MANIPAL
ACADEMY of HIGHER EDUCATION
(Deemed to be University under Section 3 of the UGC Act, 1956)

RIVERINE ECOLOGY AND INSTITUTIONAL INTERPLAY: A STUDY OF CONFLICT AND ADAPTATION IN GANGETIC FISHERIES

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BY
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UNDER THE GUIDANCE OF
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IN ECOLOGY AND THE
ENVIRONMENT

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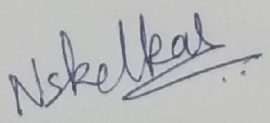
ACADEMY of HIGHER EDUCATION
(Deemed to be University under Section 3 of the UGC Act, 1956)

DECLARATION BY THE CANDIDATE

I declare that this thesis, submitted for the degree of Doctor of Philosophy to Manipal Academy of Higher Education, is my original work, conducted under the supervision of my guide **Dr. Jagdish Krishnaswamy**. I also wish to inform that no part of the research has been submitted for a degree or examination at any university. References, help and material obtained from other sources have been duly acknowledged.



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CERTIFICATE

This is to certify that the work incorporated in this thesis **"Riverine ecology and institutional interplay: a study of conflict and adaptation in Gangetic fisheries"** submitted by **Nachiket Kelkar** was carried out under my supervision. No part of this thesis has been submitted for a degree or examination at any university. References, help and material obtained from other sources have been duly acknowledged.

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Riverine ecology and institutional interplay: a study of conflict and adaptation in Gangetic fisheries

Nachiket Kelkar

Ph.D. Thesis

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Dedication

To my mother Sanjeevanee

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Executive Summary

Millions of people living along rivers of the Indian subcontinent depend on capture fisheries for their subsistence, incomes, livelihood and food security, access to affordable protein, and social dignity. Yet, riverine capture fisheries have generally been neglected both in policy-making and academic research. This is because riverine fisheries are small-scale, and their revenue contribution to the state is limited, and because land-based agriculture and aquaculture have marginalized capture fisheries. Riverine fisheries have been affected by numerous threats, due to which fish resources are declining. The major factors of decline have been large dams, barrages, and river pollution, which have severely impacted the quantity and quality of river flows that sustain capture fisheries.

River-floodplain fisheries in the Gangetic plains have witnessed protracted and intensive conflicts over fish resources, fishing rights, and access. These conflicts have severely affected fishers' livelihoods and led to continued socio-economic marginalization of fishing communities. Across the region, increasing control of fisheries by criminal gangs, and resulting violence, have directly threatened fishers. Therefore, understanding fishery conflicts is important with the multiple, entwined normative concerns of rights, social justice, ecological sustainability, and economic equity. Fishery conflicts thus represent a multi-dimensional problem, for which we need an interdisciplinary analysis and approach.

However, the study of resource conflicts remains fragmented across disciplines. Ecological and economic explanations remain fixated on aspects of resource decline by overcapacity or overfishing, or on institutional constraints in managing rights and access in the fishery "commons". Political ecology and a certain set of history studies hold power relations, social stratification by caste or class, or capitalistic relations of production, as central to continued conflicts. More recently, cultural studies have tended to focus on understanding differences in resource-use and harvesting practices, technological influences, or knowledge-systems, to explain cultural incompatibilities underlying fishery conflicts. All these explanations are partial, and therefore also problematic, when viewed in isolation. For instance, Malthusian and Neo-Malthusian narratives of "overfishing, scarcity, and conflict" do not acknowledge processes of adaptation or organization among fishing communities. They also seldom attempt to understand historic social disparities that shape

narratives of overfishing, often by state or private interests, to exercise control or alienate fish producers. Institutional explanations remain narrowly centred on transaction costs, ill-defined property rights, and economic inefficiencies in governing open-access fisheries systems. But they often ignore cultural differences, socio-economic inequalities, and the dynamic ecological settings in which conflicts unfold. Similarly, political and historic explanations deal only with social stratification and power relations, to the extent of ignoring or even denying that ecological or cultural variables can be equally important in generating and maintaining conflicts.

Fishery conflicts have material as well as symbolic underpinnings. So, we need to identify how conflicts that appear to be over material motivations (fish resources, rights, access to fishing spaces, etc.) can simultaneously be conflicts over symbolic motivations (identities, entitlements, traditions), and vice versa. Such an analysis can allow us to interpret, characterize, and perhaps even address, fishery conflicts beyond their instrumental typologies: e.g. conflicts over rights and access, due to overlapping institutional boundaries, or due to resource scarcity, or environmental uncertainty. To do so also means to study various conflict narratives and contestations both within and across these typologies, and to identify their outcomes for river ecology and fishing communities.

My thesis shows how fishery conflicts have undergone multiple shifts between their material and symbolic motivations, influenced by institutional and ecological changes over space and time, in Bihar's Gangetic plains. I also discuss the impacts of fishery conflicts on the scope for future adaptation by fishing communities. Specifically, I explore implications of history, ecology, institutions, and socio-political change on 1) conflicts over fishing rights and access, 2) conflicts over gear-use in fisheries and ideas of overfishing, and 3) conflicts over fisher identities. Resources here are defined here in a broad sense, where they include the material and biophysical resources of fish, water, land, and space, and also the symbolic resources of identities, discourses, history, and political power. As conflicts are simultaneously material and symbolic, shifts in the nature of conflicts are not linear, but driven by feedbacks, time lags, and complexity in relation to sensitivity to initial conditions, where small changes can precipitate major shifts). Institutional, ecological, and social factors generate new conflicts and change narratives that in turn reshape and transform earlier conflicts. An analysis of social and environmental change offers

clues to when and why such shifts might occur. The above approach is used throughout the thesis.

The thesis is organized in seven chapters, including the Introduction and Conclusion. The Introduction (Chapter 1) provides a template of the different theoretical strands of explanation and understanding of why conflicts occur in systems such as riverine capture fisheries. It also summarizes my personal motivations for pursuing this thesis and the epistemological frames and methodological choices I have used in my interdisciplinary work. Chapter 2 provides a historical context and analysis of how fishery conflicts in the Gangetic plains have changed since the 18th century till date, in relation to institutional factors and the influence of colonial and post-colonial policies on river fisheries management. Apart from economic rights and laws, it shows how hydrological variability and uncertainty, fisheries ecology, and caste identities of fishers, historically underpinned social perceptions of river fisheries management. Chapter 3 studies the interplay between dynamic river hydrology and jurisdictional boundaries of different institutions, in relation to conflicts over fishing rights and access. From five case studies in the Ganga, Gandak, and Kosi river-floodplains in Bihar, three common factors appear critical to the persistence of protracted conflicts over rights and access. These are linked to the incapacity of state institutional boundaries to manage fisheries in dynamic riverscapes, increasing criminal control of "mafia-style" gangs on fisheries, and weakening of community-level institutions. State institutions remain rigid and indifferent, but mafia-gangs are relatively flexible in adapting to shifting river-floodplain boundaries in order to exert control by force. With no institutional support, fishers find themselves trapped, which explains the rapid and permanent exit of fishers from riverine fisheries.

Conflicts and uncertainties over rights reflect in a predominance of declensionist narratives among fishers, who mostly blame overfishing, not socio-environmental factors, for declining fish yields. In this context, Chapter 4 attempts to disentangle the relative influences of environmental change (extrinsic variables) and fishing intensity (intrinsic variables) on fish yields in the Ganga River (in Bhagalpur, Bihar) in the last 20 years (2000-2020). I also assess the observed trends in fish yields in relation to fishers' perceptions and experiences of "scarcity". Interestingly, hydro-climatic variability, especially increasing fluctuations in flooding intensity, had a stronger effect on yields of small-sized, early-maturing fish species than fishing impacts, which influenced the yields of some large-sized, late-maturing species.

Fluctuating yields suggested that capture fisheries in the Gangetic plains were moving towards regimes of higher uncertainty, affecting fishing returns as well as enhancing conflict risks. Contestations about overfishing are also linked to age-/size-selectivity of different fishing gears used by different fishing groups in tropical multi-species, multi-gear fisheries. However, empirical assessments of these conflicts over gear use, and their ecological validation, have been lacking. In Chapter 5, I address this gap by examining the effects of different fishing nets and gears on fish yields. In the Ganga River in Bihar, gear-use conflicts between fishing groups appear to be intensifying, over the use of fine-sized mesh nets (mosquito nets and seine nets) and gillnets. Both groups have been blaming each other for declining fish catches. Further, illegal fine-meshed nets are often used with the protection of mafia gangs, who harass gillnet fishers. However, my analysis found no evidence for fine-sized mesh nets or gillnets being solely responsible for fish catch declines. Interestingly, legal gillnets (used by "traditional" and poorer fishing castes) that were targeting large reproductive adult fishes, had a greater negative impact on catches than illegal fine-meshed nets. These results indicate divergences between ecological evidence and narratives of sustainability advanced by fishers, to emphasize their vulnerability to conflicts. Sustainability narratives of different fishing practices could mask actual patterns of overfishing, and deepen cultural and political divides through gear-use conflicts.

The above chapters show that conflicts over fish resources or rights cannot be separated from conflicts over identity. In Chapter 6, I show how the interface of fishers with development and conservation discourses has contributed to a new wave of caste-based identity politics, based on claims of traditional identity within fishing communities. While these political opportunities promise representation, they do not seem to secure fishers' rights or livelihoods. Most importantly, the river and the fish that were at the centre of fishery conflicts, now become peripheral, as conflicts over identities replace them. In the conclusion (Chapter 7), I posit that shifts from interests to identities, or, between material and symbolic motivations, represent the "post-river" stage of fishery conflicts. The continuing exit of fishers from the river, in response to the growing criminal control of river fisheries, hints at a future Gangetic riverscape with many politically "traditional fishermen" who will never fish. I call this the "post-fishery" stage of the river. In these times, river-dependent fishers and associated stakeholders stand on the cusp of critical political and ecological choices and decisions that will shape their future possibilities for adaptation and action.

My thesis hopes to provide a general understanding of how resource conflict narratives transform with the crisscrossing influences of history, rights, ecology, and social identity. This analysis could allow for fresh interpretation of some links between agrarian distress and the emergence of new identity-based politics across India. It also identifies how resource conflicts respond in similar ways to the influences of conservation and development, as new groups and new forms of exclusion emerge through identity politics. As my research demonstrates, material and symbolic dimensions of resource conflicts cannot be viewed in isolation. Instead, understanding both dimensions can help identify trade-offs and synergies between the overlapping concerns of social justice, economic development, and ecological sustainability in the management of riverine capture fisheries.

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List of Abbreviations (in alphabetical order)

AMS: Army Map Service, United States of America

AMSR-E: Advanced Microwave Scanning Radio Meter for Earth Observing System, National Aeronautics and Space Administration (NASA), USA

APCCF: Additional Principal Chief Conservator of Forests

ATREE: Ashoka Trust for Research in Ecology and the Environment

BAR: Barricading mosquito nets

BC-II: Backward Classes category 2 in the state of Bihar

BCE: Before the Common Era

BJP: Bharatiya Janata Party

B_{msy}: Biomass harvestable at Maximum Sustainable Yield

CAMPA: Compensatory Afforestation Fund Management and Planning Authority

CE (=AD): Common Era (=Anno Domini)

CHANSE: Coupled Human and Natural Systems-Environment

CIFRI: Central Inland Fisheries Research Institute

COFFED: Cooperative Fisheries Federation, Government of Bihar

CPUE: Catch Per Unit Effort

CPUFD: Catch Per Unit Effort in Fisher-Days

CSD: Campaign for Survival and Dignity

CTA: Criminal Tribes Act

CWC: Central Water Commission

D-F-I-S: Decreasing-Fluctuating-Increasing-Stable

DAHITI: Database for Hydrological Time Series of Inland Waters, Deutsches Geoatisches Forschungsinstitut, Technische Universitat Munchen

DMI: Dipole Mode Index

DRG: Drag nets

ENSO: El- Niño Southern Oscillation

F: Fishing mortality

F_{msy}: Fishing Mortality at Maximum Sustainable Yield

FAO: Food and Agricultural Organization, United Nations

FHB: Francis Hamilton-Buchanan

F_{imm}: Fishing mortality on immature fish

F_{mat}: Fishing mortality on mature fish

FMIS: Flood Management Information System, Government of Bihar

FSMN: Fine-sized Mesh Nets

GIS: Geographic Information System

GMA: Ganga Mukti Andolan

GNF: Gill Net Fishing

GPS: Global Positioning System

Ibid.: in the same source

ID: Identity card

IMC: Indian major carbs

IMD: Indian Meteorological Department

IOD: Indian Ocean Dipole

JF: January-February

JJAS: June-July-August-September

L_{∞}: Length at infinity (theoretical maximum length of fish)

L_{mat}: Length at maturity of fish

L_{opt}: Length at optimal fishing harvest

M: Natural Mortality

MAHE: Manipal Academy of Higher Education

MAM: March-April-May

MEI: Multivariate ENSO Index

MEN: Moderate El Niño

MLN: Moderate La Niña

MoES: Ministry of Earth Sciences, Government of India

MOS: Mosquito nets

MOSDAC: Meteorological and Oceanographic Satellite Data Archival Centre, Space Applications Centre, Indian Space Research Organization

MSS: Multi-Spectral Scanner

N.E.: Not Estimable

NERC: Natural Environment Research Council, United Kingdom

NFP: National Fisheries Policy

NGO: Non-governmental organization

NIFAP: National Inland Fisheries and Aquaculture Policy

NINO4: Index of sea-surface temperature anomalies in the central equatorial Pacific

NISHAD: Nirbal Indian Shoshit Hamara Aam Dal

NMCG: National Mission for Clean Ganga

NOAA: National Oceanic and Atmospheric Administration, United States of America

NW: North-West

NWP: National Water Policy

OBC: Other Backward Castes

OND: October November December

op. cit.: opus citatum or the work cited

PS: Permanent settlement

QBO: Quasi-Biennial Oscillation

RJD: Rashtriya Janata Dal

S.O.: Statutory Order

SDG: Sustainable Development Goals

SE: South-East

SEI: Seine nets

SEN: Strong El Niño

SLN: Strong La Niña

SR: Satellite based Estimate of Discharge

SSF: Small-Scale Fisheries

SST: Sea Surface Temperature

STK: Stake nets

STL: Seasonal and Trend decomposition using Loess functions

TM: Thematic Mapper

TRP: Traps

USA: United States of America

USGS: United States Geological Survey

VG-SSF: Voluntary Guidelines for Small-Scale Fisheries

VIP: Vikassheel Insan Party

VSEL: Very Strong El Niño

WBMSed: Water Balance Model-Sediment

WDC-SILSO: World Data Centre for the production, preservation, and dissemination of the International Sunspot Number (SILSO=Sunspot Index and Long-term Solar Observations), Brussels, Belgium

WEN: Weak El Niño

WLN: Weak La Niña

WRD: Water Resources Department, Government of Bihar

Z: Total Mortality

Chapter 1. Introduction

My first encounter with what I came to recognize as the essence, or 'mood' of conflict on the river occurred sometime in January 2008. I was on a survey boat on the Ganga River near Sultanganj in Bihar, looking for Ganges river dolphins, when an armed gang accosted us. The leader ordered us, at gunpoint, to bring our boat close to the riverbank. We followed his orders and stood up with hands raised. After some informal pleasantries (read abuses) and enquiries, they let us go after they were lied to, that I spoke only English. The fisherman with us had almost frozen, and said that they faced this danger nearly everyday. These gangs regularly harassed fishermen and looted fish catches and money while charging them for trespass and threatening them.

Over the next 14 years, I was to realize that fishery conflicts were not restricted to fish and water alone. They encompassed several entangled issues: of history, of caste, rights, space, law, identity, freedom, conservation, and dignity. Conflicts were not just series or collections of events. Rather, conflict was the prevailing mood or 'state' of the riverscape. When fishers set out to catch fish, they were making decisions not based only on the knowledge of where fish were, or how far their boats could go. The riverscape was mapped in their spatial memory with elements and landmarks of fear and risk, for many years. Conflicts were located at the intersections of an unpredictable and complex riverine ecology on the one hand, and a long history of social inequality with feudal control of riparian land rights on the other (Kelkar and Krishnaswamy 2014). Gangs fighting over control of land and the river had been seeking rent from fishers by threatening them with violence. Many fishers were murdered in the last 30 years owing to such violence over fishing space and rights (Sharma 2006). The shadow of crime on the fishery had increased after an open-access regime replaced the oppressive but well-defined regime of private control, in 1991. With the gradual exit of fishers from the river due to the threat, local institutional capacity to organize and respond to this precarious situation had also weakened, by the fishers' own admission (Kelkar 2018). Capture fisheries had always been treated as a marginalized occupation in the agriculture-dominated management of the floodplain riverscape for many centuries.

The Manual of Fishery Statistics in the Handbook of the Government of India (2018) estimates at least 16 million active fishers across India. Of this, the population

dependent on riverine capture fisheries[1] is unknown, and likely to be a severe underestimate. Nearly 5 million fishers are estimated to live in Bihar alone, as per government census figures (Narayanan 2016). The lack of a proper estimate itself indicates a large-scale neglect of, and biases in accurate estimation of catches in riverine capture fisheries (Fluet-Chouinard et al. 2018). Ainsworth et al. (2021) estimated an annual total catch of 1,593,100 tonnes from India's inland capture and culture-based fisheries, of which the Gangetic plains contribute ~27% (approx. 4.3 lakh tonnes). Bihar, West Bengal, and Uttar Pradesh are estimated to contribute nearly 88% of the total catch from India's Gangetic plains (Ainsworth et al. 2021).

Fishing communities in the Gangetic plains comprise many castes and sub-castes broadly included in the caste-group of *Nishad* or *Mallah* fishers. These groups include full-time or semi-nomadic fishing and boat-ferrying groups, as well as seasonal/part-time fishers involved in sharecropping and farm labour (Jassal 2001, Barman 2008, Doron *et al.* 2013). These groups are categorized as economically or socially backward classes, and as Scheduled Castes by the state. Over the last six decades, dams and barrages built on rivers across the Gangetic plains for irrigated agriculture had led to reduction in river flow and reduced mobility of fish leading to dwindling and uncertain fish stocks. These changes aggravated poverty and the costs of resource conflicts, for riverine fishers (Pokrant *et al.* 1997, Sinha and Katiha 2002). Fishers have been experiencing conflicts over rights and access at various levels: with state institutions, with non-fishing groups (farmers, riparian landowners, local elites, political groups etc.), between castes, and within their own communities. Conflicts have affected the lives of fishing people, threatened their livelihoods, and damaged their wellbeing and sense of self-esteem. Risks posed by conflicts have hampered their struggles to overcome poverty in an uncertain environment.

The Oxford dictionary defines "conflict" as a serious, and usually protracted disagreement or incompatibility over shared opinions, principles, or interests. Capture fisheries pose complex questions about the nature and implications of resource conflicts for socio-economic development, livelihood security, and environmental conservation. How do we understand conflicts in relation to the different normative

[1] River-floodplain fisheries are primarily capture fisheries, which harvest wild fish stocks naturally available to fishers. Culture-based fisheries include stocked and enhanced fisheries, where fishers augment wild stocks by adding fingerlings and fry of harvestable fish species. Such fisheries are found in oxbow lakes, floodplain wetlands, reservoirs, tanks, and such habitats. Note that capture fisheries and culture-based fisheries are treated as separate from aquaculture of freshwater fish, where the entire stock is introduced into culture and artificially managed by human interventions. For more details on these three broad categories, see Funge-Smith (2018).

goals of contemporary riverine fisheries management, with its conservation and development visions? What are their outcomes for local communities to adapt to increasing risks? Conflicts do not involve just issues of access or rights to fish and space. There are conflicts over ideas of conservation, sustainability, and exploitation, and visions for community identity. What such conflicts imply for society and the environment at large is mirrored in the changes witnessed by socio-ecological systems like riverine capture fisheries.

Here I must reflect on my own normative concerns and political position, as it is problematic to introduce the thesis idea without doing so. My engagement with the issue of fishery conflicts came from riverine ecology and biodiversity research, especially on Ganges river dolphins. This research made me recognize that the normative concerns of environmental conservation and human wellbeing could not be separated from each other. At the same time, I realized that these concerns themselves lived in conflict, and could not be presumed to coexist peacefully. The future of endangered species just could not be isolated from the past, present, or future of fisher people and the conflicts they faced (Kelkar and Krishnaswamy 2014). Here, in Bihar, conflicts were directly shaping, on a day-to-day basis, the capacity and will of people to organize towards securing livelihoods, adapting to environmental and political change, and to contribute to sustainable management of resources.

Even as an outsider to the conflict scene, I also brought in my own political or normative position. It was based on the belief that sustainable, economically profitable, and socially just fisheries *could* coexist with biodiversity in a healthy and productive river environment. But how was this to happen? For my doctoral research, I wanted to understand the local drivers, and proximate and ultimate causes of conflicts in capture fisheries of the Gangetic plains. **The objective of my thesis is thus to understand why conflicts emerge, persist, and change, and how they are narrated and shaped through discourses.** I also explore the relevance and implications of fishery conflicts for livelihood security of fishers, justice, and ecological sustainability. In the introduction, I first review the theoretical frameworks and typologies used to describe, analyse, and conceptualize fishery conflicts. In doing so, I also map the major shifts in modern river management that are linked to conflicts in fisheries. I then discuss the general conceptual and analytical framework that I have used, with an outline of my thesis chapters.

Theoretical frameworks in the study of fishery conflicts

The need for a river-centric approach to the study of fishery conflicts

Fishery conflicts can be understood as originating in a historically entrenched, land-centric, or fixed-boundary paradigm of modern river management. This paradigm has relegated capture fisheries to a neglected corner of academic and policy engagement (Pokrant *et al.* 2004, Davis and Ruddle 2012). Land-based revenue interests from intensive irrigated agriculture meant that fishery issues were identified narrowly as conflicts over water for fish as against irrigation (Gowing *et al.* 2006). This was done by pitting economic returns from river management by dams and canals for irrigation demands against returns from the "unorganized" capture fisheries sector (NCAP 2004, Miao *et al.* 2010). Freshwater fisheries are often called "inland" fisheries, a term confirming the dominance of the land-centric view. Like farming, promoting aquaculture of freshwater fish over capture fisheries has been a regular feature of this dominant narrative. The stability of stocking and harvest of fishes in culture, against the uncertain nature of capture fisheries, and resulting conflicts, have been a preoccupation of fisheries management discourses (Gowing *et al.* 2006, Edwards 2015, Barange *et al.* 2018). However, the outcomes of aquaculture expansion for economic development and poverty reduction are still unclear and complicated, and not been studied objectively (Béné et al. 2016).

River-floodplain environments are dynamic and "hybrid" environments, where land and water boundaries are fluid and interchangeable (Lahiri-Dutt 2014). Thus, historically contested ideas about rigidity and fluidity, and the tentativeness or transience of space and place, lie at the core of conflicts in freshwater fisheries (Williams 1994, Sneddon *et al.* 2002, Sneddon 2007, Blomley 2008, Donaldson 2011, Song *et al.* 2017). Therefore, the fundamental question is whether we can even begin to understand conflicts in riverine capture fisheries unless we adopt a radically river-centric approach. Deb and Haque (2014) have argued that to study the history of fisheries, we need to provide a separate space for "fishantry" (fishers and fishworkers) as distinct from landed peasantry, in an interesting departure from what 'agrarian' history often constitutes (see Nakazato 1994). Indeed, this distinction is much needed, as there is no word in parallel to 'agrarian' for fishing livelihoods. Fishing groups have been included in the category of *ryot* or *raiyat* (peasants) in most agrarian history writing (with exceptions: Nakazato 1994, Reeves 1995, Pokrant *et al.* 2004).

The workplace of capture fisheries shifts in space and time in response to mobile and multi-species fish populations patchily distributed along river-floodplain gradients (Hutchings 1992, Adger and Luttrell 2000, Welcomme 2002, Salas and Gaertner 2004, Silvano and Begossi 2007, Lynch *et al.* 2016a, Song *et al.* 2017). Fishing practices are interwoven with seasonal/inter-annual variability in river flooding and hydrological disturbance events, rather than their stability (Acheson 1981, Junk *et al.* 1989, Ward 1998, Welcomme 2002, Salas and Gaertner 2004, Silvano and Begossi 2007, Russell *et al.* 2008). They also have complex arrangements of adaptive harvesting rules, customary rights, tenure, information sharing, internal regulations etc. (Acheson 1981, Basurto and Coleman 2010, Hodgson 2016). Most of these practices are very different from settled agriculture.

Existing typologies of fishery conflicts

The literature on inland fisheries has a particular vocabulary contributed by development or conservation-oriented, applied research, which speak a governmental, regulatory language. This includes the familiar lingo of "realizing the potential" or "sustaining the production environment through ecosystem approaches" or even "improving the condition of people" in inland fisheries (e.g. Sharma *et al.* 2013). Researches invest in studying climatic or ecological factors affecting fisheries production, or legislation and policy, but neglect social and institutional processes (e.g. Ray 1998, Vass *et al.* 2009, Mishra 2012), and especially, the impact of conflicts on the projections of development and sustainability. In turn, ecological studies on fishery conflicts usually lack serious engagement with socio-ecological history (Johnson 2004, Mosley 2006).

In applied fisheries research, characterizing fishery conflicts based on their mechanical and symptomatic attributes is common. Charles (1992) characterizes fishery conflicts over jurisdiction, policy and management mechanisms, conflicts between fishery stakeholders, and conflicts between fishery stakeholders and external actors. These categories, at best, describe only proximate triggers of conflict. Warner's classification (2000) is based on scales of social organization driving fishery conflicts. It includes conflicts within communities, between different communities, and between communities and state institutions. Scales of organization can be proxies for power hierarchies and cultural differences, but the attribution of different sources of conflicts to specific scales is artificial (e.g. cultural differences only at the micro-level, economic disputes only at macro-levels). Bennett *et al.* (2001) also categorize

five types of fishery conflicts, based on access (who controls), enforcement and management, relationships between fishery users, and with other non-fishery stakeholders (e.g. conservationists, non-governmental organizations, state actors, etc.). They locate specific expressions of conflicts, e.g., over gear use, as emerging from interactions across these categories, but this still prevents a general understanding. The conceptual framework of Salayo *et al.* (2006) locates conflicts in conflicting mandates of economic rationalization (performance and efficiency), welfare, and conservation paradigms in small-scale fisheries. While useful for applied research, they remain limited to identify proximate triggers for conflicts, rather than explain their origins, persistence, and transformation in time and space.

Typologies of fisheries conflict are dominated by techno-institutional, economic, and policy perspectives. The issue of "overcapacity" is also frequently discussed. Institutional interactions across river management mandates have bearings on conflicts in capture fisheries. The conceptualization of conflicts thus depends on the normative concerns around river management for fisheries, which are often disparate. The overcapacity problem is emphasized from a resource conservation standpoint (as in popular neo-Malthusian discourse). Distributive and economic efficiency is the primary concern of institutional economics, common property theory, and collective action, which has had the most influence on the resource conflict and adaptation literature (Ratner *et al.* 2013). Social justice is the main concern of political ecology and applied sociology. The broad shifts in river fishery management can be mapped out in this way: first, fisheries were just revenue (economic property rights), then resource (conservation and avoiding overfishing) and then, livelihoods and rights (for social justice, collective action, etc.).

This trajectory is correlated with different theories and concepts that have been advanced for such an explanation of conflicts. Understanding fishery conflicts in terms of revenue and the relations of production (e.g. see Campling *et al.* 2012), for capital accumulation by the colonial state has been the main contribution of agrarian history. A resource-based explanation has been based on overcapacity or "Malthusian overfishing" and technological shifts (Salayo *et al.* 2006, Finkbeiner *et al.* 2017). In fisheries, resource pessimism (as in the Malthusian view) has dominated over a cornucopian or resource optimist view, where the focus is on adaptation to overcome periodic scarcity and risks (Bernauer *et al.* 2012). With institutional economics, which users control or manage fisheries and with what property or use rights, and the scope

for collective action to manage the fishery commons, have been oft discussed (Ostrom 1990, Schlager and Ostrom 1992, Adams *et al.* 2003, Campling *et al.* 2012, Ratner *et al.* 2013). Livelihood perspectives mark a shift from formal institutional approaches towards informal approaches, which recognizes supporting functions of fisheries for human communities – e.g. in terms of nutrition, self-reliance, or identity, than just commerce (Funge-Smith and Bennett 2019). The turn towards cultural and cognitive aspects has identified differences in cultural practice and social identity as root causes of conflict (e.g. see Rothman and Olson 2001, Wieviorka 2013).

There has been a chasm in the way historians and social scientists, on the one hand, and economists or ecologists on the other, have typically engaged with resource conflicts. Capitalism and colonialism have been the focus of historical studies, while social stratification and processes of exclusion by the state, power relations, injustice and inequality, and self-identification have been the focus of sociological and political ecology studies of conflicts. Environmental decline, resource conservation, sustainability, economic inefficiency and institutional functions, property rights, access, and ownership form the main strands of the narratives of economists and ecologists. What prospects do these divergent approaches offer for an integrated theoretical understanding of fishery conflicts? Below I review and analyse theoretical explanations of fishery conflicts from history, river fisheries ecology, institutional economics, political ecology, and the sociology of identity, and how these frameworks could be combined for a more comprehensive problem definition of conflicts in riverine fisheries.

History, land revenue, and conflicts in fisheries

A long history of feudal accumulation fortified by capitalistic and colonial control, had dire consequences for social and economic inequality and ecological decline. Most historians identify these impacts as the root cause of resource conflicts in riverscapes. Fishery conflicts originated in private enclosure of fisheries through riparian rights conferred to politically powerful landowning classes (Hill 1990, Reeves 1995, Sharma 2006, D'Souza 2004, 2006; Sneddon 2007, Sinha 2014a, Sen 2015). State control over rights and taxation in fisheries of the Gangetic plains is known from early history of India (see Sharma 1980, Khan 1985, Agrawal 2007, Barman 2008, Sen 2019). But the assertion of political and economic authority

through different forms of taxation changed over time. In the British colonial period the collection of revenue from "private" fisheries was the most intensive, systematic, and formalized (Hill 1990, D'Souza 2006a,b). British systems of land revenue extraction alienated and dispossessed fishers from fishing spaces, and gradually nullified their informal or customary fishing rights to river-floodplain habitats (Reeves 1995, Pokrant *et al.* 1997, 2004; Sen 2015). Powerful landowners regularly usurped 'fishery assets' from fishers claiming riparian rights (Hill 1990, Reeves 1995, Sneddon 2007). For intensive extraction of land revenue, the colonial administration treated rivers merely as conduits of water. Left uncontrolled, these rivers were thought to amount only to destruction and waste of productive land and revenue-yielding property, through flooding or erosion or accretion (Bhargava 2007).

Rendering dynamic waterscapes subservient to land-centric agrarian production and imposing control over water became the means for consolidating colonial economic power and establishing state authority (D'Souza 2004, 2009, Lahiri-Dutt and Samanta 2013). Colonial projects to dominate waterscapes began through the construction of dams, weirs, irrigation diversions, and embankments across the Gangetic floodplains. Repeated attempts were made to draw boundaries to "survey and settle" property rights in land (Bhargava 2007), often at the expense of fisheries (Pokrant *et al.* 1997, 2004). With an unpredictable geomorphology, these stabs were futile, as floods and eroding banks repeatedly overthrew colonial attempts at 'settling' rivers down (see Mishra 2008). The costs of these interventions were borne by millions of landless peasants and fishers in northern and eastern India (Singh and Gupta 2018). The economic divides generated by this exploitative structure of revenue generation also aggravated pre-existing social inequalities and exploitation based on class, race, and caste (Pokrant *et al.* 1997, Pellow 2007, Stockhammer and Ramskogler 2007). State control over riverine ecology also severed lateral and longitudinal connectivity between the river and its floodplains (Church 2002, Tockner and Stanford 2002, Thoms 2003, Singh *et al.* 2007, Blomley 2008, Rudra 2010), and hurt fisheries productivity. These led to recurring conflicts over rights and access to fishing areas (Sen 2015), and the disruption of eco-hydrological interconnections (D'Souza 2004). The focus of both agrarian and environmental history on colonialism and capitalism (McNeill 2010) has limited fishery conflicts to class conflicts (see Campling *et al.* 2012, Sneddon 2007). Social structures such as caste that pre-dated the colonial period have not been included as latent factors maintaining conflicts,

irrespective of access to rivers through property rights or customary arrangements (Pokrant *et al.* 2004). Further, floodplain fisheries ecology has at best been a background variable rather than 'actor' in its own right, in influencing outcomes of conflict (Bakker and Bridge 2006, Sneddon 2007).

