conditions that might influence the meaningful conservation of river biodiversity (Bottrill et al. 2012); rather than dependence on statutes, declarations and privileging of space (as in FPAs) merely in legal or governance terms, and presuming their effectiveness (Pittock et al. 2008).

We will now qualify this apparently controversial stance by making our case in the spatial, temporal and social context of the Vikramshila Gangetic Dolphin Sanctuary (VGDS) in Bihar, India. Through this paper we aim to revisit our own (changing) value positions and the outcomes of the river dolphin conservation and monitoring efforts conducted by us over the last 15 years. But before the local details, we would like to offer a conceptual critique of the current frameworks and assumptions that influence ideas about FPA effectiveness.

Conservation of freshwater biodiversity and resources through riverine protected areas has been an increasing global priority given the severity of threats facing river ecosystems (Dudgeon 2000, Suski & Cooke 2006, Abell et al. 2007, Humphries & Winemiller 2009). Multiple assessments have identified clearly that freshwater biodiversity is poorly represented in existing (predominantly terrestrial) protected area networks (Abellan et al. 2007, Linke et al. 2010). Whereas increasing protected area coverage of rivers and wetlands for biodiversity is a major objective of conservation programs, there exist multiple conflicts between conceptual propositions and implemented realizations of FPAs (freshwater protected areas) (Parrish et al. 2003, Abellan et al. 2007, Bottrill et al. 2012). These chasms between theory, design and practice are linked strongly to complex ecological and social factors that are often inadequately acknowledged in mainstream conservation discourse on freshwater biodiversity. One major limitation is that there is often neglect and ignorance about the broader realities of the 'riverscapes' in which FPAs come to be designated and sustained (West et al. 2006, Suski & Cooke 2006, Robbins et al. 2006, Hansen & DeFries 2007, Choudhary et al. 2012). This neglect might be due to the spatial focus that FPAs bring about to the concerned observer. One important outcome of this focus is that monitoring is generally restricted to sites 'within' these protected areas (e.g. Choudhary et al. 2006). Due to restricted monitoring coverage, although fairly sustained, assessments of effectiveness of established FPAs have been few and far between. A priori, river segments/reaches are typically selected for protection based on certain 'outstanding' ecological attributes in comparison with neighbouring stretches (which are often arrived at from limited data, available as 'snapshots'). This is a crucial point in the case of rivers, as siting FPAs depends strongly on large-scale, interconnected ecological effects (e.g. spill-overs, productivity, population movement and persistence) in upstream and downstream 'unprotected' river reaches (Ward 1998, Robinson et al. 2002, Hansen & DeFries 2007, Gaston et al. 2008, Linke et al. 2010). Further, physically defining riverine PA boundaries physically is a major challenge in dynamic floodplain ecosystems, where channels often migrate and courses change, owing to highly complex and nonlinear hydrological and geomorphological processes (Bengtsson et al. 2003, Kelkar & Krishnaswamy 2014).

Biophysical and ecological dynamics also interact with social structures and actors, producing conflicts and litigation over spatial boundaries. For instance, the problem of defining boundaries is particularly challenging in terms of assignment of property ownership or access or rights over both the exploitation and stewardship of dynamic resources (Adger & Luttrell 2000, Klug 2002, Bengtsson et al. 2003, Abell et al. 2007). People who depend on riverscapes for their livelihood needs (e.g. fisheries, boat-ferrying, agriculture) may have conflicts over uncertain FPA boundaries (Smith et al. 2005, Bashir et al. 2010, Kelkar & Krishnaswamy 2014, Choudhary et al. 2015). It follows that the fuzziness in defining spatial or social boundaries generates variable interpretations of FPAs among individuals, institutions or governments, in the absence of effective communication (Bengtsson et al. 2003). Further, as freshwater ecosystems are increasingly threatened by altered dry-season flows, diversion of water by dams and barrages, and degrading water quality, it is difficult to identify temporal thresholds or reference conditions, which FPAs are supposed to restore rivers, back to (Junk 2002, Nel et al. 2007, Pittock et al. 2008, Humphries & Winemiller 2009).

The limited engagement with social issues is surprising given the oft-heard concern of protecting freshwater both for the ecosystem as well as for people's livelihoods (e.g. Suski & Cooke 2006, Cucherousset et al. 2007, Kelkar et al. 2010). Especially in developing countries where infrastructural and demographic pressures on freshwater resources are severe, the challenge of reconciling freshwater needs for biodiversity and ecosystems with those for livelihoods of local people on river systems is well-recognized (Smith et al. 2005, Kelkar et al. 2010). But the effectiveness of FPAs in this regard has been poorly assessed. This stems first from the dominant paradigm of exclusion that treats FPAs (in a terrestrial influence) as inviolate, no-go areas for people, a condition deemed important for sensitive riverine fauna. In this approach, freshwater protection comes to be vested in state authority, which often results in enforced and hegemonic top-down boundaries. These authoritarian 'environmental territories' of powerful actors further complicate pre-existing mosaics of social relations and boundaries (West et al. 2006). The criticality of human dependence on freshwater for basic livelihood needs implies that excluding people from FPAs, or restricting their use, might have effects on aggravating poverty and vulnerability and risking public health of local people (Choudhary et al. 2006).

Second, even the discourse on conservation by involving local communities is rife with simplistic propositions about homogeneity, traditional wisdom and processes of local (and therefore desirable) decision-making processes among local people implicated in conservation (Choudhary et al. 2015). Such propaganda appears socially sensitive, but often ignores local politics, historical conflicts and other latent influences such as caste, hegemonic relations and gender disparity. It is no doubt extremely challenging to address every single issue, but assessing FPA effectiveness must acknowledge local socio-economic benefits and costs of conservation, transitions in local livelihood dependencies, and related flow-on consequences for equity, rights, justice and adaptation to changing 'geographies of conservation' (West et al. 2006, Robbins et al. 2006). Although coexistence models are being advocated and increasingly attempted, their effectiveness remains uncertain under constantly changing cultural processes as well as exogenous influences such as political shifts and market linkages (Choudhary et al. 2015).

The half-engaged processes of either linking or delinking people from conservation lead to the common fallacy of equating the purely symbolic values of protected areas with their material ecological or social benefits. As conservationists strongly argue for protected areas (in any form), the background conditions fundamental to understanding these changing spaces must not be ignored at either the design or the implementation stages. Needless to say, monitoring and evaluation of PA effectiveness must reach out and look beyond their existing spatial and social domains for sustaining biodiversity in the long-term.

These conceptual and critical questions formed our motivation behind formulating and executing this project. We conducted a long-term, multi-criteria evaluation of ecological and social factors influencing conservation across the lower Gangetic riverscape, to assess the effectiveness of the Vikramshila Gangetic Dolphin Sanctuary (VGDS) for biodiversity as well as social benefits. In our evaluation we used a range of metrics assessed ‘inside and outside’ VGDS, namely, abundance-distribution of Ganges River dolphins, occurrence of other biodiversity, changes in hydrological variables, socio-economic profiles of fisher groups in the riverscape, socio-political & historical drivers of resource conflicts in the floodplains, processes of adaptation, awareness about the VGDS, legal issues in conservation, and temporal changes in stakeholder attitudes towards conservation and human livelihoods. These criteria have been analysed together to answer the primary question about the overall effectiveness of the VGDS.

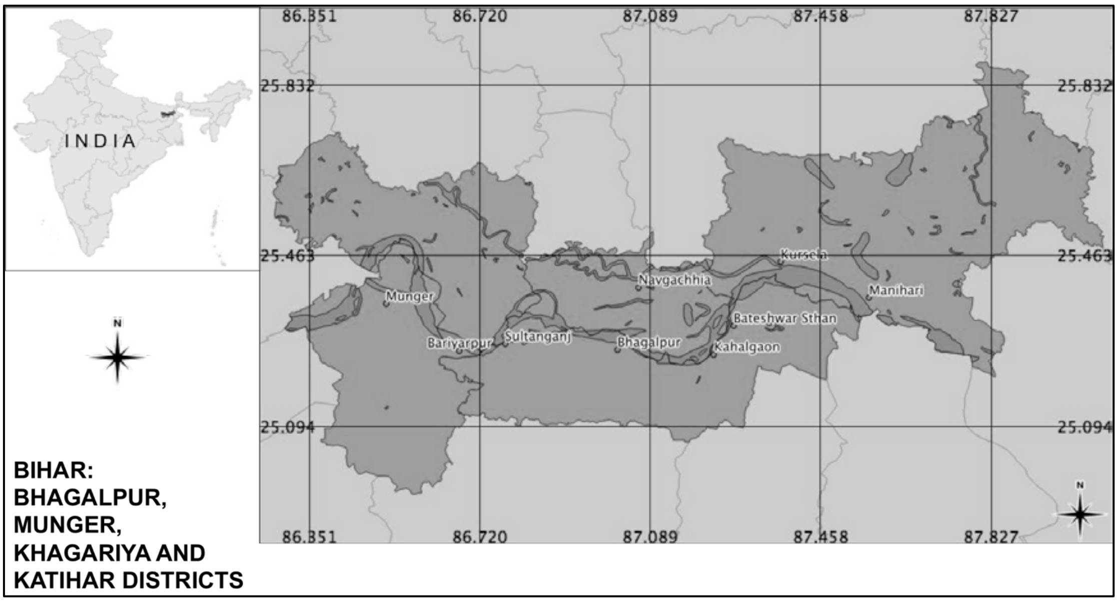


Figure 1. Map of the main study area: the Ganga and Kosi River reaches in Bihar.

OBJECTIVES

The stated objectives of the project were as follows:

1) To assess overall effectiveness of the VGDS area for the conservation of Ganges river dolphins, based on their population distribution, persistence and abundance in this protected area and adjacent unprotected river reaches, in relation to habitat variables, river channel stability, threats from fisheries and associated bycatch or mortality risk

2) To evaluate the social impact of conservation and outreach programs conducted in the

Sanctuary area over the past decade

3) To develop a framework for spatial, adaptive management for human resource extraction in the Ganges River and adjoining reaches, to strengthen dolphin conservation beyond protected area boundaries

In relation to these objectives, our priority in this report will be to construct the problem of FPA effectiveness and meaning, rather than find a 'final answer' or a last-word framework to fit it. We use detailed empirical data, close social engagement and reflection on our own changing beliefs about current dogma in river dolphin conservation, with the hope to share insights to overcome barriers between concept, implementation and policy for FPAs.

METHODS: STUDY AREA (See Figure 1)

The VGDS riverscape

The Vikramshila Gangetic Dolphin Sanctuary (VGDS) is the only protected area specifically created for Ganges river dolphins in India (Environmental Department Notification No. S.O. 382, Ministry of Environment & Forests, 1991). The VGDS is a unique, biodiversity-rich, and highly productive, (currently) 67-km stretch of the lower Ganga River between Sultanganj (25^{o}15'15"N, 86^{o}44'17" E) and Kahalgaon (25^{o}16'54"N, 87^{o}13'44"E) in Bhagalpur district of Bihar. The water depth ranges from c. 0.2 to even 60 m. The variation in channel width is between 150 m to almost 2 km in the dry season. However, in very wide channels, water depths are very shallow and various islands cut the channel. The river sanctuary is one of the areas in the lower Ganga belt characterized by highest fluvial discharge and the highest deposition of alluvial mid-channel islands, point bars and spits in the Ganga main stem. This stretch is characterized by two prominent meanders. Granite outliers called monad nocks form the tentative boundaries of the VGDS at Sultanganj in the west and Kahalgaon to the east (downstream).

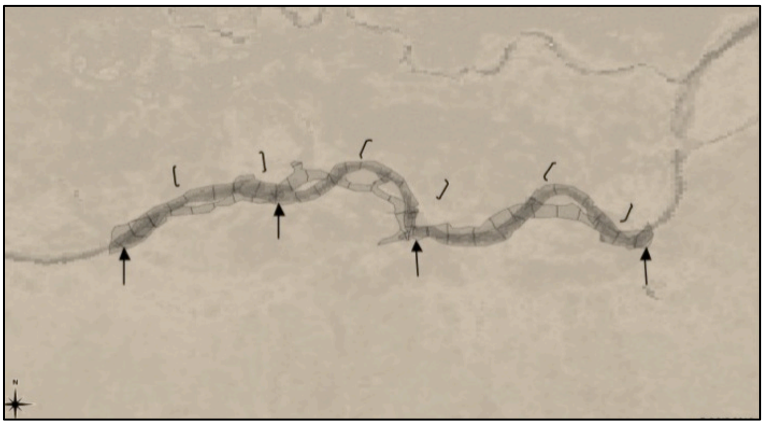


Image 1. Which of these outlines is the Vikramshila Gangetic Dolphin Sanctuary? The river stretch between Sultanganj and Kahalgaon has shifted in the years from 2000 to 2008.

In terms of management, the Sanctuary is technically under the Bihar state department of environment and forests. However, the final notification (procedure for permanent designation) has still not been achieved, due to multiple conflicts of definition in terms of settlement of fishing rights, jurisdiction (the position of fishing permissions versus bans in fisheries law versus wildlife protection law) and boundary or zone delineation. Further, there is very poor involvement of the local department of environment in monitoring or conservation activities, and even basic awareness of riverine ecology and biodiversity is lacking (Choudhary et al. 2006). There are multiple political influences behind the apathy and inaction, many of which are linked to corruption, bureaucratic exploitation and caste/class relations. Local politicians patronize criminal elements that are using destructive fishing practices in the sanctuary as well as in river channels outside. These gangs have consistently harassed fishers through excluding them from fishing areas, extortion of fish catches and violent threats, including cases of murder and physical assault (Kelkar & Krishnaswamy 2014). Bona fide fishers in the Sanctuary constantly struggle to fish with safety, especially in areas where such criminals are at large. This is linked to the political history of the riverscape, in which a large river stretch of over 140 km (between the Sultanganj and Pirpainti towns) was owned by waterlords (*Panidars*) as late as until 1991. The current sanctuary boundary was once part of this feudal control of the Ganga. A movement from fisher communities led to overthrowing this regime, but plunged the Gangetic fishery in Bihar into an open-access tragedy. The rise of criminal elements was an outcome of this shift. Details of the trajectories of socio-political changes in fisheries may be found in Reeves (1995), and linked to the issue of conservation, in Kelkar & Krishnaswamy (2014).

Owing to confusions and conflicts over boundaries and fishing rights, what has happened is that fishing is commonplace throughout the VGDS. This, at face value, may be regarded as a serious threat to river dolphins – and as we have written elsewhere, the VGDS is merely a FPA on paper (Choudhary et al. 2006). However, this brings up another issue. Is the comparison that we are making to assess the effectiveness of VGDS even valid? One could categorically argue that the ambivalence and the lack of enforcement by the sanctuary authorities in itself, renders the problem meaningless. For, what then, makes the VGDS different from surrounding stretches? We accept this as a design constraint, but describe our way of addressing this confounding factor. Firstly, we focus on the trajectory of civil society efforts concerned with river dolphin conservation in the VGDS. Efforts by VBREC (our team) since 1999-00 seem to have improved awareness among fisher communities about the Sanctuary. If there is any other somewhat clear trend (whether linked to our awareness activities or not) is that of an overall decline in dolphin poaching for oil – at least within the

VGDS, as compared to other areas. Fishers have been reporting that they would like to abandon dolphin hunting not only because it is risky (due to the legal protection of dolphins as Schedule I species in India's Wildlife (Protection) Act, 1972), but also because better alternatives for fishing are available (e.g. better gear technologies, fish oil, palm oil etc.). In sum, this underlines the reduction in hunting as a whole. So if two potentially major differences within and beyond VGDS are factored in, our comparison of VGDS with unprotected stretches holds valid. Secondly, we also plan to test the currently dominant idea, that enforcement of rules in terms of fishing might actually affect river dolphin populations in the current scenario, and hence effectiveness of FPAs must be judged from presence of monitoring or enforcement. To address this issue, we cast the net wider - by highlighting the social and historical contingencies and conditions that might protect or threaten biodiversity in the lower Gangetic floodplains, the existence of an FPA being immaterial at the larger scale of river degradation and processes of social change.

The surrounding 'unprotected' riverscape

We selected three river stretches in the upstream and downstream reaches of VGDS (total length of 45 km and 64 km respectively), and the Kosi River from Kursela (Ganga-Kosi confluence) upstream to Osraha Thana (74 km), for ecological and social surveys. The surveyed upstream stretch of the Ganga River were (45 km) between Munger and Janghira (adjacent to Sultanganj), and the downstream stretch extended from Kahalgaon to Manihari (64 km, Bihar), and for one survey we extended this stretch from Manihari to Farakka (91 km, through Rajmahal in the state of Jharkhand, up to the Farakka barrage in West Bengal state, near the Indo-Bangladesh border). These stretches were selected using a combination of GIS and field-based studies to identify reaches similar to VGDS in terms of hydrological (depth, discharge, channel changes etc.), geomorphological (erosion-deposition patterns) and social criteria (fisher settlement distribution, fishing practices, caste similarities, demographic variables etc.). Bank land uses were the same as in the VGDS: alluvial floodplains, scrub and grasslands, agriculture, fallow lands, floodplain wetlands (ox-bows, cut-offs etc.) and small settlements and towns formed the main categories. Channel widths were the highest between Rajmahal and Farakka (over 5 km in some reaches), much more than in VGDS or in upstream areas, but depth and temperature profiles were, as expected, highly similar. What is referred to as inside and outside VGDS throughout the report refers to the Ganga River only.

The Kosi River stretches were narrower in channel width (average 150-200 m) and had shallower depths (2-3 m). The Kosi floodplains mostly had grasslands and agriculture as the predominant land uses. Settlements were highly clustered and linked to large embankments built for flood control. The lower Kosi is a highly flood-prone region due to the influences of Himalayan neo-tectonics aggravated by embankment building during colonial times. This has rendered this 'once flood-dependent region into a flood-vulnerable area' (Singh 2008). The Kosi region also has large settlements of displaced refugee households. Broken bridges and slipped bank levees are a common sight along the channels. The flow velocity was notably higher in the Kosi and water turbidity generally higher than the Ganges. The Kosi also had somewhat different fishing practices - more dependent on the use of fixed passive gears, maybe due to the faster flow velocities.

METHODS: DATA COLLECTION & ANALYSES

Surveys were conducted thrice across the river stretches, in December 2013, May 2013 and December 2014. At the beginning of each sampling season an independent reconnaissance survey was conducted to assess feasibility of boat navigation, for mapping of villages and settlements, for conducting surveys of other biodiversity and for spatially stratified interview surveys and focal group discussions with fisher settlements at selected sites within and outside the VGDS.

Ganges River dolphin surveys

We conducted boat-based downstream (with the river flow) independent-observer (double-platform) surveys for both estimating abundance and mapping the distribution of Ganges River dolphins. We used a visual survey method as described in Kelkar et al. (2010) at boat speeds ranging between 8.7 and 9.4 km/hr. Frequent breaks were taken and observations between both the teams periodically checked, to ensure the correctness of dolphin matches based on sighting time and distance, and to reduce observer fatigue. Dolphin age-classes were recorded as 'Adult', 'Sub-adult' and 'Calf'. For each sighting, we recorded channel width and estimated animal group distance and angle from our boat. Depth, channel width, bank land-use, weather (wind/glare/fog state), channel habitat types, fishing boats and nets being used, and other forms of human activity were noted at 1-km intervals. We also added a 'third observer': a bidirectional hydrophone-based acoustic device (A-Tag, MMT Corp. Japan, with Hydrophone SH-200K with aquafeeler III amplifier - System Intec. Japan, and EZ-7510 Recorder (NF Corp, Japan)) that was towed 80m behind our boat to record directional bearings of river dolphin clicks. The A-Tag was used mainly to add sightings missed by both observer teams due to diving behaviour of dolphins. In addition, we recorded dolphin surfacing and diving behaviour to estimate approximate time spent underwater between dives.

Data analyses

The dolphin sightings data pooled over both observer teams were mapped by estimating the approximate coordinate positions of river dolphins from the sighting distance and angle bearing information taken on the boat. These sightings were plotted on the latest LandSat 8 OLI images available from the USGS Earth Explorer Data Portal (www.earthexplorer.usgs.gov) in a latitude-longitude grid and the Universal Transverse Mercator projection system (UTM-45N, datum WGS84).

Careful matching of all sighting data was conducted between the two teams at three stages for filtering out any errors in matches. The first stage of matching was done in periodic breaks during the active survey effort period, to ensure consistency of observations for each period and to correct for local and individual effects in detection on the go. The second stage involved matching sightings at the field station manually, between 3-4 observers. The third and final stage of matching was a confirmatory one wherein we mapped dolphin and boat locations relative to each other in a GIS platform (Quantum GIS 2.4 'Chugiak') simultaneously as data entry into a spreadsheet was in progress. The final stage helped in correcting for any inadvertent errors during the manual matching stage.

Once the correctness of the matches was confirmed, we generated capture histories of dolphin cluster sightings as follows: a history of (1,1) indicated a matched sighting by both teams, (1,0) indicating animals sighted by team 1 but not team 2, and (0,1) indicating animals missed by team 1 but seen by team 2. We used the Chapman's bias-corrected estimator to derive initial estimates for Ganges River dolphins, separate estimates for age-classes (Kelkar et al. 2010, Richman et al. 2014). We used Bayesian hierarchical models to estimate abundance based on the observed capture histories in relation to habitat covariates and conditions of detectability (mainly weather, distance and observer effects). From these models we arrived at robust estimates of population size for dolphins subject to perception bias (imperfect detection). In addition, we used the acoustic tag data and dolphin dive data to estimate crude estimates of availability bias (the problem of not seeing animals that were diving during the observation window). We also simulated the dolphin dive-time data as a Poisson point process and the probability of missing diving animals was estimated through simulations, conditional on known boat speed. The modelling work is in progress and has not been reported in the present report, but population estimates are. For the sake of comparison between inside and outside stretches we divided the estimated population size by the river channel lengths surveyed (effort) to calculate dolphin encounter-rates (dolphins/ river km).

Image 2. Our customized double-platform country boat used in river dolphin surveys.

Surveys of other biodiversity

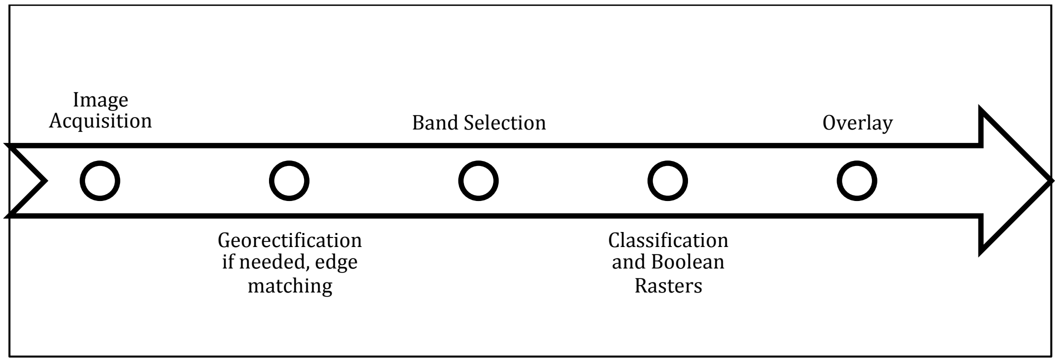
For these surveys we focused mainly on two taxa of conservation importance, which were easy to monitor during our surveys, i.e. Smooth-coated Otters (*Lutrogale perspicillata,* Vulnerable as per the IUCN Red List) and avifauna. One or two independent observers (those not part of the dolphin observer teams) recorded bird species seen across the river stretch during all surveys. We also took periodic stopovers to look for any signs of Smooth-coated Otters on the riverbanks (direct sightings of otter packs, spraints or latrines, pug-marks, holts/dens, rolling marks and fish remains). These signs were recorded from wherever possible, and in addition, we also collected data on otter sightings from fishers on a regular basis (through a monitoring network program formed by involving some interested fishers). Opportunistic data on occurrence of freshwater turtles (6 species), the Critically Endangered gharial *Gavialis gangeticus* and the Vulnerable marsh crocodile *Crocodylus palustris* were collected during interviews with key informants and fisher folk, as these animals were either absent or rare in the study area (crocodilians and hard-shelled turtles), or difficult to obtain information on, due to severe hunting in the area (soft-shell turtles). From these data, we estimated a rough index of the 'extent of occurrence' of these species across river channel segments inside and outside VGDS.