Environmental scarcity and resource conflicts

The Malthusian overfishing narrative (see Pauly 1994) remains a dominant aspect of fishery conflict studies and discussions (Finkbeiner *et al.* 2017). In simple words, it says that as finite resources decline, competition increases, resources become scarce to access and harvest profitably, and conflicts emerge. Neo-Malthusian explanations of environmental scarcity based on technological change or overcapacity (e.g. Salayo *et al.* 2006), suggest that ecological decline can even determine conflict intensification and violence (e.g. Homer-Dixon 1999). Neo-Malthusian thinking continues to influence first-world positions about international security and armed conflicts as if they were linked just to natural resource scarcity (Bayramov 2018). Insights from classical cultural ecology and anthropology also extend similar deterministic attributions, with ecological scarcity underlined as the primary cause of conflict. For instance, Park (1992) ascribed the origins of inequality to particular forms of flood-recession agriculture. Behavioural ecology (Dyson-Hudson and Smith 1978; Smith 2003) shows that the degree of competition for resources is directly determined by the density, productivity, and predictability of resources in nature. Densely clustered and predictable resources will be guarded under individual territories with high scope for conflicts. In contrast, diffuse and uncertain resources will be accessed through cooperative means of foraging. These ideas are tractable from a mathematical viewpoint. But they are limited, because conflicts involve much more than just violent fights between people (or animals) as they scramble for access to resources. Peluso and Watts (2001) show from multiple studies that violent conflicts are associated to a greater extent in resource-abundant than resource-scarce environments, and shaped by particular forces of the larger political economy. Cultural/racial differences, historical factors, structural inequalities, and power relations further complicate links between resources, conflicts, and violence (Peluso and Watts 2001, Pellow 2007, Sneddon 2007, Navas *et al.* 2018).

The primary problem of such explanations is in their environmental or "neo-environmental" determinism (Sluyter 2003). Environmental determinism suggests that geographic and ecological factors drive human societies, institutions, and economic change – and conflicts as well. Deterministic explanations are poorly supported by empirical evidence (Hauge and Ellingsen 1998, Timura 2001, Urdal 2005, Bayramov 2018). Malthusian overfishing, scarcity or unpredictability narratives never engage with the social construction of scarcity (Woodgate and Redclift 1998, McLaughlin 2001). Resource scarcity as a basis for social conflict therefore has a shaky foundation (Sneddon *et al.* 2002, McNeill 2010). Experiences of scarcity may aggravate conflict outcomes, but cannot explain why and how social conflicts originated, persisted, and have transformed. The now out-dated discourse on scarcity also ignores context and history, institutional capacities, adaptation, social learning, and innovation that could allow for cooperation or negotiation in managing resources, independent of environmental drivers (Barnett 2000, Krause and Glaser 2003, Pahl-Wostl 2006, Nelson *et al.* 2007, Coulthard 2009, Young 2010, Bayramov 2018).

In the context of riverine capture fisheries, there are major problems with scarcity-based explanations. Part of the problem lies in the stated reasons for ecological decline itself. According to Malthusian overfishing principles, as the population or technological capacity of fishing people increases, they end up overwhelming the capacity of fish stocks to recover. In fact, external human interventions have damaged river fish stocks and habitats to a much greater extent than fishermen themselves. River flow fragmentation by dams, barrages, hydropower projects and embankments have homogenized river floodplains and altered their natural environmental variability (Ward 1998, Sneddon *et al.* 2002, Tockner and Stanford 2002, Nilsson *et al.* 2005, James and Marcus 2006, Doll *et al.* 2009, Vörösmarty *et al.* 2010). Large dam projects justified for irrigated agriculture production, power generation, or industrial/urban water supply, have led to collapses of riverine fish in many regions (Dudgeon 2000, Marmulla 2001, Sneddon *et al.* 2002, Dudgeon *et al.* 2006). Human alterations of flows, in quantity and quality, have strongly decreased freshwater biodiversity and fisheries productivity (Dudgeon *et al.* 2006, Welcomme *et al.* 2010, Welcomme 2011, Arthington *et al.* 2010, Beard *et al.* 2011, de Graaf *et al.* 2015, McIntyre *et al.* 2016, Lynch *et al.* 2016a, b, Nguyen *et al.* 2016). Human impacts on river flow regimes may have increased overfishing and destructive fishing practices, threatening ecological sustainability and aggravating

conflicts (Welcomme 1995, 2002; Allan *et al.* 2005, Dudgeon 2011, Sneddon and Fox 2012, de Graaf *et al.* 2015, IPBES 2018). In spite of declines, riverine fisheries still support livelihoods, food and nutritional security, and incomes of millions of people (Payne *et al.* 2004, FAO 2005, Sneddon and Fox 2012, Hall *et al.* 2013, Lynch *et al.* 2016a, Funge-Smith and Bennett 2019). Many rivers have managed to sustain minimum productivity despite major transformations in flow volumes and variability (Thorp and Delong 1994, Marmulla 2001, Thorp *et al.* 2008, Humphries and Winemiller 2009, Donaldson 2011). Therefore, the overfishing-conflict link needs to be critically revisited.

Social stratification: class, caste, race

Fishing people across the globe are said to share a common experience of being at the margins. Fishing, both due to its ancient origins as an occupation, and because of its high-risk and fluctuating nature, has often been assigned pejoratives such as 'primitive', 'backward', or 'unorganized' by agrarian societies (Jassal 2001, Ruddle 2011, Deb and Haque 2014). Fishers usually occupy lower classes in the social hierarchy across cultural settings (Ratner *et al.* 2014, Katiha *et al.* 2017). Conflict thus has a strong link with social stratification and resulting discrimination against fishers (Sneddon *et al.* 2002, Pellow 2007, Davis and Bailey 2008). Ethnic and racial inequalities have emerged as factors driving conflicts appearing as class struggles, alienation, or elite capture (Moore 2002, Pellow 2007, Wieviorka 2013). Conflicts have been denoted as expressions of struggles of resistance against dominant power (Sneddon *et al.* 2002, Doron 2013). Classical sociological conflict theory (Dahrendorf 1958) recognized conflict between social structures as a driver of social change. Conflicts opposed notions of order, which led to re-negotiation, politics, even cooperation, and the creation of new social structures (Horton 1966, Hirshleifer 1995). But a general theory of conflict including cultural aspects remained wanting (Fink 1968). Social or cultural stratification as a basis for resource conflicts has been a new turn over the classical class struggle dimension (Bartos and Wehr 2002, Sneddon 2007, Wieviorka 2013). In political ecology, power relations based on stratification, and problems of distribution, have been mostly invoked as explanations for resource conflicts (Goldman 1998, Goldman and Schurman 2000, Woodgate and Redclift 2004, Robbins 2012). Robbins (2004) characterizes "ecological distribution

conflicts" as struggles for environmental benefits or costs from socio-economic inequalities and power relations, embedded in the context of race or class. Differences in cultural practices, moral ideas, and symbolic attributes can lead to conflicts (Alexander 1985, Opotow and Weiss 2000, Wieviorka 2013, Brown and Duguid 2015). Struggles for resources because of social stratification have both material (e.g. class struggles) and symbolic (e.g. ethnic divisions) dimensions (Anthias 2001), though they are separately treated in most explanations. Anthias (2001) identifies that "material inequality, as a set of outcomes relating to life conditions, life chances, and solidary processes, is informed by claims and struggles over resources of different types, undertaken in terms of gender, ethnicity, race and class".

With the focus on class, caste-based drivers of conflicts have been neglected (Sharma 2017). Caste stratification is correlated with class divides (Beteille 2012). However, caste has not only economic underpinnings, but also a social, biological, historical, and ethnic-racial context (Beteille 2012, 2014; Lindt 2013, Mosse 2018). Development discourses addressing conflicts have also maintained the focus on economic inequity rather than on the workings of caste (Mosse 2018). Caste conflicts are somewhat unique to resource conflicts in Asia, and must be understood for a deeper analysis of fisheries in the Gangetic plains. As mentioned before, fishing caste-groups constitute a range of sub-castes (Jassal 2001), with variable and contested claims about social hierarchy and kin relations that bear upon local modes of resource access and use.

Institutional theory and fishery conflicts

Institutions matter to the management of fisheries by addressing conflicts, regulating behaviours, and negotiating interests between different groups or communities (Jentoft 2004). Capture fisheries operate as a 'complex' of local and informal decision-making under uncertainties, but also within the formal boundaries of the state, of the law, and based on environmental opportunities and constraints (Vatn 2005, Scott 1998). Individual or group motivations held in common reflect in what institutions become, in a formal or informal sense (Hall and Taylor 1996, Cleveland *et al.* 1997, Ostrom 2005, Hotimsky *et al.* 2006, Vatn and Vedeld 2012). We can understand institutions in fisheries as social relations, and interactions between the individual agency of fishers and the wider social structures they are

embedded in (Giddens 1984, de Sardan 2013). Institutions can help regulate behaviour and action towards social, political, economic or cultural objectives (Hanna *et al.* 1996, Vatn 2005, Young *et al.* 2008), and facilitate adaptation by addressing conflicts (e.g. Schlager and Ostrom 1992, Rothschild and Shannon 2004, Gerber *et al.* 2009, Young 2010). Are institutions the same as fishing 'communities'? Community is another term that is used by conservation and development practitioners in a loose manner (Kellert *et al.* 2000, Ratner *et al.* 2014). Commonly shared interests and attitudes, or origins, make communities resemble institutions. But there are political implications of delimiting so-called communities this way, as within-community differences are overlooked (Brosius 1998, Agrawal and Gibson 1999). The term "institution" moderates these political implications and provides a flexible unit to measure social organization, making it useful in the study of resource conflicts (Hanna *et al.* 1996, Agrawal and Gibson 1999, Anderies 2000, Young *et al.* 2008, de Sardan 2013).

Hall and Taylor (1996) identify economic rationalization, socio-cultural self-identification, and political assertion as the three motivations leading to distinct "institutionalisms". Economic theory is concerned with efficient resource management by minimizing the 'costs' of conflict, while cultural and political theories study the formation and maintenance of institutional group identities based on cultural differences and objectives. In this context, I discuss some relevant paradigms in the study of fishery conflicts through the lens of institutional theory. These are linked to: 1) fishery conflicts over common property resources and their management, 2) conflicts from institutional interplay and institutional capacity to cope with environmental change across space and time scales, and 3) conflicts between the motivations of formal and informal institutions.

Common property theory and conflicts

By their very nature, capture fisheries and fish are common pool resources or 'common property' and thus do not belong to anyone, in legal principle. But the history of freshwater capture fisheries in many regions of the world shows that fisheries have been treated as private property under some form of enclosure (Sneddon 2007). After Hardin's (1968) influential paper on the "tragedy of the commons", private ownership and rights to resources were thought of as the only way to overcome "tragedies" of managing common pool resources (Adams *et al.* 2003,

Gerber *et al.* 2009), such as capture fisheries (Gordon 1954, Berkes 1985, McCay and Jentoft 1998). But this ideology ignored the fact that common property resources have been managed through collective action by people for years, through local institutions with a range of modalities to resolve or buffer the costs of conflict (Ostrom 1990). Going beyond private property rights and markets, Ostrom's (1990, 1994, 2005) theory of collective action and common property resource management demonstrated how cooperation has been achieved by various groups through communication systems, rules, informal norms, nested coordination structures, and sanctions (Cleveland *et al.* 1997, Ostrom 2005, Cox and Arnold 2010). It has also been argued that common property institutions are not only efficient economic instruments, but also that calls for reclaiming the commons have formed the basis of political projects against feudal and capitalistic control (Goldman 1998, Moore 2002, McCarthy 2005).

Common property theory also, however, rests on the assumption of economically rational individual self-interest leading to collective benefits by minimizing risks of conflict (Ostrom 1990, 2005; Cox and Arnold 2010). Analyses of the commons are thought to lack historical context and remain too economic (Johnson 2004). While common property theory has analysed economic asymmetries in the distribution of benefits, it has been criticised for not addressing social inequality and environmental injustice, which has impaired institutional capacities to govern commons (Nightingale 1998, Obeng-Odoom 2016). The limitations of common property theory in explaining why several fisheries across the world have seen protracted conflicts may be in this gap. Further, most documented examples of successful collective action in fisheries come from relatively stable environments. Young (2002) argues that collective action efforts based on Ostrom's 'design principles' have not seen much success in ecological settings with extreme variability and uncertainty, involving abrupt geological and socio-ecological transitions (e.g. see Taylor and Garcia-Barros 1995, Berger 2006). In dynamic riverscapes with fuzzy land and water boundaries, there are high transaction costs of managing fickle riparian property boundaries (Zenger *et al.* 2000, Musole 2009). In such settings, conflicts may persist irrespective of whether the fishery is managed as a commons, as transaction costs may limit meaningful participation in collective action (Adger and Luttrell 2000, Edwards 2003, Gledistch *et al.* 2006, Young 2010). With reference to the Gangetic plains, these criticisms appear rather important to consider.

Institutional interplay, fit, and scale

In riverine fisheries, institutions are constantly interacting across scales of space and time, in relation to areas of interest, conflicts between regional policies and informal customs of working fisheries, etc. Conflicts between different institutions are correlated with their capacities to deal with environmental change, which may be governed by their match with the ecological processes they seek to manage, the nature of their interactions with other institutions, and scales of interaction. Young (2002, 2010) described "institutional fit", "interplay", and "scale" as analytic themes to assess institutional adaptations to environmental change. Fit referred to "the congruence between underlying properties of ecosystems and institutional attributes" (Folke *et al.* 2007, Basurto and Coleman 2010), whereas interplay to the "interactions between and among discrete institutions" (Young 2002). Interplay could be vertical (between nested institutions; Young 2006) or horizontal (between institutions at the same level in organizational hierarchy). Interplay generates conflict or cooperation due to divergences or convergences in the plural and overlapping motivations of interacting institutions (Vatn and Vedeld 2012). Scale referred to effects of scaling up or down by institutions on the resources to be managed (Young 2002, 2010).

These themes can be illustrated for riverine fisheries with the following example. A village-level cooperative set up to manage local capture fisheries might "fit" well-defined village ponds, but might be a poor fit for a large stretch of a shifting river in its jurisdiction. The cooperative institution will interact, horizontally, with other cooperatives and interest groups for the same stretch of the river, and vertically, with state departments regulating fishing there. Interplay of this nature might generate conflicts. Vatn and Vedeld (2012) argued that the ideas of institutional interplay and fit need theoretical attention. Another influential idea has been the co-evolution of ecological and institutional dynamics (e.g. Krause and Glaser 2003, Pahl-Wostl 2006), i.e. how different institutions emerge alongside changing ecological conditions. Linking such coevolution with changing fit and interplay in dynamic riverscapes is an exciting avenue for research. I find the concept of interplay useful for understanding fishery conflicts, and use it in my thesis.

Formal and informal institutions

Freshwater fisheries comprise of mobile and adaptive behaviours of tracking and harvesting resources. Due to their mobility, riverine fisheries straddle multiple institutional boundaries, including formal and terrestrially drawn institutional boundaries such as of administrative units (Blomley 2008, Song *et al.* 2017). Fishing people may not be able to comprehend 'parcels' of the river demarcated on political boundary maps. Fishery conflicts thus emerge from the differences between formal state and informal or non-state institutions claiming fish resources, ownership and access, and rights, thus forming a large component of the post-commons literature from 'new' institutional theory (Zenger *et al.* 2000, Huppert 2005, Scoones *et al.* 2007, Mahoney and Thelen 2009, Musole 2009).

Formal institutions are defined usually as per economic and political rules: e.g. state fishery departments, registered trade outfits, or private proprietors (Schlager and Ostrom 1992, Taylor-Moore 1999, Carruthers and Ariovich 2004, Hanna *et al.* 1996, Zenger *et al.* 2000, Gerber *et al.* 2009). Ribot and Peluso (2003) advance a theory of 'access' as different from 'rights' by distinguishing formal and informal institutional processes. The ability to use resources without owning them (individually or even as commons), through informal arrangements, would enable access but not ownership rights (Huppert 2005). Access of fishers to water bodies is often governed by local customary arrangements and not written rules. These forms of access are in fact 'informal institutions'. Informal access may be decided on the basis of cultural practices, beliefs, shared knowledge-systems, and local norms, rather than on economic factors of organization (Reckwitz 2002). Here, the cultural acceptability of shared motivations matters for group membership as much as, or even more than economic interests (DiMaggio 1997, Rothman and Olson 2001). Cultural group formation also includes a perceived conflict between knowledge systems (Chambers and Gillespie 2014, Brown and Duguid 2015), or between technological means to access resources in changing environments (Santha 2008b).

Haggerty and Goldman (2010) have theorized technological change as a dominant factor triggering institutional change: "technical adaptations will serve to create a period of greater heterogeneity and conflict between institutional actors… before settling into new periods…". Hård (1993) also suggested that conflict in social ideas and interests is central to the emergence of technology in shaping social

relations. Stankiewicz (2009) described the complex interplay between technological change and cultural change, especially as it almost always plays out through great uncertainty about "new" technology. The implications of and speculation about the uncertainty can become a source of conflicts. Gear-use conflicts (Bennett *et al.* 2001) are an interesting instance of the intersection between cultural practices and economic outcomes. Increasing specialization in fishing technique and the entry of new gears can produce new fashions and memes, which can change local cultures of gear-use. Changing practices also imply differences in economic returns – which might trigger conflicts between different gear users within a fishery.

Institutional categories (state vs. community, formal vs. informal etc.) are artificial and can create stereotypes of groups involved in conflict (Scott 1983, Brosius *et al.* 1998, Honneland 1999, Kelly 2000, Vatn 2005). These categories may also assume homogeneity within, and heterogeneity in interests beyond their group boundaries. They may limit appreciation of divergent views within formal institutions, or convergences of interests across formal and informal institutions (Agrawal and Gibson 1999). Greater attention towards the individual positions of actors within institutions is needed (Singleton and Taylor 1992). Processes of legitimation, collective identity, and power relations also shape individual positions within and between institutions, and need to be studied in relation to wider social transformations that can engulf local informal institutions (Mahoney and Thelen 2009). Even informal, traditional, or community-level institutions that may be resilient to change at one level may experience conflicts through micro-scale divisions and inequalities of gender or caste, for instance (Brosius *et al.* 1998, Opotow and Weiss 2000, Nightingale 1998).

These processes highlight an important aspect of conflict studies – the formation of groups and inter-group identification and differentiation. Institutional interaction and differences in core motivations can form new group-level identities. Group identities are not static and may change as per frames of negotiation (Pinkley and Northcraft 1994, Laws *et al.* 2014). We saw in the gear-use example above that differing practice and economic returns may generate conflicts, but identities also play a major role. For example, if particular gear-uses are made illegal by state authorities (over some concern of sustainable fishing), 'illegal' and 'legal' fishers could become strong group-level identities and generate new conflicts. Identity formation thus has an institutional basis, but its study enters individual-scale cognitive dimensions.

Social identity theory

Intersections of cultural practices with ecology, technology, social stratification, and institutional memberships can generate new social identities (Ritzer 2000, Hogg 2018). Conflict or cooperation within and across social strata and groups confer new affiliations and transform older identities. Social identity theory enables a multi-scale, causal understanding of conflicts, by adding cognitive and psychological dimensions (Hogg *et al.* 1995, Turner and Oakes 1986, Callero 2003, Abrams and Hogg 2004, Owens *et al.* 2010, Hogg 2018). This shifts the focus of conflict from the asymmetries of economic or social stratification, towards the reinvention of cultural turfs based on racial history, traditions, and ethnicity (Wieviorka 2013). In fisheries, differences in norms, beliefs, codes, or knowledge-systems are often exaggerated or articulated with an emphasis on historical injustice, honour or 'reputation' in folklore or mythology, or indispensability of profession (Figueredo *et al.* 2004, Santha 2009, Doron 2013). Subramanian (2009) showed how conflicts over resources are intertwined with cultural practices and identity politics in the artisanal and commercial coastal fishers of Tamil Nadu. Similar analyses, though, remain absent from most fishery conflict studies.

Conflict is also not restricted to social inter-group differences, but includes cognitive variables that influence self-identification and choices of affiliation and membership by individuals (Hogg *et al.* 1995, Stryker and Burke 2000, Callero 2003). Identity studies in sociology focus on the expression of collective identity to represent and challenge historic exclusion by class hierarchies, or by the state (Scott 1998, Brosius *et al.* 1998, Campbell 2002, Dove 2006, Gartzke and Gleditsch 2006, Wimmer 2008, Tint 2010). Hall (2000) described identity as a strategic and political positioning, contingent upon constantly changing social situations and conditions. For marginalized fishing groups, such reinvention or rearticulation can become a necessity to cope with changing political situations, and to find a space in the sweeping changes brought by globalization, neoliberalism, development, and conservation interventions in their lives (Ahmed 1997, Charles 2002, 2011; Dove 2006, Abbott and Campbell 2009, Lam and Pauly 2010, Davis and Ruddle 2012, Ruddle and Davis 2013, Delgado-Serrano 2017, Mosse 2018, Song and Soliman 2019). Rearticulation of identities results in new concepts of the self, of community,

of rights and entitlements, which become important not only to overcome conflict but also to adapt to environmental change.

Conflict and adaptation

Human rights have become entwined with fishing rights of small-scale fishers across the world, due to several reasons cited above (Charles 2011, Ratner *et al.* 2014, FAO 2014, 2017, Zheng 2018, Funge-Smith and Bennett 2019). Concerns of human dignity, livelihood security, safety, ecosystem services, vulnerability, poverty, and wellbeing are crucial to small-scale riverine fisheries (Béné 2003, 2009; Béné *et al.* 2010, Smith *et al.* 2005, Dugan *et al.* 2010, Song and Soliman 2019). Protracted conflicts over fishing rights and access have affected the capacity of fisheries institutions to organize collective action to manage fisheries (Bennett *et al.* 2001, Allison and Badjeck 2004, Jentoft 2004, Katiha *et al.* 2017), and pose threat to their wellbeing and future prospects for adaptation (Ratner *et al.* 2013). But conflicts also provide the stimuli for new adaptive responses and coping strategies in the face of increasing 'extreme' environmental variability and large socio-economic transitions (Nelson *et al.* 2007, Coulthard 2009, Young 2010, Reser and Swim 2011, Watts 2015, Eriksen *et al.* 2015). Conflicts are thus both "opportunities and resources" for adaptive co-management and can positively affect policy processes in dealing with change (Armitage et al. 2008, Laws *et al.* 2014).

Adaptation is not simply an evolutionary or ecological pathway, where social changes can be assumed to track "stages" of environmental or biological change (Alland 2015). Eriksen *et al.* (2015) and Watts (2015) linked adaptation processes explicitly to the articulation of conflict narratives in political spheres. History and politics, innovations, and transformation of identity, play a key role in how fishers may be able to overcome the barriers imposed by existing conflicts (Laws *et al.* 2014). In their pursuit of finding pathways to adapt to change, motivations of fishers are not restricted only to higher incomes and formal ownership rights, but also include numerous intangible resources: pride, dignity, memory, and identification as fishers (Béné 2009, Charles 2011, Deb and Haque 2014, FAO 2014). Conflicts may spring from structures and processes that deny fishers these intangible resources, even if economic and social benefits become accessible (Arthur et al. 2016). Thus, adaptation includes the drive to secure factors that sustain fisher identity. My thesis hopes to

contribute some insights on what institutional changes, political shifts, and management interventions may facilitate or impede dynamic socio-ecological processes of coping and adaptation in Gangetic fisheries.

Towards an integrated understanding of fishery conflicts

The theoretical frameworks discussed above show the importance of plural and integrated perspectives on the dynamic interplay of history, river ecology, social stratification, institutional factors, and social identity in originating conflicts. What is perhaps needed is a "meta-theory" to integrate these aspects in a coherent manner. Abrams and Hogg (2004) suggested that: "a metatheory is like a good travel guide – it tells you where to go and where not to go, what is worthwhile and what is not, the best way to get to a destination, and where it is best to rest for a while." According to Turner (1990): "metatheory is… about the structure and implications of existent theories…" and "should be used to generate theories that are more parsimonious, abstract, and useful in explaining how the social universe operates". In my thesis I attempt to study fishery conflicts in the Gangetic plains in a way that can contribute to a meta-theory of social conflict, if one were to emerge in the future. I investigate different theoretical perspectives with empirical data and materials, to understand the origins, persistence, and transformation of conflicts over fish resources, rights and access, and fishers' identities. In the following section, I outline my central thesis and present a chapter-wise structure of how the thesis has been organized.

Structure of the thesis: chapter summaries

My thesis argues that fishery conflicts have shifted between material motivations (resources, access, economics) and symbolic motivations (identities, entitlements), in relation to ecological and technological change. Resources are central to these motivations or interests. I define resources in a broad socio-ecological sense, where they include not only material and biophysical resources: fish, water, land, and space, but also symbolic resources: identities, ideas, discourses, history, power, social influence, and narratives (Appadurai 1981, Harrison 1999, Alatout 2001, Bakker and Bridge 2006). Conflicts are simultaneously material and symbolic, and the shifts are not linear, but driven by feedbacks, time lags, criticality, and complexity (where small changes can precipitate major shifts). We can understand the

shifts with the metaphor of the shifting braided channels of a river[2]. In non-equilibrium river-floodplain geomorphology, it cannot be predicted *when* braids will shift, and *what* braids will get activated. Similarly, the factors that may activate material or symbolic interests underlying shifts in the expression of conflicts keep changing from time to time. Institutional, ecological, and social factors can generate new conflicts and change the narratives and discourses associated with them. An analysis of social and environmental change offers clues to *when* and *why* such shifts may occur between the material and symbolic interests underlying conflicts.

My thesis attempts an interdisciplinary study of the environmental history, ecology, institutions, and socio-political factors that underlie fishery conflicts and impact the scope for adaptation by fishing communities in Bihar's Gangetic plains. Specifically, it undertakes an exploration of historical and recent changes in institutional management, ecology, and politics in riverine capture fisheries, to understand implications for conflicts over fishing rights, access, fishing gear-use, and identity politics. The thesis is composed of seven chapters, including the Introduction (chapter 1) and Conclusion (chapter 7). Chapter 2 provides a historical overview and analysis of how conflicts have changed in time and space, in relation to changing institutional and socio-ecological factors. This chapter maps out the broad, long-term trajectories of institutional change in riverine fisheries management since the 18th century. Chapter 3 is based on the concept of ecological and institutional interplay (Young 2002, Basurto and Coleman 2010), within the framework of institutional theory in economics. It conducts empirical investigations on conflicts over fishing rights and access in riverscapes with constantly shifting physical boundaries, emerging through the confusions and uncertainty about jurisdiction, control, and ownership, with 5 case studies. The framework is applied to understand how different institutions related to riverine capture fisheries interact with each other along the dynamic Gangetic riverscape. Scale mismatches, institutional hierarchy, and power relations play strong roles in generating conflicts between formal and informal institutions (Sneddon *et al.* 2002, Cumming *et al.* 2006). These are assessed in relation to how fishers attempt to seek and negotiate rights and access to fishing areas.

Chapter 4 attempts to understand the relative influences of environmental change (extrinsic variables) and fisheries-induced change (intrinsic variables) on

[2] See chapter 3 for technical details on what braided channels mean in terms of river channel morphology.

fisheries productivity, and its effect on the experience of conflicts over declining fish resources. Fishing impacts and environmental variables are both advanced by fishers as causes of overfishing, a theme that I investigate here. Specifically, this chapter explores the impacts of river hydrology, climatic factors, fish biology, and fishing effort investments of fishers, based on population ecology and environmental studies, using socio-ecological regime theory and fisheries biology (Vert-pre *et al.* 2013). In this regard, technological differences (gear use, selection, and effort) also interact significantly with fisheries ecology (Santha 2008a,b). Conflicts over gear use raise fundamental questions about the contested narratives of selective and unselective fishing. These narratives overlap with legality, custom, tradition, and with claims about the (un-) sustainability of fishery harvests (Klug 2002, Friend and Arthur 2012). These issues are analysed in chapter 5 through a detailed interdisciplinary investigation of gear-use conflicts through population ecology, statistical analyses, and mathematical modelling. Gear-use conflict narratives represent one of the most classical, and continued theoretical debates in fisheries biology, about 'overfishing' in relation to gear selectivity, age-specific fishery targets, and new theoretical insights on 'balanced harvesting' (Pauly 1994, Garcia *et al.* 2012, Kolding and van Zweiten 2011). Chapter 5 unravels the 'overfishing' effects of different fishing gears and related conflicts in multi-gear, multi-species tropical fisheries. As the issues of tradition and custom are linked with these conflicts, they further open doors to conflicts about identity and entitlement, and raise complex issues of "who should be fishing". In chapter 6, I use sociological theory on caste and social identity (Lindt 2013, Mosse 2018, Hogg 2018) to look at the symbolic, discursive, and cultural realm in which conflicts over fishing rights are articulated, through identity politics based on caste and tradition. In this chapter I also discuss the outcomes of identity politics for river fisheries sustainability, conservation, and socio-economic development prospects for fishing communities.

In chapter 7 (conclusion), I focus on the implications of changing forms of resource conflicts for ecological sustainability, conservation, and social justice. I first explore the relevance of my thesis to emerging fishery conflicts in India and elsewhere, through the shifts in conflict narratives from their material motivations to more symbolic and identity-driven motivations. I then link my findings to existing policy frameworks at the state level, national level, and international level, with a focus on draft national fisheries policies (2019-2020) by the Government of India, and

the Voluntary Guidelines in Support of Small-Scale Fishworkers (FAO 2014). I also highlight the potential limitations of my work. Finally, I discuss opportunities, challenges, and potential outcomes of conflicts in riverine capture fisheries. These outcomes hold relevance for adaptation by fishers faced with the multiple and complicated realities of rapid climate change, ecological degradation, weakened institutional capacities, criminal control, and new waves of caste-based identity politics across the Gangetic plains (see Kelkar 2018).

Methodological approaches

I have used a diversity of methodological approaches to understand some of the proximate and ultimate causes of fishery conflicts over time. Primary data collection in my study has involved regular fieldwork for over three years after PhD registration with the Manipal Academy of Higher Education (MAHE), plus nearly ten years of my own fieldwork before the registration has also contributed to the PhD research (from 2007 onwards). In 2011-12, I conducted a five-month field survey of over 370 fishers along rivers in six states (West Bengal, Bihar, Uttar Pradesh, Jharkhand, Madhya Pradesh, and Rajasthan; see Figure 1.1), to understand issues they faced and perceptions of conflicts (reported in Kelkar 2012, 2014a). I estimated from my surveys that river fish contributed about 20% and at best, 40% of the total annual catches sold in fish markets (Table 1.1). The rest 60%-80% comes from aquaculture from Andhra Pradesh and West Bengal. Invasive fish species (esp. Tilapia, Common Carp, and Red-bellied Pacu) now dominate fishers' catches in rivers of Uttar Pradesh (Table 1.1). I also found that while the major threat to fish production varied, the experience of conflicts was similar across regions, with criminal control being a nearly omnipresent element of fishers' attempts to gain access to fishing areas. During this time, I could expand my core training in biology and quantitative ecology towards interdisciplinary studies in sociology, political ecology, and history at ATREE. In parallel, a continued engagement with conservation conflicts in Bihar and other regions of India helped shape many of the ideas explored in the thesis. I conducted about 200 interviews and focus group discussions with various stakeholders relevant to fisheries management in the state of Bihar, with added insights from interviews in Uttar Pradesh and West Bengal. I also conducted history research through archival and textual analysis methods (Ventresca and Mohr 2002), qualitative and textual

analyses of interview data and other socio-economic data on riverine fisheries, and policy studies to these data sources. For my historical analyses, I followed Wiliam Cronon (1992) in using narratives as useful starting points to understand conflicts from the perspective of local fishers. Narratives are vehicles of conflict, and in them sit competing hypotheses and disagreements, which may hold explanations for why conflicts occur.

Regular recording of fish catch data from landing sites and market sites, hydrological data collection, and boat-based surveys to map fishing effort over space and time also contributed strongly to the thesis. I collected secondary data on multiple hydro-climatic variables and fish life-history characteristics. For this, I also conducted field hydrology measurements and satellite-gauged discharge datasets (Brakenridge *et al.* 2017) to gain insights into hydrological trends in different rivers of the Gangetic plains. This is a small but important contribution, given that the "classified" river discharge data for the Gangetic plains were not accessible to me. My research benefitted a great deal from the long-term monitoring of fish catch data that was spearheaded from 2000 onwards by Subhasis Dey, my collaborator since 2006-07, who shared his remarkable time-series data to help me conduct time-series analyses of trends in fish yields and catch-per-unit-effort in relation to environmental variables. Apart from statistical analyses, I also undertook mathematical modelling of fish populations under different scenarios of harvesting (for chapter 5). Thus, the interdisciplinary research in the thesis has spanned a range of methods from qualitative and quantitative studies. Some analyses take a positivist and phenomenological approach. Others engage with the diverse positions, subjective constructions, and political narratives of diverse actors, all of them viewing and experiencing conflicts both in a historic and "current" sense. Epistemologically, combining these different analyses and approaches is complicated. But broadly, the components of environmental history, biology and ecological theory, and the sociology of identity politics allow for integration based on the common theme of conflict. **With its strongly interdisciplinary scope, the thesis can be said to speak to the field of political ecology.**

Relevance of the study

As said at the outset, the study of conflict is situated in not one but many crisscrossing normative concerns. Whereas my academic thesis offers an interdisciplinary analysis of causes of conflicts, it is not aloof from engaging with real-world implications for riverine capture fisheries and their management. I hope that the problem analysed by the thesis, and the contradictions highlighted in policy and in fishers' voices, will help various stakeholders expand their understanding of fishery conflicts in the Gangetic plains. Attempts at "closing the loop" by taking the findings of the thesis back to them, have been described in the thesis conclusion. The study hopes to provide fishers, policy-makers, and conservationists with fodder for discussion about pathways to address conflicts and adaptation challenges.