Image 3. Tracks in the floodplain sand. Photo credit: © Kadambari Deshpande.

Hydrological and geomorphological data: assessing river channel dynamics

We measured depth and surface water temperature across the channels surveyed in winter and summer (for Ganga), and in summer only (for Kosi), using a Hondex Depth Sounder and TASI 656 temperature probe. Using GIS techniques, we estimated river channel dynamics and their implications for associated anthropogenic factors, such as embankment construction, fisheries and the boundaries of VGDS and neighbouring reaches. The objectives of the GIS analysis were: 1) to analyse long-term space-time signatures of floodplain river channels in the Ganga-Kosi rivers and interfluvial zone over 75 years (1937-2014) using map overlays of imagery from multi-temporal satellite data and aerial photographs and 2) to assess the importance of stable and dynamic channels for human settlements, fisheries and Ganges River dolphins. For objective 1, multiple images of the study area were obtained from those years with available data, between 1937 and 2014. The 1937 channel data were derived from a topographic map and from 1972 onwards I used a combination of Thematic Mapper (TM), Multi-Spectral Scanner (MSS) and LandSat imagery. Except for the toposheet map, water bodies in all images were classified from land extent. I performed multi-temporal land-use change analyses for the category "water" to reveal broad trends in the gains, persistence and losses in water areal extent from the satellite images.

Figure 2. Schematic diagram indicating major steps in GIS image analysis.



Out of a total of 13 years (in the interval 1937-2013), LandSat images for 10 years were acquired from the United States Geological Survey (USGS) Earth Explorer website. Image data sources and image types along with selected bands for classifying water bodies are given below (Table 1). LandSat image bands 3,4 and 5 were used for classifying water bodies from other land uses (barring a few exceptional images). River channels (flowing water as well as ox-bow lakes, cut-off channels and wetlands) were large in area and easily separable in terms of their spectral reflectance characteristics, as reflected in the high average classification accuracy of images at 95% using the unsupervised classification algorithm CLUSTER in the IDRISI Selva package (Eastman 2012). All images were carefully checked for geo-registration information or manually georectified in Quantum GIS (QGIS Development Team 2014) and checked for errors by matching with pre-georectified images before the classification was conducted. From the clusters classified, I created a Boolean binary image by selecting the classes 0=No Water and 1=Water extracted from unsupervised classification of images. This helped in filtering out all undesired data for calculations and helped in rapid measurements. The Boolean class raster images were made semi-transparent and overlaid atop each other in QGIS. A rectangular sampling polygon of 7200 km^2 (c. 120 km long x 60 km wide) was digitized from the images based on the area covered by most images, and only the common area from each image was used for measurements (Figure 2). The sampling polygon was divided into grids at two spatial scales: 1. 8-km: which roughly corresponded with the mean size of villages on the diyara land (floodplain settlements) in the area, and 2. 20-km: which was chosen to represent the scale of administrative sub-blocks in the area. The sampling grids encompassed the area of the Ganga-Kosi interfluvial zone and river channels, from Munger on the West to Manihari on the east. From river channel units included in these grids, multiple channel parameters were measured in meters using the Measure tool in QGIS. The river sinuosity parameter was used to measure channel dynamics and persistence at different spatial and time-scales. In addition, number of channel cutoffs, net shift in river channel position over years (8-km) were other parameters used to support interpretation of dynamic behavior based on graphical analyses in the framework suggested by Hooke (2007). Indices of persistence and movement and identified time-scales of change (in years) averaged across segments were used to generate hypotheses about objective 2. For this, data from our field-based mapping of settlements, fishing areas (see next section) and Ganges river dolphin distribution were used. The implications of stable and dynamic channel behaviours for settlement, fisheries-based livelihoods and river dolphin conservation were discussed. Together, these analyses were used to test if the hydro-geomorphological dynamics of river reaches both inside and outside VGDS followed highly similar trajectories over time.

We also conducted mapping of motorized boat counts across river channel segments, number of fishing boats, fixed nets and gillnets, and other forms of human activity observed during surveys. These were linked both to the distribution of river dolphins and fishing activity. In addition, we did a rapid appraisal-based mapping of channels in which fishing was regularly conducted. Given the strong social and political implications of these variables in assessing social effects of VGDS and associated changes, we conducted a range of interview-surveys and group discussions across selected fisher settlements inside and outside VGDS. This forms another major contribution of our work, along with the ecological assessment.

Socio-economic surveys: comparing the state of fisheries, stakeholder awareness and vulnerability of fisher livelihoods inside and outside VGDS

History of fisheries in river stretches inside and outside VGDS: We compiled and reviewed literature (papers, monographs, reports, gazetteers and policy documents) regarding fishing rights in the region more generally, and also specific information to the Bhagalpur District area. In this we mainly looked at the past occurrences of conflicts over ill-defined fishing rights across the river stretch, both in upstream and downstream reaches separately. Temporal changes in the management of the VGDS were also compiled and a chronology prepared for referring respondent narratives.

Site selection: We conducted village and diyara mapping with the help of key informants throughout our study area, using boat-based and land-based surveys. We selected a few fisher settlements inside and outside VGDS, and along the Ganga and Kosi Rivers, for detailed interviews and focal group discussions with fishers in these areas. Settlements were selected based on local contacts, bearing in mind similarities within and outside, in terms of size, number of households, practices used, and coverage of upstream and downstream reaches. Figure 1 shows the names of the sites where interviews were conducted. These included seven settlements in the Bariyarpur block (upstream of VGDS, Munger district), and two settlements in Ghorghat and Janghira (upstream, Bhagalpur district). Downstream settlements included Bateshwar Sthan and Kursela. Surveys at Naugachhia and Kursela (Bhagalpur and Katihar districts) were conducted to include information on fishing both in the Kosi and Ganga Rivers. Within VGDS, fishers from settlements in three blocks were surveyed: Sultanganj, Bhagalpur (Jagdishpur block) and Kahalgaon, all along the southern bank of the River Ganga (Figure 3).

Figure 3. Map of the Ganga and Kosi river stretches included in the study area, showing interview survey locations (white outline). District names of Bihar are also indicated, as is an outline of the Vikramshila Sanctuary stretch on the Ganga River, from Sultanganj to Kahalgaon (boundaries as seen in the year 2009). Note: Naugachhia is only a police district, not a full-fledged state district.

Interview and group discussion-based surveys: data collection and analysis: Semi-structured interview surveys via questionnaires, and focal group discussions were conducted with fishers (n=182) across all selected settlements over the dry seasons of 2013 and 2014. Of these, 92 fishers were interviewed from outside VGDS settlements, and 90 from within VGDS. Questions asked to fishers involved five main heads: 1) basic socio-economic information, means of livelihood, insurance and financial security, 2) perceptions about the state and trends of fishing in rivers, problems leading to ecological degradation, and other threats faced during fishing, 3) modes through which coping mechanisms are accessed – alternative occupations, risks associated, interactions with government departments in-charge of fisheries issues, access to basic facilities for education, health, drinking water and livelihood security, and 4) interactions with river biodiversity and conservation concerns, and 5) futures associated with river fisheries and expectations for change. Most responses in the categories 2-5 were recorded ad libitum based on detailed verbatim narratives provided independently by fisher individuals / small groups (family level). Quantitative responses were recorded mainly in category 1. In addition, informal discussions included subjects such as the recent central government elections and their implications for fisheries, tacit links to power shifts at the local level, new policies, governmental corruption, and potential for seeking fisher support for river conservation and protection from threats to fisheries. All interviewed respondents were men; women were not involved in fishing, although they did work in fish retail trade and marketing fish. Fisher responses were analysed both with quantitative and exploratory analyses, and qualitative / interpretive methods that focused on discourses and narratives that fishers tapped into for constructing their responses. Analyses involved three broad objectives: 1) to tease apart differences (if any) between fisher responses and perceptions about fisheries, and current levels of potential fishing pressure inside and outside the VGDS; 2) to draw out common trends of decline, vulnerability and socio-economic status of fisher settlements across the riverscape; and 3) to compare trends in certain key indicators over time – based on results from the present surveys, and earlier data (Choudhary et al. 2006). Other than interviews, we also conducted detailed net and gear surveys, and in-water surveys of fishing activity to collect associated data on fishing pressures and risk. The fishers interviewed were all members of the Nishad (Mallah) caste including allied sub-castes and identified themselves as 'traditional fishing castes' of the region (Jassal 2001, Kelkar & Krishnaswamy 2014). The age range surveyed included respondents from 15 to 80 years. About 15-20% of households were interviewed from the total number of households known to be resident in the study area (estimated at approx. 1200). Most respondents (85%-90%) were primarily dependent on fishing in the present day, with a minority engaged in non-fishing jobs for most of the time (Table 1).

Table 1. Details of sites, sampling coverage and sampling criteria of the study.

	Bhagalpur (Barari)	**Kahalgaon**	**Sultanganj & Janghira**	**Bariarpur + (Saraswatinagar, Kalyanpur, Ghorghat)**	**Bateshwarsthan**	**Naugachhia and Kursela**
Rivers	Ganga	Ganga	Ganga	Ganga	Ganga	Ganga, Kosi
Districts in Bihar	Bhagalpur	Bhagalpur	Bhagalpur, Munger	Munger (includes multiple settlements around Bariarpur)	Bhagalpur	Bhagalpur, Katihar, Khagaria
Interview sample size (indiv./groups)	n=33	n=28	n=29, (S) n=10 (J)	n=60	N =12	n=10
Inside or outside VGDS	Inside	Inside	Inside/Outside	Outside (upstream)	Outside (downstream)	Inside/Outside
Fishing castes	Mallah (Nishad), sub-castes included					
Age range	15-80 years					
Sampling coverage (% households of total)	Inside: 90 / 477, i.e. 18.87%			Outside: (estimated) 92 / 550, i.e. 16.72%		
Primary occupation of respondents	Fishing (85.2%), also involved in- farm labour and other unskilled jobs (5%)			Fishing (90%), also involved in- farm labour and other unskilled jobs (10%) ±		

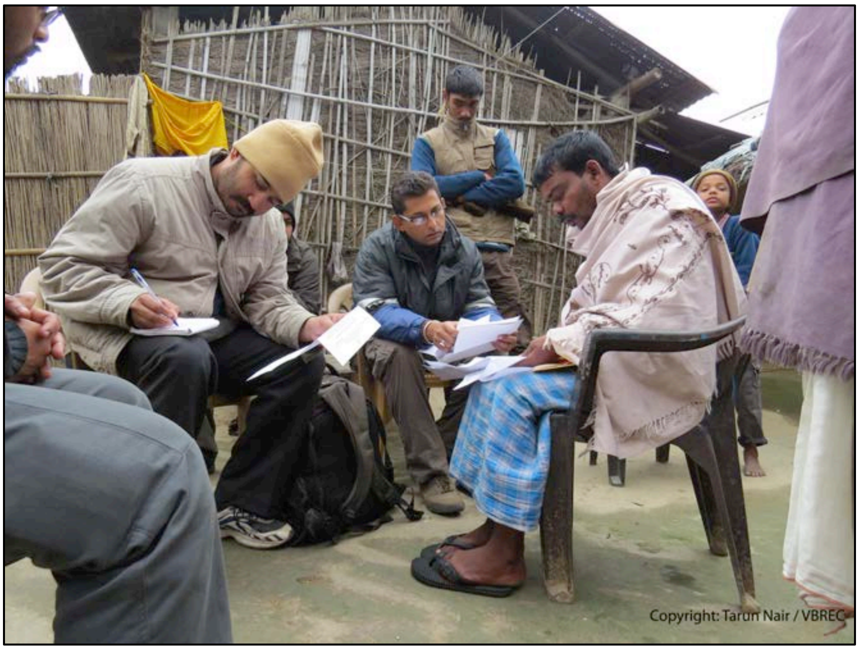


Image 4. Interview surveys and group discussions with fishers in the Kosi region.