Tables

Table 1.1. A summary of information from field surveys of river fishing areas and markets across the Gangetic basin, in the states of Uttar Pradesh (UP), Bihar (BR), West Bengal (WB), Madhya Pradesh (MP), Jharkhand (JH), and Rajasthan (RJ). Grey shaded rows indicate declining trends in river flow and water availability and non-shaded rows indicate stable river flows. Averaged trends reported by riverine fishers in their catches over the last 30 years, and estimated annual contributions of river fish to local markets (from field surveys) are also shown. Proportions of invasive fish species in market catches are also shown. The major threats perceived by fishers to their livelihoods were flow regulation by dams and barrages, river pollution, the use of destructive fishing methods or overfishing, invasive fishes, and climatic changes, but their relative importance differed across regions. However, the experiences of fishery-related conflicts were strikingly similar, with the influence of criminal control on the fisheries evident across regions.

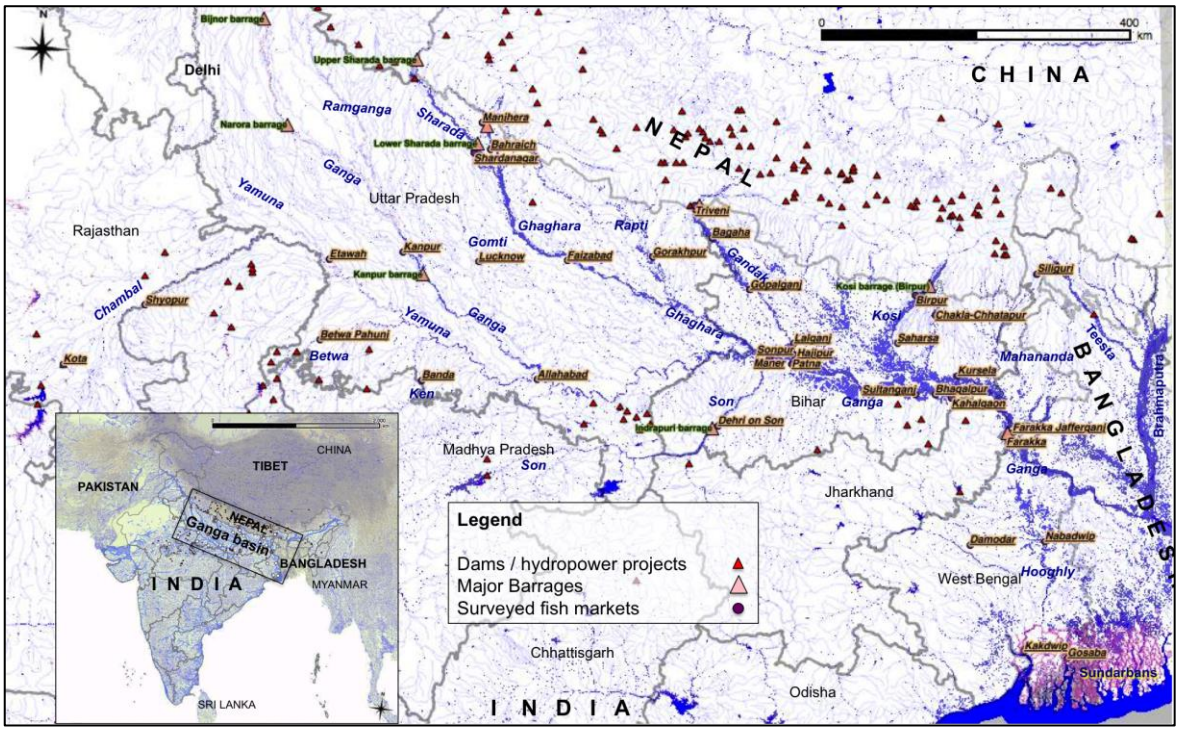
River	Site name	State	Mean reported trends in fish catches (%)	Contributions of river fish, invasive fish to local market production (%)	Primary threats perceived by fishers to their livelihoods	Conflicts of fishers with other actors
Ganga	Kanpur#^	UP	-80	20-25, 20	PO, FR, DF	RIP, MAF
	Allahabad^	UP	-75	30-40, 35	PO, FR, DF, INV	CRM, RIP, MAF
	Bariarpur^	BR	-85	40, 0	DF, OF, FR	CRM, RIP
	Janghira^	BR	-85	50, 0	DF, OF, FR	CRM, RIP, MAF, GOV
	Bhagalpur (Barari)^	BR	-85	40, 0	DF, FR, PO	CRM, RIP, MAF, GOV
	Kahalgaon^	BR	-90	40, 0	DF, OF, FR	CRM, RIP, MAF, GOV
	Rajmahal#^	JH	-80	40-50, 0	DF, FR	CRM, MAF
	Farakka#^	WB	-85	40, 10	DF, OF, FR	GOV, CRM
Yamuna	Etawah#	UP	-94	10, 40	PO, DF, INV	CRM
	Allahabad^	UP	-75	25-30, 40	PO, FR, DF, INV	CRM, RIP, MAF
Chambal	Kota#	RJ	-70	10, 40	FR	CRM, GOV
	Shyopur^	MP	-55	30, 10	FR, CL	CRM, GOV
Betwa	Pahuj-Jhansi#^	UP	-87	30, 25	DF, PO, OF, FR	CRM, RIP, MAF, GOV
Ken	Banda#	UP	-75	40, 40	DF, OF, INV	CRM, RIP, MAF
Gomti	Lucknow^	UP	-94	10, 10	DF, PO, FR	CRM, MAF
Ghaghra	Bahraich#	UP	-70	50-60, 25	DF, FR, PO	CRM, RIP, MAF
	Manjhra#	UP	-95	80, 10	FR, DF	CRM, GOV
	Faizabad#	UP	-96	30-40, 5	DF, FR, OF	CRM, MAF
Sharada	Sharadanagar#	UP	-85	50, 10	FR, DF, CL	CRM, MAF,

						GOV
Rapti	Bahraich#	UP	-80	50-60, 30	DF, FR, PO	CRM, RIP, MAF
	Gorakhpur#	UP	-95	-	FR, PO	CRM
Gandak	Triveni^	BR	-99	40-50, 0	FR, DF	CRM, RIP, GOV
	Bagaha-1#^	BR	-75	40-50, 10	OF, CH	MAF
	Lalganj^	BR	-75	40-50, 0	DF, OF	CRM
	Hajipur-Sonpur^	BR	-85	40-50, 0	FR, DF	CRM
Kosi	Birpur^	BR	-95	50, 5	DF, OF, FR, PO	CRM, RIP, MAF
	Chakla-Chhatapur^	BR	-75	40, 25-30	DF, OF, FR, PO	CRM, RIP, MAF
	Saharsa (Nauhatta)^	BR	-96	40, 20	DF, OF, PO, FR	CRM, RIP, MAF
	Naugachhia^	BR	-60	65-70, 0	DF, OF, FR	CRM, RIP, MAF
	Kursela^	BR	-85	50, 10	DF, OF	CRM, RIP, MAF
Son	Dehri^	BR	-82	30, 20	FR, OF, DF, CH	CRM, MAF
	Maner^	BR	-60	-	FR, OF, DF, CH	CRM, RIP, MAF, GOV
Damodar	Durgapur^	WB	-85	30, 20	FR, OF, DF, PO	CRM, RIP, GOV
Hooghly	Feeder Canal^	WB	-85	70, 5	PO, FR	GOV, CRM
	Nabadwip#^	WB	-95	60, 20	DF, FR, OF	CRM, RIP
	Kakdwip^	WB	-99	70-75, 10	OF, CL, PO	CRM, GOV
Sundarbans	Gosaba#^	WB	-60	60-70, 15	OF, DF, CL, PA	CRM, RIP, GOV
	Jhorkhali#^	WB	-50	75-80, 5-10	DF, OF, CL, PA	CRM, RIP, GOV
-	Siliguri (hub market)	WB	-80	25-30, 30	FR, PO, DF	-

Key: Sites: # Contract fisheries (fished through auction-leases); ^ Free or open-access fishing, with relatively minor barriers of entry or exit; #^ Contracts, government ownership, and free-fishing systems exist in tandem or overlap; Siliguri is one of the largest wholesale hub markets for freshwater fishes in the Gangetic plains (responses of traders). Primary threats: DF=Destructive Fishing, OF=Overfishing, FR=Flow regulation by dams and barrages, PO=Pollution of rivers, INV=Invasive fish species, CL=Climatic changes, CH=River channel changes. Conflicts with other actors: CRM=Criminal elements, RIP=Riparian landowners, MAF=Contractors operating fisheries with the aid of criminal gangs or mafia, GOV=conflicts with government officials or jurisdictional conflicts.

Figures

Figure 1.1. A map of the Gangetic river-floodplains with locations of major fish markets, river gauging sites, major barrages and dam surveyed from 2011-12 to present. Text labels indicate market locations.



Chapter 2. Towards an ecologically and socially grounded history of conflicts in Gangetic fisheries

Introduction

Fishery conflicts have interwoven material and symbolic dimensions[3]. However, these dimensions are often understood as separate from each other, through three main lenses: 1) institutional weaknesses in addressing conflicts in the fishery "commons", 2) perceptions of ecological scarcity, and 3) social stratification and power relations in terms of class-based or ethnic stratification[4]. Institutional explanations primarily concern themselves with property rights and rules of access. Perceptions of resource scarcity are underscored by "Malthusian overfishing"[5] and related neo-Malthusian arguments[6]. Class or ethnic identity-based divides[7] have links to historic marginalization of fishing communities, who were mostly seen as peripheral to the dominance of settlement and agriculture.

All these explanations are important, but partial and inadequate. First, they are underpinned by different normative concerns (economic efficiency, sustainability, conservation, and social justice). Further, even though they are not treated as such, they are inter-dependent. At one end, institutional and ecological explanations are often ahistorical and focus too narrowly on proximate causes and effects. They thus ignore the deep-seated social and political factors behind fishery conflicts. At the other end, sociological studies and economic history often emphasize structures of class difference in capitalism or colonialism, or power relations, to the extent that the links between ecological or cultural change and conflict may be neglected. Both streams of explanation need to be contextualized through an environmental history of fishery conflicts.

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[3] See thesis introduction (chapter 1), where I describe these material and symbolic dimensions. full references to footnoted citations can be found at the end of thesis.

[4] I have reviewed the literature on these dominant explanations and ideas in my chapter 1 (introduction), along with the major variables identified by some existing "typologies" of fishery conflicts, e.g. Charles (1992: pp. 379-393), Bennett et al. 2001 (pp. 10-17), Salayo et al. (2006: 57 p.).

[5] See Daniel Pauly (1994: pp. 7-14) for what Malthusian overfishing implies in the context of small-scale fisheries. Finkbeiner et al. (2017: pp. 1180-1191) criticize Malthusian explanations of scarcity and resource constraints in fisheries.

[6] Overcapacity is a dominant theme in modern typologies of fishery conflicts, which could be driven by technological change in fisheries, and by fish yields constrained by perceived or experienced scarcity, e.g. see Salayo et al. (2006).

[7] See Anthias (2001: pp. 367-390) on how social stratification represents both material (class divides) and symbolic (ethnic divides) in social conflicts. Also see Sneddon (2007: pp. 167-193) for an example in Cambodian fisheries.

Aquatic ecosystems have fluid and dynamic boundaries, with fishes using a diversity of reproductive and migratory strategies, and mobile fishing people using a range of harvesting practices changing in space and with seasons[8]. Capture fisheries of seas and rivers thus involve methods for regulation and control that are fundamentally different from the manner in which land-based resources have been managed[9]. The characteristics of riverine capture fisheries are even more complex. Large river-floodplains are highly dynamic and seasonally pulsed ecosystems, often with unpredictably meandering and braiding channel courses[10]. This challenges terrestrial notions of fixed property rights, because land-water boundaries are never constant in floodplain ecologies. River fishers are located near middle on the spectrum of strategies between largely sedentary (agricultural) and largely mobile (marine fisheries). Riverine fishers display seasonal differences in the extent of movements that often make them straddle the boundaries of multiple private or state-owned, and typically land-based institutions[11]. Capitalistic relations of production in riparian landed property also engulf small-scale riverine fisheries[12]. Fishery conflicts over rights, territories, and access to space, thus result from claims to a fishery "commons", with insecure rights and tenures stuck in overlapping boundaries of private riparian enclosures[13]. With the fragmentation and diversion of river flows for irrigation and other human water needs, fishery resources have also been declining worldwide[14]. Within the river fishery commons, conflicts also emerge from competing harvesting techniques and cultural practices of different fishing groups. At the same time, fishers also work out local rules and informal arrangements that can conflict with those of state-governed and private economic property and administrative political jurisdictions[15].

The complexities of riverine fisheries show us why institutional, ecological, and socio-cultural factors invoked for explanation need deeper historical insights that

[8] Acheson, J. Anthropology of fishing (1981: pp. 275-276), and Scott, J. (1998: p. 324).
[9] Acheson (1981: pp. 275-278). Also see Scott, A. (1983: 57 p.).
[10] See Junk et al. (1989: pp. 110-127) and Dudgeon et al. (2006: pp. 163-182) for the defining ecological features of the flood-pulse and productivity of riverine fisheries. Also, R. D'Souza (2020: pp. 31-49) on how the ecological processes of flooding interacted with historical socio-economic transitions, and how these were not merely natural calamities.
[11] Song et al. (2017: p.17) define this as "intersectorality" in small-scale fisheries.
[12] See Campling et al. (2012: pp. 177-203), Sneddon (2007: pp. 167-193), Davis and Ruddle (2012: pp. 244-254).
[13] See Adnan (2013: pp. 87-128), van Schendel, W. (1991: pp. 74-77), on riparian land grabbing and primitive accumulation, and Hodgson (2016: 94 p.) on the problem of insecure water tenure in small-scale fisheries.
[14] Dudgeon (2000: pp. 793-806), Vörösmarty et al. (2010: pp. 555-561), de Graaf et al. (2015: pp. 64-70).
[15] See Sneddon (2007, op. cit.) and Mamun and Brook (2015: pp. 772-807) for examples of riverine-estuarine fisheries in tropical Asia. Also, Hahn (1982: 37-64) for an example from the United States.

can tell us more about the interplay between these factors and their changing relative contributions in transforming conflicts in space and time. At the outset, I emphasize why this is critical in case of riverine capture fisheries of the Gangetic floodplains, where fishers have experienced the costs of protracted resource conflicts over rights and access to fishing areas[16]. These conflicts, in various forms, have severely impoverished millions of fishers, undermined fisheries' productivity, and devalued fishery livelihoods. Violent and oppressive control of fishers by contractors with links to organized crime has become the very stuff of river fishery conflicts[17]. These trends are telling, because the nature of institutional control is variable across the three major Indian states of the Gangetic basin: Uttar Pradesh (with private auction-leases), Bihar (open-access), and West Bengal (under a complex patchwork of cooperative, private, and government-managed fisheries)[18]. The ecological condition of rivers also differs greatly, with the effects of river flow regulation by dams, barrages, and embankments being the greatest in Uttar Pradesh, followed by West Bengal and Bihar.
Despite these differences, the experiences of injustice and inequities are similar, and conflicts over rights for fishing communities intensive, across the Gangetic plains[19]. Overall, the Gangetic basin is among the most human-dominated and climate-sensitive regions of the world, with intensive and increasing water demands pressurizing riverine fisheries[20].

In this chapter, I undertake a historical overview of how and why fishery conflicts emerged, have persisted, and been transformed in the Gangetic plains. What have been the narratives[21] of conflict that shaped different conflicts, and how did they change ecological and social control of riverine capture fisheries, under different institutional regimes? What were the material and symbolic dimensions of these shifts? In other words, I examine the past precedents for the conflicts of the present. My analysis attempts to critically engage with major change-points as well as some underlying continuities[22], starting from the 18th century CE. I first provide an

[16] For an introduction to these conflicts, see Kelkar, N. (2014a: pp. 225-231).
[17] See Ch.1, thesis introduction, Kelkar, N. (2012: 40 p.; 2014b), and Narayanan, S. (2016: pp. 3-60).
[18] See Kelkar, N. (2014b), Katiha et al. (2013: http://ssrn.com/abstract=2219347), and Saha, K.C., Fisheries of West Bengal (1970).
[19] See thesis introduction, and references therein.
[20] See Vass et al. (2010a: pp. 374-384; 2010b: 385-394, 2009: pp. 138-151), and Das, B.K. et al. (2019: pp. 79-95).
[21] Cronon (1992: pp. 1347-1376), and Gaddis (2002: pp. 14-15) emphasize the importance of narrative in writing history.
[22] D'Souza (2019: pp. 242-249) has emphasized that a critical study of the disagreement between "colonial watershed" and "continuities with change" concepts can help a richer understanding of notions of scarcity and environmental politics, and their links to resource conflicts.

overview of existing work on the history of riverine fisheries in the Gangetic plains. Based on this overview, I identify some gaps and directions for new analyses, which I attempt in this chapter.

Overview of earlier work on the history of inland fisheries in the Gangetic plains

My overview, in spatial extent, draws from studies on the history of fisheries of "Bengal" that would include present-day Bangladesh, West Bengal, Bihar, Jharkhand, and Orissa, the "United Provinces", i.e. present-day Uttar Pradesh, and Burma. The focus of most studies has been on the colonial administration[23] of fisheries, due to the availability of written records and archival material. Colonial studies of riverine fisheries have been placed within the broad domain of agrarian history. However, fisheries have received limited attention, and mostly occupied just the marginal notes of modern scholarship in agrarian history[24]. Among the major scholarly works on the subject, the general approach of historian scholars has been to cast the net mainly on economic and institutional aspects, with scattered notes on the cultural and ecological elements of riverine fisheries[25].

Following the Permanent Settlement of Bengal in 1793, consolidated revenue extraction policies through private landed property and rigid systems of allocating property rights on the fluid riparian, have been a recurring theme in economic history of the Gangetic plains[26]. Many authors have described how such rigid control of

[23] And to a lesser extent, on the Mughal administration. Early histories of river-based fisheries are limited to a few events of particular interest, or just note the existence of taxation and revenue regimes (e.g. Sharma, R.S. (1980: p.182-185), Thapar, R. (2003: p. 203) Agrawal, S.C. (2007: pp. 21-56), and Furui, R. (2019: pp. 155-174). Indian environmental history writing has been dominated by the colonial period (McNeill 2010: pp. 345-374).

[24] Pokrant et al. (2004: pp. 112-114) mention this as a gap. There are notable exceptions to this, especially the work of Peter Reeves, Bob Pokrant, and John McGuire (between 1995 and 2004). Other studies, such as those of Nariaki Nakazato (1994) and Iftekhar Iqbal (2005-2010) devote significant attention to the subject of fisheries. More recently, studies by Shourya Sen (2015, 2019), and Vipul Singh and S.K. Gupta (2018) have engaged with the colonial history of riverine fisheries. Blair (1996: pp. 475-476) notes that fisheries have received little attention even in contemporary studies on the governance of common property resources. N. Bhattacharya (2018: Intro. p. 1-15) argues that the colonial image of rural India as "agrarian India" caused the marginalization of marginal communities from history as well.

[25] See Pokrant et al. (1997: pp. 27-48, 2004: pp. 93-117), Reeves (1995: pp. 260-292, 2003: www.ari.nus.edu.sg/pub/wps.htm), Nakazato (1994: pp. 225-230), and V. Singh (2019: pp. 179-181).

[26] Many studies show that fishery revenues, irrespective of the nature of land accretion or avulsion in river-floodplains, were included with riparian rights in fluvial estates that were almost always extended to *zamindars*, e.g. see C.V. Hill's (1991: pp. 263-279; 1997: pp. 85-105) studies on shifting riparian of the Kosi floodplains, and N. Sinha (2014a: pp. 209-237), describes how the fluvial landscape of the Ganga's *diara* regions of Bihar was categorized and controlled by state policies to the effect that highly uncertain flooding was used by the colonial bureaucracy as opportunity to maximize revenues from speculative farming, . D'Souza, R., in his book Drowned and Dammed (2006a: 290 p.) argues that flood control policies to protect land led to the severing of floodplain land and water, affecting both agriculture and fisheries, which were integral features making the agrarian

riparian rights shackled riverine fisheries to land-based property, and led to the erosion of customary rights to access fishing areas, and also affected fisher-landowner-trader relations[27]. Shourya Sen (2015: pp.159-179) shows how these economic problems gave way to legal contestations and contradictory policies and decisions on customary fishing rights and access in Bengal. Singh and Gupta's 2018 study represents well the tradition of identifying a 'colonial break' in policy, and suggests that "modern" management of fisheries brought in systematic and intensive taxation of fisheries and boat-ferrying with the colonial administration of British India[28]. A related argument emphasizes that colonial control and modification of river flows (with embankments, dams, canals) to protect agricultural land from river floods and erosion, set in motion the marginalization of fishing communities by the mid-19th century[29].

There are two significant gaps evident in the focus on colonial economic and revenue history. The first gap is that most analyses[30] focus on customary access and fishing rights in flood-recession regions, but do not locate these economic or legal deliberations, or agrarian relations of production in the context of the hydrological and ecological diversity of floodplain environments. Through the colonial period, river-floodplain fisheries seem to have been under a range of institutional regimes, with private *zamindari*-owned fisheries on ponds, tanks, and floodplain inlets, "public fisheries" on navigable river channels, and state-owned fisheries on all kinds of water bodies[31]. But, with the focus on private fisheries[32], we do not seem to know enough

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environment of the Mahanadi delta. These studies foreground the critical context of floodplain hydrology and ecology, for site-specific outcomes of Permanent Settlement and revenue policies.

[27] See Reeves, P. (1995, op. cit.), Pokrant et al. (1997, 2004, op. cit.), Singh and Gupta (2018: pp. 122-133).

[28] These authors suggest that before colonial administration, taxation of fisheries and fishing rights was either absent, or relatively minor. However, sources from pre-colonial and even early periods suggest that this was not always the case.

[29] D'Souza, R. (2006b: pp. 621-628; 2009) shows that the colonial capitalistic regime was centred on hydrological transformation. Also see Singh, P. (2008: pp. 239-260), Bhargava, M. (2007: pp. 183-208), Sinha, N. (2014a, op. cit.), and Lahiri-Dutt (2014: pp. 17-22) on how embankments led to further intensifying forms of land control.

[30] Like those of S. Sen (2015: pp. 25-49, 105-147), or other aforementioned studies of the impacts of Permanent Settlement on fisheries, focus on fishing rights to floodplain wetlands formed by receding floodwaters within private estates, but not on the river itself. In this regard, also see Ali et al. (2010: 39 p.), and Sen and Sen (1989: p. 38) for seasonal dynamics of dependence of poor fishers on floodplain wetlands. A notable exception is Nakazato (1994, op. cit.), who describes fishery regimes both in floodplains and active river channels of eastern Bengal. He also indicates cultural differences, and physical (distance-based) separation between these fishing groups that used different methods.

[31] Deliberations on the public right to fish have been described by Sen, S. (2015, op. cit.). Reeves (1995: pp. 260-292) described the prevalence of these diverse forms of fisheries management and control in Bengal's *Jalkars* and other river channels. He also suggested that the attention of colonial administrators towards river fisheries was probably low, because they did not often know what their revenues were. Hunter's A Statistical Account of Bengal (20 vols.) give an idea of how many different leasing and ownership regimes prevailed across the districts of Bengal in the 1870s.

about how these regimes changed in space and over time, in relation to the ecological settings. The influences of human transformation of unpredictable river floodplain hydrology, and hydro-climatic variability, and their impacts on fisheries ecology have seen limited historical analysis[33]. Especially, we need to understand how colonial ideas of "abundance" or "overfishing" by fisher subjects were translated to fisheries legislation and policies, and how they influenced ideas of fisheries as property.

Further, even though historical analyses have explored in depth the policies and economics of private and state control of river-floodplain fisheries, they have ignored cultural and social identities of fishing people. Pokrant *et al.* (2004: pp.115-116) acknowledge this as an important gap: "*Little attention was given to fishers' lives and work and their embeddedness within local religious and cultural traditions, gender relations, how fishers identify themselves, and how they are seen by outsiders, relations between fishers and the agricultural, trading, and clerical communities with whom they have to interact, and fishers' relations with the natural world. …Whereas we know something about the broader social, political, and economic structures within which fishers lived and worked. While useful in their ways, official archives do not allow us to penetrate the public and private faces of fishing peoples*"[34].

As for fisher identities, it is really important to discuss caste and occupational categories as important to the experience of conflicts. Recent noteworthy studies have addressed relationships between caste identity, cultural practices, and economic history[35]. Other studies addressing caste and cultural practices of fishing groups have been of a descriptive nature, where critical insights on fishery conflicts are not offered[36]. Caste identity limited the options and choices that fishers had in terms of

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[32] The focus on private fisheries was also due probably because of some incredible cases of freehold private fishing rights on the entire *Gangapath Jalkar* (Ganga River) in eastern Bihar, from Bhagalpur to Rajmahal, see page 15.

[33] A notable exception is Iqbal (2010: pp. 134-190) who shows how the ecology of floodplain fisheries in the Bengal delta was affected significantly by land use change, pollution, and the proliferation of invasive species in relation to extreme floods, waterlogging, and related transformations.

[34] Pokrant et al. (2004: pp. 111:117) also suggested that a good way to understand the social ecology of fisheries was to engage with semi-fictional, novelists' accounts of fishers' lives, of which some classical works were written in Bengali during colonial and postcolonial periods. These accounts involved a combination of anthropological and ecological writing, and highlighted the poverty and marginal living conditions of fishing communities. Also see Blowfield and Haque (1995), Pokrant et al. (1998: pp. 123-138, 2004, op. cit.), and Biswas (2011: pp. 15-34).

[35] Important works focusing on fishing castes and their categorization by the state include studies by Smita Tewari Jassal (2001) and the studies of Assa Doron (2013 to 2016) in Uttar Pradesh. Importantly, these studies assess the consequences of caste to the identity and organization of fishers in the present day. Also see Reeves (2002: pp. 121-135).

[36] Surjendu Dey (2012: 252 p.) on the fishers of coastal Bengal provides a detailed chronology of taxation regimes and associated fishing practices, but follows a descriptive style. Similar studies from Bengal and Bangladesh, esp. Alam (2002: pp. 246-260), Rashid (2005: 302 p.), and Barman (2008: pp. 13-28), also have a descriptive style, but include substantive details on issues of caste and fisher-trader relations. A.K. Deb's study (2015: pp. 536-565) focuses on fishing practices and ecological knowledge among fishing castes as key variables of analysis.

livelihoods, which operated under class constraints. How different fishing communities and castes were seen by the state also affected the mobility and access of fishers, but this aspect does not usually get discussed with conflicts over rights. Similarly, at the micro-level, sub-caste hierarchies *within* the constructed category of "fishing community" have been often neglected by earlier analyses, in terms of fisheries' relations with other livelihood forms in rural economies[37]. All these have had a strong bearing on fishery conflicts, but have not been discussed alongside economic, ecological, and hydrological changes.

Based on these gaps, I argue that a new analysis is needed to integrate historic shifts in property rights, institutional regimes and fisheries management policies with aspects of 1) ecological and hydrological changes, and 2) the issues of caste and fisher identity. I explore how these interactions and shifts influenced the material and symbolic motivations underlying changing narratives of fishery conflicts. Finally, I discuss the implications of history for our present understanding of fishery conflicts in the Gangetic plains and their relevance to institutional management and adaptation by fishing people.

Methods

In this chapter, I have conducted a review of the historical literature on colonial and post-colonial policy and institutional arrangements in riverine fisheries of the middle and lower Gangetic plains (from Uttar Pradesh to Bengal and Bangladesh). I referred to journal articles, papers, books, news reports, gazetteers, archival records, legal and policy documents, statutes, and government acts[38]. The analysis covers the colonial and post-colonial period from the 18th century CE onwards, but also includes notes on what is known about river fisheries from earlier periods, where needed for context. For ease of analysis, I divide this into three broad time frames, as: 1) East India Company rule from 1757-1858, 2) British government administration from 1858 to 1947, and 3) independent India from 1947 to 2019. As discussed above, the chapter follows three major tracks and their interactions: 1) fishery policies and institutional regimes concerned with revenue extraction from river fisheries, 2) changes in

[37] There is scope to further examine where fishers were located within the agrarian economic and market webs along the Gangetic plains, and how they interacted with other livelihood seekers as well.
[38] Sources and full references provided at end of thesis.

hydrology[39] and colonial perceptions of fisheries ecology[40], and 3) anthropological and ethnographic research on fishing castes, occupational categories within fisheries[41], and their inter-relationships. Qualitative and textual analyses were used[42]. I also provide a chronology of key events and major shifts in institutional and policy regimes (Table 2.1) and major hydrological changes (Table 2.2). I also summarize, for easy reference, the names of major fishing castes and their occupational categories as identified in colonial and later accounts (Table 2.3). Additionally, I compiled information on historical factors that fishers perceived to have influenced present conflicts, from my own fieldwork (from 2007 to 2019), which involved fisher interviews (n=220) across Bihar, Bengal, and Uttar Pradesh.

Before we start with a historical analysis, a brief overview of the variable influences of river-floodplain hydrology, fisheries ecology, and fishing practices across different fishing groups, on institutional management and conflicts is in order.

Changing river courses and unpredictability: geology and hydrology

River-floodplain environments and hydro-climatic events and gradual changes need to be understood as the backdrop to, as well as manifestations of, fishery conflicts[43]. The Gangetic floodplains form part of the Himalayan foreland, which is a

[39] Many studies have used a combination of geographical information, old maps, and satellite-based remote sensing to document historical changes in river channel courses in the Gangetic plains. For useful examples, see Philip et al. (1989: pp. 50-57), Sarkar et al. 2000: pp. 121-148, Swamee and Parkash 1992: pp. 219-231, Chakraborty et al. 2010: pp. 143-160. Older maps also provide reference information (Rennell, J. (1776, 1781), Hamilton, W. (1815: p. 557), Beglar (1878).

[40] It is possible to assess changes in the ecology and hydro-biology of riverine fisheries because of the availability of detailed accounts over time, e.g. Hamilton-Buchanan 1810-1822, Francis Day (1869-1877), W.W. Hunter (1875-1877), K.G. Gupta 1908 (37 p.), K.C. De (1910: pp. 34-35), T. Southwell (1914-1917), James Hornell (1920: 74 p., 1924a: pp. 173-198, 1924b: 201-208), A.C. Lahiri (1940), Roy Chaudhury (1962), Saha (1970), Payne et al. 2004 (op. cit.), and other reports on river fisheries, including by the Central Indian Fisheries Research Institute (CIFRI; 1951 to present).

[41] British India's anthropological pursuits included the production of lengthy and detailed accounts of the 'tribes and castes' of different regions of India. In addition to the studies cited above, I have referred to the following volumes extensively: James Wise (1883), Herbert Risley (1892), Rose, H.A. (1892), Russell and Hira Lal (1916), Nakazato (1994), and Jassal (2001). They provide many important clues on diversity and differences in fishing practices across groups, especially between full-time fishers, part-time fishers, traders, and farming communities who also fished part-time. Many studies have shown how British studies of caste in the Indian subcontinent were directly linked to a multitude of colonial motivations, from revenue interests (Chatterjee 1999: pp. 14-34) to state surveillance of tribes or castes with what were considered as "criminal tendencies" (e.g. see Crooke, 1896a, b), to orientalism and academic anthropology (Pels 1997: pp. 163-183, 2008: pp. 280-299), and even a philosophical engagement with caste as an economic and socio-political institutional structure of Indian society (see Riser-Kositsky 2009: pp. 17-52).

[42] I followed the broad guidelines of an ecological history analysis, as per Ventresca and Mohr (2002: pp. 805-828).

[43] Sneddon (2007: pp. 167-193) underscores the importance of understanding river-floodplain ecology both as cause and outcome of class conflicts in riverine capture fisheries.

geologically young and evolving landscape and waterscape[44]. The high tectonic activity of the region has a direct bearing on unpredictably meandering and braiding channel course changes and high rates of sediment dynamics[45]. The weathering and erosion rates of Himalayan river systems generate and transport vast amounts of sediment to the plains, and along with massive monsoonal floods, rendering river channel courses highly unstable[46]. Abrupt river course shifts form the canvas for confusions and conflicts over floodplain land and water rights, social adaptation, and even policy processes[47]. The history of river-floodplain fisheries is thus deeply embedded in its complex and unpredictable geography[48].

Further, the Gangetic plains have witnessed over 150 years of human modification to river flow by embankments, dams, barrages, and canals. Although embankments were constructed since the 17th century and even before[49], the construction of the Ganga Canal in 1854[50] marked the beginning of large-scale hydrological change in the region, with large dams, barrages, and networks of irrigation canals. These changes further increased river erosion of floodplain lands, reduced connectivity between the river and its banks, affected ecological productivity and altered sediment fluxes[51]. In turn, these changes aggravated flood frequencies and intensity, making a flood-adapted human population a flood-vulnerable one[52]. The protection of revenue-yielding land from the "dangerous" force of water became a

[44] The collision of the Indian and Eurasian plates, around 30 million years before present, led to the uplift of sediment that is still rising, and formed the Himalayas highest mountain chain the world (see Singh et al. (2007: pp. 144-175), Sinha and Friend (1994: pp. 825-845), Sinha et al. (2010: pp. 81-86)).