RESULTS & DISCUSSION

Ganges River dolphin abundance and distribution

In the total study area covering 341 km of river length (Kosi (L=74 km), Ganga (L=267 km)), we estimated a population size of 693 ± 15 dolphins (approximately 700 animals). Our results indicated no meaningful differences in Ganges River dolphin encounter-rates inside (3.04 ± 0.39) and outside (3.12 ± 0.71) the VGDS, and in the Kosi River (2.67 ± 0.5) (Table 2, 3, 4). The coefficient of variation (CV) across inside and outside stretches was very low (5.6%). Although abundances showed some fluctuations from survey to survey (CV range of 13%-22%), no major trends were detected for river dolphin population size either inside or outside (rate of discrete population change ranged between -0.7 to 1.2; Table 2, 3). These trends remained more or less consistent through the sampling period for adults, sub-adults and calves in both areas (Table 2, 3, 4). Long-term distribution showed high persistence at specific 'hotspots' and low abundance / probable absence of dolphins in intervening stretches, both inside and outside the VGDS (Figure 5, 7, 8). However, within the study periods, we noted that some hotspots were stable while at others the dolphin abundance fluctuated widely. But this happened in qualitatively similar ways both inside and outside. Our GIS analysis suggests that dolphin aggregations occur by a greater probability in more stable channels, as compared to other dynamic habitats (Figure 5). This explains the common observation that river dolphins occur in clusters fairly close to human settlements. This appears counterintuitive because the public perception is often that the Ganges River dolphin is sensitive to human 'disturbance', but at least at the level of space use by dolphins this does not appear likely. The observation that dolphins and people use mostly the same areas has been confirmed by studies from different areas (Kelkar et al. 2010, Smith et al. 2010). The population estimates and encounter-rates that we report here are among the highest known in the world. The lower Gangetic region is therefore clearly among the most promising riverscapes for Ganges River dolphins. This also clearly suggests that dolphin populations have been stable and fairly high in densities irrespective of commonly recognized 'threats' being strongly overlapping their ranges spatially and temporally.

Other biodiversity

We did not find any major differences in terms of the occurrence of otters, crocodilians and threatened bird species in the river stretches in and outside VGDS (Table 5). In the case of turtles, although we couldn't do detailed surveys, we noted relatively better encounter-rates within VGDS. However, this result may not be regarded with much belief. Overall, the pattern in which species were encountered throughout the study area, barring rare crocodiles and turtles, were almost identical throughout the study area (Table 5).

Table 2. Population estimates (Mean ± SD) and encounter-rates (ER) of Ganges River dolphins from the VGDS area. Only double-observer estimates are shown. Modelling of additional effects on heterogeneous detection probability, and availability bias is on-going and not used in these estimates. Detection probability estimates ranged from 0.6 to 0.8 across all surveys. Naïve estimates of availability bias range between 0.10-0.15 (represents proportion that may be missed due to diving animals). River survey effort (navigable length) was standardized at 67 km (± 0.5 km) for all surveys.

Survey	Adult	Calf	Sub-adult	Total	CI (95%)	ER	Remarks
March 2008	93 ± 12	22 ± 5	82 ± 8	197 ± 12	180 – 224	2.97*	Averaged over 2 surveys in 2008, as a baseline
October 2011	86 ± 7	29 ± 4	76 ± 7	191 ± 6	180 – 203	2.85	
February 2012	76 ± 5	51 ± 8	90 ± 7	217 ± 7	203 – 230	3.24	
June 2012	83 ± 9	48 ± 5	70 ± 6	201 ± 7	188 – 215	3.00	
February 2013	83 ± 4	58 ± 3	91 ± 5	232 ± 4	224 – 240	3.46	
December 2013	110 ± 8	29 ± 1	116 ± 12	245 ± 9	227 – 263	3.66	
May 2014	69 ± 4	44 ± 4	66 ± 6	179 ± 5	169 – 189	2.67	
December 2014	77 ± 5	9 (0)	80 ± 7	166 ± 5	156 – 176	2.47	

Table 3. River dolphin 'counts' from single-observer upstream line-transect surveys in the lower Kosi River (Kursela to Osraha Thana). Encounter-rates (mean ± SD averaged over the two count surveys) are highly similar to the Ganges, indicating higher river dolphin densities compared against river water volume. Double-observer surveys were not feasible given navigability constraints in the shallow depths and narrow channels of the river.

Kosi River (lower)				
Survey occasion (Effort Length)	**Adult**	**Calf**	**Sub-adult**	**Total**
March 2014 (L=35)	48	4	54	106 (3.03)
May 2014 (L=74)	73	29	70	172 (2.32)
Encounter Rates				2.67 ± 0.5

Table 4. A comparison of river dolphin estimates from inside and outside VGDS (Ganga River). Survey lengths and encounter rates (ER mean ± SD) are indicated in the bottom row for all occasions. One may note the estimates to be highly similar even over time. The nature of fluctuations is also similar, and more analysis might help in teasing apart effects of demography and detection. Data used here are only from surveys conducted in good sighting conditions (state of <= 1 for wind and fog). Outside surveys in February 2012 were single-observer upstream transects with detection probabilities similar to downstream double-observer surveys.

	Inside VGDS				**Outside VGDS**			
	Adult	Calf	Sub-adult	Total (ER)	Adult	Calf	Sub-adult	Total (ER)
February 2012	76 ± 5	51 ± 8	90 ± 7	217 ± 7 (3.24)	40	14	44	98 (3.38)
December 2013	110 ± 8	29 ± 1	116 ± 12	245 ± 9 (3.66)	81 ± 4	25 ± 3	74 ± 4	180 ± 4 (3.96)
May 2014	69 ± 4	44 ± 4	66 ± 6	179 ± 5 (2.67)	132 ± 7	48 ± 4	122 ± 6	302 ± 6 (2.82)
December 2014	77 ± 5	9 (0)	80 ± 7	166 ± 5 (2.47)	180 ± 10	22 ± 1	159 ± 8	361 ± 7 (2.33)
Encounter Rates	3.04 ± 0.39	**Survey lengths**		L = 67 km for all	3.12 ± 0.71	**Survey lengths**		L = 29 km L = 79 km L = 109 km L = 155 km

Table 5. Other biodiversity recorded inside and outside VGDS (Ganga) and the Kosi River.

Species	**Inside VGDS**	**Outside VGDS**	**Kosi River**	**Remarks**
Mammals Smooth-coated Otter *Lutrogale perspicillata*	90%	75%	Rare	Percentages denote river segments (2 km) with otter presence, out of total surveyed
Crocodilians Gharial *Gavialis gangeticus* Marsh crocodile *Crocodylus palustris*	Very rare Occasional	Very rare Occasional	Very rare Occasional	Most records of stranded or washed-down animals
Freshwater Turtles (*Pangshura* spp., *Kachuga* spp.)	Fairly common	Uncommon	Uncommon	
Aquatic avifauna #				# Only threatened species considered * Breeding populations
Ferruginous Duck	1	1	1	
Greater Adjutant Stork	1	1	1*	
Lesser Adjutant Stork	1	1	1*	
Painted Stork	1	1	0	
Asian Woollyneck	1	1	0	
Black-necked Stork	1*	1*	1*	
Black-headed Ibis	0	1	1	
Spot-billed Pelican	1	0	0	
Oriental Darter	0	0	1*	
River Lapwing	1	1	1	
Eurasian Curlew	0	1	0	
Indian Skimmer	0	0	0	
River Tern	0	0	0	
Black-bellied Tern	1	1	1	

Hydrological variables

Depth and surface temperature were highly similar between the inside and outside stretches, both in winter and summer (Figure 4). Average depths (m) ranged between 6 to 9 m, and the maximum depths were up to 50 m at Kahalgaon in the VGDS, and up to 25 m in other channels. Kosi River had average depths of 2-3 m (range 1-12 m), and surface temperature in summer was higher than in the Ganga River by about 2^{o}C (Figure 6). Interestingly, summer depths of river stretches inside the VGDS were higher than surrounding unprotected areas. This was an interesting and unexpected effect, and needs to be explored further. It is possible that geomorphological profiles of channels within the VGDS might produce local ponding effects and lead to higher depths. Also, summer depth was slightly greater for VGDS than winter depth. However, we did not see any clear contrasts in terms of river dolphin distribution related to depth differences. River channel morphology differed slightly for these stretches. Larger complex meanders than those inside VGDS were encountered in upstream and downstream reaches of the Ganga, as well as in the Kosi River. Meander loop ends were often fairly stable river channel spots, where dolphins consistently occurred in both the summer and winter seasons.

In terms of channel dynamism, GIS studies showed that large meanders in the region of the Monghyr-Saharsa ridge (a fault zone in which the study area was located) produced cut-offs over 20 year periods. The Ganga River in the study area was a single phase channel with wider thalwegs at meander bends and common occurrence of water chutes. River channel widths have ranged from 575 m to 3.7 km in this period. As all LandSat images used were from the dry season, confounding factors such as flood-induced widening and bank spill over were not estimable. Yet, there was still wide variation in the movement behaviour of different channels clearly following different regimes of stability (Figure 5). Although the mean channel movement per year was 338 m, many channels also showed remarkable persistence over time. The largest movements happened at meandering stretches of Munger and Sultanganj in the late 1970s and 1990s, with a maximum magnitude of 4.5 km per year! Net movements until cut-offs occurred were typically northward looping, with nearly 25-30 km moved by the river in total over 6-8 years. In the last decade a major meander has been forming between Bhagalpur and Kahalgaon in the VGDS, and embankments are being built in response. Importantly, channels that showed long-term stability were the ones that ran adjacent to the larger towns in the area such as Bhagalpur, Kahalgaon, Bariyarpur-Gangania and Bateswar Sthan. River sinuosity ranged between 1 and 3.13, the latter following the condition for cut-off based on self-organizing critical limits. The maximum value river channel sinuosity can attain is constrained hypothetically by the value of π (pi) ~ 3.14, because after that there will be a full cut-off into an ox-bow lake.

The second objective of GIS studies was to assess implications of long-term channel dynamics for human settlement, river dolphin conservation and problems for fisheries tenure and related issues. Indeed, many settlements on the diyara land have been at the mercy of the eroding and depositing riverscape. Figure 5 shows the Sonbarsa Baihar, once a flourishing town has been struck off the map now, following flooding and channel change. There are many such examples, the most recent one being Kamalkund near Tintanga diara off Kahalgaon. The northern bank of the Ganges has greater alluvial megafan deposition from north-south flowing rivers, and river movements here range from regularly extreme to catastrophic. In highly dynamic areas, settlements if any, are very short-lived and ephemeral. This has implications for conflict over resources such as fisheries and floodplain agriculture. Perhaps linked to this is the problem of governance and regulation by local fisheries institutions (described above). Bearing over the uncertainty offered by space, the floodplain diyara lands have been controlled by criminal elements through force and threat. The diyara land has witnessed massacres of fisher caste members and Dalits (a label for backward and untouchable castes) over such issues through the 1980s, which have been infamous in Bhagalpur’s chequered history. Such violent conflicts still sporadically persist, though their magnitude has fortunately reduced. For biodiversity conservation, river channel dynamism leads to new complex issues for spatial planning. As we have highlighted, the Vikramshila Gangetic Dolphin Sanctuary is a riverine protected area that physically moves because every year. On the ground, conflict over its boundaries remains a complex issue (Kelkar & Krishnaswamy 2014).