[45] Wells and Dorr (1987: pp. 204-207), in their seminal paper on the river Kosi's channel migrations and avulsions since 1720 CE, attributed the changes largely to neo-tectonic controls on the Gangetic basin, and found no clear connection between abrupt course-changes and floods or earthquakes. Also see Hooke (2011: pp.238-253) for technical details on meandering processes.

[46] See Singh et al. (2007, op. cit.), Sinha, R. (2008: pp. 42-47), Bhargava (2007, op. cit.), and references on instability of river courses in chapter 3.

[47] See Berger (2006: pp. 3-9), Rudra (2010, op. cit.), and Moench (2010: pp. 975-986), for discussions on how tectonism, which involves geological processes beyond human control, but can have implications for everyday life, management policies, and adaptation in dynamic environments.

[48] See Williams (1994: pp. 3-21), Gaddis (2002: pp. 18-52).

[49] See Bhargava (2007, op. cit.) and Singh, P. (2008, op. cit.). Embankments were not only built to protect land, they also intensified the control of *zamindars* on riparian lands. Details on pre-17th century embankments can be found in J. Sarkar (1948: pp. 108-144).

[50] See Cotton, A. and Cautly, P. (1864) The Ganges Canal. A discussion regarding the projection and present state of the Ganges Canal, and the measures required to make it reliably useful and profitable. Private Memorandum, 138 p.

[51] See Goodbred and Kuehl (1998: pp. 239-258), James and Marcus (2006: pp. 152-171), Hofer and Messerli (2006: pp. 254-283), Mohindra et al. (1992: pp. 643-662), and Rudra (2010: pp. 161-169) for the impacts of floodplain modification on sedimentary processes.

[52] This shift has been described by many authors: see C.V. Hill (1997, pp. 85-105), D.K. Mishra (2008: pp. 47-52), R. D'Souza (2004: pp. 237-272, 2006b, op.cit., 2009), R. Sinha (2008: pp. 42-47), Lahiri-Dutt and Samanta (2013: pp. 51-77).

constant preoccupation of the colonial regime[53]. The impacts of such hydrological transformations on human life are best illustrated by ethnographic research on people living on floodplain peninsulas and large islands, called *diaras*, *chars*, or *chaurs*, in eastern India and Bangladesh[54]. These "hybrid"[55] and dynamic land-waterscapes are inhabited by several thousands of people practicing temporary farming, fishing, boat-ferrying, minor livestock-rearing, who are dependent on constant movement, transhumant lifestyles, boat navigation, and resettlement[56]. Needless to reiterate, riverscape dynamism is directly linked to the uncertainty of property boundaries.

In addition, long-term non-linear, and non-stationary climate variability also affects river flows. Such variability ranges from continent-scale changes in sea surface temperature, ocean currents, and solar intensity cycles, to variable land surface heat emissions at the regional scale, to irrigation intensification and land cover change at local scales[57]. Hydro-climatic changes directly affect the chief inputs to river flow and flood-pulses: monsoonal rainfall and glacial melt, and can effect extreme climatic events from droughts to floods[58]. Famines in the Gangetic plains, since the 18th century, have had direct links with climatic events such as the El Niño Southern Oscillation (ENSO), which should also be recognized as an important non-human actor in the history of the Gangetic plains[59].

Floods were seen as disastrous and floodplains as sites of "un-governability" and lawlessness by the colonial administration. The fluidity of these environments, the rivers' disregard for rigid land-property boundaries, and their challenge to the maximization of agricultural revenue, at times bringing fertile and productive silt, or

[53] D'Souza (2004, 2006, 2009) describes the colonial drive for revenue maximization as having ruptured the hybrid floodplain environment by severing water from land and creating an artificial ecological division.
[54] See Sarker et al. (2003: pp. 61-80), Mukherjee (2011: 91 p.), Lahiri-Dutt and Samanta (2013). Hofer and Messerli (2006), and S. Iqbal (2010: pp. 201-211) describe the causes and impacts of erosion and floods for life and property on *chars*.
[55] Following Lahiri-Dutt and Samanta (2013: pp. 1-30).
[56] Ibid. Also see Iqbal (2010: pp. 51-52, 63) and Kumar et al. (2014: p. 181).
[57] For a summary of such changes, see Whitehead et al. (2015: pp. 1057-1069), footnote 55, and refs. In chapter 4.
[58] Anand et al. (2018: pp. 32-53) document effects of increasing glacial melt; Pervez and Henebry (2015), and Agrawal et al. (2019) show increasing variability but an overall weakening of summer monsoon rainfall in the Gangetic plains. These studies show, that climate in a small part of the Gangetic plains is also a result of a shifting "climate normal", with global climate change (by warming, intensification of extreme events, droughts, etc.).
[59] See Fagan, (1999: pp. 3-25), who shows us how the great famines of Bengal, which were extreme ENSO events, changed the fate of millions of people in the Indian subcontinent. Weakening of monsoon rainfall and increasing dry-season temperatures across tropical Asia are driven by non-linear and non-stationary interactions between the ENSO and the Indian Ocean Dipole (IOD). The ENSO is an irregular periodic variation in sea surface temperatures over the tropical Pacific Ocean and interacts with the IOD, which is a spatial dipole encompassing a thermal gradient in the eastern and western Indian Ocean. Although the ENSO is a recurring climatic phenomenon, global climate change has increased its unpredictability and recurrence patterns. See Krishnaswamy et al. (2015: pp. 175-184), and refs. in chapter 4 for details.

at times swathes of sand, was perplexing to colonial administrators[60]. Such a view obscured the critical importance of the flood-pulse for reproductive cycles of fish, for fish production, and for fishing people[61]. The other issue was of mobility – the mobility of riverine fishing communities depended to a fair extent on the nature of river channel changes. But in the colonial vision of floodplain settlement, mobility immediately became illegal trespass[62]. If we understand these changes for different castes of affected fishers, more clarity can emerge on the variable nature of settlement and movement across different fishing groups.

Fishers of the Gangetic plains: practices, castes, and identities

Fishing castes of the Gangetic plains have been differentiated by anthropologists and sociologists on the basis of racial-ethnic correlations, relative dependence on fishing as primary occupation[63], and even the fishing practices (types of nets and gears) used by different fishers. There are a vast number of sub-divisions within a complex taxonomy[64]. James Wise (1883) noted that: *"…the exact bearing to one another of the different fisher and boating tribes along the Ganges has always been a puzzle. Little information can be derived from the men themselves, for an enquiry of this nature has no interest for them…*"

There is remarkable diversity of fishing practices across the geography of the Gangetic plains[65]. From the upper and middle Ganga towards the lower Ganga, these practices become increasingly differentiated, and the number of groups and caste names increases[66]. But it is difficult to exactly match specific practices with specific identities. From fishers' self-identification[67], and multiple anthropological accounts[68],

[60] See C.V. Hill, River of Sorrow (1997: pp. 9-25, 85-105): Cederlöf (2009: pp. 513-540), Blomley (2008).
[61] See Pokrant et al. (1997: pp. 27-48), and D'Souza, R., Event, Process and Pulse (2020: pp. 31-49).
[62] Nitin Sinha (2008: 1-33 p.) shows that the control of mobile communities in the Gangetic plains was not independent of their caste and class identities.
[63] It is important to note here that, for many fishers, fishing is one out of a portfolio of activities, and for others it is the primary source of livelihood. Also see Raychaudhuri (1980: 274 p.), Blowfield and Haque (1995), Dey (2012, 252 p.), de Graaf et al. 2015: pp. 64-70, and Funge-Smith and Bennett (2019: pp. 1176-1195), who all emphasize the diversity of practices, fluidity of labour relations and mobility, within fisheries.
[64] See Table 3. Crooke (1896b) identified 625 sub-divisions among Hindu fishing castes and 22 in Muslim fishers: discussed in Jassal (2001: pp. 324-326). Narratives of origin-tales and ranks of sub-castes and castes are so complicated, that, as Jassal has shown, an "accurate" census always remained elusive.
[65] See Ray (1998: pp.198-226) for detailed accounts of fishing gears and nets used in the Gangetic plains.
[66] Hamilton-Buchanan wrote in his journals of the districts of eastern India in 1810 (pp. 230-257) that anyone in Bengal would be practicing some form of floodplain fishing or another. Note that fishing is recognized as one of the oldest human occupations, and it is problematic to attribute it as an activity exclusive to particular groups. Rather, fishing was one of a set of strategies involving various sedentary and mobile practices, including agriculture, trading, animal husbandry, occasional raiding, etc. (see Morrison, K.D., 2007: pp. 321-339), and Sen, S. (2019: pp. 90-100).
[67] Reported during my interactions with different fishing groups in UP, Bihar, and West Bengal (2007-2019).

it can be said broadly that floodplain cultivators or part-time fishers seasonally captured fish by putting up passive gears such as screens, traps, or barricades on water inlets in the flood-recession period (September to November). On the other hand, professional or full-time fishers used active and selective fishing nets, especially gillnets and seine nets, and many also built and used their own boats, to fish in the main river channel. That leaves the criteria of racial/ethnic[69] and occupational correlations with caste identity. It is generally believed that the earliest people to migrate into the Indian subcontinent depended on fish as a primary source of food[70]. The racial correlation of these tribes with fishing and allied activities (river-faring, hunting, fishing with nets, traps, and baited fishhooks) has been described from 1500 BCE and through later centuries[71], post contact between into-India immigrants[72] and earlier foraging/hunting tribes along the Gangetic floodplains[73]. Phases of contact and admixture with later immigrant populations might have divided the tribes into incoming groups[74], who adopted organized religious practices, while other tribes would have retained original totemistic septs (such as the *Majhis* or *Santhals*)[75]. Tribes remained outside caste hierarchy, but incoming groups remained lower in the caste system.[76] Hunting and fishing practices, and dietary taboos by upper castes on fish eating also maintained caste divisions[77].

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[68] See Table 3 for a comprehensive listing of page numbers and sources.
[69] Origin-tales may or may not accompany self-identification of fishers with a particular caste. However, mythological and scriptural references, especially related to the Ramayana and Mahabharata, are common (see Doron 2013: pp. 57-141).
[70] Early (Dravidian and Austro-Asiatic) tribal groups immigrating from the west and east (see Kumar and Reddy, 2003: pp. 507-522). Fish hooks and scales/bones have been discovered from ancient human settlements across the plains of northern and northwestern India (Petrie et al. 2017).
[71] For cultural references in Vedic texts, see Reeves, P. (2003). Later texts such as the *Manasollasa* (~1100 CE) also described several similar fishing practices (Sadhale and Nene 2003: pp. 177-199).
[72] Recent research indicates multiple waves of immigration from western Asia (Iran) and central Asia, as well as shared a genetic "gradient" with Southeast Asia (Narasimhan et al. 2019: pp. 6457). These later immigrants are often described in popular literature as 'Aryans' and the earlier tribes as 'non-Aryans'.
[73] See Bagchi and Jha (2011: pp. 85-118), and Reeves, P. (2003, op. cit.).
[74] Following Sharma, K.L. (2002: 491 p.). See Thanseem et al. (2006) for maternally shared caste-tribe genetic lineages.
[75] See Risley (1892) for details of totemistic tribal septs in regions of present-day Jharkhand, West Bengal, and Bihar.
[76] Both Hindus and Buddhists apparently maintained a 'low' status for fishers as seen from the late Vedic period and Smriti literature (1000-400 BCE), when there was stronger consolidation of religious practices. Manu-Smriti, the basis of caste discrimination in Hinduism, attached stigma to the act of fishing (Agrawal 2007: pp. 21-56; Reeves, 2003).
[77] Hindus forbade 'scale-less' fishes from consumption, presumably due to their predatory or scavenging habits (predatory catfishes; see Bagchi and Jha (2011: pp. 85-118), and Majumdar, R.C. (1943, op. cit.). With the later diffusion of Hinduism into Bengal, Brahmins and other so-called 'upper castes' were allowed to consume only 'white fish' with 'scales' (e.g. herbivorous carps; Bagchi and Jha (2011, op. cit.). Interestingly, Russell and Hira Lal (1916: p. 270) and Risley (1892: p. 19) note that Muslims and some Hindu lower caste groups also forbade consumption of scale-less fish.

With regards to occupational mobility, the major criteria that distinguished fishers seem to be 1) fishers who cultivated[78], 2) fishers who used boats, 3) fishers who were involved in trade, and 4) fishers who only fished. In Bengal, fishers were also distinguished as *Jiratti* and *Bhassan* fishing *ryots*, with the former being "settled" in and along private *zamindari*-owned fisheries, and the latter being temporary or transient visiting fishers to different floodplain water bodies[79]. Both *Jirati* and *Bhassan* fishers paid rents to landowners, but *Jirati* rents were lower and varied seasonally. *Bhassan* fishers would pay rents according to net types used and the amount of expected fish captures. Such criteria had obvious caste and class distinctions, with cultivation, boat ferrying, and trade regarded higher than only fishing, probably in that order.

About eight to twelve endogamous and hierarchically ordered sub-castes reportedly form the *Nishad* and *Mallah* caste-groups, associated with boat ferrying and fishing in rivers of the Gangetic plains[80]. *Nishad* and *Mallah* fishers are regarded as having low status in the caste hierarchy but not considered untouchable[81]. However, they were derogated as "*Chandalas*", a generic term used for people whose animal-killing practices were considered sinful or impure[82]. Occupational title-names further complicated the situation of identifying fishers from their names[83]. For instance, in Bengal, many fishers went by the names *Chaudhuri* or *Haldar*, or *Mallah* or *Manjhi*, which had mostly occupational connotations. For those involved in fish trade there are several names, viz. *Bepari*, *Bajari*, *Nikari*, *Jiani*, *Paikar*, *Aratdar*, etc. in the different regions of Bengal[84]. Within fishers, the relatively 'higher' *Kaibarttas* and *Mahaldars* (Gonrhis), with both Hindu and Muslim fishers, who managed to earn surplus profits from fishing, would usually move into fish trading, and agricultural work, which were both seen as upward movement overcoming the status of being

[78] According to R.C. Majumdar (1943: pp. 591-592), within *Kaivarta* (or *Kewat*) fishers' caste, two sub-castes, the *Dasas* (cultivators) and *Dhaivaras* (fishermen) are described in the Amara-Kosha, of which *Dhaivaras* may not have land rights.
[79] See Lahiri, A.C. (1940), and J. Taylor (1840: pp.152-153) for more details.
[80] See Table 3 and Jassal (2001) for details. Different accounts have enumerated between 5 and 12 sub-castes, with minor differences in attributed ranks and practices from the United Provinces to the Bengal presidency. Wise (1883) attributed the use of the name "Mallah" to boatmen, according to the Arabic word of the same meaning, of Bihar and Bengal's Muslim-influenced regions, and recognized the name "Nishad" as denoting Hindu fishers or hunters. Many other sub-caste names are also provided, that may not be among the 5-12 sub-castes, or may have been synonymized later.
[81] See Jassal (2001): This distinction was based on whether higher castes accepted water or food from them.
[82] According to Wise (1883).
[83] See Pokrant et al. (1997: pp. 27-48).
[84] Ibid. and see notes to Table 3.

fishermen[85]. The complexity of caste hierarchies and structures had a strong bearing on how different fishing groups were governed by colonial and post-colonial administrations, and, as I shall describe later, these distinctions have remained relevant even to present-day fishery conflicts.

Fisheries in the pre-colonial period: a brief note

To provide a context to the colonial administration and control of fisheries, I will briefly summarize here what is reasonably well established about fisheries taxation, revenues, institutional management, rights and access, and associated conflicts. In India's ancient history, imposing of fines on fishers as religious sanctions has been stated[86]. Later, state-controlled regimes of taxation on fish produce, in the form of fixed shares of fish captured, are thought to have existed from around 600-300 BCE, along with the formation of large empires and kingdoms in the Gangetic plains[87]. Fish trade by river routes, mostly of dried fish, also expanded significantly[88], and formalized taxation. From the 7th to 12th centuries CE, the growth of tank-based fish culture is also noted[89]. In this time, land grants were regularly made by kings to elites, but did not always include the rights to fish in rivers, even if pond and tank fishing was included[90]. But this varied across different regions. In the 11th century CE,

[85] See Wise (1883: 281 p.), and see notes to Table 3.
[86] In the Smritis and Puranas, according to Agrawal (2007: pp. 21-56), and P. Reeves (2003, op. cit.).
[87] It is sometimes wrongly assumed that prior to colonial rule, fisheries were either not subjected to taxes in early modern regimes, and that, by and large, fisheries were scattered as an economic activity and thus not considered an important source of revenue (see Sharma, R.S., 1959: pp. 329, 375). However, in the Maurya and Gupta empires, river fish were regularly an item of taxation and duties. Sihag (2005: pp. 723-753) notes that the *Arthashastra*, dated uncertainly around this period, also mentions regulations for collection of toll-dues from fishers, duties on sale of dried and fresh fish in markets, and fees for fishing in enclosed or 'owned' waters. Fishers had to pay between 1/10th to 1/6th of their fish catch as fees for fishing licenses to private landowners and state authorities and officials. Seasonal bans and fee exemptions on ferries are also recorded. State systems of fishing bans, sanctions, and prohibitions were complex and sophisticated in Emperor Ashoka's reign (around 300-246 BCE). According to Hora (1950, I and II: pp. 43-56) these bans were sound in that they aimed to protect fish in the critical periods of spawning and migration. Bans on flood fishing (from July-September and November) covered from 56 to 72 days per year, connected with the lunar cycle.
[88] See S. Darian (2016: pp. 62-87).
[89] See Hora, S.L. (1950, I and II: pp. 43-56).
[90] R.S. Sharma (1980: pp. 182-185) notes that copper plate inscriptions indicate variations in the nature of land grants and allied assets. In the *Pala* and *Pratihara* land grants, river fishery rights were not always transferred. Between 1114-1155 CE, fishery rights were transferred to the king by the *Gahadvala* grants. Later, during the Pala kingdom's reign, fishery rights and allied concessions were likely included back again in private land grants. Also see Sen, S. (2019: pp. 230-231, 278), Furui, R. (2019: pp. 155-174), Thapar, R. (2003: p. 372), Sharma, R.S. (1983: pp. 202, 219, 228, 231), and Majumdar, R.C. (1943: pp. 648, 658) for details on fishery rights included in land grants. This period is said to connote a time where "*Matsyanyaya*" or the "law of the fishes" prevailed, referring to oppression and lawlessness (Sen, S. 2019: p. 231).

a major rebellion of *Kaivartta* fishers was recorded against the Pala king of the Gaud region of Bengal, possibly to resist land grants and new schemes of taxation[91].

Not much is known of the period from the 11th century to Muslim rule from the 13th to 15th centuries, with regard to fishing revenues[92]. But in the Mughal period, the rent collection system involved landowning elites drawing regular royalties, ferryboat charges, and rents from fishery assets, attached to their land rights[93]. Fish catch tributes (*Sairat* or *Sair* incomes or royalties), *abwabs* (pecuniary tributes, rewards) and *peshkashes* (gift-offerings) and *Muhtarifa* (customary cesses) and other minor taxes on fishing boats for passage, were regular additions to *zamindari* revenue records[94]. *Zamindars*' allowances included *nan-kar* lands, to which *ban-kar* (allowance of revenue collection on wood produce), and *jal-kar* (from fishing) assets were allocated[95]. Such rent extraction systems significantly influenced the revenue production from fisheries since the later 16th century in particular, when under Akbar's administration, systematic and complex guidelines for tax regimes were laid out, in 1582 CE[96]. Major fishery revenues were extracted from ponds, tanks, and rivers, including for fish culture[97]. Sales of fishing rights were allowed for individuals or to be given as leases to *ijaradars* or sub-lessees, under larger *zamindari* estates[98]. Importantly, the Mughal rent collection system was based on determinations of the value of land property based on calculations of erosion and accretion[99]. Major embankments were constructed along large rivers for protection of agricultural lands[100]. Periodic surveys for investigation of the value of land and other assets were

[91] Furui (2015: pp. 93-98) interpreted copper plate inscriptions of the Pala kingdom from the 11th century CE along with notes from the Ramcharita by Sandhyakaranandin, to show that the rebellion likely emerged due to unjust taxation of river fishers and boatmen by the Pala King Mahipala II. This appears to be a well recorded event: see Sudipta Sen (2019: p. 278), R.C. Majumdar (1943: pp. 199-200), and R. Thapar (2003: p. 410).

[92] Habibullah (1976: pp. 225-231) described a highly structured system of revenue extraction and judiciary by the late 13th century under the Turkish Delhi Sultanate, but its spatial reach as limited. By the 14th century, a central interest in land revenue and rent collection took shape (Habibullah, pp. 259-260; Sen, S. 2019: p.262). Moreland (1929: p. 60) records water rights and revenues from old settlements along rivers during Alauddin Khalji's and Muhammad Tughlaq's rule of the *doabs* or interfluvial regions of the "river country" of the Gangetic plains in the 13th and 14th centuries, but there is no specific detail about fishery rights or revenues. Sarkar (1948: p. 216-233) notes that revenues were taken directly from cultivators in north India, but from middlemen and *zamindars* in Bengal, during the Mughal rule in Bengal. Also see Ansari (1986: p. 54-72) for details on *Chero* tribal rule and early Rajput fortress settlements in the present-day Bhojpur region.

[93] Banerjee, D.N. (1936) describes charges extracted for embankment maintenance (p. 22), and customs chaukies (posts) set up along river banks by *zamindars* to collect ferry and goods tolls (pp. 168-169).

[94] Reeves, P. (1995: pp. 260-292), Khan, A.R. (1985: p. 152).

[95] A.R. Khan (1982: pp. 290-295) describes these numerous perquisites.

[96] See J. Sarkar (1948, op.cit.) for details.

[97] See Khan, A.R. (1982, 1985, op. cit.)

[98] M. Alam (2002: pp. 246-251) describes the strong control of the *ijaradars* of *jalkars* on fishers' access to water bodies, as compared to *zamindars* or traders. The French merchant Bernier (1669: p. 252) noted that in Agra and Delhi, *Omrahs* (noble elites) forced fishers to fish by using whips.

[99] See Addy and Azad (1973: pp. 71-112), and Bhargava (2007, op. cit.)

[100] Bhargava, M. (op. cit.), Sarkar (1948: pp.108-144) describes embankments from the 15th and 16th centuries.

handed to officials like *amils* or *qanungoes*[101]. In lieu of their loyalty to Mughal administrators, private fishery grants were given to individuals or even sold[102]. Grants of private fishing rights passed on through inheritances and were often granted in perpetuity and exemption from payment of dues throughout that period[103]. These grants also enjoyed exemptions of rents or any dues, and from any official interference with regards to their enjoyment[104]. There were *farmans* (orders) issued by the Emperor allowing claims of hereditary rights that could be sold or leased multiple times[105]. With such immunity, many private fisheries on rivers, parcelled into several lessees and sub-lessees, had their own gangs to "protect" their individual boundaries. The most incredible example of this format was seen in the granting of fishing rights from Patna to Farakka on the main Ganga River in 1604 CE to the family of Mahashay Taraknath Ghosh[106]. Ghosh, who was *qanungo* (clerical official) of Bhagalpur for the Mughal Administration, got the inheritable right to hold the 'jalkars' of Gangapath and Chanan and extract rent from fishers, but without remitting any revenues to the rulers[107]. Over time, this regime became a highly oppressive, feudal, and despotic one, although the Ghosh family argued that it was a 'protected' space for fishers who complied to pay the taxes (half to 2/3rd of fish catches) expected from them. In 1923, Ghosh's successors sold the *Panidari* rights and river stretch from Pirpainti to Farakka to Haji Aziz Pramanik in a registered sale deed[108]. Along with sub-lessees, these two family groups in effect controlled fishing rights of this entire stretch for 387 years, until 1991, with fishers having to part with over half of their catch or, upon refusal, getting beaten or violently assaulted[109].

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[101] Sarkar, J. (1948: op. cit. and pp. 393-417). Even though corruption was fairly widespread, there were instances of severe punishments to *zamindars* for non-repayment of arrears, occasionally leading them to be stripped of their landed assets. But the authority of *zamindars* varied from time to time during this time. Also see Nurul Hasan (1964: pp. 107-119).

[102] Khan, A.R. (1985, op. cit.)

[103] According to Latif's Travels in Bihar, 1608 AD, translated by Sarkar, J. (1919: pp. 597-603): cited in Khan (1985: pp. 108-109, 298-299).

[104] A.R. Khan (1985: pp. 298-299) cites an example from Saran along the Gandak, where "Narain and Bhowal in Kasmar Parganna in 1619 complained to Emperor Jahangir, that Mughal officials were seeking bribes and interfering in their access to nallahs and river-channel wetlands", to which they had held perpetual fishing rights, and received exemption from Emperor Jahangir from further official interference.

[105] Ibid.

[106] See. B.G. Verghese (2007: pp. 267-269).

[107] Ibid. The Ghosh family's *'Panidari' Jalkar* weathered legal challenges from the colonial administration in 1805, 1810, and 1873, and then 1952, 1961, and 1965 after independent India passed an act to abolish the zamindari system. Other court cases on fishing rights to *beels* and tanks also covered this period, e.g. Mussamat Bibi Ahmodi Begum vs. T.N. Ghose 1909, and so on.

[108] Ibid.

[109] Ibid. Parts of the *Panidari* were also sublet to other local contractors and sub-lessees (*ijaradars*). Since the PS, armies of stick-wielding *sipahis* (or *lathials* or *lathaits*) were employed by sub-lessees and the owner's family as retainers to protect the fisheries from encroachment of space by outsiders, but also to monitor fishers and extract taxes (see Raychaudhuri, T. 1969, op. cit.). Armed control later led to violence, including physical assault and

Here, it is important to note that the Mughal system of rent collection was directed mostly towards consolidation of political power and military authority. Thus, in spite of the resource capture involved, the economy of the Mughal administration was an adjunct to its political control[110]. Powerful landowners, under or independently of Mughal administration controlled their subjects through imposition of local military power and rent extractions[111]. In the early 18th century, trade networks and commercialization also grew, and in spite of contestations over agricultural land, economic growth was witnessed along the Gangetic plains[112]. On the social front, the Mughal control of Bengal was also accompanied by the parallel spread of *Vaishnavism*. During the late 16th and early 17th centuries, many fishing castes, regarded as very low but not untouchables, got absorbed into Hindu society as peasant cultivators, and many also adopted Islam[113]. But there was largely no interference in the links between social structure, land ownership, or legal propriety[114].

The most important change witnessed with the transition from the Mughal to British colonial administration may be loosely regarded as a shift from status to contract[115], with land control not remaining a signifier of political hierarchy, but becoming an economic right[116]. It implied a shift in the fundamental understanding of agricultural cultivation from the peasant's duty to the state, to the right of an individual[117]. This marked the beginning of the formal, rational, and systematic

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murder of many fishers in the 1980s. These trends led to the formation of gangs and the present sway of criminal control on the Ganga in Bhagalpur. Even though the *Panidari* was removed in 1991, following the *Ganga Mukti Andolan* by fishers of Kagzi Tola, Kahalgaon, the district's *diara* (floodplain) region was controlled by dacoit gangs who frequently looted and harassed fishers. See Mukul Sharma, Landscapes and Lives (2006: pp. 12-41) for details, and later in the chapter. Even after the freeing of flowing river waters in Bihar in response to the Ganga Mukti Andolan (a fishers' movement in the 1980s to protest against oppression by private owners), court cases over the Chanan and Gangapanth Jalkars have continued (e.g. Abdul Ghani Khan and others vs. State of Bihar). Details of this issue are discussed later in this and other thesis chapters.

[110] See Moreland, W.H. (1929), who shows that during the Mughal period, land rights were irregularly distributed, with full of dubious and contradictory claims (p. 158). He further points out the private right to land could barely be separated from political hierarchy and power, to even be called "ownership" with legal title. Also see Sen, S. (2019: pp. 274-275).

[111] See Nurul Hasan (1964, op. cit.)

[112] See P. Robb (1992: pp. 97-119), Alam (1991: pp. 43-71), and Sinha, N. (2012: pp. 446-470).

[113] See R. Eaton (1993: pp. 49, 53, 99-131). According to C. Singh (1988: pp. 337-339), a gradual but significant movement of pastoral-tribal societies into sedentary society in northern India was linked with their involvement in the Mughal political, economic, and military apparatus.

[114] As per Mendelsohn (1993: p. 836): "Unlike the British, the Mughals did not conflate the administrative problem of maximizing revenue with conceptual enquiries into the true and/or proper basis of land ownership in India".

[115] Shift from social status to economic contract has been discussed by numerous scholars, see for example Cohn, B.S. (1959: pp. 79-93), Sen, S. (2004: p. 136-154), and Dhillon, R.K. (2012: p. 101). Mohapatra (2009: pp. 96-125) argues that, in turn, contract reinforced social status in a different manner, due to the nature of employment and the resulting ranks, pensions, and incentives offered by the state for particular categories of labour work. See N. Sinha (2014b: pp. 24-39).

[116] Following Moreland (1929: p. 158), who says that the Company administration inherited from the Mughal administration a system "where might counted for more than right".

[117] Moreland (1929: p. 63).

economic revenue and resource regime of the East India Company's rule. By the 16th century, contractual landholdings existed in many regions of India, with residual as well as transferable rights. From the 1650s, the East India Company was obtaining property along riverfronts for river trade and navigation. Trade interests were hampered significantly as local rulers extracted taxes on company boats bringing goods for trade[118].

In the early 1700s, land rights were irregularly distributed, with dubious claims and ad hoc and wide local variations in the nature of titles or contracts[119]. But in general, across riverine tracts under the control of the Mughal administration, private fishing rights and revenues were attached with landed estates in almost all cases, with the exception of tidal rivers, the Ganga-Brahmaputra delta, and the Sundarbans, where fishing was relatively free of rent extractions[120]. In adjacent regions where Mughal control did not extend, as in Burma, river-floodplain fisheries and other inland fisheries were more clearly divided into public fisheries (state-owned) and private fisheries with heritable rights until 1752[121]. In Burma too, riparian landowners controlling private fisheries paid taxes to the state by exploiting fishworkers who laboured for them. During 1752-1760, Emperor Alaungpaya's confiscation of many private fisheries on *inns* (water-bodies on the Irrawaddy floodplains) led to fuller state control on inland waters[122].

Period 1. Fisheries under Company Rule: 1757-1858[123]

Company experiments, Permanent Settlement, and impacts on fisheries

The Permanent Settlement (hereafter, PS) of Bengal in 1793 and its lasting impacts on the peasantry of Bengal have been studied in great detail[124]. But the

[118] See Raye, N.N. (1927: pp. 52-53, 112-113) for details of boat trade since the Bengal Pilot Service was set up in 1668.
[119] See Moreland (1929: pp. 143-144, 158). Also Hunter, W.W. (1872: pp. 61-68), and Wilson, C.R.'s (1911: Early Annals of the English in Bengal, vols. 1 (pp. 38-290) and 2 (p.126) bear regular mention of ferry boat revenues, and fisheries/ fish trade revenues from 1711 to 1719 CE.
[120] See Hunter, W.W. (1875, vol. 1: p. 176, p. 301-303), Barman (2008: pp. 39-74), and Iqbal (2010: p. 63). Iqbal argues that the deltaic and fluid environment "diluted" the intensity of landowners' oppression, as fishers had a larger space with multiple resources available. Also, Barman (2008: pp. 39-74), and Chacraverti (2014).
[121] Reeves et al. (1999: pp. 249-262)
[122] Unlike the Ganga-Brahmaputra delta, some private fisheries persisted in the Irrawaddy delta region, see Reeves et al. (1999, op. cit.).
[123] See Table 2.1 for a summary of the major events from 1757 to 1793: revenue collection or diwani rights were granted in 1757 by the Mughal administration to the company.
[124] See Guha's A Rule of Property for Bengal (1963: 264 p.), Banerjee and Iyer (2002: pp. 1190-2013), and other studies cited in this chapter.

impacts of PS on fisheries and the fishing communities have not been as well described[125]. Throughout discussions from 1765 to 1770, land ownership based on riparian rights, according to the principles of English Law, was the foundation of the PS[126]. The devastating Bengal famine of 1770 saw the loss of almost half of the peasant population from many districts of eastern Bihar and western Bengal, either by death or outmigration[127]. The shocks of the famine rendered several large and small estates desolate. Reports of dacoity and looting were on the rise[128]. A total overhaul of taxation regimes with revenue extractions based on systematic and extremely detailed revenue calculations followed[129]. At this time, massive river course changes, flooding, sediment accretion and erosion processes, and shifting land-water boundaries were a major source of confusion in determining property boundaries, and thereby, revenue calculations. Major James Rennell was given the task of surveying the rivers of the Ganga and Brahmaputra basins, to help understand the shifting nature of the fickle floodplains and how revenues could be exactly assessed. Rennell undertook detailed topographic surveys of the Ganga-Brahmaputra plains and delta from 1774 to 1780 across Bihar and Bengal, and his team provided detailed maps of channel courses new and old, their banks, flooding heights, and river discharges to demarcate active channels, older palaeo-channels, and occasional floodplain inundation areas[130]. Rennell's estimates of the rate and extent of channel movements informed the period of assessment for surveys of expected revenue – at every ten years.

Despite all this information, the Company Administration had to deal with major revenue losses to successive floods in the 1780s, and a severe ENSO drought across India from 1789 to 1793[131]. Through the 1780s, apart from the fears of banditry, the Company also faced many rebellions from local rulers[132], which caused

[125] But see Toufique et al. (1997: pp. 457-467).
[126] See Hill, C.V. (1990).
[127] B.B. Chaudhuri (1975: pp. 105-165). This severely affected major industries but artisanship survived and continued at smaller scales (Bagchi 1976, Krishnamurty 1985: pp. 399-416).
[128] Sinha, N. (2008: pp. 1-33).
[129] Regulating Act of 1773 by Warren Hastings.
[130] See Rennell (1776, 1781: pp. 87-114) for his remarks on channel course changes: "By two surveys of a part of the adjacent bank of the Ganges; taken about the distance of nine years from each other, it appeared that the breadth of an English mile and a half had been taken away. This is however, the most rapid change that I have noticed; a mile in ten or twelve years being the usual rate of incroachment (sic.)".
[131] See Table 2.1, and Grove (2007).
[132] See Singh, K.S. (1978: pp. 1221, 1225-1232). Reginald Hand (1894: pp. 6-14) describes revolts in the 1780s by local Rajput kings along the Ganga, against the company. District collectors were told to stop all levies and tolls on boats between Banaras and Dhaka, and new rules were made (Sen, S. 2019: p. 328). Tolls (*Ghatwari, Rahadari* tolls on ferries, and sair taxes) were resumed from 1800, and customs houses again set up by 1810 at regular distances along rivers, which negatively affected river trade in Bihar (Chatterjee 1996: pp. 61-62, 130).

severe fluctuations in the stability of revenues[133]. It was thus ensured in the PS Regulation XXVII of 1793 that fishery assets remained part of *sair* incomes, i.e. incomes from non-land assets[134]. With the "common veneration of private property"[135] among officials in the Company administration of the PS, it was believed that only giving private property in perpetuity would improve the condition of Indian subjects. Apart from this ideology, the common belief in free trade was seen as the solution to implementing the PS. Importantly, these influences made colonial powers consider the pre-existing institutions of caste and class in Indian society as the basis of property rights, land ownership, and security[136]. In this context, the fallacious assumption that *zamindars* and *ryots* would interact as two free contracting parties, without information asymmetry and with fair contracting terms, was unsurprising[137]. Such revenue policies homogenized peasants and fishermen into the uniform category of *ryots* under the binary of *zamindar* vs. *ryot*, and rendered the latter's rights invisible[134]. At the turn of the 19th century, the recurring dynamics of accretion and avulsion along river-floodplains remained a headache for implementing many PS regulations. A slew of embankment laws and regulations followed until 1806-07[138], and along with the consolidation of rigid private rights, were the start to many complications regarding the status of customary rights of fishers to access floodplain

[133] See Soeftestad, (2000: 22 p.).
[134] See Toufique (1997, op. cit.). Hill, C.V. (1991) argues that riparian rights and 'water ownership' by landowner classes, with these rights fixed in perpetuity, made the extraction of fishery revenues convenient. These changes alienated large populations of tenants and peasant groups, with many floodplain communities turning to banditry and dacoity in response to the harsh pressures of PS revenue systems. For more details on the spread of rural crime in Bengal, see McLane (1993), Yang (1979: pp. 37-58, 1998: p. 188), and Mukherjee (1981: pp. 153-183, 1993: pp. 237-243). This spread of banditry can be placed broadly in E.J. Hobsbawm's conceptualization of "social banditry". Hobsbawm considered such banditry to be symbolic of rural rebellion against state oppression or dominance, with bandit gangs typically involving groups from lower socio-economic strata, with mobility in livelihood practices and smaller labour demands than for settled agriculture (Hobsbawm 1969: pp. 18-38).
[135] Guha, R. (1963: p. 17).
[136] According to Cohn, B.S. (1959: pp. 79-93). The interest of officials such as Philip Francis in "English interference, on the lines of native practice", and sustaining the "ancient institutions of the country", basically, maintained caste and class structures. Riser-Kositsky (2009) shows that while British officials had seen the deep structural injustices against the lower castes, they chose to uphold and accept it as a traditional institution maintaining India's social order and custom. Identities of "subjects" were also maintained and categorized to suit colonial agendas of social and economic control (Cooper and Stoler 1988: pp. 609-621).
[137] See Sinha, N. (2016: pp. 163-190) for an analysis of how *ryot* rights became invisible in the colonial record with the role of *zamindars* and intermediaries becoming stronger. Though the category of '*ryots*' may help in an analysis of economic contract implicit under the PS, (as shown in Sen, 2015), it assumes that tenant farmers were the only ones using customary access to fish, and makes fishers invisible. As discussed earlier, fishing communities represented highly heterogeneous assemblages, using multiple practices of resource harvesting. In this connection, Deb and Haque (2014: pp. 77-101) have argued that we need to recognize "fishantry" and not just "peasantry", while writing a complete agrarian history of Bengal, as both livelihood systems had very little in common. Additionally, fishing allowed great flexibility to farmers too, in times of environmental scarcity, and many seasonal labourers and sharecropping cultivators often supplemented their incomes with fishing (Iqbal 2010: pp. 51-63).
[138] In 1807, Regulation X ruled against partition of small estates. See Reginald Hand (1894), Sinha, N. (2014a, op. cit.).

wetlands[139]. Here, it must be emphasized that the erosion of customary rights under the PS would have differentially affected *ryots* who were involved in part-time fishing (during the flood-recession and monsoons) in their fields, as compared to more commercial regular fishers[140]. There is also no clarity in this time about fishing in the main channels of rivers, which were supposed to be under public fishery even in the PS[141]. *Ryots* were sandwiched between the customary rules set by local satraps, *zamindars*, and rules of the PS[142]. As many estates were owned by absentee *zamindars*, the power of lessees (*ijaradars*) over fishers' access also grew stronger[143].

Another interface of economic contract between some fishing and boat-ferrying castes and colonial administration was through boat-based trade along major rivers[144]. At the time of Rennell's surveys, nearly 30,000 boatmen ("dandies" or "*manjhees*") were involved through labour in the plying of trade by merchants and company officials. Many dandies lived in settlements along the banks of publicly navigable rivers. Direct contracts with British officers provided a buffer to boatmen from impacts of the PS. Due to the skills of boat-ferrying dandies in great rivers, the reliance on them was high, but not without suspicions about their manners and fears of slacking or corruption in work, and increases in river dacoity and banditry in this period[145].

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[139] See Sen, S. (2015).

[140] Nakazato's (1994: pp. 225-230) and Pokrant et al.'s (2004: pp.93-117) descriptions of fisheries in eastern Bengal clearly suggest a differentiation (or coexistence) of ryots fishing in small channels and rivulets from regular, full-time fishers who fished all round the year in the main stem of larger rivers for commercial purposes, except during the monsoons. But these descriptions do not involve details on fisher castes using the respective methods.

[141] This was perhaps full of exceptions, as private riparian rights even extended to entire river stretches in some cases, e.g. the *Panidari* of Bhagalpur.

[142] See Cohn, B.S. (1959: 79-93), Raheja (2014: pp. 497-522). Bhargava (2007, op. cit.) describes an example: between 1807 and 1810, conflicts erupted between the Champaran district administration and local zamindars and kings, over the ownership of *Gangashikist* (carried away by the river) and *Gangaberamud* lands (thrown up by the river: referring to new floodplain deposits) eroded and swept away by the Gandak River. In such cases of discord, settlement on riparian rights was attempted whenever these lands became available for surveying. But these attempts largely failed, and conflicts between estates continued, so that costs of conflicts were borne by local peasants, who were made to pay excess rents.

[143] McLane (1993: p. 67): In 1775, Bengal *ryots* had argued that they had never paid rents on fish, trees, and straw, which the *ijaradars* were now demanding. Due to absentee landowners who lived far from their riparian properties, estates were mostly under the control of and supervisor officials, who maintained bands of "feudal retainers" who used sticks, clubs, and other traditional weaponry to deter trespassers and encroachers. Often, even river dacoits became retainers, as they accepted zamindari authority and power. These retainers also acted as intermediaries between *zamindars* and *ryots*, by offering "protection" to tenant farmers and other floodplain residents (see Raychaudhuri, T., 1969: pp. 167-173). Conflicts between fishers, lessees, and riparian villagers in the Brahmaputra plains of Assam erupted due to auction-lease systems brought in by the British at the start of the 19th century (Saikia, 2019: pp. 142-155). Also see Sinha, N. (2016, op. cit.).

[144] See Sinha (2014b: pp. 11-43).

[145] Ibid. Also see Malhotra (2012: pp. 148, 152) for British depictions of bandits in fictional writing, later used as justification for military expansion by the 1820s. Banditry was said to have increased significantly between 1800 and 1840.

Francis Hamilton-Buchanan's Surveys

Francis Hamilton-Buchanan (FHB hereafter) travelled across the Gangetic plains from 1807 to 1824[146]. Like many of his contemporary explorers[147], he travelled across a riverscape, which was on the verge of witnessing major economic and hydrological transformation. Large landed estates were being assessed for revenues in perpetuity, major embankments being built to contain the disastrous floods of these rivers, and disparities between landowners and the hapless peasantry were growing. He also perceived a great deal of secrecy and confusion surrounding the nature of tenure and revenues, rights, and even fishing practices, and fish[148]. Rennell's descriptions and survey maps of the Ganga and Brahmaputra rivers from the 1770s inspired FHB to travel and document how these rivers had changed since then, and his descriptions allowed for some useful insights[149]. In general, he remarked for the smaller rivers, that: "*the difference of species makes very little alteration in the value, a sér of fish selling for nearly the same price, of whatever kinds or sizes the fish may be*[150]." He noted richer fisheries with more knowledgeable fishers on the Ganga and Mahananda in Bhagalpur and Dinajpur, than along the Kosi in Purnea. Wherever he went, he consistently noted that fishing rights were attached to the system of riparian rights, and that fishers would often share less than they 'ought to': *"…in most parts the right of fishing is annexed to the land and is let to renters (Mostajirs*[151]*), who sometimes employ men to catch the fish for wages or for a share, and sometimes relet them to the actual fishermen, giving them either an exclusive right to the use of a certain extent, or a right of frequenting a certain extent along with others. The nominal value of the fisheries is a trifle, most of the landlords pretending to give them to their servants as a reward for their trouble; but as I have said, there is no knowing the amount of a zamindar's profit from the nominal rental. The leases of the fisheries*

[146] Between 1807 and 1813-14, FHB produced 21 volumes and seven tables of statistics on the geography, physiography, agriculture, fisheries, economics, flora and fauna, and cultural diversity of the Purnea, Bhagalpur, Tirhut, Shahabad, Dinajpur, Rangpur, and Patna districts, and earlier, even the Chittagong hill tracts and the rivers of these regions. His naturalistic and opinionated journals are rich in detail on fisheries of the Ganges: his account of the fish species of the Gangetic plains (Hamilton-Buchanan 1822) continues to be a seminal reference material for even recent taxonomic studies. Also see Vicziany (1986: pp. 625-660).

[147] See the reports of Colebrooke (1803: pp. 1-31, 1804: p.73), Williamson (1810: pp. 281-288), Hamilton, W. (1815: p. 557), Deane (1823: pp. 85-86), and others that corresponded with Buchanan's survey years.

[148] See Hamilton-Buchanan, F. (reproduced in pp. 68-70 in Fisheries and Botany of eastern India, 1877), and Reeves, P. (1995: pp. 260-292).

[149] Krishnamurty (1985: pp. 399-416) and others (e.g. Vicziany, op. cit.) have cautioned about the use of numerical revenue estimates from FHB's journals for longitudinal comparisons. But they still provided excellent descriptions of what the fisheries of the day would have looked like.

[150] Hamilton-Buchanan, 1812 (p. 291)

[151] Same as *ijaradars*.

are generally renewed annually, a Salami or homage is paid, and without knowing the amount of this we know nothing. A great many of the actual fishermen pretend to give one-half of all they take to the renter, but he is in general defrauded.[152]"

FHB's anthropological notes on the fishing and boat-ferrying castes of Bengal also represent perhaps the first instance that, in the revenue record, differences in practices and 'habitats' of fishers were described by caste. He recorded of fish trade in the region that in the 1810s, fishing people across Bengal's rivers sold fish either fresh to Murshidabad or Kolkata; but most fish would be dried and sent to Nepal, Bhutan, and to farm labour settlements along the Himalayan foothills and *duars*. These observations are fairly similar to the present chains of fish distribution. Apart from trade, the technologies of fishing, from FHB's surveys to the present times are also curious, in that very few changes can be seen over the last 210 years. But I will return to these in more detail later[153].

Hydrological uncertainty and legal confusions about fishing rights

Along the Ganga, estates that were constantly affected by sedimentary processes and changed in their features were taken under direct control of the company administration[154]. In the early 1800s, rivers were under surveillance and monitoring to prevent dacoity and smuggling along waterways, with guard boats of river police patrols stationed at important ports and *ghats*. The presence of surveillance stations, and the takeover of estates by the company, further limited customary access for fishers. A determined shift towards more centralized and rigid control of 'scattered pursuits' such as fisheries was evident in these years. As a result, considerable debates on the status of 'customary fishing rights' came to be a regular feature of policy deliberations between 1810 and 1822, as they attempted in vain to sensibly put to practice their own numerous regulations after 1793. The Regulation of 1819 by Holt Mackenzie, the Secretary of the Board of Revenue, exempted some fisheries from taxes, in cases where alluvial action (shifts in river courses) had shifted their fishing areas away from demarcated private estates. He claimed that settlement of rights should not be declared in perpetuity, unless villagers' customary rights were

[152] F. Hamilton-Buchanan (reproduced on p. 55 (fish and fisheries of Purniah) in Fisheries and Botany of Eastern Bengal, Hunter, W.W., A Statistical Account of Bengal, 1877, vol. 20.)
[153] See page 65-66.
[154] These areas were "resumed" when some stability was expected, but typically maintained under somewhat tentative arrangements of rights of use (Sinha 2014a).

recognized. This was attempted in Regulation VII of 1822, which discussed settlements of rights at the whole village-level. However, this did not lead to much change in the positions of power enjoyed by landowning elites and officials[155]. At this time, a public fishery for the city of Calcutta was also proposed[156]. By this time, the impacts of irrigation canals, major embankments, and weirs were already perceived to have affected fisheries[157]. Overall, though, in spite of such attempts, there was poor awareness of customary rights, floodplain land resumptions, and lands available for settlement among tenants and peasantry[158]. The mobility of large sections of floodplain-dwelling people also became registered increasingly under illegal acts, as customary forms of access and movement were undermined. Tacitly, policing various floodplain communities for trespass, poaching of fish and minor produce, or as bandits, were a direct outcome of the hydrological uncertainty and confusion of PS laws and land tenures[159]. The Alluvion-Diluvion Act of 1822, ferries regulations, and Regulation III of 1828 that followed, added more confusion about fishing rights[160], and added accreted land to existing property[161]. To meet targets of revenue collections, such assessments underestimated the extent of change in river channel courses, and as a result conflicts kept boiling between landed estates[162]. Overall, the gap between the PS' vision of permanence and the transience of riparian ecology never led to its full implementation, and alluvial revenue assessments were suspended in 1846[163]. Uncertainties and confusions thus remained, and affected active landlords and the peasantry[164]. By the late 1840s, the duration of leases and the interference of company trade and revenue rules with the administration of different regions under princely rule also became another subject of heated debate[165]. Conflicts between rigid

[155] Banerjee and Iyer (2002: p. 1199).
[156] Mitchell, T. (1822) Proposal for establishment of a public fishery to serve the city of Calcutta, F/4/7/4 No. 19483. Bengal Publications.
[157] Singh, P. (2008, op. cit.).
[158] See Robb, P. (1997: pp. 145-179), and Sinha, N. (2008, 2014a). Bhattacharyya (2018: pp. 1036-1073) has argued that law became a site for the production of geographically specific knowledge, and was productive in defining intricate rules of making property from land, especially in the uncertain and amphibious ecology of the Gangetic plains.
[159] See Mukhopadhyay (2002: pp. 968-986), Sinha (2008)
[160] See Table 2.1.
[161] This severely affected highly dynamic river courses, such as in the Kosi; see Hill (1997)
[162] The company extracted about 60% of *zamindari* asset shares as administrative revenues.
[163] Based on E. Mukherjee (2019: pp. 20-31).
[164] Sinha (2014a, op. cit.), describes that *toufir*, and other 'excess' *diara* lands were temporarily settled and were added to 'resumed *mahals*' or estates of the state, or to private or *khas* lands. In the later decade (1830-40) resumed lands were also brought on state revenue rolls at reduced rates (van Schendel 1991: pp. 74-77).
[165] The passing of Act X of 1847 allowed for land assessments in the floodplain to facilitate Decennial Settlement became a conflict issue, but no proper surveys were made until 1862-1863. Negative sentiment among princedoms and landlords against company rule had been growing since this time; see Sinha, N. (2009: pp. 33-51).

laws and fluid ecology, and complex local customs contributed to negative sentiment among princedoms and landlords, who participated in the mutiny against the company in 1857[166].

Period 2. Fisheries under the Crown: 1858-1947

In 1858, with the transfer of administration to the British Empire (the crown administration), strong and uniform economic, social, civil and criminal legislations (e.g. the Indian Penal Code) were codified and implemented. For the first time, a common set of laws for the whole of British India came into operation[167]. These changes, along with a highly structured machinery and ideology of imperial science, were to have a lasting impact on livelihoods dependent on aquatic ecosystems. For fisheries, the major transition after 1858 was greater state control on lease allocations, even though the importance of private fisheries was upheld for maximizing revenues[168]. Noting that systems of sub-leasing and contracting already existed on many large and small *Jalkars*, revenue was to be taken from not only the actual produce of fish from the water, but also from fixed rents and royalties for using water bodies too[169]. Rents were too substantial to allow "encroachments" of any kind[170]. These acts hardened the previous ambiguous stand of the company administration on fishing rights, and pushed for stronger private control. This precedent dealt a blow to later attempts from even within the administration to promote the 'Public Right to Fish'[171], by revoking *Jalkar* rights in the larger navigable rivers for the recognition of public fishing rights[172]. But *Ijaradars* (contractors) who extracted large profits from these fisheries strongly opposed the plan.

[166] Indian rulers were labelled as rebelling despots by the company, but the rulers' dissent against company trade and interference in local administration was not renegotiated, see Sen (2004: pp. 136-154).
[167] Local cultural realities had mostly remained at odds with state law, and outcomes across regions diverged after the PS implementation (see Dirks: 1986, 71 p.). Several studies have analysed the implementation of unified laws, which were nonetheless linked to local realizations of land laws and rights, and the state of commercialization of agricultural systems, across different provinces: Bengal, Madras, Punjab, and the western and northwestern frontiers. See, for example, Acharyya 1914 (p. 229), Robb (1992: pp. 97-119), Chakravarthy-Kaul (1996: pp. 63-261), Roy (2007: 33 p.), Dhillon 2012: pp. 44-45, Hillmann (2013: pp. 251-273), N. Bhattacharya (2018: 522 p.).
[168] Baden-Powell (1892: 443 p.) recorded that the Bengal Land Revenue Act of 1859 provided for new land tenancy rules and rents, and the Revenue Board's proceedings that followed, stressed on the importance of private fisheries for fish protection and revenue maximization.
[169] Baden-Powell, ibid.
[170] Here, encroachments included even long-held customary access and informal rights of fishing 'ryots', and only specific tenures of fishing ryots were allowed, e.g. see Taylor (1840: pp. 152-153).
[171] Notable in the Estates Manual of 1860.
[172] See Ausness (1986: pp. 407-439), Blomley (2008: pp. 1825-1843), Donaldson (2011: pp. 155-170), and Appleby et al. (2018: p. 40) who describe the legal arguments for having fisheries as a public right in larger rivers and 'open' waters. In 1883, C.D. Field's report (Field, 1883: 54 p.) echoed the 1859 decision of the Lieutenant

Beginnings of decline and ideas of scarcity

With the increase in trade networks in the 1840s and 1850s, especially driven by the railways and improved roads, fish trade and commoditization received a major boost[173]. Irrigation infrastructure expanded rapidly, through canal projects, weirs, and embankments across the Gangetic plains. Embankment construction also grew multifold because of their need to protect railways, roads, towns, and brick kilns along the banks of the Ganga[174]. The negative impacts of irrigation intensification on fisheries also became evident from losses in fishery revenues being reported[175]. The hydrological risks and alterations from these systems also led to important ecological transitions: water logging in floodplains increased, and embankment breaches regularly caused massive rushes of sand flows resulting in agricultural losses and siltation of ponds and ditches[176]. Embankments worsened flood risks in regions such as the Kosi plains, resulting in accelerated rates of levee erosion and subsidence, and displacing millions of villagers[177]. In the early 1860s, huge increases in eutrophication, and the establishment of water hyacinth dented fisheries production, especially in culture ponds and wetlands[178]. All these changes triggered repeated malarial outbreaks[179]. Lateral connections between the river and floodplain are critical for many fish species to disperse into inundated areas for spawning in the flood season, and for the subsequent growth of fish fry for a year, after which they return to the main river channel[180].

Importantly, fish trade expansion followed right after transformations of river flows, and fish availability. Declines in fish availability and abundance, and the pressures of demand, for both dried and fresh fish, were likely a double-whammy for

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Governor, stating that fisheries had to be privately owned according to the basis of *Jalkars* in Bengal. See notes to Table 2.1.

[173] Sen, S. (2015) shows how the rise of a Bengali middle-class (or bhadralok) was a significant factor behind the expansion of 'fish' trade and growth of the public significance of Bengal's aspirational 'Fish-Loving Culture'. Salt for fish preservation was more easily available. Until this time, fish markets had a long but largely localized history (Yang 1998).

[174] Iqbal (2005: p. 501, 2007: p. 329); Singh, V. (2014: pp. 23-28). The Northern India Canal and Drainage Act (1873) led to further developments of navigation routes, irrigation canals, and road-railway embankments and bunds. Embankments blocking river flows also led to major channel changes by the 1860s and 1870s, as river channels frequently breached the arresting force of embankments.

[175] Singh, P. (2008, op. cit., 2009: 54 p.), R. D'Souza (2003a: pp. 41-69, 2006b).

[176] See Mishra (2009: pp. 309-328), Sinha R. (2008), Iqbal (2005: p. 151, 2007: p. 329), and C.V. Hill (1990: pp. 1-20).

[177] See Rorabacher (2008: pp. 45-53), Mishra (2009: pp. 309-328), Mukherji and Mukherji (2012: 94 p.).

[178] Iqbal (2005, op. cit.)

[179] See Iqbal (2010: p.189), and also Klein (1973: pp. 639-659), Singh (2008: pp. 239-260) who all point towards an ecological context for greater malarial spread in the lower Gangetic plains.

[180] See Craig et al. (2004: pp. 271-286) for details of fish ecology in flood-pulses ecosystems.

riverine fisheries across the Gangetic plains. The growing commerce also brought demand-supply calculations to the forefront, and concerns of "destruction", both of breeding fish and small fry, took centre stage. The issue of inland fisheries was now not merely about who extracted rents or owned particular fisheries; but became one of how fish had to be 'protected' from excessive exploitation by rural people[181], whose actions had to be policed. This motivation, combined with the scientific and ideological discourse of the imperial government, led to the implementation of a range of policies to 'manage' fisheries and fishers. The British government felt that a full department was needed to prevent the commercial collapse of the fisheries of the Gangetic plains at the hands of local fishers.

The Indian fisheries department: the evolution of durable state discourse

British officers had long perceived fisheries as a relatively unimportant subject due to the focus on agricultural revenue, and the seasonally fluctuating and relatively minor (or ambiguous) revenue additions from fish produce to major estates. With the growth in fish trade, however, this perception changed dramatically by the 1850s. Despite the push for private control of *Jalkar* fisheries, a general perception that fish resources were declining steeply became stronger. With that, the need for greater state intervention was perceived, and with the appointment of Dr. Francis Day as the Inspector-General of Fisheries in 1868[182], the shift to state control of British India's fisheries became complete. In his active years from 1868 to 1877, Day's academic interests were not just naturalistic and zoological[183]; he also made significant political forays into understanding and dealing with conflicts affecting freshwater fisheries. Day acknowledged that diversions of river water by irrigation weirs and canals had caused significant injury to fisheries, but he also identified numerous technical and institutional problems, e.g. free fishing without protection in regions of Bengal, disincentives to fish trade in Assam. However, he placed strong emphasis against

[181] Curiously, despite the acknowledgment of fish declines due to irrigation weirs and canals, the primary threat was thought to be the actions of "ignorant" and "short-sighted" peasants in indiscriminately and destructively hunting fish. Adas (1989) has noted the role that Western technology played in the colonial state's judgment about the limited abilities and sensibilities of non-Western peoples. It is not uncommon to find descriptions of boats, nets, and fishing gears in British accounts that disregard the use of primitive techniques and "rude" design of these contraptions, as against "modernization". This attitude was also a part of the toolkit of the "civilizing mission" of the colonial government for native people.

[182] Reeves (1995) notes that Day's appointment was also the subject of much ridicule among his official counterparts.

[183] Day also described and updated a detailed taxonomy in his 1873 "Report on the Freshwater Fish and Fisheries of India and Burma", apart from his detailed analyses and comments on fishery regulations (118 + 357 p. appendices).

native fishing practices, which he regarded as highly destructive and unsustainable, so that "ignorant" *ryots* contributed to enormous wastage of fishery resources by catching fish round the year.

Day's visit to Burma in 1869 led to heated debates with Major-General Albert Fytche, the Chief Commissioner charged with fixing a state share from fish production from the river fisheries of the region. Day, based on what was an apparently cursory and superficial visit to Burma, recommended auction-lease systems on fisheries in the river *inns* (=inlets and floodplain water bodies) of Burma[184]. This became the bone of contention, as Fytche thought of it as a gateway to a gambling-oriented, short sighted, oppressive, and predatory regime. However, Fytche agreed with Day's other suggestions of five-year leases and imposing limits on mesh sizes. He proposed that the British administration be the grantor of fishing licenses and lease fisheries to villages most adjacent to the river or wetland stretch[185]. Taxes and rents for licensing and sub-letting processes fell on fishers, because traditional lessees were alienated by the new state system of five-year leases. Later, in 1905, the amended Burma Fisheries Act extended the public fishery license system to 'any person', and the effects of this additional pressure on the fisheries and fishers' livelihoods were certainly burdensome to bona fide and previously active fishers. In Bengal's *Jalkars*, the state directly worked with the private controllers of fisheries. State control of fisheries in Burma and Bengal thus complemented each other. In Bengal and Assam, it was decided fisheries controlled by the state in Bengal would also award auction-leases to contractors[186], as *zamindars* did for private fisheries.

In India, the discourse of excessive fishing used to justify greater state control of riverine fisheries was not without internal contradictions. A diverse literature, including gazettes, travelogues, field reports, and official reports from the 1870s referred to fish in rivers and wetlands as 'inexhaustible' and abundant resources, with tremendous importance and 'potential' to feed thousands of poor farmers. However, all these accounts also described fish as being "subject to indiscriminate capture in the breeding season"[187]. Only one of these ideas can actually be true: either fish were

[184] Reeves et al. (1999) show that the auction-lease system in Burma had important lessons for the fisheries of Bengal and for state control.
[185] Ibid. Fytche also wanted taxes on the fishery specific to types and numbers of mesh sizes and nets used by fishers.
[186] See Saikia (2019: pp. 142-155), Barman, R.K. (2008: p. 39-74), Hunter, W.W. (1875, vols. 1-20). Often, these leases would be granted to the same lessees, or their inheritors, sometimes even over decades, which developed vested interests and steeper rents against fishers (see Southwell 2017: pp. 32-35).
[187] For example, see The Bengal Magazine Volume 1, 1872/1873, p.160.

abundant or inexhaustible despite indiscriminate capture, so that capture was not cause for concern. Yet it was precisely such capture that Day and many of his counterparts deemed destructive and unsustainable. These discourses set the tone and grammatical canon for future 'governmental' writing on fisheries management, which may be said to have continued until today. Their language expressed optimism about fisheries but with the rider that they were most secure in the hands of the government, and not fishing peoples, whose short-sightedness would lead inevitably to the destruction of the bountiful resource.

Towards these issues, Day suggested a range of prohibitions and rules to regulate fisheries and ensure its protection from "utter annihilation" by people, if they were granted open access[188]. Discussions on the issues of regulating mesh sizes, net types, gear dimensions, and seasonal (monsoonal) bans on riverine fishing became regular among fishery officials across India, who Day asked to share their comments for his 1873 Report[189]. Day particularly lamented the destruction and wastage of eggs, larvae, young fry, and fingerlings captured by small-meshed nets. He remarked that "…*the size of the mesh is decreased, weirs are augmented, and everything taken, no matter how small, as fishermen never appear to consider from whence the next year's supply is to come, but only the easiest method to take at the present time all they are able*"[190]. Both breeding fish and small fry were destroyed in great numbers, almost throughout the year, and throughout India.

For his Report, Day requested information about the smallest mesh sizes in fishing operation from officials across different provinces of India[191]. In the 161 replies he received, nearly all reported the use of extremely fine-meshed nets, except from Sind where only large meshed nets were reported to be in use[192]. These reports documented the use of mesh sizes from 1/32 inch to 1 inch, which would be from 0.7 mm to 25.4 mm, and up to $1^{1/4}$ inches or 32 mm[193], to capture small fish and juveniles of several species in inundated fields from the end of the flood-season to the early dry-season, across the country. Day's reaction to these data was his proposal of

[188] See Day, F.'s Report (1873: p. 48).
[189] In the Report Day meticulously summarized, with his objections and agreements, and what he thought of the officials's opinions about mesh size regulations in particular.
[190] See Day, F.'s Introduction to the Fisheries and Botany of Eastern India (1877: p.18).
[191] The provinces included Sind, Punjab, United Provinces, Bombay, Mysore, Travancore, Madras, Bengal, and Burma.
[192] According to officials, these nets were so fine that they would not allow the passage of even a mosquito, or an ant, or other articles, e.g. wheat, barley, red gram, peppercorn, ant, needle, quill, moth, pea-sized, and so on.
[193] See Day's Report (1873: p. 67-70), and Appendix Figure S1. All English units converted to mm.

implementing minimum mesh size regulations across India and Burma. However, most officials opposed his proposal, only very few expressly supporting the recommendation of minimum size restrictions. The responses that Day summarizes and critiques in his Report are fascinating, for they highlight the historical contestations over restricting small-meshed fishing gears, which harvested juveniles of larger species and all sizes of small fish species[194].

Day classified the reasons provided by fishery officials against minimum mesh-size regulations into nine broad practical and conceptual categories. Many officials thought that there was no need to interfere in age-old and traditional fishing practices. Others said that legal enforcement of minimum mesh-sizes would be unrealistic and nearly impossible. Some officials also said that instead of enforcing minimum mesh sizes, "*if anything would repress their destruction to any extent, it would be the forbidding to catch fish with roe…*"[195]. Still others invoked divine reasons against interfering with the laws of nature, or zoological reasons pertaining to the balance of abundance between smaller and larger, herbivorous and predatory, fishes. Not only that, minimum mesh size regulations, if enforced, would deprive *ryots* during difficult periods when they subsisted on small and nutritious fish. Most officials even felt that regulation was not needed, because the impact of all fishing put together would not add up to affect the abundance of the resource! Demand for fish resources was not as high to cause overfishing, and, if anything, fish distribution to remote markets was a greater issue than sustainability.

Day, however, persisted in spite of the opposition or the neutral responses to his proposal. He painstakingly commented, invoking complex ecological principles about fish growth rates, predation rates, and population dynamics, on why he did not agree with the nine reasons cited by officials, which he included in his Report. Day's forceful arguments about the prevention of overfishing and destruction prevailed, and he stressed on foresight for future sustainability than just the current status of fisheries. Although he was concerned about the capture of reproductive adult fishes, and suggested bans during the monsoon breeding period, his focus remained on

[194] Minimum mesh size regulations are such a common feature of fishery legislations globally, that it is hard to believe how many objections were raised to Day back in 1873. There is a whole new conceptual literature now on "balanced harvesting", which has challenged assumptions made by conventional fisheries biology for multi-species and multi-gear systems such as river-floodplain fisheries in tropical regions; see Kolding and van Zweiten (2011: pp. 267-297), for details of this concept. See Chapter 5 of this thesis, where gear-use conflicts are empirically analyzed using this conceptual basis.

[195] Day's Report (1873: p. 88). W.W. Hunter noted in his *Statistical Account of Bengal*: "Restrictions on the size of the meshes would be prejudicial, as many varieties of good fish never grow large" (1877: v.13, p. 227).

minimum size restrictions. Day's regulation policies did not stop at prescriptions. He also recommended the appointment of water watchers or 'bailiffs' to patrol rivers and regularly check and even correct instances of wrongdoing, through fines and penalties on the use of small meshed nets. He also proposed rewards to fishers for killing of 'vermin' animals such as crocodiles, otters, and porpoises (i.e. river dolphins), which he perceived as threats to fish stocks. Day's recommendations on mesh size regulations were fully included in subsequent fishery laws. They also remain highly contentious, if we appreciate the many objectives raised in 1873, and deserve to be critically revisited. The continuity of colonial fishery legislations post-independence has had important implications for current gear-use conflicts and even conservation discourses in the Gangetic plains[196]. Day's lingering impact on present-day fishery legislation in the Indian subcontinent is the best illustration of why history matters critically to our understanding of present conflicts.