Figure 4. Similarities in summer / winter depth and temperature inside and outside VGDS.

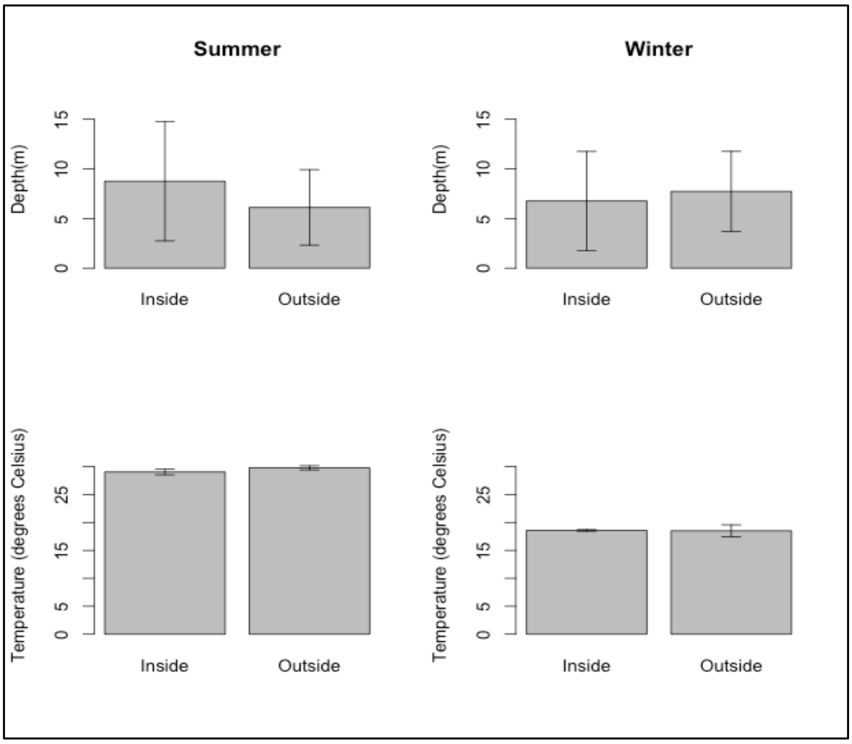


Figure 5. Overlay of satellite imagery from 1972 and 2013 to show channel dynamics of the Ganga and Kosi Rivers (just a small area for illustration). River channel changes lead to long-term persistence and extinction of human settlements, and river dolphin distribution. Orange arrow indicates a settlement that was destroyed by channel change, Sonbarsa Baihar. Green arrow indicates a stable channel of the river at Bhagalpur town. Map prepared by Nachiket Kelkar.

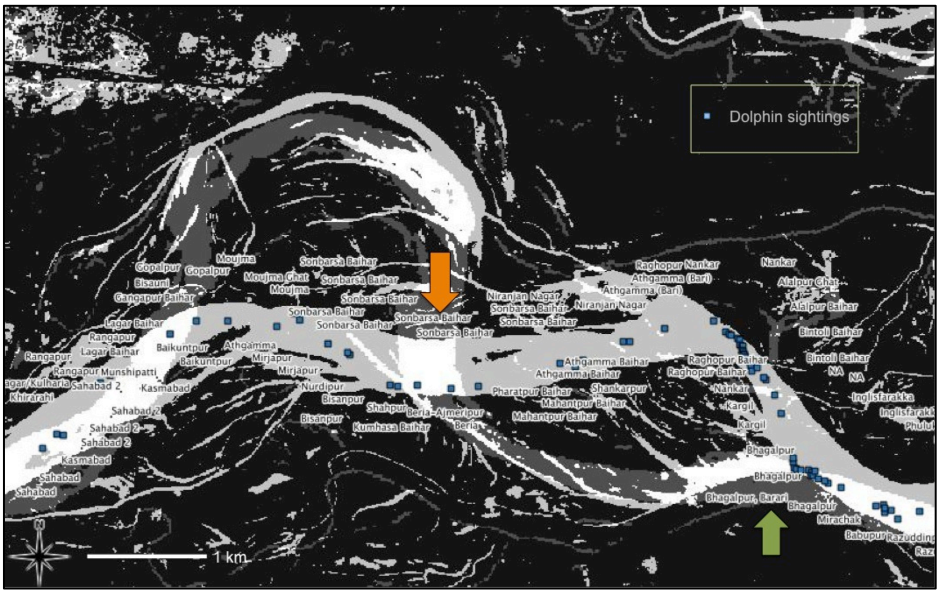
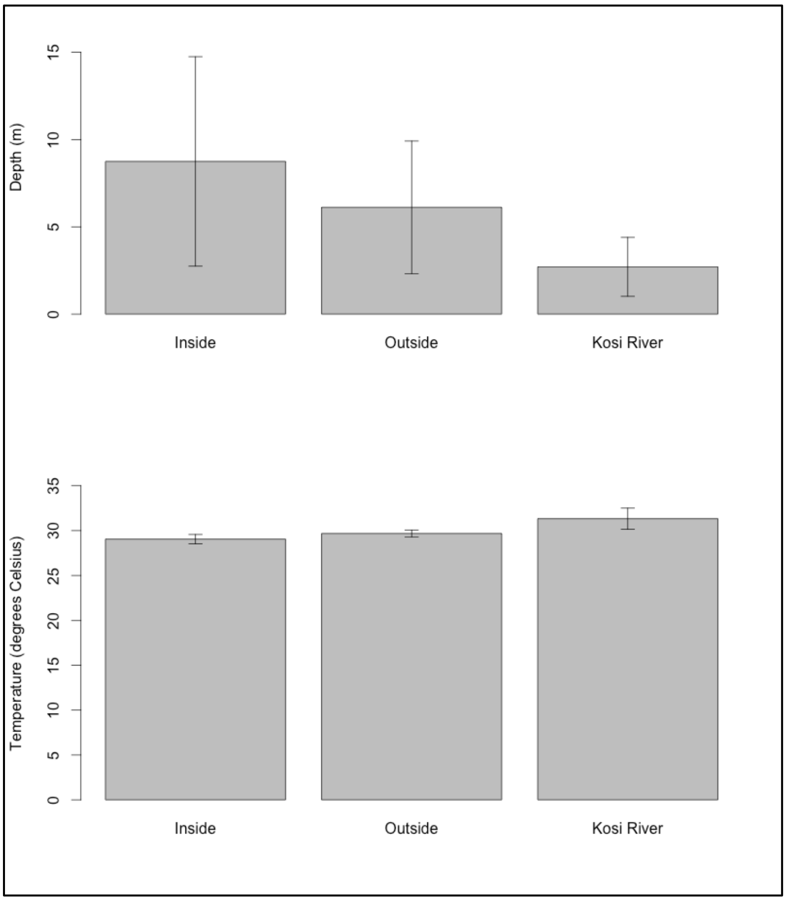
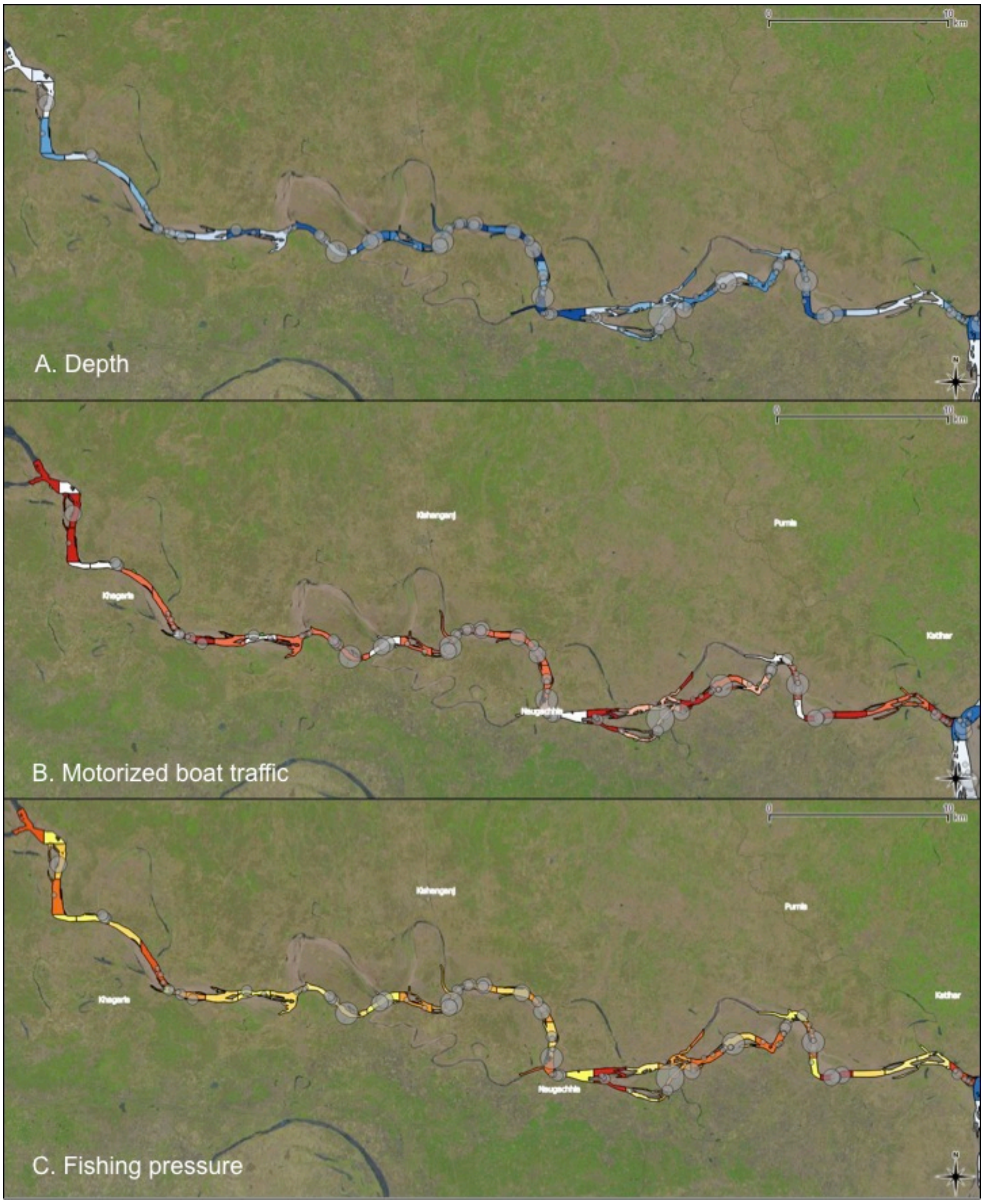


Figure 6. Summer depth and temperature inside and outside VGDS, in the Kosi River.



River dolphin clusters generally occurred in straight channels with deep pools, and along meandering arms (Figure 7). Magnitude and intensity of fisheries were not directly related to dolphin abundance and presence both inside and outside the Protected Area (Figure 8). Fishing pressure was concentrated about a few towns in the entire stretch: Bariyarpur, Jahangira, Raghopur, Bhagalpur, Ismailpur-Tintanga, Kahalgaon, Bateshwar Sthan, Kursela, Karhagola, Manihari, Sahibganj and Rajmahal where, without exception, dolphins were recorded in high numbers.

Figure 7. Depth profile, motorized boat use and fishing pressure (effort plus intensity) along the Kosi River. Darker colours represent higher magnitude of each variable. Dolphin abundance is shown in grey circles to scale.