Criminal tribes and castes

State control and penetration into fisheries management matters was not delinked from the empire's larger policy of surveillance and control of colonies, which caused criminalization of marginal and mobile people across the country[197]. In 1871, the same year as Day's appointment, the Criminal Tribes and Castes Act (CTA) was passed, to identify people who could be assumed as 'criminals by birth', which included 'ungovernable' and itinerant groups, including many fishing castes[198]. In the first edition of the CTA, fishing castes mostly from the United Provinces and Punjab were included. In Bengal, relatively fewer fishing castes were considered 'criminal', because more *Mallah* and *Nishad* boatmen were involved in river navigation in Bengal for the administration, and perhaps because there were substantially more castes – with heterogeneous and complex affiliations and inter-relations[199]. *Gonrhi* and *Mallah* boatmen, in particular, were among the more accessible and hierarchically

[196] In chapter 5 of my thesis, I analyze gear use conflicts, which form an overwhelming narrative between fishers using gillnets and mosquito nets today. What is curious is that, even though similar practices have been in use for at least 150 years, i.e. since the times of Francis Day, today's conflicts are over traditional use and illegality of fine-meshed nets, and concern themselves with their sustainability. It appears that to understand these conflicts better, one needs to start from Day's Report in 1873 for nuance and context. Note that the ichthyologist C.F. Hickling, in his 1953 Memorandum to the Secretary of State for the Colonies, Circular 118/53, had proposed deregulation of minimum size restrictions, which did not happen (also see Malasha, 2003: pp. 253-266). Hickling provided empirical evidence from multiple fisheries in the African and Asian Commonwealth countries of the time to show that there were no examples to show that such regulations had actually worked.
[197] See Jassal (2001, op. cit.).
[198] Nigam (1990: pp. 131-164)
[199] See Table 3.

'upper' sub-castes and were not included in the CTA list. Other *Mallah*/*Nishad* sub-castes considered 'lower', such as the *Binds*, *Chains*, and *Sorahiyas* were put in category B of the CTA list in 1913-14, in the United Provinces. Category B was for 'criminals by birth' who had 'reformed' themselves and were taking up agriculture activities[200]. Officials had also become suspicious of Mallah involvements in great river dacoities by helping bandits[201]. Turner's 1931 report on the status of criminal tribes listed *Chains*, *Binds*, *Sorahiyas*, *Kadheras*, and *Tiyars* as depressed, backward, and criminal classes[202]. The criminal listing of Mallah fishers was not geographically uniform, but usually arbitrary, both within and between the United Provinces, Bihar, and Bengal. However, the criminalization of many sub-castes intensified intra-caste group hierarchies and impacted the self-identification and self-image of the *Mallah* fishers and boatmen, at large[203]. This had particularly negative consequences for the 'lower' subcastes of the *Binds*, *Sorahiyas*, and *Chains*. British orientalist and anthropological interests and racial investigations and surveys significantly contributed to the aims of settlement and control[204], and triggered processes of linking ethnic identities with the governability of their subjects. The 1872 caste census was the formal beginning of caste-based surveillance[205], and decadal caste censuses were continued until 1931. From 1871 to 1931, many regional anthropological inventories and caste glossaries were compiled by British officials[206]. These researches used diverse approaches involving large field surveys, anthropological fieldwork, morphometric measurements, cultural ethnography, and racial classification[207], often with the stated motivation of understanding social stratification and class differentiation according to principles of so-called 'cultural evolution'[208].

[200] See Reeves (2002). As per Cohn (1959: p.106): Mallah and Kahar were also listed as minor cultivators in different tenancies, and worked on *khud-kasht* lands or held small pieces of land since the 1840s.
[201] See Mukhopadhyay (2002: pp. 968-986).
[202] See Reeves (2002).
[203] See Doron (2013: pp. 36-45, 57-141; 2010: pp. 753-783; 2009a: pp. 517-533), and Jassal (2001, op. cit.).
[204] See Pels (2008), and Fuller (2017: pp. 603-621).
[205] This is what Appadurai (1993: pp. 328-331) called the 'statistical panopticon' of the British administration, where caste offered a key to understand social difference as well as behavioural types of Indian subjects.
[206] e.g. see Sherring (1872), Rose (1892), Russell and Hira Lal (1916). Wise's (1883) *Notes on the Races, Castes, and Trades of Eastern Bengal* set a benchmark for regional racial and cultural investigations until the 1920s.
[207] see Wise (1883).
[208] See S. Mathur (2000: pp. 89-106), and Bayly (1993: pp. 20-75). Brown (2003) has argued that while the need to control, police, and alter "native behaviour" was always an important agenda of British colonial administration in India, ethnographic studies were also influenced by political doctrines on ideas of property rights on the one hand, and the evolutionary theories put forth by Charles Darwin and the German biologist Ernst Heckel ("ontogeny recapitulates phylogeny"). Ethnographic science during colonial rule thus led to teleological ideas about social progress, cultural backwardness, and racial and caste identitiy.

Colonial caste characterizations, physical measurements of land productivity, and gazetteer statistics that went beyond revenue figures, played a major justificatory role for the regulating and banning acts that virtually extended to every aspect of administrative control on India[209]. New ferry regulations and tenancy acts brought new rules for attachments of private fisheries and ferry-*ghat* revenues to landed estates[210]. These regulations caused the transition from a period of 'great confusion' since the PS, which was marked by hydrological and social uncertainties, to a period of 'criminalization and regulation' marked by the paranoia about decline and scarcity of the empire's resources, from the 1870s. The 1880s were a decade full of legal disputes and litigations over rights, illustrated in case of fisheries particularly by the Meherpore court cases of 1886 and 1887-88, which had complicated debates about customary fishing rights[211]. In one case, customary fishing rights were upheld, but these rights were rejected in the other. The Chief Secretary of the Government of Bengal in his *Notes on the Criminal law in India affecting the Julkurs* stated that *Jalkar* rights were always a part of the assets of landed estates as per the Permanent Settlement of 1793. Further, growing class stratification within tenant peasants after Bengal's tenancy laws in 1885 may have contributed to conflicts[212]. Conflicts were not articulated only by legal representation, they also involved protests by active trespass of private lands rights that had blocked customary rights to access fish in wetlands[213]. Faced with such uprisings, the government's focus shifted from revenue priorities towards policing, control, and further curtailments on any informal access. The state's response was to pass, in 1889, the Larceny Act (which included fish poaching), and the Bengal and Assam Private Fisheries Protection Acts, which had

[209] Hunter's volumes of "A Statistical Account of Bengal" (in 1877) and other gazetteers published in the 1870s and 1880s provided detailed information on state operations on every aspect of life.
[210] See Table 2.1: 1878-1885, for The North India Ferries Act, Bihar Ferries Rules, and Bihar Tenancy Act, 1885. Also see P. Robb (1988: pp. 319-354).
[211] The Meherpore court cases and related cases are discussed in detail by Reeves (1995: pp. 260-292), Sen (2015: pp. 25-180), Sen and Adelstein (2019: 48 p.). Verdicts of court cases at times mirrored seasonal and customary fishing rights, and at other times created new confusions about customary rights. Court case details are provided in references. Courts also held that fish were *Ferae Naturae* and could not be owned, but water could (see Reeves 1995, op. cit.). The Indian Easements (or Encasements) Act passed in 1882, allowed and codified some forms of customary access to fishers to public water bodies, use of roads passing through private estates, etc. But these acts were highly contested matters between estate ownership and those considered "trespassers".
[212] See Robb (1979: pp. 97-126).
[213] The 1870s and 1880s were marked by a series of tensions and rebellions by peasants and tribals against the British administration, mostly from conflicts over customary fishing rights. In this series, the *Polo Bidroha* by *Santhal* fishers in Pabna in 1873 occurred during a major famine, and nearly 300 "*Polowallah*s" descended over ponds and fished there, as a symbol of collective resistance against restrictions on customary fishing (Guha, R., 1983: pp. 125-134).

strong sanctions and punishments for 'unauthorized' fishing[214]. These interventions culminated in the passage of the Indian Fisheries Act (1897) to protect fish with mesh size and gear type regulations, seasons to avoid fishing, and so on. Yet, even after so many laws and policies, most stipulations and restrictions of the Act were difficult to implement. Overall, hydrological control for land revenue, uncertainty, confused and contradictory legislations, and complicated rulemaking in colonial fisheries worsened conflicts[215]. Not only that, regulations and bans incapacitated communities in organizing fisheries management through their own informal mechanisms. These outcomes caused greater diversions of river water, which triggered continued declines of fish resources, and further fragmentation of fisher caste and class-based identities.

Revisiting fishery matters: welfare, aquaculture, and co-management

The partition of the Bengal Presidency in 1905 brought in fresh cadastral and property surveys and remapping operations for the delimitation of rights continued till 1915[216]. A major focus of the surveys was to identify lands alluviated and diluviated by the moving Ganga[217]. During these operations, the issues of determining rights, ownership, and entitlements on fisheries returned to haunt the new administrations of Bihar, Bengal, and Orissa once again[218]. From the 1890s to 1910s, enquiry into legal principles for codification of fishing rights (territorial and incorporeal rights), individual or collective ownership, and rules of access (customary or formal) had received an impetus[219] with the passage of the Indian Fisheries Act of 1897. But the legal philosophy was difficult to translate and implement on the ground, especially with regards to customary and incorporeal rights, and conflicts between river navigation and public rights to fisheries[220]. K.G. Gupta's 1908 report focused on the

[214] The Larceny Act even gave rights to landed proprietors to summon or arrest fish poachers or anglers stealing fish from their private waters, and seize their fishing nets and gears, and other implements.
[215] See Bhattacharyya (2018: op. cit.), and page 21 above. T. Roy (2007: 33 p.) shows that these conflicts emerged from the economic rationalization offered by European ideas, and were not aligned with colonial politics around Indian custom.
[216] For examples, see Table 2.1.
[217] In 1921, despite many surveys remaining incomplete, the Alluvial Lands Act (1921) was passed, exactly 100 years after the previous Alluvion-Diluvion Act of 1822.
[218] Raye (1927, op. cit.), O'Malley (1924), Mitra, B.B. (1934).
[219] Detailed legal monographs were published in this time, with discussions about principles of riparian rights, alluvion-diluvion, and fishery, borrowed from Roman, English, American, and European legislature on the matter of property in fisheries. Monographs by Doss (1891: 422 p.) and T.N. Ghose (1930: pp. 455-477) were major studies on these matters.
[220] The basis of codes pertaining to territorial fishing rights was the Private Fisheries Protection Act of 1889, but incorporeal rights were open to legal interpretation. Despite T.N. Ghose (1930) citing that navigability and public right to fishery went hand in hand, public rights to fisheries were undermined nonetheless. Public rights to fish seemed to have been undermined by private riparian land rights.

importance of private fisheries, but also indicated that public rights to fisheries should be continued for the benefit of poorer fishers[221]. However, another official, K.C. De, in 1910, remarked that there were "no free fisheries except the sea", an observation indicative of poor implementation and legal confusions about public fisheries. T. Southwell, the inspector general of fisheries, felt that while customary rights and access of people to fisheries were taken away after the permanent settlement of Bengal, no attempt was made to bring new forms of control to manage fisheries, although he too upheld the importance of private fisheries, and derided 'free fisheries' continuing de facto in many riverine tracts of Bengal[222]. But his writings indicate a sympathetic approach towards the poorest fishers who were being systematically exploited by long chains of lessees, sub-lessees, middlemen, and traders that kept benefits shrinking as they went down to fish producers, even as intensive irrigation development continued to damage fisheries[223]. The Indian Fisheries Act regulations of closed seasons and minimum mesh size regulations were also not being implemented[224]. Southwell perceived that freshwater carp aquaculture development was particularly important to augment freshwater fish production in India[225]. Fish culture had existed as a small-scale activity of floodplain-dwellers in the Assam and Bengal provinces, and provided stable revenues to landowners and government. In the 1910s, developments in fisheries and aquaculture science had started informing a vision for fisheries as an industry[226], with not only revenue generation goals, but also a larger normative concern for food security and poverty alleviation[227]. At this time, there was considerable emphasis and interest on commercial development of marine and coastal fisheries[228], especially at Madras and Bombay.

[221] This period may be seen as the beginning of welfare interventions in fisheries.
[222] See Southwell, T. (1914: pp. 1-25, 1917a: pp. 2-4, 32-35).
[223] Southwell (1917b: pp. 739-740) that: "throughout India agriculture has been developed at the expense of the inland fisheries without even a passing thought for their well-being, and in this country it is hardly possible for these two industries to develop side by side."
[224] O'Malley found no closed fishing season in 1917, and stated that "inconceivable numbers of eggs of fish were being destroyed yearly". Such reports pointed to a 'hopeless' situation in river-floodplain fisheries, in terms of their productivity, conservation, and economic benefits.
[225] Southwell (2014: pp. 1-5, 6-24) conducted pioneering investigations on possibilities of captive breeding of Hilsa to augment supply, studied the economics of demand and price fluctuations in fish markets, and explored bio-economic aspects of enhancing fish productivity through identifying carps and other species for profitable aquaculture.
[226] As I show later in this chapter, aquaculture eventually became synonymous with inland fisheries in state policy and techno-science in independent India, and came at an expense to freshwater capture fisheries.
[227] Kent (1995: pp. 11-14), Payne (2000: 3 p.).
[228] Marine fisheries then were mostly artisanal, and involved near-shore netting and seining practices, and pearl fisheries. See Southwell (1917, op. cit.).

With attention getting devoted towards aquaculture and commercial marine fisheries, improving the state of governance or production of riverine capture fisheries remained difficult and was neglected[229]. New studies also criticized embankments that had disregarded Bengal's ancient flood irrigation and fishery practices[230]. With the decline in productivity becoming the dominant perception among officials, cooperative management of fisheries was suggested. Edye's 1923 report on fisheries of the United Provinces outlined how cooperative institutions and community entitlements could increase fisheries production to meet demand[231]. However, he proposed the *Jalkar* regime in Bengal as a model of cooperation between fishers, middlemen, and owners, which extended the problems of Bengal westward[232]. Village livelihood programs of the Congress, and rural engagements of the freedom movement, also enabled the formation of cooperatives and policies to support co-management[233]. Alongside such initiatives, private fisheries continued in the larger estates, and so did some free fisheries, in the deltaic regions. Compared to K.C. De's observation, new institutional 'mixtures' were now emerging in Gangetic fisheries[234]. It seemed that, by the 1940s, the British administration had appeared to somewhat surrender its obsession with perpetual revenues, after repeated, confused, and even partly successful stabs at establishing rigid capitalistic and contractual arrangements and structures on fluid fisheries[235]. But the impact of imperial policies nonetheless continued to hurt fishing and farming[236]. In 1943, a severe famine struck Bengal, with the Second World War already affecting the Commonwealth. Over three million

[229] Discontent among fishers was also perceived from continuing instances of "pond looting" and "fish poaching" in many regions (see Reeves 2002, op. cit.).
[230] British officials such as Willcocks (1930: pp. 59-71, 88, 91-93) described in great detail the practices used for flood adaptation by local people, who channelized flood waters into inundated rice-paddies and fish culture systems, especially during heavy floods. Willcocks (pp. 97-130) also criticized the suppression of such systems by embankments, dams, and intensive agriculture. He also expressed concerns about eutrophication, fish kills, and spread of malaria due to the poor management of floods.
[231] Reeves (2002, op. cit.). Edye also noted that in the United Provinces, fishing was mostly a part-time profession, and not a full-time activity as in Bihar and Bengal. In general, diversity of fishing practices also increases from UP to Bengal, correlated with the greater diversity and extent of riverine and deltaic features eastward.
[232] Ibid.
[233] The Bihar State Cooperative act (1935) and the Bengal Tanks Improvement Act (1939), for instance, provided local fisher households with rights and access to fishery ponds, tanks, lakes, and sometimes to river stretches, at the village block or district level.
[234] See A.C. Lahiri (1940). Report on the rights in fisheries in the main rivers of Bengal. Alipore: Bengal Government Press, Calcutta. Proceeding of the Government of Bengal, Revenue Dept, 1939, No. 22-23, File No. 8-A-80(5) OF 1938, No. 23829-30 LR, dated Calcutta, the 15 Nov. 1938. W.B.S.A., and Basu, M.C. (1946: p. 141).
[235] In 1940, the Floud Commission's report for Bengal proposed a formal abolishment of the PS and granting land ownership rights to tenants, with the removal of the control of intermediaries.
[236] R. D'Souza (2015: pp. 128-146) shows that even at this time, the British comprehension of rivers as projects of control in progress had not completely ended. It was regarded that the poor condition of rural Bengal's peasantry was just a fateful outcome of the unpredictable behavior of the region's riverscapes.

people were killed in the famine. The government then announced its Boat Denial Policy, by which thousands of boats were prevented from operating, which led to great suffering for fisher folk, and boatmen involved in local river navigation[237]. When India attained independence, fishers stood beholding the confusions about tenures and rights, uncertainty about customary modes of access, private control and oppression, and staring at baseline shifts and declines in riverine fisheries.

Changes in technological capacity in riverine capture fisheries

From the beginning of the 19th century to India's independence, i.e. in the nearly 150 years since Hamilton-Buchanan described several fishing practices in his journals, it is possible to track changes in nets, boats, and gears used in riverine fisheries. From the accounts that are available[238], it is evident that technological capacity and major fishing practices did not change in a big way during this period. The use of fishing nets and traps, such as the *Anta Jal*, was reported to be widespread from the medieval period[239]. Hamilton (1812) reported regular use of harpoons, baited hook-lines, and traps, and seine nets across districts of Bengal. Francis Day's and W.W. Hunter's descriptions (1873-77) of fishing nets and gears specified ranges of net mesh sizes employed by different fishers, from nets with mesh sizes less than 1 mm and similar to mosquito-nets, 10-25 mm seine nets, to above 330 mm gillnets and drag-nets called *Gochhel Jal*, a distribution that is mirrored in present fisheries. He reported minimum mesh sizes from 0.79 mm onwards to 25 mm, from his compilation of data from officials across provinces[240]. After the 1870s, Southwell's (1914-17) and James Hornell's (1924) reports also described nets with similar characteristics and mesh sizes. Meshes of seine nets (often made with multiple meshes) were reported by Hornell to be from 6 to 50 mm[241], and of multi-mesh gillnets mostly between 38 and 52 mm. Specialized gears such as brushpile traps (*Sirki Jal*) and carpet-gears (*Chatti Jal*) also date at least to the early 1800s.

[237] See Iqbal and Mukerjee (2011)
[238] For example, see Hamilton-Buchanan (1810: pp. 198-201, 290-294; 1812: pp. 300-303), Taylor (1840: pp. 44-45), Hunter, W.W. (1875-1877: vols. 1-20), Grierson 1885 (pp.11, 116, 125), O'Malley (1907a, b: p.8-9, 1917: pp. 249-251), Gupta (1908, op. cit.), Garrett (1910: pp. 91-95), Southwell (1917: 78 p.), Hornell (1924a, b, op. cit.), Rushbrook-Williams (1925: pp. 175-176). For related works, also see footnote nos. 238-241 and 37.
[239] See Reeves (1995, 2003), and refer to page 11.
[240] All English units are converted to mm, see Appendix Figure S1.
[241] These ranges closely overlap with presently mesh sizes of seine nets, between 8 and 25 mm (see Hornell 1924b).

Similarly, no significant changes were seen in the length, hauling capacity, or design of fishing boats (called *dinghis* or *denghis*[242]). Boat lengths from 6 to 8 m are reported consistently in the literature from 1800 onwards[243]. Balthazar-Solvyn's excellent illustrations in *The Boats of Bengal* (1824) indicate fishing boats of similar lengths across the Ganga and tributaries. Similar sizes, rib-work, and clinkering designs have continued till the present date[244]. Since the 1970s, major changes were seen in fishing gears, but only in net materials, not in the nature of use or mesh sizes. Materials have changed from plant fibers[245] (esp. hemp and flax), cordage, or cotton, to industry-manufactured nylon, plastic fibre, and synthetic monofilaments and multi-filaments. Nylon filament nets took off only from the 1970s, but spawn collection of wild Indian Major Carps (or IMCs: Rohu, Catla, Mirka) was done with fine nylon meshes since the 1950s[246]. In the early 1970s, most nets in use were still woven from cotton fibre, with the leading lines made of cotton, jute, or hemp twines, or coir[247]. The use of monofilament gillnets increased from the 1970s and synthetic mosquito nets from the 1980s-90s, but the general use of small and large-meshed nets continued. Today, nylon and synthetic mosquito nets are used widely across the Gangetic plains for a range of nets and traps, which is a major transition in terms of greater net disposability, soaking and drying times, and injurious trapping of fishes[248]. With regard to boats, small oared boats remain the mainstay of fishing, although motorization with outboard engines has increased only over the past decade.

These trends show that technologies of harvest in Gangetic fisheries have not changed significantly, barring net materials, in two centuries. This is important, for their relative technological inertia sets riverine fisheries apart from marine systems, where the extent of industrialization by trawlers and purse-seining vessels underscores the well known narrative of conflict between artisanal and industrial/commercial fisheries[249]. Interestingly, conflicts over gear-use, which form a major narrative even

[242] Hamilton-Buchanan's (1807, 1812) described *dingis* (or *donghas*) as the fishing boats used in Bhagalpur and Purnea.
[243] e.g., see Williamson (1810, op. cit.)
[244] Based on the accounts of Hornell (1920, 1924a, op. cit.), George (1971), CIFRI (2004: 74 p.), Dey (2012: 252 p.), Varadarajan (2016: 318 p.), and my own measurements. Hornell provided detailed descriptions of boat designs and fishing gears, indicating Egyptian-Mesopotamian influences on boats of the Indus-Ganga plains, and Chinese influences increasing in Bengal and Assam.
[245] Hemp fibre nets would be dyed in Gab (*Diospyros glutinosus* or *D. malabarica*).
[246] Rahman (1946: 37 p.), Datta Munshi et al. (1979: pp. 153-157), Rahman (2008: pp. 127-140).
[247] See George (1971).
[248] Kelkar (2008) found that gillnet mesh sizes had also reduced after 2000, with reduction in larger fish. Fishers commonly refer to these nets as "Current Jal" and "Hawa Jal" for their lightness and airiness.
[249] See A. Subramanian, Shorelines (2009: pp. 171-205) for marine fishery conflicts and development politics along the Tamil Nadu coastline.

in Gangetic fisheries, place the blame on gears such as mosquito nets for depleting yields[250]. However, such nets seem to have always been in use[251] even before they were declared illegal by fishery legislations. Modern debates on fishery legislations, and even current discourses about overfishing, or indiscriminate fishing, may do well if they engage with historic trends that indicate very limited change in technological capacity and the diversity of fishing practices[252].

Period 3. India's fisheries: 1947-2019

New laws in a new India?

Independent India inherited fishery legislations, as it did many colonial policies. The new nation also attempted to bring about policy reforms, especially for land redistribution, and new institutions for management. The Bihar Land Reforms Act was passed in 1950, and was followed by the Zamindari (Abolition) Act of 1952. But the bill for abolishing *zamindari* control met with severe opposition from many elected landowning representatives, especially in Bihar's assembly[253]. With the passage of the act, the status of the *Panidari* in Bhagalpur also became contested in the court of law; however, courts upheld the right of the *Panidars* to continue to extract fishery revenues 'attached' to their riparian rights[254]. Post 1950s, fishers in Bihar and Uttar Pradesh had different experiences of land reforms and reallocations. Fishers in UP received land rights to cultivate small parcels since the 1960s-1970s. In Bihar, however, most fishers had remained landless, and solely dependent on river fishing[255]. Fishers in Uttar Pradesh likely suffered more from the construction of more major dams and barrages, but got land rights that may have buffered them.

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[250] I study the linkages between fisheries biology and social perceptions behind these conflicts in thesis chapter 5.
[251] Over two centuries, it is unambiguous that the diversity of fishing gears, involving selective and unselective nets for fish species and sizes, active and passive gears, fixed and drifting gears, small and large nets, handheld and boat-drawn nets, hooks-lines, harpoons, etc., has been in place for several generations, e.g. see Kibria and Ahmed (2005: pp. 43-48), Ray (1998: pp. 198-226). Overall, fishing hooks and lines were allowed free fishing, but fishing with traps or nets was taxed.
[252] Pokrant et al. (2004, p. 114) remind us that recent writings on fisheries issues are "…*written within a modified modernisation paradigm which contrasts a traditional fishery system, sometimes assumed to have existed since time immemorial, with that of a modernised one which is said to have emerged since the 1950s. Thus, the traditional system is treated in a largely ahistorical manner in which a set of institutions associated with the traditional sector is assessed in terms of its adaptability to modern conditions. Where historical information is provided it usually consists of brief summaries of a highly generalised nature describing some particular event, person, or state policy, which shaped present circumstances. These summaries rarely go back to colonial times*…"
[253] Sharma, S. (1985: pp. 60-81) shows that *zamindari* abolition was opposed by landowners, and the abolition failed to achieve agrarian reform in Bihar, in spite of the efforts and plans of the Congress towards land redistribution.
[254] See details in footnote nos. 23, 130, 162, 213, and others above.
[255] Findings from a large-scale survey by Kelkar (2012).

Riparian principles of water ownership were reemphasized by judicial assessments even in independent India[256]. The Indian government also repealed the Criminal Tribes and Castes Act in 1949 and abolished it in 1952. But the Habitual Offenders Act continued the surveillance of certain groups from earlier 'criminal' castes. This led to de-notification, but not necessarily to de-criminalization of these groups by the state or society[257]. State fisheries acts were legislated for newly formed Indian states of the Gangetic plains. They drew from the Indian Fisheries Act (1897) but included local differences in harvest control rules, mesh regulations, spatial and seasonal bans, etc.[258]. In 1959, the Central Inland Fisheries Research Institute (CIFRI) was set up as a full-fledged research institution at Barrackpore in West Bengal.

Dams, barrages, embankments, aquaculture

India's dam-building spree from the 1950s to the 1980s had massive impacts on riverine fisheries production. Several barrages and dams were built on tributaries of the Ganga in this period. Embankment constructions also intensified, especially after major floods were witnessed in Bihar and Assam between 1948 and 1951[259]. Embankments could, however, only control the lateral spreading of floods. Multi-purpose barrages were thus designed on tributaries of the Ganga with the primary objectives of flood control and irrigation, and minor hydropower development. Dam building for intensive irrigation, especially in Punjab, Haryana, and Uttar Pradesh was deemed essential to the Green Revolution's objective of boosting agricultural production and food security. A global effect of increase in farming production during the Green Revolution has been seen in more marginalization of fisheries, local food crops, and wild plant foods[260] from markets. Similar effects were seen in the Gangetic plains, as related increases in irrigated land area came with direct and massive costs

[256] See Puthucherril (2009: pp. 99-131), Upadhyay (2009: pp. 134-148).
[257] Among fishing sub-castes, the *Bind* or *Bin*, for instance, still carry the tag of a tribe whose occupation is of stealing and petty crimes. This is not a perception only held by peasants, but even by other 'upper' fishing sub-castes. See details in chapter 6 of the thesis.
[258] Government of Bihar. 2006. Bihar Fish Jalkar Management Act (Bihar Act 13), with amendments till 2010, 12 p., and Bihar Fisheries Policy, 2008, 23 p., Directorate of Fisheries, Animal and Fisheries Resources Dept., Govt. of Bihar, Patna, India. Government of Uttar Pradesh. (1948) Uttar Pradesh Fisheries Act. UP Act No. XLV of 1948, and the UP Fisheries (Development and Control) Rules, 1954, Dept. of Fisheries, Lucknow, Uttar Pradesh, India. 18 p.,West Bengal Inland Fisheries Act, 1984, with amendments till 2018, Dept. of Fisheries, Kolkata, Government of West Bengal. (2011). Also see (Dubey and Ahmad 1995: pp. 21-25).
[259] Ray, K.B., The Economic Weekly (1954: pp. 1121-1126) who argues for alternatives to embankments for flood management. State and national governments failed to completely overcome the deficiencies of poor embankment upkeep under British rule. See P. Singh (2008: pp. 239-260).
[260] See Pingali (2012).

for riverine capture fisheries[261]. Flow regimes were significantly altered and base flows (dry-season river flows) reduced by the dewatering and divertive effects of dams and canals. These changes decimated stocks of several commercially valuable fish species, especially Indian Major Carps or IMCs, whose breeding success was badly affected[262]. As river flows were being increasingly regulated and modified, CIFRI also conducted extensive prospecting collection drives of wild river spawn of IMCs to supply aquaculture seed farms, hatcheries, and pond-based aquaculture[263]. Spawn collections, together with dams and barrages, inflicted serious damages on wild IMC stocks[264]. However, with aquaculture development being a priority action since the 1920s, and also a primary objective of CIFRI, it may be said that this decline did not really matter to the government – rivers were in fact used as stocks only to feed the freshwater carp culture boom in the late 1970s, especially in Andhra Pradesh and West Bengal in India, and a similar process was afoot also in Bangladesh[265]. Rivers of the Gangetic plains were used as mere 'stocks' for carp spawn collection to feed this new drive for intensive fish farming across the Indian subcontinent.

The Farakka barrage on the Ganga River was constructed in 1975 just upstream of the India-Bangladesh border, ostensibly to rejuvenate the silting port of Calcutta[266]. Within a few years, the barrage effectively caused the collapse of upstream fisheries (along the Ganga in Bihar and Uttar Pradesh) of migratory clupeid fish Hilsa (*Tenualosa ilisha*) and other prized species, such as freshwater shrimps (*Macrobrachium* spp.)[267]. Major reductions in river flows allocated along the Ganga River (called Padma downstream) from Farakka also led to a decline in the flood rice-

[261] See CIFRI reports (1951-52 to 2011-12), and Sinha et al. (1999: 325 p.).
[262] The decline in IMCs, the most preferred food fishes across the Gangetic plains, is regarded as the primary damage caused by dams and barrages. However, intensive collections of wild IMC spawn for aquaculture also accompanied these declines. See Shetty (1971), Shetty and Malhotra (1983: 33 p), Jhingran and Ghosh (1978: pp. 141-162), Sinha et al. 1999, Marmulla (2001; pp. 22-23, 115), Das et al. (2007: 120 p., 2013: pp. 395-407), Vass et al. (2010, op. cit.).
[263] Several reports, e.g. David (1959: pp. 327-341), CIFRI annual reports (1956-57 onwards) show spawn collection statistics across different rivers, and reported major declines.
[264] Increasing pollution loads from agricultural runoff and untreated industrial and domestic sewage entering rivers also contributed to IMC declines (Sinha et al. 1999, Sinha and Khan (2001: pp. 493-504), Das et al. (2007: 120 p.). According to CIFRI's estimates (see Jhingran and Ghosh (1978, op. cit.), Datta Munshi et al. (1979: pp. 153-157, Jhingran and Sugunan (1988: 79 p.) Ray 1998: 241 p.), the percentage of IMC spawn reduced from 80% to 30% of the total spawn collections, from the 1950s to 1980s. Shetty and Malhotra (1983: 33 p.) reported that barrages on tributaries of the Ganga had led to a collapse of viable carp spawn resources.
[265] Kumar et al. 2003, Katiha et al. 2005: pp. 237-264, Rahman (2008: pp. 127-140), Belton et al. (2016: pp. 196-206), Hernandez et al. (2018: pp. 456-468).
[266] With the independence of Bangladesh in 1971, the Farakka barrage construction was also a key element of geopolitical strategy, see Nandy (2001: pp. 709-731), Adel (2001: pp. 356-368), and Gyawali (1999: pp. 443-452).
[267] See Adel (2001, op. cit.), Payne et al. (2004: pp. 229-250), Vass et al. (2010, op. cit.), Kawser and Samad (2016), and Dey et al. (2020: pp. 140-154).

paddy systems of northwestern Bangladesh[268]. The Farakka barrage also induced environmental distress migration of fishers from Bangladesh to India in the 1970s, especially in West Bengal, Assam, Bihar, and central India[269]. Migration of fishers from "eastern Bengal" had consequences for local ethnic conflicts between them and local fishers in the Ganga and Brahmaputra plains, since the 1947 partition[270].