Socio-economic indicators of fisher vulnerability and perceptions of fisheries decline: stories across an artificial boundary

Literacy rates, number of years of formal education, number of dependents per fisher family and percent of people who owned a house, a boat and fishing nets/gear, were highly similar inside and outside the VGDS (which we call here a constructed, artificial boundary; Table 6). Literacy rates were very low (25%-30%) and number of dependents per family was between 5-6 on average. Nearly all fishers (80%-95%) had their own house and fishing gear, but about a half owned fishing boats. Half of the fishers worked in the *Mallahi* system (Table 6), which was based on working on boats owned by others (usually non-fishing castes such as farmers and landowners). Ten to twenty percent of fishers depended on the Ganga River for drinking water needs, although almost all had access to shallow tube-wells. Dependence on river water for drinking had also reduced overall, quite substantially over the last 10 years (from about 52% to 17%). Almost all fishers were under debt and had taken loan from local moneylenders / banks / microcredit schemes, for buying fishing gears (82%) and notably, for healthcare and treatment of illnesses (73%).

Other than these broad indicators of vulnerability, some differences in practices emerged as surprising and important. Inside VGDS, fishing was practiced as the sole occupation by 78% of respondents, whereas outside, only 52% were solely dependent on fishing. Outside VGDS, fishers depended on multiple accessory occupations, primarily as farm labour and construction labour. Almost 60% fishers inside VGDS perceived themselves as incapable of working on any other occupation, which was nearly three times of those outside. It was no surprise therefore that many more fishers inside the Sanctuary fished for almost the whole year, than fishers outside. Fishers within VGDS had also a lower proportion of membership in cooperative societies (e.g. COFFED (Cooperative Fisheries Federation of Bihar / others) and a low proportion (20%) had bank accounts.

Table 6. Comparing basic socio-economic indicators of vulnerability among fishers inside and outside the VGDS. Responses indicate agreement 'yes' responses unless otherwise specified (this applies to subsequent tables as well).

	Inside VGDS (% fishers)	**Outside VGDS (% fishers)**	**Remarks**
Education (years of formal education)	5 ± 4 (0-10)	2 ± 5 (0-12)	mode = 0
Literacy Rate (%)	29.9% (Primary-11%, Secondary-3%	25.5% (Primary-10.5%, Secondary-15%)	
Number of dependents / family	5 ± 4	6 ± 3	
Fishing is sole occupation?	Yes – 78.1%	Yes – 52%	

Alternative occupation Farm Labour Construction Labour Local minor business (shops, fish retail trade etc.) No other skills	 10% 8.53% 4% 61%	 39% 28% 5.6% 26%	
Own house?	92%	95%	Nearly 90%-100% houses did not have attached toilets.
Drinking water supply River water Tube-wells	 17.7% 93.9%	 10% 95%	There has been reduction in the dependence on river water for drinking, roughly from 50% to 15% overall, over the past decade, due to tube-wells springing up
Loans taken	100%	93%	Loan interest rates typically between 5% and 10%; approx. 71% from local moneylenders (*Mahajan*), 47.6% from relatives, 9.75% from microcredit, and 1.2% from banks. Most fishers borrowed money for buying nets and gears (82%), and importantly, 73% took loans for healthcare
Have bank accounts?	22%	39%	About 45% do not have bank accounts in respondents outside VGDS
COFFED Card? Membership of Cooperative society?	NA 12.19%	40.3% 14% other than COFFED	Co-operative Fisheries Federation of Bihar (COFFED) cards possessed only by fishers at Bariarpur block.
Own boat?Rented boat/ No boat	42.68% 50%	56% 44%	Mallahi: a practice of ferrying and fishing using other people's boats, on rent basis
Own nets?	89%	84%	
Number of fishing months / year <= 4 5-7 8-9 10-12	 3.8% 6.5% 16.8% 73.17%	 9.7% 15.3% 20.8% 47.2%	Dependent on farm labour (months) This column is blank.

Inside the VGDS, average monthly income was Rs. 3422/- from fishing and approx. Rs. 2461/- from other activities. Average expenditure was Rs. 3658/- p.m. and average savings up to Rs. 2225/- per month. Outside settlements had slightly higher monthly incomes, (ranging between Rs. 5500/- and Rs. 7500/- per month from both fishing and labour activities) and savings too were proportionally higher (Table 7). Overall, annual income profiles across inside and outside settlements were fairly similar, except that the higher income categories (from 40,000/- p.a. and above) had three times more members in the outside settlements than inside. This difference was explained mainly by the higher proportion of fishers involved in farm and construction labour activity, that paid them reasonably well though under hard conditions, in far-flung regions such as Haryana, Punjab and Delhi. The comparisons between income profiles also points to the state of monetary poverty in the fisheries – 65-85% people earned less than Rs. 40,000/- p.a. Very often (60%-

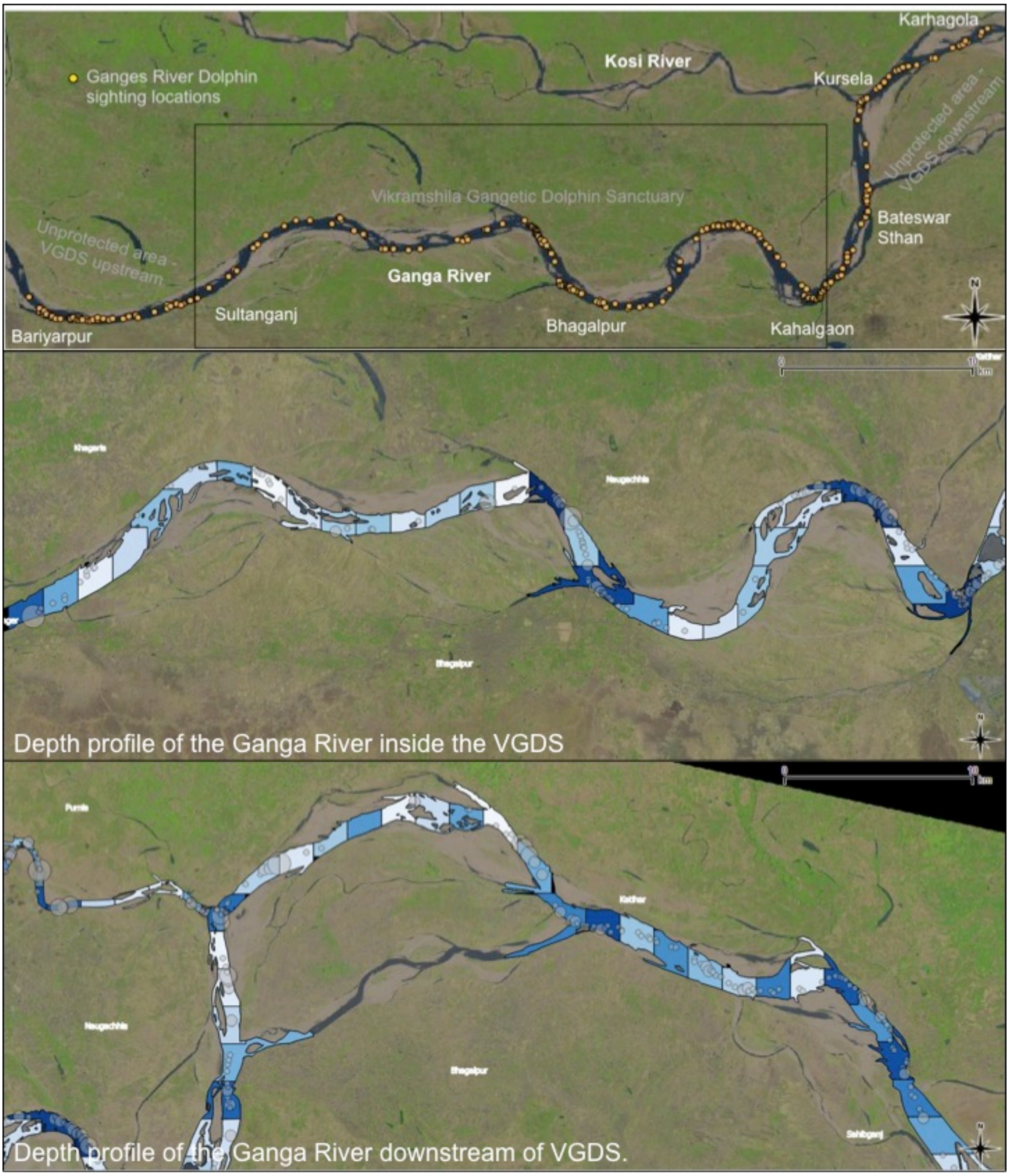
70%) these fishers were the sole earners in families which had on average 5 to 6 dependent members. Per capita this translated to low earning capabilities of c. Rs. 7000/- per annum for more than 3/4th of the population. The need for supplementing fisheries incomes with alternative livelihoods, mostly from unskilled labour, is clearly rising, as mentioned by fishers (Table 7). Shri Ashok Sahni, a local fisher leader from Kahalgaon, summarized this grave reality as follows: “The last monsoon [of 2014] was so poor that the river did not bear any fish, other than those minor trash fish that we are forced to live off today. We have all seen low floods in the past, but this time it is a run-down. For the first time in my life I had to go to Kolkata for earning for construction work.”

Table 7. Comparison of annual income ranges of fishers inside and outside VGDS. Inside-VGDS estimates are corrected for inflation rates @ 5% as the data on incomes are from 2013.

Annual Income Range	Inside VGDS (% fishers)	Outside VGDS (% fishers)	Remarks
< Rs. 10000/-	17.27 (7.8)	12.50	Standard deviations for inside surveys come from replicated surveys, which was not possible for outside settlements
Rs. 10001/- to Rs. 20,000/-	35.7 (7.2)	18.06	
Rs. 20001/- to Rs. 30,000/-	24.8 (1.8)	23.61	
Rs. 30001/- to Rs. 40,000/-	10.6 (7)	15.28	
Rs. 40001/- to Rs. 50,000/-	5.7 (3)	15.5	
Rs. 50001/- to Rs. 60,000/-	4.5 (2.5)	12.5	
Rs. 60000/- and above	2.7 (2.5)	5.6	

Some crucial trends were noted when we compared interview responses from within VGDS, between two time periods, 2013 and 2004 (from Choudhary et al. 2006). In this decade we found that boat ownership reduced from 62% to 42%, which may be regarded as an indicator of increased vulnerability. Fisher responses suggested two possibilities that surely do not bide well for the state of Gangetic fisheries. First, the complaint of frequent boat theft or destruction by anti-social/criminal elements operating in the floodplain diyara lands might have led to the reduction. Boat loss might mean a sudden blow of Rs. 30-40,000/- to a fisherman, and substantial costs that constrain further mobility for fishing. Recovering this cost might take more than two years, rendering the continuing of regular fishing next to impossible, given annual savings. The second possibility, however, would be more indicative of the overall decline in the fisheries. The reduction in owned boats is significant to the extent that it points to an exodus out of fisheries – people deciding to exit the fisheries for other options, due to poor returns and risky conditions. Some fishers may have thus sold their boats because of migration to urban centres in search of alternative livelihoods, mainly as unskilled labour. These options, mostly of unskilled wage labour, may be with greater security and paying better than fisheries, but incur other issues of marginality, exploitation and migration, and the fisheries economy might be turning towards a remittance-based one from a more selfsubsisting enterprise. A similar suggestive trend was seen in the nearly 50% reduction in the average number of nets owned per family, which reduced from 5.7 ± 0.8 to 3.2 ± 0.6 in one decade. Results also indicate that the exit from fishing might have been the highest in Sultanganj (upstream endpoint of the VGDS). In contrast, the number of full-time fishers continues to be fairly similar in Bhagalpur and Kahalgaon.

Figure 8. The distribution of Ganges river dolphins was highly similar both inside and outside the VGDS (top row). Dolphins occurred mostly in deeper channels throughout the study area. Middle and bottom rows show dolphin abundance (grey circles to scale) and depth profiled of different channels inside and outside VGDS, respectively. Darker colours represent deeper areas.