The conditions of fisher folk dependent on degrading capture fisheries, and witnessing increasing conflicts, also worsened with the continued neglect by Indian government. With the marine fisheries sector getting industrialized from the 1960s, and with the boom in freshwater fish aquaculture in the 1970s, riverine capture fisheries almost vanished from policy priority. Aquaculture production that had exponentially grown at the cost of river fish stocks, also came back to outcompete river fish contributions to local markets. It captured over 60% to 80% of the market share in the coming decades[271]. Intensive aquaculture development also involved repeated and unchecked introductions of many alien (foreign) species of food fish, and an increased use of hormones, steroids, weedicides, and antibiotics[272]. Aquaculture has been justified by fishery scientists for its contribution to food security, provision of cheap protein to rural communities, and benefits to small-scale cooperative producers[273] but its multiple negative environmental impacts[274] have not

[268] See Mirza (1998: pp. 613-630), Adel (2001, op. cit.), Kawser and Samad (2016: 16 p.) Banerjee (1999: 29 p.), Dai et al. (2009: pp. 2773-2792) estimated a significant reduction of 50% to 60% in downstream flows since 1975.
[269] See A. Swain (1996: pp. 959-973), M. Alam (2003: pp. 422-438).
[270] Bengali Hindu fishers were settled along riparian lands in the Gandak and Ganga plains of Bihar, and in Assam and West Bengal (see Sengupta, 2017: 28 p.). Local ethnic conflicts were related to their "refugee" status and their coming from 'East Pakistan', but more importantly, was related to the highly commercial and intensive fishing practices of Bengali fishers, which included the use of huge mosquito nets, seine nets, as well as large gillnets and drag-nets. After the zamindari abolition act was passed in Bengal after India's independence, a raiyatwari settlement was instituted in both East and West Bengal, taxes were reduced, and local revenue officials assisted peasants, although tenancy rules continued (see van Schendel 1991: pp. 184-191). Alam (2002: p. 256) indicates the years under military rule in Pakistan (1958-1971) to be treated by fishers in Bangladesh as continuation of colonial rule, with insecure tenures (see Rashid 2005: pp. 57-65, and van Schendel 1991, op. cit.), and intensification of state-controlled fishery rents. Most fishers moved to fishing in floodplain wetlands after 1947 (Sen and Sen 1989: p. 38). In Assam, Bengali fishers were the ones involved in active fishing in the main channels of rivers, while local Assamese fishers used rice-fishing practices in the flood-recession period (pers. comm. with Prof. A. Saikia, and Saikia, 2019: pp. 142-155).
[271] In the 1960s, it is clear that river fish dominated market catch shares, e.g. see P.C. Roy Choudhury (1962: pp. 202-204). But by the 1990s, pond fish were dominant across markets (Payne and Temple 1996: 154 p.). Kumar et al. (2003: pp. 3-4) report that India had become the second largest "inland" fish producer in the world, by aquaculture production. Even today, 15%-21% of global inland capture and culture-based fishery production comes from India (Funge-Smith 2018, FAO 2020, Ainsworth et al. 2021).
[272] Aquaculture contributed significantly to river pollution and the entry of biochemical inputs into natural water bodies, especially rivers and wetlands (Vinci et al. 2003: 216 p., Das et al. 2007). More seriously, the entry of invasive alien species of fish into rivers with depleted flows, especially in Uttar Pradesh (Sarkar *et al.* 2012: pp. 251-272). Invasive fish species outcompeted native species in most of these rivers, including at the Ganga at Allahabad.
[273] See Katiha et al. (2005: pp. 237-264), Dey and Prein (2006: pp. 21-27), Ramakrishna (2007: pp. 12-18), Jha (2009), Belton et al. (2016: pp. 196-206).
[274] The promotion of aquaculture in semi-arid regions such as Andhra Pradesh and Rajasthan has meant a major dependence on groundwater resources extracted for maintaining ponds, e.g. see Adhikari et al. (2017: pp. 835-

always been included in cost-benefit analyses[275]. Aquaculture has thus totally altered ecological and economic baselines of freshwater fisheries[276]. Riverine capture fisheries were thus downgraded – by dams ridding them of water, and by aquaculture ridding them of river fish and space in the market[277]. Fishers who exited from river fisheries have not been able to find alternative occupations in aquaculture[278].

Cooperatives, institutional failure, and fishers' movements

Although cooperatives existed in Bengal and Bihar since the 1920s, the cooperative movement expanded to the village- and block-level significantly by the 1960s[279]. Cooperatives extended to all water bodies on paper, but in keeping with the domination of aquaculture, most cooperatives restricted themselves with pond fisheries. Further, rivers and floodplain wetlands were also leased out directly by private landowners or by state fisheries departments through auction-lease systems, further narrowing the reach of cooperatives. Thus, state control of auction leases on river-stretches did not allow for effective devolution and decentralization of the power to allocate fishing rights through democratic processes[280]. Further, contestations over pre-*zamindari* fishing rights and legal tussles over riparian land properties significantly interfered with cooperative functioning[281]. Local power hierarchies, caste and class differences, corruption, elite capture, and violence led to a systematic weakening of any efforts by local fishers towards collective action[282]. Cooperative

841), Abraham et al. (2010: pp. 41-48). The impacts of consumptive water use on pollution are direct. Capture fisheries do not have impacts on water extraction due to their non-consumptive water use.

[275] See McIntyre et al. 2016 (pp. 12880-12885), Barange et al. (2018: 268 p.).

[276] See Payne et al. (2004: pp. 229-250), and Kelkar (2012, 2014, op. cit.).

[277] After the construction of the Kanpur barrage in 2000 and Tehri dam in 2006, river fish production has dwindled further (see Payne et al. (2004: pp. 229-250), Vass et al. 2009, 2010, op. cit.). All these changes have also triggered a gradual process of exit of people from Gangetic fisheries (Kumar and Bhagat 2012: pp. 134-144). Belton et al. (2014: pp. 77-87) find a common pattern across the region that they describe as "Faltering Fisheries, Ascendant Aquaculture". James Scott (1998: p. 353) treats this as a conflict faced by marginal communities from state simplification of ecology to agriculture.

[278] See Narayanan, S. (2016, op. cit.).

[279] The objective of fishery cooperatives was to work as a bridge between the state departments and fishing communities, with participation of local fishers in co-management, see Deacon (2012: pp. 258-277).

[280] See Narayanan (2016) for more insights on this issue.

[281] These tussles also represented conflicts between state institutions, feudal interests, power hierarchies, which limited the formation of community-based institutions and plunged cooperatives into elite capture. See Clements (2005: pp. 3-29).

[282] The High-Powered Committee on Cooperatives set up by the Govt. of India (2009: p. 12, 21-23) reported that very few fishery cooperatives across large parts of Bihar and Uttar Pradesh were able to function autonomously; also see Tyagi (2013: pp. 90-93). Further, at the local level, caste and class differences were sustained, affecting cooperatives, and maintaining severe corruption, elite capture, and grabbing by politically powerful actors (see Raheja, 2014: pp. 497-522). Also see Pankaj and Singh (2001: pp. 407-428) for a closer look at how processes of rural self-governance contributed to legitimizing the power of rural elites. Kelkar (2012: 40 p.) estimated from interviews and surveys that less than 15% of existing cooperatives in UP and Bihar were likely to be effective for fishers' participation in decision-making, and all of them were concerned with fish culture ponds.

policies also ignored or remained aloof to the historical context of fishery conflicts and did not factor in corrective measures to halt continued social discrimination in many regions of the Gangetic plains.

In the 1970s and 1980s, agrarian conflicts were witnessing horrific incidents of violence against *Dalits* and many low caste groups[283]. Peasant resistance against landlords and the threat of dacoits triggered agrarian violence in the Gangetic floodplains[284]. Dacoits controlled access to floodplain lands for their political bosses, many of who were powerful landlords or *Panidars* (fishery lessees). They also extorted rents from fishers and other floodplain-dwellers, and functioned as institutions in their own right, creating their own regimes of control through the threat of violence[285]. This functioning was a departure from the origins of many gangs due to agrarian distress in the past decades. Resistance from peasants and fishers was mainly through non-violent local struggles. Their movements appealed to the state for a secure space to earn their livelihood rights[286]. The response of state governments was often to underplay caste violence by citing threats from collusions of village protesters with Naxalite extremism[287]. In this time, the use of violence, physical assault, and crimes by gangs, against fishers along rivers, had reached extreme levels[288]. Pollution in the Ganga had increased, and the Ganga Action Plan was initiated in 1986. In 1982, the Government of India also declared the Ganga as a National Waterway to revive water transport. River fisheries suffered from declining fishery yields and the threat of caste-based violence against fishers.

At this time, the *Ganga Mukti Andolan* (Campaign for Freeing the Ganga; henceforth GMA) emerged as a fishers' movement against the *Panidari* by the *Jal Shramik Sangh*, Kagzi Tola, in Kahalgaon, Bihar. From 1982 to 1991, conflicts between *Panidari* contractors and the GMA increased[289]. In this time, the GMA became a major movement involving not just fishers, but also students, activists, and

[283] See Chaubey (2006: pp. 3-17), Sharma, M. (2006: pp. 12-41), Shah (2014: pp. 605-614), and Ankit (2018).
[284] Anon. (1986) Bihar: Peasants, Landlords and Dacoits', Economic and Political Weekly, 21(34), 1531-1535.
[285] Violence by *Yadav* and *Gangota* gangs was widespread in Bihar and Uttar Pradesh (see Rajesh 1995: pp. 16-68, Chaubey 2006, op. cit.), and Prasad, P. (2014: pp. 847-852). Hobsbawm (1969: p. 90) gives the example of the dacoit and freebooter Gajraj who was appointed in the 1830s to collect tolls and control the ghats and ferries over the Chambal River.
[286] Though mostly local in scope, many such struggles were influenced by regional and transnational movements for rights, e.g. see Sinha, S. (2014: pp. 364-389), Dwivedi (2001: p. 11).
[287] See Chaubey (2006, op. cit.), Kumar (2009: pp. 8-11).
[288] Over a hundred fishers and floodplain dwellers were murdered in 1981-1990 by gangs (also see Sharma 2006: pp. 12-41).
[289] See Rajesh Raj (1995: p. 63-66) indicate that one part of the conflict between Kahalgaon fishers and the *Thikadar* or *Panidari* contractor was that Bengali fishers were brought in to fish.

women[290]. The GMA also appealed to *Dalit* unity to overthrow the *Panidari,* and "free the Ganga", which it finally achieved in 1991[291].

The Mandal Commission report recommending caste reservations was implemented in 1989-90, the new wave of caste-based electoral politics, and earlier social movements by *Dalits* and other backward castes since the 1970s, contributed to this outcome[292]. The newly elected Lalu Yadav government decreed that all flowing waters within Bihar could now be fished as open-access under the "*nishulk shikaarmahi*" or free fishing scheme. In Bihar, the shift to open-access followed a shift towards private auction-leases or *Pattas* on river stretches in Uttar Pradesh in the mid-1980s[293]. Fishers in Bihar believed that the free fishing scheme would set right the historic injustices fishing communities had faced. However, in spite of the end of the *Panidari*, the violence and threats have continued. Gangs took control of the open-access fisheries, and with local criminal elements, formed a 'fishery mafia', which led to an intensification of fishery conflicts since 1991[294].

The GMA ended private feudal control and symbolically reclaimed river space for fishers. But, with the rapid degradation of fisheries by the 1980s, river fisheries had perhaps not remained important for the state, or for private interests[295]. The GMA also could not create community-based institutions to secure this space from mafia gangs[296]. Today, fishers appear rather disillusioned by the GMA, with many claiming that leaders of the GMA used the sacrifices and contributions of fishers to further their own political ambitions[297]. A result of the ineffective symbolism of the GMA[298] is seen in that fishing auction-leases in floodplain inlets, and fishers' access to the main

[290] See Bharti (1991: pp. 111-112), Gupta (1993: pp. 22-24), Sharma (2006, op. cit.).
[291] Ibid. Also see Mukul Sharma (2017: pp. 195-201).
[292] See S. Bagchi (2018: pp. 563-565) for an analysis of caste-based small party politics. Also see chapter 6 of this thesis.
[293] Kelkar (2014a, 2018, op. cit.) describe how these opposing trends in the two states did not matter to outcomes for fishers, as conflicts and criminal control continued, and oppression and corruption grew.
[294] My thesis chapters 3, 5, and 6 closely examine these conflicts and also discuss the connotations of the words used, such as "mafia", bandits, dacoits, etc.
[295] But, court cases were filed even after the declaration of open-access fisheries in flowing waters (e.g. Abdul Ghani Khan and others vs. State of Bihar, 1991).
[296] See Gupta, C. (1993, op. cit.), Kelkar (2014a, op. cit.)
[297] See chapter 6.
[298] Mukul Sharma, in *Caste and Nature* (2017: pp. 195-201) describes the GMA in a nostalgic manner, and highlights its efforts towards organizing subaltern voices and reclamation of space. But the story of the aftermath of the GMA has not been told, and has prevented critical analysis of the movement's impact. I have seen in my own interactions with GMA leaders and members since 2007-08, that the GMA is organized mostly around nostalgia and rhetoric than being reflective about actually improving the conditions of fishers, who are becoming increasingly detached from the movement. According to Goldman (1998: pp. 26-27), the symbolic importance of "free access" may not always appeal to the formal logic of common property resource management around specific localities.

river, is under criminal control. Irrespective of this outcome, the GMA did contribute to more recent caste-based politics seeking more representation of Mallah fishers[299].

Riverine fisheries post-1991: markets, conservation, and development discourses

After 1991's market reforms, economic liberalization saw rapid changes, increased connectivity with new markets, and substantial rises in selling prices[300]. Fisheries of the Gangetic plains were also influenced by these changes. Semi-formal market access of fishers appears to have increased despite dysfunctional cooperatives, intensifying criminal control, exit of fishers, low contributions of river fish to markets, and the general apathy towards riverine capture fisheries[301]. The ability to sell to wholesale hub markets, with improvements in transportation, post-harvest processing, and trading activities have also helped fishers seek work in supply chains. Increased access to markets has lengthened supply chains and changed the dynamics of fishing intensity across the Gangetic plains. In particular, the development of a regional hub market at Siliguri[302] in 1992-93 probably concentrated fishing effort especially on small-sized fish, which are highly preferred in West Bengal and in Northeastern (NE) India, both as fresh and dried fish. Later, improved connectivity with NE India has exerted a stronger pull on dried and fresh river fish from Uttar Pradesh and Bihar, which now have their biggest sink in Assam. New machine-made nets imported from Indonesia, China, and Thailand had entered local fishing markets and settlements from the 1980s onwards, but their penetration into Bihar was likely post 1991. According to fishers as well as traders, these changes not only caused significant depletion of fish resources but also contributed to rising conflicts between locally limited subsistence fishers and other fishers who were already linked to new market sinks and had capital, through contractors, transporters, and ice- storage providers. Small-sized fish are caught mostly with mosquito nets, seine nets, and huge barricades across flood channels, which are illegal and run with the support of

[299] Discussed in depth, in chapter 6.
[300] Based on data and communications with Subhasis Dey, as part of our collaborative monitoring projects.
[301] Kumar et al. (2003: pp. 3-12, 59), Davis and Ruddle (2012, op. cit.), Sharma et al. (2013: 21 p.), Kelkar (2014b, op. cit.).
[302] The Siliguri hub market has a daily turnover of 15-20 tonnes per day, of which river fish contribute nearly 20% to 25%. It directly employs nearly 2000 people, excluding those involved in transportation (pers. obs.). Prior to Siliguri, Kolkata, Maldah, and Farakka were the major markets for catches from across the Gangetic plains, and they remain significant sinks even today.

criminal gangs. These market links increased monetary investments by mafia groups into river fishing, which has strengthened their grip on fisheries[303]. These changes are likely to be causing severe depletion of fish in the Gangetic plains, through their "boom and bust" operations[304]. In spite of improved market connectivity, access to fishing areas remained insecure, with fishing rights undefined and uncertain.

In the 1980s and 1990s, the implementation of the Ganga Action Plan, along with economic change, brought fishers closer to discourses of environmental and biodiversity conservation from university-led research and civil society outreach campaigns. There were also new discourses on issues of rural social justice in relation to economic liberalization and its impacts on land rights. In many regions of the Gangetic plains, grassroots movements to fight for rights and against social injustice sprung up and continued post 1991[305]. Fishers also interacted with state-sponsored projects and plans for rural development initiatives in the Gangetic basin. These experiences and encounters since the 1990s, irrespective of their outcomes, have had profound influences on the individual and collective identities of floodplain fisher communities[306]. Alignments of fishers with conservation and development opportunities have also intensified local conflicts and politics, which are now over issues of illegal gear usage, grabbing or corruption by staff of local forest and fisheries departments, and the differential compliance and involvement of fishers towards biodiversity conservation programs[307]. Severe conflicts over gear usage, especially against the use of mosquito nets, have been an overwhelming narrative of most fishers in the last two decades[308]. In a historical sense, it should suffice to say here that the interactions of fishers with markets, conservation initiatives, and development programs have had major implications for micro-level identity politics. This is due to the emergence and articulation of new group identities: 'conservation-friendly' and 'unfriendly' fishers, 'traditional' and 'non-traditional' fishers, 'sustainable' and 'unsustainable' fishers, and so on. Fishery conflicts between fishers and state and private interests have now deepened divides within fishing communities. Sub-caste level identities within *Mallah* and *Nishad* groups are rapidly generating

[303] See chapters 5 and 6 of my thesis.
[304] See Kelkar and Krishnaswamy (2014: pp. 58-80).
[305] For example, in the Kosi, the Barh Mukti Abhiyan's campaigns against dams, embankments, and river-valley projects, continue to engage with a range of local issues of post-colonial social and environmental justice. See Thakur, M. (2014: pp. 212-228).
[306] See Doron (2013, op. cit.), Jassal (2001, op. cit.)
[307] See chapter 6, and Kelkar (2018: pp. 9-33).
[308] See chapter 5, and parts of this chapter for details.

new caste and class hierarchies and political group affiliations within fishers. There is now greater representation of fishers in caste identity-based party politics[309]. While these changes happen, the steady exodus of fishers from rivers continues. A scramble for political space appears to have made fishery resources in question peripheral to the present articulations of fishery conflicts and demands for justice[310].

In 2019, a draft National Inland Fisheries and Aquaculture Policy (NIFAP) was formulated by the Ministry of Agriculture and Farmers' Welfare, Govt. of India, and its implementation and objectives are still being discussed. The NIFAP did not explicitly recognize fishery conflicts over rights and access in fisheries[311], but focuses mostly on economic development of aquaculture. In 2020, the NIFAP was dissolved and its objectives merged into an overarching Draft National Fisheries Policy (NFP), which included both marine and inland fisheries and aquaculture together. The NFP has mentioned the problems and uncertainty around tenure systems in inland capture fisheries and the minimal right to water for fishing communities. However, the decision to have an overarching policy further limited the scope for riverine capture fisheries. The impacts of these policies on the future of riverine capture fisheries now need to be carefully tracked, against their historical background.

Historic transitions: rights, practices, and identities

In my subsequent thesis chapters, I study the conjoined and changing material and symbolic dimensions of fishery conflicts in the Gangetic plains[312], in light of some broad historical transitions that I summarize below. After the PS of Bengal in 1793, fisheries came under greater private control and rigid boundaries, in most parts of the Gangetic plains. Some fisheries on large rivers, tidal rivers, and deltas remained public, but riparian rents extracted from fishers appear to have been a regular feature. Confusions over floodplain land-water boundaries and resulting hydrological

[309] For an overview of caste conflicts in Bihar in recent years, see Jha and Pushpendra (2012: 33 p.). See Sahay (2004: pp. 113-136) for an explication of how Bihar's caste politics has sustained and transformed post-independence in India. Also see Banerjee-Dube (2014), who argues that in spite of dissent against caste discrimination, movements of caste-based resistance find it hard to transcend caste identities and move from the local to the global, and acknowledge contradictions involved in their own focus on culture and identity, which were once indicative of colonial categorizations.

[310] Williams and Mawdsley (2006: pp. 660-670) emphasize the importance of political recognition and aspirations of the most marginalized people to link their struggles with state politics and power in their appeals for environmental justice.

[311] See Kelkar (2019: pp. 28-33) and National Platform for Small-Scale Fishworkers-Inland (2019: 11 p.) for critical analysis and overview of the draft NIFAP. It has been argued that the NIFAP risks increasing private control in inland fisheries, at the cost of the rights of small-scale fishers.

[312] Also see Choudhary et al. (2015: 30 p.), Kelkar and Krishnaswamy (2014: pp. 58-80), and Kelkar (2018: pp. 9-33) for descriptions of these conflicts that summarize their evolution in the last few years.

uncertainty eroded the customary modes of access of fishers to river-floodplains, increasing conflicts over fishing rights. With the shift from social status to economic contract in relations of land-based revenue production, fisher identities witnessed major changes. Many fishing castes became homogenized into the economic category of peasants or *ryots*, and allied boat-ferrying castes came under the category of contract workers and labour providers in river-based trade and navigation for the colonial administration.

In the 1870s, with inland fisheries coming directly under the control of the British administration and the creation of the Imperial Fisheries Department, fishers' identities were transformed further on the basis of not just caste affiliations, but also based on legal compliance and ecological behavior. Caste enumerations in the Census of 1872 and the passage of the Criminal Tribes and Castes Act in 1871 led to increased surveillance and criminalization of fishers becoming state-sanctioned. The new Fisheries Department's systems of gear bans, fines, and net mesh size regulations further divided fishers based on colonial perceptions of ecological destructiveness, scarcity, and the illegality assigned to specific fishing practices. Further, the takeover of many private fisheries by the state intensified such control, resulting in new conflicts over the legitimacy of fishing practices. The core assumptions behind many rules and laws of the Indian Fisheries Act (1897) were never critically assessed, and have continued in the Indian subcontinent till date.

After independence in 1947, further changes and continuities were witnessed. At one level, reformist laws for *zamindari* abolition, land redistribution, co-operative management, and revoking of the criminal tribes and castes act were brought in. At another level, the construction of large dams, canals, embankments, and promotion of marine fisheries development and aquaculture, plunged riverine capture fisheries into a state of neglect and decline. On the ground level, however, agrarian violence and oppression against floodplain communities and depressed castes, including of fishers, reached grim levels. River pollution also added to declines in fisheries production. Following this, the 1970s and 1980s saw regional and transnational fishers' movements, which played a role in uniting fishers on the basis of a common cultural identity. With economic liberalization and the mobilization of caste-based politics in the early 1990s, this identity became fragmented once again. Fishers' interactions with the discourses of economic development and environmental conservation created

new divisions between fisher sub-castes and articulations about traditional identity[313]. Post 1991, a shift towards open-access or and weak state-led auction-lease systems in the Gangetic plains exacerbated conflicts over fishing rights and access, and also led to increasing criminal control over riverine capture fisheries. Conflicts between fishers and the market-state now became conflicts within fishing communities.

Conclusion: the shifting frames of fishery conflicts

As this analysis shows, fishery conflicts in the Gangetic plains of India, and the narratives that shaped them, underwent complex shifts in the last 300 years. So far, history studies have focused most on property rights and customary access as the major contentions in these fisheries. I show that the colonial administration constantly grappled with ideas about hydrological uncertainty, ecological scarcity, and the complexity of caste identities, in their repeated attempts to "settle" rights to fisheries. Often, prolonged debates on these issues, within the administrative machinery, accompanied ideas and imaginaries about river fisheries and fishing peoples, as institutional management and control regimes changed over time and space. Even though most colonial legislations and policies on inland fisheries were inherited and carried forward by post-colonial government, these debates have continued, and remain relevant for river fisheries management in general[314]. Identities of fishing people, based on caste, class, community, and practice, were also made and unmade by interactions with the colonial and post-colonial state in various ways. These ecological shifts and changing identities contribute new elements to our understanding of the protracted nature of fishery conflicts in the Gangetic plains.

I conclude in this chapter that we need to go beyond the explanations of colonial capitalism, alienation, or state control, towards a more "ecologically and socially grounded" history of Gangetic fisheries, in order to understand the evolution and transformation of fishery conflicts, and their implications for the future. Such a move will allow us to integrate material motivations underlying resource conflicts with their cultural politics. It can also help contextualize present and future conflicts by moving beyond partial and problematic narratives of ecological scarcity, economics, or politics alone.

[313] See Kelkar, N. (2018), and chapter 6 of this thesis, for details.
[314] Malasha (2003: op. cit.) argues that these colonial debates continue to affect small-scale inland fisheries across the developing global south, especially Africa and Asia.

Tables.

Table 2.1. A chronology of policies, institutional control, and shifts in riverine fisheries legislation and governance regimes in the Gangetic floodplains (1710-2019).

Timeline: Years	Acts, laws, major events, and policy changes related to fishing rights and access in the Gangetic plains
1710-1720	East India Company maintain and supervise Zamindari accounts, almost all accounts mention fisheries[a]
1757-1761	East India Company assumed control of Bengal Presidency after the Battle of Palashi (Plassey) in 1757. Land survey exercises began, maps of Bengal appeared in popular reading.[b]
1765	Acquisition of *Diwani* rights and other revenue collection rights by the company from the Mughal Emperor[c]
1765-1773	Regulating Act of 1773; Experiments by the British in land revenue systems[c].
1769-1770.	Bengal Famine after major ENSO drought, Revenue farming auctions in early 1770s and fragmentation of estates [d].
1774-1778	Topographic surveys of the Gangetic plains and delta by James Rennell[e]
1779-1788	Old landlords dispossessed, multiple defaulters, absenteeism, and waves of de-peasantisation across Bengal. Many landlords reinstated in 1784[f]
1789-1794	Major ENSO period (1789-1794), severe droughts and famine across India[g].
1791-1793	Permanent Settlement of Bengal announced in 1793 by Lord Cornwallis[h]. Tenancy acts fixed landlords' rents in perpetuity, with stiff penalties for default. Regulation XXVII of 1793: Fisheries added to all landowners' incomes through rents and royalties (previously *sair* or *sayar* incomes)[h].
1807-1814	Hamilton-Buchanan's surveys across Bengal and Bihar districts[i]; the first detailed journals on fisheries, zoology, and anthropology of fisher people.
1819-1822	Regulation II of 1819 – some fisheries exempted due to alluvial action. Some customary rights in fisheries reassessed and provided, while it was felt that no settlement of land rights be declared in perpetuity (by H. Mackenzie, Secretary of the Board of Revenue)[j] Regulation VII of 1822, which laid the basis for village-level settlements and proprietary bodies, but previously appointed large landlords retained positions[j]. Regulation VII: Ferries regulation, taxes and rents from ferry rights to fishers and other boat-ferrying communities extracted by landowners. A public fishery proposed for the city of Calcutta in 1822[k].
1825	Regulation XI of 1825, Bengal Alluvion and Diluvion Act and rules.[l]
1828-1829	Regulation III of 1828 – Resumptions and reassessment provisions for lands acquired after accretion, and Embankment Regulation Act, 1829[m]
1833	Santal Pargannas Tenancy Act[n]
1830s-50s	Start of large-scale statistical surveys of Bihar and Bengal regions[o]
1853	Mudhoo Mundle Case over the issue of customary fishing rights[p]
1855	Major irrigation projects begin with the opening of the Ganges Canal in 1854 [q]. Intensification of embankment constructions. Strong northward movement of rivers after southern walls were embanked [q]. Correspondences related to the Ferry Funds of Bengal till 1860. *Santhal Hul* in 1855-56, acts of rebellion through "pond-looting" to assert customary rights over fisheries now taken away by the Company Government.[r]
1857-1858	Indian Mutiny. The British Empire's Indian Administration replaces the Company Government.
1859	New Land Tenancy Rules, Bengal Land Revenue Act. Fisheries move to state control from private control, and "government fisheries" settled in many areas. [s] Bengal Revenue Board Proceedings recognize fishery rights in landed estates as strictly private and needing protection from poaching and trespass. Attempt to revoke *Jalkar* rights in navigable rivers, to recognize public rights to fishery, but strong opposition from *ijaradars*[s]
1860	Estates Manual. Public Right to Fish, with principles from English Law[t]
1861	Indian Councils Act: Bengal Legislature
1862	Indian Penal Code[u]

1864	Bengal Canals Act
1868-1873	The Imperial Fisheries Department established, with Francis Day appointed as the Inspector General of Fisheries for British India. Francis Day's Investigations into the Fisheries of India and Burma (1870s). Series of fishery regulations in discussion and many implemented. Statistical surveys of Bengal[v]
1871	The Census of 1872, involving fisher caste enumerations. Criminal Tribes (and Castes) Act passed in 1871-72.[w]
1870-1880	The Laws (Local Extent) Act, 1874, 17 p. Tensions and confusions over customary fishing rights continue, agitations and multiple court cases with ambiguous and contradictory judgments upholding or disregarding customary fishing rights.[x]
1873-74	Major Famine in North Bihar. *Polo Bidroha* in Pabna (1873)[y]
1873-1876	Northern India Canal and Drainage Act (1873) to regulate irrigation, navigation and drainage. Bengal Irrigation Act of 1876.[z]
1872-1877	Statistical Account of Bengal in 23 volumes, by W.W. Hunter (1872, 1874-77)
1878	Northern India Ferries Act [aa]
1880	Bengal Drainage Act
1882	Bengal Embankment Act 1882[bb], Indian Easements Act
1883	C.D. Field's legal report (echoing 1859 report of the Revenue Board) ruled that fisheries had bounds and were to be privately owned[cc]
1885	Ferries and Tenancy Act for Bihar rivers, legal disputes over tenancy acts and customary regulations continue [dd]
1886	Bengal Tenancy Act (Act 8 of 1886) [ee]
1887-88	Fish stealing court case: Meherpore Case and Maya Ram Surma case Divergent judgments on customary fishing rights, confusions continue. Berby's *Notes on the Criminal Law in India affecting the Jalkars*[ff]
1889	Private Fisheries Conservation Act 1889 Larceny Act: right to proprietor to summon or arrest fish poacher/ angler. [gg]
1892-1894	Baden-Powell's The Land Systems of British India, cadastral surveys attempted in Bihar and Bengal. Passage of Land Acquisition Act, 1894. [hh]
1897	Indian Fisheries Act (Act No. 4 of 1897)
1905	Partition of Bengal. New acts and rules for divided provinces, esp. Bihar and Orissa, where issue of poor and oppressed peasantry and absentee landlords still rife
1906-1915	State recognition of public rights to fish codified, proposal to separate public rights from private rights more clearly. Plans for cooperative management of fisheries with fishermen, reported to have failed[ii]. Numerous problems perceived with fish leases, and declining river fisheries due to irrigation. A push towards aquaculture research and development to augment fish supply[jj] .
1903-1912	Bihar Survey and Settlement exercises conducted, but most remained incomplete.[kk]
1913-1914	*Mallah* fisher subcastes included as Criminal Tribes entered into Category B.[ll]
1916	Bihar and Orissa Public Demands Recovery Act, Decentralization Act, and Bihar Tenancy Act in 1920, amended since, till date
1921	Alluvial Lands Act (Act No. 5 of 1920) Edye's report (1923) on the United Provinces fisheries emphasizes the need for cooperative fishing institutions managed by state departments and people – but based on the *Jalkar* system in Bengal that he perceived as a model system. Fishers request for middlemen to be involved in fish trade and transactions. [mm]
1922-1923	*Santhals*' pond looting and fish poaching cases increase as acts of resistance against colonial policies curbing access to fishing and hunting areas[nn]
1927	Indian Forest Act
1925-1930	Interest in conservation and welfare interventions in inland fisheries [oo] Bihar Cadastral Survey conducted in 1930.
1931	Census figures on fishers, 1931. Turner report identifies and updates list of criminal sub-castes among fishers.[pp] Embankment problems, water logging, and malarial outbreaks. Expansion of road and railway networks seen as responsible for reduction in criminal tendencies and activities.[qq]
1932	Bihar Private Irrigation Works Act 1932
1934	Bengal Alluvial Lands (Amendment) Act, 1934
1935	Bihar Co-operative Societies Act 1935. The cooperative movement in Bihar planned to

	promote tank, pond, and wetland fisheries, involving culture and some capture.
1938-39	The Bihar Tenancy (Amendment) Act, 1938, Bengal Tanks Improvement Act, Bihar Public Irrigation Works Act
1940	Floud Commission report proposes to abolish intermediaries land administrations systems as from the Permanent Settlement, and land reassessments[rr]
1943-44	Great Bengal Famine and severe impact on fishers and farmers due to the Boat Denial Policy[ss]
1947	India's Independence, Partition of India and Pakistan (Bangladesh as East Pakistan)
1947-50	Bihar Public Irrigation Works and Drainage Act 1947, Bihar Land Reforms Act 1950
1952	Zamindari Abolition Act passed.[tt] *Panidari* on some large river stretches continued, notably in Bhagalpur.[uu]
1954	Embankment policies, intensive, large-scale embankment constructions of thousands of km undertaken.[vv]
1956	West Bengal Act X of 1956, Land Reforms Act
1958	Kosi barrage, beginning of intensive spawn collection[ww]
1960s	Spawn collection drives in the Ganga for pond-based aquaculture of Indian Major Carps (IMCs)[xx]
1967-1969	Expansion of fishery cooperatives in northern Bihar and Bengal Construction of Gandak barrage, and other barrages on tributaries in the Ganga basin, added to declines in Indian major carps[xx]
1972	Wildlife (Protection) Act, 1972
1975	Farakka barrage on the Ganga completed. Massive decline in Hilsa fisheries across the region seen by early 1980s.[yy]
1981-1983	Boom in IMC aquaculture production in Andhra Pradesh and West Bengal supplements declines caused by barrages and dams to riverine fisheries.[zz] West Bengal Inland Fisheries Act, 1984. Ganga river declared as National Waterway in 1982.
1984-1990	Ganga Action Plan announced in 1986 Violence and massacres claim the lives of several fishers and other floodplain dwellers at the hands of criminals and bandits, in Bihar. [aaa] In Bihar, Ganga Mukti Andolan claims fishers' rights to the river and asks to overthrow Panidari regime. In Uttar Pradesh, private control on river fishing. [bbb]
1990	Bihar Land Reforms (Amendment) Act 1989, Bihar Act 11 of 1990
1991	Fishing in rivers of Bihar made open-access. Abolishment of *Panidari* by Govt. of Bihar (vide notification 39191–1-892, dated 22 April 1991) after the *Ganga Mukti Andolan*. Private auction-lease contract system continues in Uttar Pradesh.[ccc] Economic reforms in India.
1992-1993	Expansion of fish trade and markets, and longer supply chains to hub markets (e.g. Siliguri). Increase in pressure on marketing small fish for Bengal and Assam supply.
1994-1995	Increases in the use of mosquito nets. Entry of multiple non-fishing castes and criminal "mafia" gangs into river fisheries. Despite free fishing, but threat of extortion and violence to fishers from gang members intensifies.[ddd]
1997-1998	Severe ENSO drought.
2000	Conservation initiatives for river dolphins and other biodiversity begin.
2000	Kanpur barrage constructed on the Ganga
2002-2006	Phase of weak but prolonged ENSO drought
2006	Bihar Jalkar Act and Amendments in 2010, 2011, 2013, 2017, 2018 [eee] Tehri Dam on the Ganga - phase 1 completed.
2007-2008	Major flooding in Bihar, severe damage to human life and property
2009-2010	Ganga declared India's National River.
2013-2014	New cooperative schemes and insurance plans for aquaculture e.g. COFFED in Bihar[fff]
2013	Launch of community conservation initiatives involving fishers, e.g. Dolphin *Mitra* Program in Bihar.[ggg]
2014-2016	Phase of severe ENSO droughts
2015-2020	Formation of *Vikassheel Insan Party* and other fishers' parties in Bihar and UP.[hhh]
2018-2021	Clean Ganga Mission, many fishers involved in government outreach and campaigning for environment and biodiversity conservation
2019-2021	Draft National Inland Fisheries and Aquaculture Policy (NIFAP 2019) and later, the Draft National Fisheries Policy 2020. [iii]