Conflict, risk and adaptation on the ground: frictions between fishers, anti-social elements and dominant power

Box 1. The political history of the riverscape has been a major contributor to current human conflicts. [It may be noted that this region also fell within the *Permanent Settlement Act (1793)*, for Bengal – the history behind land access conflicts]. The year 1991 represented a temporal socio-political watershed: in this year the *Jalkar* or *Panidari* system (the river counterpart of *Zamindari*), which had severely exploited fishers through centuries of debt-bondage, was abolished, and fishing in the river was made 'free-for-all'. The year 1991 was also when the Sanctuary was declared. The Ganga Mukti Andolan, a fishers' movement against *Panidari*, also has been strongly opposed to the Sanctuary over this time. Only recently, this bitter perception seems to be changing to a more reasonable one, somewhat due to our team's awareness activities. At present, the position of the fishers is in a perplexing quandary as they eke out their livelihoods by facing the brunt of ill-defined use, access and property rights; collapse in fisheries productivity aggravated by destructive fishing methods like mosquito netting, beach seining and whole-channel poisoning; and unclear legal sanctions regarding river fishing.

Harassment faced from anti-social gangs by fishers was the most commonly perceived threat to fishing, expressed by all respondents within VGDS, and by 90% of respondents outside VGDS. Grabbing and destruction of nets, theft of gear and boats, and threats to beat / kill fishers were cited as major problems which led to significant actual as well as opportunity costs. However, fishers from Janghira village, just upstream of the VGDS, claimed that there was substantially higher risk of criminal grabbing inside the Sanctuary, than outside. Sanjay Singh Nishad of Janghira mentioned, "The moment you wander below the Sultanganj ghat, the diyaras towards Kajjalban and Kasmabad on the south are full of criminals. An encounter will prove so costly that all the fish caught by you, well, at least half of it, is gone to the waste. Either the fish go, or you, yourself." He surmises that the criminals were at large from Sultanganj towards the downstream as this was the historical control stretch of the Panidari system (from Sultanganj to Pirpainti). On average 1/3rd or half of the fish catch happens to be grabbed by criminals per month, in VGDS. Janghira fishers said that they always went upstream towards Bariarpur and Munger to fish – it was generally safer there.

However, the influence of anti-social elements on fishers was no less in Bariarpur block either. Anti-socials accounted for losses of, on average Rs. 5000-10000/- per year for individual fishers, which sometimes even went to Rs. 40,000/- in cases of boat theft. It appears that the threat of violent force may be higher inside the sanctuary stretch, but arm-twisting by criminals involved in destructive fishing seems to be a common thing at Bariarpur. Fishers of Najira said that they were forced into using mosquito nets (*Assi jaal*), because if they didn't they would be forced out of the river and would not be allowed to fish by those who control this boom-bust fishery (Kelkar & Krishnaswamy 2014). The anti-socials claim that they have the stretch leased to them from the cooperative and their order must prevail, if anybody must fish in it. The use of highly destructive mosquito nets that kill fish larvae, fry and might seriously affect population recruitment, from which criminals take away a large share of catch, has become the ticket for protection for fishers (Choudhary et al. 2015). The reality is that the river is an open-access system for all to fish in, so there is no question of any lease. Mosquito nets are but obviously legally banned because of their tiny mesh size of 1 mm. Hence the fisheries stand driven by force and exploitation through multiple modalities, both inside and outside the VGDS, and across the lower Ganga in Bihar (Box 1).

The line between tolerating exploitation and evasion-as-adaptation by fishers, between coping and conformity, seems to be growing thinner by the day. This is seen in new forms of nets and gears that have sprung up, under the protection of criminal groups having political connections. Another example is the fine-meshed *Bahuwa jaal* (a kind of stake net) that is being deployed increasingly along embankments built over unstable meander banks (Choudhary et al. 2015). Embankments lead to avoidance by fishers using gillnets and other common types, but then clear the space for non-traditional fishing castes to deploy the *Bahuwa* nets that target small-sized fishes by their fine mesh-sizes. These changes are linked strongly to larger political shifts and changing interests and stakes in the declining fisheries. It is surprising that vested interests should enter a fishery that is being exited by fishers themselves. This complex trajectory of change needs to be understood in the light of past, present and prospective regimes of local power and control, and property rights and access (Kelkar & Krishnaswamy 2014). A common narrative that runs across fishers dependent on river fishing in the Ganga in Bihar is that of a vicious circle is an indecisive one in response. It cannot decide if the past regime of Panidari, with despotic control and oppression, was still better than the new and risk-prone open-access free-for-all (Kelkar & Krishnaswamy 2014). There seems no clarity about what they wish to see managed for fisheries, and by whom. Fishers are slowly but surely realizing, out of their current state of oppression, of how false the symbolic promise of ‘free fishing’ has turn.

Other than criminals, fishers fishing within VGDS reported frequent harassment by government department staff, particularly lower ground staff of the Forest and Fisheries Departments. Complaints of harassment suffered by fishers at the hands of officials involved allegations of offenses such as grabbing fish catch and confiscating fishing gear and nets (in the name of the Sanctuary rules, which have never been stated), threats to life and property, and demanding heavy bribes to allow them to fish. Fishers (48% of the total) within the Sanctuary stressed that the forest department officials, technically in charge of the sanctuary, were letting criminals that employed destructive and illegal fishing gear go scot-free, while terrorizing and threatening poor traditional fishers who were opposed to such nets. In the Sanctuary, government officials thus added, rather than curbed, the threat of criminals (*lathait*s (musclemen) who worked for the fishing mafia).

Interactions with biodiversity, conservation and awareness about the Vikramshila Gangetic Dolphin Sanctuary

Fishers within VGDS were mostly aware (73%) of the presence of the sanctuary, but about 50% of the fishers still had major confusions about the rules, access rights and boundaries of the sanctuary stretch. Fishers of Barari and Kahalgaon still think that the legal bans on fishing are still enforced, but do not understand how fishing can be free-for-all at the same time. In contrast, Sultanganj/Janghira and Naugachhiya fishers are clear that there is no ban on fishing anywhere in the Ganga and Kosi Rivers (across Bihar). Many fishers from Kahalgaon felt strongly that the Sanctuary should be de-notified as it was antagonizing their rights – while not clarifying how they were continuing to fish in the stretch. In all, 51.2% fishers felt the need for de-notifying the VGDS. However, almost 87% gave ambiguous responses or were non-responsive, which we interpreted as wary and strategic responses to questions about the contentious sanctuary boundaries. About 12.2% fishers had at some time participated in dolphin conservation activities, which involved civil society organizations (VBREC, T.M. Bhagalpur University, that has been working towards securing fisher rights and building an inclusive base for river conservation, and the forest department). Overall, 20% fishers had interacted with the forest department in various outreach programs and discussions, mediated by the VBREC. Seven fishers were also involved in the *dolphin mitra* (friends of dolphins) program by the Bihar Forest Department, but poor financial handling and corruption led to an inadequate termination of this activity. Many fishers did not receive their promised honorarium because of corruption by local officials.

In terms of conflict with riverine species, responses were interesting. Due to efforts by the VBREC, almost all fishers have given up killing of dolphins for their oil, to be used as bait for catching catfish species. However, doubts about the sanctuary, calls for its denotification, indirectly implicate river dolphins as a hurdle, a problem, and an issue of conflict. This is highlighted by the disparity between negative perceptions about the sanctuary on the one hand, but only 6% people perceiving dolphins as competition for fish or as animals causing gear loss and damage. Fishers reported that dolphins account for net and gear loss only 5% of the time, with damage caused by dolphins estimated to be less than Rs. 1000/- per year, if at all they broke nets with their teeth, while capturing small fish prey. Almost no fishers were aware that the river dolphin had been declared India's national aquatic animal. Of the fishers outside VGDS, only 2 respondents had experienced gear damage by Ganges river dolphins (3%). All fishers generally agreed that gear damage by river dolphins was easily repairable at low cost. Among these fishers, 30-35% were aware of the Vikramshila Sanctuary, only as a name, but did not much else.

As many as 25.6% of fishers perceived otters as causing substantially higher damage to nets and gear than dolphins. Otters were estimated to be causing losses of up to Rs. 30,000–40,000/- per year per fishing group. Especially around Barari, otters were reported to break nets very often and take away large catfishes caught in them. However, surprisingly enough, fisher perceptions were not at all antagonistic to otters. Fishers inside VGDS thought that dolphins and otters had increased inside the Sanctuary (over 10 years) but fishers outside perceived reduction (for dolphins) or no change (for otters) in population size. All fishers agreed that freshwater turtles had declined everywhere, due to hunting.

The issue of destructive fishing: profiles of fishing pressure inside and outside VGDS

Other than threat and harassment from criminals, the second biggest concern explained by fishers both inside and outside was the strong prevalence of destructive fishing practices – mainly mosquito nets and beach seine nets. An empirical, qualitative assessment of potential fishing pressure within and beyond the so-called VGDS boundary can help identify relative impacts on fish resources and biodiversity, in the presence and absence of a discourse of conservation surrounding users, no matter how ineffective or token. There was no difference between the uses of destructive net types, or even commonly used net types within and outside VGDS (Table 8). Prevalence of destructive methods was fairly high (c.40%) in both areas.

Table 8. A comparison of the relative usage of different net and gear types inside and outside the VGDS.

Net type	Inside VGDS	Outside VGDS	Average cost per unit	Remarks
Beach seine (4 mm)	12%	8%-10%	Rs. 20,000/- to 30,000/-	
Mosquito-nets (1 mm)	36.4%	40%	Rs. 900/-	
Monofilament gillnets (range: 12 to 200 mm)	89.3%	85%	Rs. 400 to 3000/-	Almost 100% fishers own gillnets, but relative use is not entirely of gillnets
Bamboo traps	35.5%	40%	NA	

Basket nets	29.35%	45%	NA	Very high use in Kosi river
Cast nets	6%	15%-20%	Rs. 2000/-	
Hook-lines	24%	30%	Rs. 100 to 1000/-	
Dragnets (200 mm+)	25%	30%	NA	
Scoop nets	22%	12%	NA	
Stake-nets (Bahuwa jaal)	30%	28%	Rs. 4000/-	Very high use in Kosi river
Fish oil / palm oil	3.65%	NA	Rs. 200/-	Fish oil is thought to be an alternative to dolphin oil (clandestine use may be < 2%), so this is an important choice

NA = Data Not Available

Table 9. Gillnet dimensions, costs and effort invested by fishers inside and outside VGDS. Certain key dimensions are compared against baselines set by fisheries acts in Bihar (e.g. Bihar Jalkar Management Bill 2006 (amended 2013)) and previous studies (Choudhary et al. 2006).

	Inside VGDS (n=278)	**Outside VGDS (n=334)**	**Remarks**
Average number per fisher	3.2 ± 0.6	3.9 ± 1.75	Fisheries acts have set a standard allowable limit of 40 mm mesh size. Choudhary et al. (2006) prescribe a slightly lower limit of 24 mm as allowable, given the reduced fish size spectra in the river. They also prescribe that allowable gillnet length be less than 150 m and width less than 7 m. **Accordingly, it appears clear that while larger nets were used more often outside VGDS, and fishing effort was more intensive, smaller mesh sizes are used inside VGDS than larger mesh sizes used outside.**
Gillnet length (m)	90 ± 6.6	121 ± 71	
Gillnet width (m)	3.7 ± 0.73	7.83 ± 12.5	
Gillnet mesh size < 24 mm > 24 mm < 40 mm > 40 mm	 53.77% 46.23% 74.52% 25.48%	 31.77% 68.23% 54.55% 45.45%	
Prevalence of destructive netting practices	15%	10%	
Per capita gear investments	4000/- ± 1330/-	8810/- ± 6650/-	Fishers outside VGDS invested in gears to twice the extent of those inside VGDS.
Average distance covered (km/trip)	20 ± 12	7 (4-20)	
Average time effort (person hours / trip)	11 ± 6	11 ± 2.5	
Rise in costs of commercially valued fish species (x times)	3 to 5	4 to 10	100 for trash fish in both areas

Our basic analysis shown in Table 9 clearly shows that fishing pressure outside VGDS might be greater in terms of intensity and effort, but fishers inside VGDS used significantly lower mesh sizes than outside. Fishing pressure inside or outside might thus have similar effects on fish population stocks and recruitment through different pathways. Overall, these indicators point to severely exploited fisheries staring major declines or even collapse in the near future. This state has been pointed out by previous publications – but in this report the contrasts highlighted between the river reaches within and outside VGDS present themselves as a critical indicator at a larger scale. Apart from local destructive fishing practices linked to the influence of criminal elements in promoting these practices, almost 65% fishers frequently cited damage to fish breeding habitats through altered and reduced flows by barrages, such as the Farakka barrage built in 1975 on the Indo-Bangladesh border (Adel 2001).

Political shifts and effects on conservation

The general elections of India in 2014 led to the resurgence of the right-wing nationalist party BJP at the center. However, at Bhagalpur, the BJP candidate was defeated by a local leader who was representing the Gangota caste – a community with influence and power on other lower castes living in the floodplains of the Ganga River – including fisher castes. The rise of Gangota access to the seat of power led to multiple visible shifts on the river and its banks in 2014. Embankment construction for saving farmers' lands from river erosion has received a major boost. A negative outcome of this power shift has been seen in at least a dozen dolphin deaths in the Ganga, near the Bhagalpur Bridge - of which about 8 or 9 have gone unreported either to us or to the forest officials. This has never been the case till date, as the fisher networks we work with have been sensitized to the issue of dolphin deaths since a long time, and as a result they have reported cases of mortality due to accidental entanglement in gillnets. However, recent threats from local criminal gangs (comprised mostly of Gangotas) have scared fishers from reporting dolphin deaths, to avoid any complications or legal run-ins. These gangs had forced fishers to keep quiet as any intervention by conservationists or department officials might disrupt their activities of using destructive nets in a side-channel of the Ganga at Bhagalpur. Through this chain of events it becomes clear that political shifts at apparently larger scales can lead to immediate cascading effects in the field. This only illustrates the point that conservation efforts centered on river biodiversity must look at political change as much as ecological trends. The above bearing of the new recent elections on the ecological space and the fates of fishes, dolphins and people bring to light an issue we seldom consider as important, at least never do we take it as a direct effect or cause of change. Identity matters. In a conflicted and declining resource space, is it that assertion of some identity alone might enable subsistence and coping against vulnerabilities? It is now becoming clear that questions like: 'who is a traditional fisher?' will form the crux of the language of conflict and discourse around conservation of Gangetic fisheries and river dolphins (Choudhary et al. 2015).

The end of the line: new dangers for the Ganga River

There are serious and life-threatening dangers that await the Ganga River ecosystem: there are multiple proposed plans to build more barrages on the river at every 100 km, proposed interlinking projects, canalization and dredging for development of inland water highways (to carry coal to thermal power plants) and so on. These dangers are for real – they are highly likely to be implemented without any consultation or appraisal process by a government for which the environment is an obstacle rather than a responsibility. The same government has been talking about cleaning the Ganga to reduce pollution, but there is no clarity about the contradictions in their plans. It is clear to us on the ground that the situation is going to be a very risky and unfortunate one, and we dare say that a protected area somewhere does not stand any chance in being able to prevent the current plans for highly insensitive development in India. There are signs of local resistance - the people dependent on the Ganga, including fishers, are seriously worried. But they also are aware that they will never have a voice that will likely make any difference. The fisheries are already scraping the bottom and can be vanquished by impending projects through compensation schemes and alternative incomes. In this scenario, where highly unequal and environmentally damaging projects are being cleared without any careful assessments, the Ganges River dolphin is more threatened today than at any time in the past. Much like the state-led development behemoth, the pigeonholing of currently commonplace conservation discourse (blaming the lack of freshwater protected areas, excessive fisheries pressure and human 'disturbance' for dolphin decline) needs to expand its vision, lest it becomes a common case of missing the river for just a volume of water. We advocate a much wider riverscape scale engagement with Ganges River dolphin conservation which goes beyond the current fixation with action plans, state departments and meeting minutes or debates over tiny protected areas.

CONCLUSIONS

Our results show that the VGDS – a protected area especially designated for Ganges River dolphins – has been a completely ineffective attempt at their conservation, a finding that seems to hold true for other river biodiversity in the region as well. These failures also equally indicate the very limited effectiveness, if any, of our conservation, monitoring and awareness efforts as representatives of civil society for the last 15 years. These are indeed discouraging findings, but we believe that they are still rewarding because of the new insights they have generated food for thought 'out of the box'. Our analysis raises several critical questions about 1) the emerging paradigm on expanding riverine protected areas, 2) appropriateness of river conservation targets, 3) conflicts between conceptual design and implementation, and 4) the costs of ignoring socio-economic complexities in mainstream conservation discourse.

Before discussing the implications of our results for riverscape-scale conservation beyond FPAs, we begin with a rejection of the likely counterargument: 'had VGDS been better protected by state agencies, our findings would be different and encouraging'. We do not think so for two reasons indicated earlier. Importantly, the dolphin densities in this region are the highest known in the world (Kelkar et al. 2010) and populations show a fairly stable trend inside and outside the VGDS. Had protection even been excellent inside VGDS, and if we assumed a rate of zero mortality of dolphins due to hunting or accidental entanglement in gillnets – this still might not have explained the high numbers outside the so-called borders of the Sanctuary. It is fairly obvious that the region of the lower Gangetic floodplains, as a whole, has relatively better water flow volume and dry-season water availability than many upstream areas and tributaries – so generalizing our findings beyond the regional specificities may not be a good idea. We instead argue, that the poor effectiveness of VGDS will not seem so discouraging if one looks at the larger region and the fairly large population estimate that we have reported here. Our estimates also showed fairly stable patterns of local persistence of river dolphins in this area. At a larger scale, these results appear positive for Ganges River dolphins as a whole. With more detailed analysis – both of population dynamics, estimation and ecological variables, as well as social issues to follow soon, there will be many emergent facts of interest that we believe will improve and expand our understanding of river conservation at large in all its complexity.

A possible – and political reading of our report, we are aware, maybe regarded as a wishful oversimplification. Such a naïve interpretation may be of the kind: "protected areas do not seem to matter for conserving Ganges River dolphins". Hence, caution against both a dismissal of our results by the blindly passionate, and their complete embracing by the indifferent or the opportunistic, are highly undesirable. We would like to stress that we completely support the symbolic and educational value of FPAs such as the VGDS. We are not in favour of extreme measures such as denotification of 'paper' protected areas. Denotification of PAs might lead to eroding conservation support and potentially irreversible changes in social appreciation of biodiversity (Mascia & Pailler 2011). Protected areas, at face value, must remain important for raising awareness and public concern about species conservation as a matter of social pride and cultural ethos. But confusing symbolic values with ecological effectiveness can be a huge mistake.

Also, the idea of territorialisation implicit in FPA designations might unleash social conflicts, injustice and inequities, unless there is sustained and deep engagement with social, economic and political drivers of change sweeping across the landscape. We find at this juncture, that despite 15 years of engagement with fisher communities, we cannot comfortably vouch for presence of complete trust between us, as conservationists, and they, as resource users, in the VGDS. The main reason for this is that our limited ability as civil society to effect political change or fully dissolve locally situated power inequities based on caste and class – in ways that would actually bring about desirable changes for fisher communities (Choudhary et al. 2015). Building goodwill has been extremely difficult, especially with historically disillusioned and marginalized people – and we are aware that losing that still-fragile trust will be very easy. This is a position conservationists have often found themselves in – one of powerlessness and disempowerment. It is easy to realize in such a situation that FPAs are not reducing the complexity of conservation but adding to the mess – for they simply fall atop the whole pile of sediment of social history, political processes and large-scale ecosystem processes (West et al. 2006, Abbott et al. 2009). It is these layers that are being blatantly ignored by rhetorical prescripts on expansion of protected area coverage for dolphin conservation in different rivers. This is seen in an abundance of local, regional, national and international conservation plans that identify including local communities, ensuring compliance and so on – as essential in river conservation (e.g. India's River Dolphin Conservation & Action Plan 2011-12). The lack of detail on what these statements mean on the ground is clearly apparent in all such plans. Given the apathy of conservationists to wider political and social realities, we believe that putting all our eggs in one basket of freshwater protected areas / networks may not really help for sustaining ecological or social integrity.

Spatial distribution of river dolphins shows often-clumped patterns at specific sites in relation to their productivity and hydraulic complexity habitats. Action plans are now increasingly advocating protection of multiple such hotspot zones rather than large river reaches as a better strategy for locally effective monitoring. Indeed, more localized efforts could improve focus and efficiency, but in connected river systems that determine on adjacent as well as distant reaches for sediment transport, productivity flows and consistent discharge. Hence, further fragmenting PAs may be questionable as it might lead to sharper boundaries at closer ranges (Gaston et al. 2008, Bottrill et al. 2012). In the framework of our study, we stress that this will be tantamount to a further level of pigeonholing of conservation effort. As we have indicated, conservation needs to be embedded gradually into the larger social consciousness – something that smaller and smaller hotspot protected areas might actually lead away from. As river conservationists or ecologists, there may be multiple positions about this problem. Our critique may be considered by many as cynical, and the alternatives too idealistic. In the process the readers of this report will consider us to be negative and parasitic about other peoples' efforts. But why not begin by boldly critiquing rather than defending age-old dogmas about more and more protected areas in an increasingly threatened global ecology? To be sure, the critique can never dilute passion for conservation – it might instead revise and develop the argument further.

This reflection brings us to another complex question: do species such as the Ganges River dolphin actually need protected areas? At the risk of sounding censorious, our findings (although detailed analyses are in progress) may reject ideas commonly employed by conservationists about the reasons for saving *Platanista gangetica*. This species may neither be the best indicator of water quality in the Ganges, nor a reliable indicator of fishing overexploitation. The stable population trends re-emphasize the findings of previous studies that the dolphin is a resilient freshwater mammal, and may not be as sensitive to local human effects as generally portrayed. Rather, larger effects of water diversion and alterations of river flows form far bigger dangers. Might reliance on more protected areas make us complacent of these actual threats, but too much concerned with the local fisher's actions? Also, by constructing the dolphin as an umbrella species, a blind mammal, or the National Aquatic Animal, conservation might make itself biased against concerns for other riverine species that are substantially more endangered (Roberge & Angelstam 2004, Darwall et al. 2011). The gharial *Gavialis gangeticus* is a good case in point. A sensitive and large riverine predator, the gharial is critically endangered and its future looks rather grim. The Ganges and Kosi have lost their gharials to near-extinction. But by building up doomsday scenarios and alarm over river dolphins, are we ignoring shifting ecological baselines for the Gangetic floodplains? Our answer, at present, is an unsettling 'yes', and begs for further detailed studies on issues concerning the riverscape, its ecology, social change and overall biodiversity (Kelkar & Krishnaswamy 2014).

The final point is then this: how do we move from restricted spatial protection frameworks to wider socially adaptive frameworks? How could we link conservation arenas to wider interconnected issues? Much has been said about managing FPAs for resource users as well as biodiversity. Our report is an attempt to generate questions that disturb the smooth top layer of action plans, solutions and panaceas, rather than try to find answers to these questions. Just the appreciation of the complexity, looking within and beyond conservation arenas, can be a good starting point in reconciling this seemingly endless problem. The Ganga River ecosystem stands awaiting a fate worse than any time in its history, at this moment. Ecological responses to averting this state of crisis might fall short in terms of scale as well as in comprehensive argument, given the political economic dimensions of impending threats. This makes the entire question of protecting the environment and biodiversity a socio-political and not ecological problem. Awareness about the prospects of crisis at regional and national scales is perhaps the most critical need for a constituency that seeks environmental justice for species and people, rather than more technology, to emerge.

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MAIN OUTCOMES OF THE STUDY

1. The results of this study will be submitted as papers to peer-reviewed international journals on ecology and conservation biology. We plan to submit three manuscripts from this report.
2. The final report will be made into a state-of-art policy brief on the Vikramshila Sanctuary, which will be shared with the Bihar state department.
3. Results of the study will be used as a continuing baseline for future detailed investigations and analyses.

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