Notes: [a] Wilson, C.R. (1911: v.1, pp. 38-290) and v. 2 (p.126) [b] The Gentleman's Magazine, 1757, p. 356-359. [c] Pitt and Chatham Papers relating to Trade with India, Grant of Dewani of Bengal, Bihar and Orissa, and see Banerjee and Iyer (2002: 1190-2013). [d] See Raye (1927: pp. 280-282), Guha (1963, pp. 21-41), Fagan (1999: p.3-25), Sen (2019: p. 326). [e] Rennell (1776, 1781). [f] See Guha 1963, Chaudhuri 1975, Yang (1979: pp. 37-58); Hill (1991: pp. 263-279). [g] See Grove, R.H. (2007: 75-98). [h] See Toufique (1997: pp. 457-467); Pokrant *et al.* (1997: pp. 27-48); Reeves (1995: pp. 260-292). [i] Hamilton-Buchanan (1810-1822, op. cit.). [j] Banerjee and Iyer (2002, p.9). [k] page 21. [l] See Acharyya (1914: p.229), Doss (1891: The law of riparian rights, alluvion and fishery, 422 pp.), Ghose (1930: The Law of Alluvion and Diluvion, Including the Law Relating to Fishery in Private Rivers, with Commentaries on Regulation XI of 1825, the Bengal Alluvion and Diluvion Regulation. Rai M.C. Sarkar Bahadur and Sons, Calcutta, pp. 769.), and Mitra, B.B. (1934: The Laws of Land and Water in Bengal and Bihar, with the Case-law Thereon, Eastern Law House, Calcutta, India, p.185.). [m] see Hill, C.V. (1997: pp. 9-105), and Singh and Gupta (2018: 122-133). [n] Santal Pargana Tenancy Act (1833) 15–17, Hunter (1876: Statistical Account, vol.14). [o] Some notable surveys include those by Trevelyan 1834 (495 p.), Taylor (1840: p. 152-153 provide detailed notes on "Julkurs"), and A. Wyatt (1848: 12 p.). For example, see: Dr. McClelland's information regarding the Suleah fish found in estuaries of Hooghly and the Ganges. 1843-1844, F/4/2/27 No. 100638. Bengal Publications 15 Jan 1844, P/13/46, nos. 63-65. [p] See Sen (2015, pp. 105-147, op. cit.), and Reeves (1995, op. cit.). [q] See Cotton, A. and Cautly, P. (1864), page 8., Bhargava (2007, op.cit.), Singh, P. (2008: pp. 239-260), and Singh, V. (2014: pp. 23-28). [r] see Singh, V., ibid., for details of Ferry Fund discussions, Guha, R. (1983: p.125-130) for a detailed account of the Polo rebellion. [s] Barman (2008: pp. 39-74) indicates that after 1859-60, the subject of fisheries moved from private control to state control. Baden-Powell's monograph (1892: section 75) lists government shares of 45% to 55% from fisheries and other sources of profits to landowners, where private rights to fisheries were continued. Also see Hunter, W. (1876: vol. 12). In the Brahmaputra floodplains of Assam, Saikia (2019: pp. 142-155) shows that river fisheries moved from the *raiyatwari* regime to state control, with a system of auction-leases. On the opposition from *ijaradars* to state control, see Reeves (1995, op. cit.), and Pokrant *et al.* (1997, op. cit.). [t] see Sen (2015, op. cit.), who cites Appleby, T. (2005, p. 202.). [u] IPC sections 379 and 447 on trespass affected customary access in river-floodplain fisheries, as noted in numerous court cases over fishing rights in the 1870s and 1880s (Sen, S. 2015, op. cit.). [v] see Day's (1873) Report With Francis Day's appointment, formidable state control through rules, regulations, bans, and provisions on fisheries came into place, and were instrumental to the implementation of the Private Fisheries Protection Act (1889) and Indian Fisheries Act (1897). Statistical surveys led to many systematic district/regional gazetteer publications, with Hunter W.W.'s 20 volumes published as A Statistical Account of Bengal (1875-1877). [w] Many fishing castes and sub-castes (esp. Binds, Chains) described as criminals by birth, but with potential to be "improved", were listed under the 1871 act, and their status revised in the 1913-14 lists (see Reeves 2002: pp. 121-135). In some cases, Mallahs were added for being involved in river dacoities (Sinha, N. 2008: pp. 1-33, and Sinha, N. (2014b: pp. 39-40). State surveillance and control had a severe impact on the social status and identities of fishing groups (see Jassal 2001: pp. 319-356), Nigam (1990: pp. 131-164), and Doron (2013: pp. 36-45). [x] Reeves (1995, op. cit.), Sen, S. (2015, op. cit.), and Sen and Adelstein (2019: 48 p.) summarize the court cases, their backgrounds, and outcomes. Formal case-summaries also referred in The Law Journal for the Years 1832-1949: Comprising Reports of Cases in the Courts of Chancery, King's Bench, and Common Pleas… and cases connected with the Duties and Office of Magistrates decided during those terms. Vol. 5. James Holmes, London, MDCCCXXVII. [y] see Guha (1983, op. cit.). [z] see D'Souza, R. (2003: pp. 41-69). [aa] Singh and Gupta (2018, op. cit.). [bb] Bengal Act II of 1882, pp. 459-497. [cc] Field, C.D. (1883: 54 p.), described in Dey, S. (2012, ch. 4) as strongly supporting Jalkar basis for private grant of fishing rights. [dd] see Robb, P. (1997: pp. 145-179), *Ancient Rights and Future Comfort*…. [ee] Rampini, R.F. and M. Finucane (1889) The Bengal Tenancy Act. Act VIII of 1885. Thacker, Spink and Co. Calcutta. [ff] Sen, S. (2015, op. cit.). [gg] Reeves (1995, op. cit.), Sen, S. (2015, op.cit.), Singh and Gupta (2018, op. cit.). [hh] Baden-Powell's Land Systems (1892: 443 p.), also see India Office Return to The House of Commons. (1893) East India. Behar Cadastral Survey. Printed by her Majesty's Stationery Office, London. [ii] see K.G. Gupta (1908: pp. 1-37), and De, K.C. (1910: p. 35). [jj] Reports by T. Southwell (1914: pp. 1-24, 1917a: pp. 32-48, 1917b: p. 733-740), provided detailed information on surveys of river fisheries, and the need for aquaculture promotion. Many monographs were published in the 1910s and 1920s on various aspects of fisheries of Bengal: e.g. Bengal department of Fisheries Bulletin 1913, onwards (continues after 1920) V/25/550/1; Bengal Dept. of Fisheries Bulletin 7, Freshwater pearl-mussel fisheries in Bengal and Bihar 1915. V/25/550/1 no. 7. [kk] Survey and settlement reports (1905-1920) focused on alluvion-diluvion dynamics along the Ganga River (e.g. Sen, B.R.K. 1915: 16 p.) and the historic impacts of Permanent Settlement, e.g. see Kerr (1903; for Saran district), Murphy (1912; Bhagalpur), James (1914: 179 p., Patna). [ll] see Reeves (2002: pp. 121-135) and Jassal (2001, op. cit.). [mm] Reeves, P. (2002, op. cit.). [nn] See Sarkar, A.K. (2016: pp. 29-40). [oo] Rushbrook-Williams (1925: pp. 175-176) reported increasing demand and consumption of fish, and proposed strong laws to curb "indiscriminate and ruthless" fishing by local fishers, but also need for education of fishers' children, and for cooperatives. [pp] Reeves (2002, op. cit.). [qq] Willcocks (1930: pp. 59-62, pp. 71-93) Iqbal (2007: p. 329), and Singh and Gupta (2018, op. cit.). [rr] Iqbal (2010: p. 107). [ss] Iqbal and Mukerjee (2011: 271-282). [tt] Sharma, S. (1985: pp. 60-81). [uu] See Kelkar and Krishnaswamy (2014: pp. 58-80), and Sharma, M. (2006: pp. 12-41). [vv] see Mishra (2008: 47-52), Gyawali (1999: pp. 443-452), and Iqbal (2007, op. cit.). [ww] David, A. (1959: pp. 327-341). [xx] Numerous reports from scientists within and outside the Central Indian Fisheries Research Institute cited decline in fish spawn: e.g. Shetty and Malhotra (1971, 1983: 33 p.), Jhingran and Ghosh (1978: pp. 141-162), Datta Munshi *et al.* (1979: pp. 153-157), Vass *et al.* (2010a: pp. 385-394), Rahman (2008: pp. 127-140). [yy] see Mirza (1998: pp. 613-630), Ray (1998), Banerjee (1999: 29 p.), Adel (2001: p. 356-368), Kawser and Samad (2016: 16 p.), Iqbal (2010: p. 189), and Payne *et al.* (2004: pp. 229-250). [aaa] Massacres involved caste-based violence and conflicts over riparian rights, for details see: Raj (1995: pp. 60-68), Sharma, M.

(2006: pp. 12-41), Jha and Pushpendra (2012: 33 p.), Prasad (2014: pp. 847-852) [bbb] see Sharma, M. (2006, op. cit.), Sharma, M. (2017: pp. 195-201), Gupta (1993: pp. 22-24) for details on the Ganga Mukti Andolan. [ccc] see Kelkar (2014a) for a summary of later impacts in Bihar and Uttar Pradesh. [ddd] see Kelkar and Krishnaswamy (2014, op. cit.) for details. [eee] Bihar Fish Jalkar Management Act, 2006 [fff] URL: http://www.coffed.coop/contents/en/about . [ggg] see Kelkar (2018: pp. 9-33) and chapter 6 of this thesis, for a related analysis. [hhh] see Bagchi (2018: pp. 563-565). [iii] National Inland Fisheries and Aquaculture Policy Draft, Ministry of Agriculture And Farmers' Welfare (Department of Animal Husbandry, Dairying and Fisheries), and the Standing Committee on Agriculture. (2017-2018). Scheme on Development of Inland Fisheries and Aquaculture - An Analysis. Ministry of Agriculture And Farmers' Welfare, New Delhi, India.

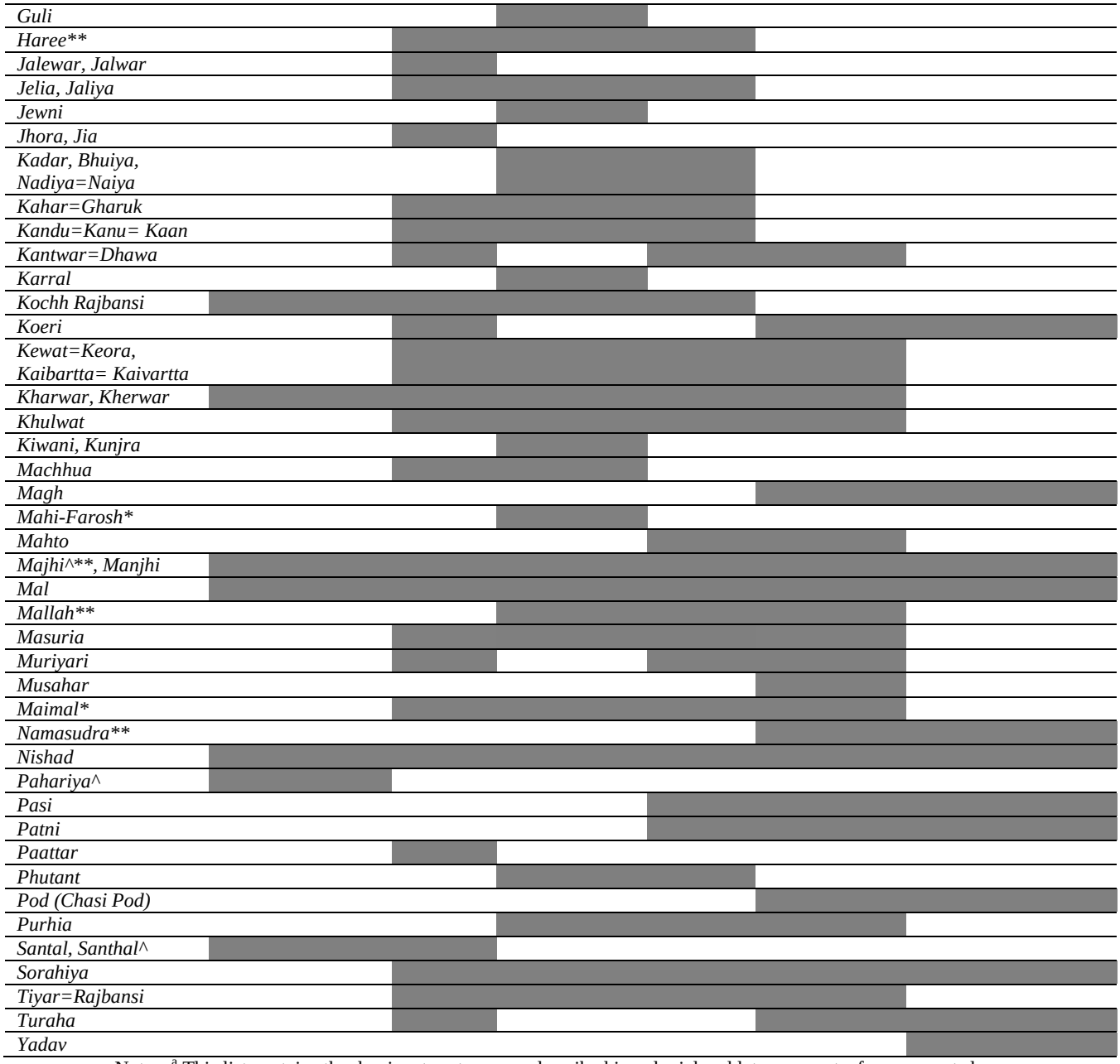
Table 2.2. A chronological record of years with major earthquakes, river channel changes, floods (F), droughts (D), and ENSO phases* that affected the regions of eastern Bihar and western Bengal.

Earthquakes	**Major river channel changes**	**Floods and droughts**	**ENSO phases**
1720	1770	1770 D	1790-94
1737	1775	1775 F	1828
1762	1807	1779 D	1876-78
1775	1839-40	1783 D	1891
1810	1873	1788 D	1903
1812	1893	1791 D	1906
1828	1921	1848-49 D	1912
1833	1926	1855 F	1914-15
1842	1930	1857 D	1919
1866	1931	1860 D	1926
1885	1936	1864 D	1941-42
1888	1942	1866 F	1947
1897	1948	1870-72 F	1952
1905	1949	1874 F	1954
1934	1963	1876-77 D	1958
1947	1976-78	1892 F	1963
1950	1987	1897 F	1966
1954	2008	1918 F	1968-69
1960	2009	1920 D	1973
1966	2011-13	1935 F	1977-79
1980	2016-17	1943-44 D	1982-83
1986		1951 D	1986-87
1988		1965 D	1992-95
1997		1966 F	1997-98
2008		1972 D	2002-06
2011		1978-79 F-D	2009-10
2016		1979-80 F	2014-16
2017		1987 D-F	2018
		1994 F	
		1997-98 D-F	
		2001-02 D-F	
		2004 D-F	
		2005-06 D	
		2007-08 F	
		2009 D	
		2011 F	
		2013 F	
		2014-15 D	
		2016-17 F	
		2019 F	

*Data sources: Blanford 1884: pp. 3-22, Anon. 1924: p. 143, Wells and Dorr 1987: pp. 204-207, Chakraborty *et al.* 2010: pp. 127-143, Rudra 2010: pp. 161-169, Mishra *et al.* 2016: pp. 102-112; and author's own remote-sensing based studies of river channel changes.

Table 2.3. An indicative list of major fisher caste names and their associations with occupational categories (greyed cells) in the Gangetic plains[a]. The names *Mallah* and *Nishad* are used by 8-12 endogamous fishing sub-castes (*Bind, Banpar, Tiyar, Chain, Muriyari, Sorahiya, Kewat* or *Gonrhi, Manjhi, Khulwat*) to denote a common caste-group or cluster[b]. Asterisks (*) identify caste names of Muslim fishers and ** identify fisher caste names with both Hindu and Muslim fishers, while the remaining may be grouped as Hindu-incoming castes[c]. The sign ^ indicate castes that were not always be grouped with fishers, or were explicitly recognized as tribal fishers. Note that this list is by no means exhaustive[d], and many caste names are regionally considered as synonyms[e], which can be identified in spite of a diversity of archaic or Anglo-Saxon spellings available in the literature[f].

Caste/ sub-caste names (alphabetical order)	**Tribals or aboriginal peoples who would rely on fishing and hunting**	**Regular fishers, who may or may not use boats**	**Regular fishers fishing with boats, and/or involved in fish trading, some being exclusively traders**	**Fishers primarily involved in boat-ferrying work**	**Part-time fishers, involved mostly in opportunistic / subsidiary fishing and other farming or non-farming activity**	**Farmers or tenant-labourers, who also fished in flood-recession period (post-monsoon) periods, usually with barriers, screens, or poisons, not recognized traditionally as fishers**
*Ardi=Bagdi***		■	■		■	■
Baiti		■	■	■	■	
*Bauri***					■	
Banpar=Malo		■	■	■	■	
Bansi		■	■		■	
Barman		■	■		■	
Bathwa			■	■	■	
*Bebajiya***		■	■		■	
*Bhoi^*		■	■			
Birhor	■	■	■	■	■	
*Bhatiyara^***	■	■	■			
Benda		■	■			
Berua			■			
*Bind^***	■	■	■		■	
Chain=Chai, Nuniya, Chabi		■	■	■		
Chaklai					■	
Chamar					■	
Debansi		■	■	■	■	
Dhinwar=Dhimar= Jhinwar		■	■	■		
Das Shikari		■			■	
*Datiya**		■			■	
Dom					■	
*Dulia, Dohuriya**		■	■	■	■	
Dusadh					■	■
Gangota				■	■	■
Gangrar=Ganrar		■	■	■		
Gayotri			■	■		■
Ghashi=Ghasi, Sais			■	■		■
Ghunia=Guria		■	■	■		
Gonrhi (Mahaldar)		■			■	■



Notes: [a] This list contains the dominant caste names described in colonial and later accounts, from present-day Uttar Pradesh to Bangladesh, sourced from: Hamilton-Buchanan (1810: pp. 198-201, 230-257; 1812a: pp. 241-244); Taylor (1840: p.234-237, 245); Sherring (1872: pp. 339-347); Hunter (1875-1877: vol.1-20, lists of fishing castes provided in the volumes for all regions of Bengal. Hunter also reports a few Jaliya fishing castes identified as "proper" in vol.5: p.24, vol.7: p.29-31 list twelve major fishing castes in Maldah and Rangpur, including the Gangota and Karral, vol.12: p.33 lists distinct fish-trader caste names from Gaya and Shahabad, pp. 197-200 list the classification of "semi-Hinduised" boating and fishing castes; Wise (1883: pp. 90-91, 208, 267, 281-285, 296-300, 318-320, 391-394); Risley (1892, vol. 1: pp. 13, 19, 23, 37, 52, 59-60, 82-89, 130134, 166-168, 183-189, 196, 216, 224-228, 238-239, 259, 270, 277, 287, 294-297, 303, 340-347, 367-382, 396, 424-429, 454-458, 491-496; vol. 2: pp. 26, 37-51, 63-67, 170-172, 312-320, 329-331); Russell and Hira Lal (1916: vol.1: pp. 15, 270, 384, 415; vol.2: pp. 502-514, vol.3: pp. 422-426). Also see Jassal (2001), Barman (2008), Iqbal (2010: p. 63), and Doron (2013: pp. 36-45) for more details. [b] See Jassal (2001) for details of sub-castes in the *Bhojpuri*-speaking region, although there was substantial variation across the region, e.g. see Hunter (1872: vol. 7: 29-31). [c] See Wise (1883: pp. 281-300), and Hunter's volumes, refs. listed above). [d] Crooke (1896b) identified 625 divisions within Hindu fishing castes and 22 within Muslim fishing groups, as per Jassal (2001, op. cit.). [e] Synonyms are indicated, where known, by an equality (=) sign. [f] For example, *Majhi* and *Manjhi* in the table.

Chapter 3. Riverine ecology and institutional interplay: conflicts over fishing rights and access in the Gangetic floodplains

Introduction

River floodplain-based capture fisheries support complex social-ecological systems. Fishers track seasonally variable, uncertain, and spatially patchy fish species and stocks in river-floodplains (Tsai and Youssof 1997, Smith *et al.* 2005, Welcomme *et al.* 2010). Flow variability and the seasonal flood-pulse are essential elements that sustain and subsidize the high biological productivity of riverine capture fisheries (Junk *et al.* 1989, Welcomme 1995, Dudgeon *et al.* 2006, Reeves and Duncan 2009). Fishers' memory of major floods and channel course changes also influences their seasonal and inter-annual fishing effort investments and decisions (Dey *et al.* 2020). For example, strong flood pulses followed by a long dry-season typically attract higher fishing effort in the Gangetic plains (see chapter 4 of the thesis). Fishing involves a portfolio of activities and is often not governed by strict procedures: there is a constant need to move, adapt, and innovate fishing practices according to fish movements and breeding cycles (Welcomme 1995, Tsai and Youssof 1997, Smith *et al.* 2005). As a result, river fishing activities regularly straddle rigid and fixed boundaries of state institutional jurisdictions (Reeves and Duncan 2009, Donaldson 2011), which are usually defined as per agricultural land revenue systems (D'Souza 2004, Sinha S. 2014). 'Intersectorality' is an inherent feature of inland fishing (Song *et al.* 2017), and can generate conflicts over the fuzzy boundaries of fishing places (Edwards 2003, Reeves and Duncan 2009), seasonally reshaped by the movement of water (Gleditsch *et al.* 2006, Blomley 2008). Whereas changing boundaries of land and water in the floodplain are a fundamental problem for land-centric production systems, they are a critical need of riverine capture fisheries (Welcomme 1995).

Small-scale inland capture fisheries support millions of marginalized people worldwide (Allison and Badjeck 2004, Welcomme *et al.* 2010). The marginality of fishers owes itself to domination of settled agriculture over dynamic and mobile foraging systems such as fisheries (Sneddon *et al.* 2002). Power inequities perpetrated and maintained by feudal accumulation (Sneddon 2007, Adnan 2013) and colonial/state projects to control water for protecting land-centric consolidation of revenue (D'Souza 2006a, 2009; Blomley 2008, Lahiri-Dutt and Samanta 2013, Song

et al. 2017) have also affected fisheries historically (Reeves 1995, Singh and Gupta 2018). 'Property' in river fisheries needs to be understood differently from an aquatic, rather than terrestrial viewpoint (Edwards 2003, D'Souza 2004, Blomley 2008, Lahiri-Dutt 2014, Sinha N. 2008, Sinha N. 2014a). In legal terms, rights to fisheries are both territorial and incorporeal, a distinction that is easier to articulate than to effect in practice (Doss 1891, Ghose 1930, FAO 2016; see thesis chapter 2). Hence, conflicts over access and resource ownership in riverine fisheries are complex outcomes of battles over shifting land-water boundaries (Sneddon *et al.* 2002), scrambles over diffuse or uncertain fish stocks (Dyson-Hudson and Smith 1978, Gleditsch *et al.* 2006), entrenched social stratification, colonialism, and other historical inequalities (Sneddon *et al.* 2002, Sneddon 2007, Pellow 2007, Wieviorka 2013, Singh and Gupta 2018). On their own, these explanations may be simplistic or inadequate and might convey the impression that resource conflicts are inevitable in dynamic environments. Fishing communities are also heterogeneous and often live at the margins of society, which might constrain their organization, actions, and adaptive responses (Song *et al.* 2017). Yet fishing communities also develop their own strategies to navigate conflicts through social learning and adaptive behaviours to navigate conflicts (Salas and Gaertner 2004, Bavinck 2005, Lahiri-Dutt 2014). Hence it is important to understand how and why institutional management may be constrained at different levels (from the state to communities) in abruptly changing floodplain ecosystems. Studying institutional interactions can thus identify scale mismatches, communication gaps, and confounded or overlapping mandates that induce fishery conflicts (Bennett *et al.* 2001, Cumming *et al.* 2006, Hotimsky *et al.* 2006, Vatn and Vedeld 2012).

Theory on the role of institutions in managing fishery conflicts follows three broad tracks. The first track is paved by the theory of rational choice, as it applies in the context of formal-legal definitions and interpretations of the efficiency and legitimacy of property rights (Adger and Luttrell 2000, Berkes 1985, Jentoft 2000, 2004, Johnson 2004). Theories of collective action for managing conflicts over common pool resources and common property rights in fisheries (Ostrom 1990, 2005; Adams *et al.* 2003), with locally evolved systems of rules, sit on this track. An important assumption of common property theory is that of well-defined boundaries of resources in space and time (e.g. Ostrom 1990, Armitage *et al.* 2008, Cox and Arnold 2010). This assumption is downright violated in the shifting and dynamic

commons of river-floodplain fisheries. Scott's (1995) view of institutions expands their scope beyond just rules, to norms, morals, and knowledge that can enable and regulate social action (Jentoft 2004). The second track of new institutional economics focuses on 'transaction costs' that cause and are in turn increased by conflicts (Vatn 2005, Musole 2009), as transaction costs increase with uncertain boundaries. The third track reflects cultural turns in institutional theory and emphasizes 'practices' and 'habits' of actors that influence resource management (Johnson 2004, de Sardan 2013). Ribot and Peluso (2003) identify the important role of cultural interactions and customary arrangements for communities seeking access to a commons. These tracks crisscross and diverge, and need to be combined for a thorough institutional understanding of conflict and adaptation processes (Vatn 2005, Gerber *et al.* 2009).

Ecological and socio-political regime shifts are common background variables of these institutional approaches (Rothschild and Shannon 2004, Reeves and Duncan 2009). Changes in institutional structures and boundaries are typically assumed to be gradual (Mahoney and Thelen 2009). But this assumption may be of limited value in understanding fishery conflicts occurring in socio-ecological systems with abrupt shifts and non-equilibrium threshold behaviours (Reeves and Duncan 2009, Young *et al.* 2008, Young 2010). This is often the case in meandering or braiding alluvial rivers (Bhargava 2007, Camporeale 2008, Rudra 2010, Hooke 2011), where fishing hotspots may shift many kilometres after major floods. Transaction costs of institutions in such systems might be prohibitive, and could lead to 'institutional or community failure' (McCay and Jentoft 1998, Jentoft *et al.* 1998, Kellert *et al.* 2000, Bennett *et al.* 2001, Jentoft 2004). Not just that, the politics of collective action can involve discrimination based on class, caste, or gender, for cultural variables can drive conflicts even if institutional or legal structures are accessible (Agrawal and Gibson 1999, Kellert *et al.* 2000). Power relations, structural inequities, and social injustice have generally received low attention in the common property literature (Singleton and Taylor 1992, Carruthers and Ariovich 2004, Obeng-Odoom 2016), but need to be explicitly studied in the context of fishery conflicts.

Bennett *et al.* (2001) state that "…strong and flexible institutions such as clear property rights, management systems rooted in community traditions, fair law enforcement and a competent state are needed for effective fisheries management… (p. 5)", while recognizing "institutional failure" as a primary predictor of fishery conflicts. In abruptly changing riverscapes, management is challenged by spatial and

temporal scale mismatches between biophysical processes and institutional features (Berkes 2002, Cumming *et al.* 2006), and from social limits to adapt to unpredictable change (Young *et al.* 2008, Adger *et al.* 2009). To investigate these problems further I draw upon Young's (2002) theoretical framework of institutional fit, interplay, and scale. Fit refers to the congruence between biophysical characteristics of the ecosystem – and institutional structures and rules; interplay to relationships between vertically nested and horizontally interacting institutions (Young 2002, 2006), and scale to organizational levels over which institutional processes can be similar (Young 2002, Young *et al.* 2008, Folke *et al.* 2007). But as Vatn and Vedeld (2012) assert, these are not three separate 'attributes' of institutional regimes. Instead we need to reinterpret 'fit' in a much wider sense, as the whole set of relationships between biophysical/ecological systems and institutional governance regimes (Taylor and Garcia-Barrios 1995, Kalikoski *et al.* 2002, Krause and Glaser 2003). Institutional interplay (overlaps and power relations among interacting institutions) and scale (structures of authority, communication flow, operational designs) issues are then specific aspects of the problem of fit (Kalikoski *et al.* 2002, Vatn 2005). I follow Vatn and Vedeld in interpreting Young's theory. I focus attention on the ways in which the motivations, mandates, positions, and hierarchies between and within different state and non-state (formal/informal) institutions can precipitate complex fishery conflicts.

Here I link riverine ecology and institutional interplay (following Basurto and Coleman 2010) with some existing conceptual typologies of fishery conflicts (Charles 1992, Warner 2000, Bennett *et al.* 2001), in a simple analytical framework for the Gangetic floodplains of the state of Bihar in India. Bennett *et al.* (2001) grouped fishery conflicts under five overlapping 'types', of which I am concerned here with Type I (issues of access and property rights) and Type II (issues of legal enforcement, compliance, co-management allocation) conflicts. In this framework, I propose that conflicts over fishing rights and access are influenced by 1) historical contestations over space in relation to river channel changes, 2) systems of codification and interpretation of rights by contemporary state institutions, and 3) access to specific fishing areas and the social and legal fishing practices used. In Bihar's floodplains, legal contestations over property rights, customary rights, and pathways of access have been historically complicated problems (Hill 1990, 1991; Gyawali 1999, Sinha N. 2014a,b). Colonial rule and the 'Permanent Settlement' of Bengal in 1793 (of which Bihar was a part) in British India granted fixed tenures to riparian landowners

'in perpetuity' (Reginald Hand 1894, Guha 1963, Hill 1997, Soeftstad 2000, Reeves 2002). The impacts of centralized irrigation projects, weirs, and embankments led to significant declines in river fisheries according to investigations that followed (Southwell 1914). Temporary channel stability brought by embankments strengthened private control and created a false sense of security in state institutions as well as farmers and fishers, exposing them to greater uncertainty and risk, e.g. from flooding and displacement (Bhargava 2007, Mishra 2009, Singh 2008, 2014). Wasson et al. (2020) have described this as a "technological lock-in", where particular and often singular solutions dominate thinking by decision makers. Hydrological transformations and private enclosures eroded earlier customary arrangements and aggravated the exploitative outcomes of unfair contracting between fishers, tenant farmers, and landholders (Banerjee 1936, Reeves 1995, 2002; Hill 1997, Tsai and Youssof 1997, Sinha N. 2014b, Sen 2015). Conflicts and contestations continued over access and resource rights, having assumed new forms since then (Reeves 1995, Sen 2015). The history of colonial institutions has had a strong impact on present day policies (Banerjee and Iyer 2002), even as river fisheries moved from private control, to state control, to open-access over 200 years (Singh and Gupta 2018).

I analyse conflicts over access to fishing areas by describing five case studies from the Ganga, Gandak, and Kosi river-floodplains in Bihar, India (Figure 3.1 shows locations of the case studies). These are among the most hydrologically dynamic and complex river-floodplains in the world, with monsoonal flooding every year, abrupt river course changes of meandering and braiding channels, and high sediment erosion and deposition (Swamee and Parkash 2004, Berger 2006). The floodplains form the geomorphological and biophysical backdrop to poverty, displacement, and marginality in the Gangetic basin (Sarkar *et al.* 2000, Sarker *et al.* 2003, Rudra 2010, Lahiri-Dutt 2014). They provide the stage on which conflicts emerge, and are experienced. The primary actors experiencing conflicts are different groups of fishers, using varied fishing practices. Fishers' identity is connected to their positions in negotiating conflicts over rights and access. Mallah and Nishad fishing caste-groups are regarded as 'traditional' fishing castes, and other castes involved in fishing are called 'non-traditional' (see Kelkar (2018) and chapter 6 for details). The Gangota and Yadav castes that are mostly cultivators, livestock keepers, or labourers, also undertake part-time fishing, but many are also involved in dacoity and crime, forming mafia-style gangs controlling floodplain territories. Over time, these gangs have also

strengthened control of fishing areas (Kelkar and Krishnaswamy 2014). The state fisheries department is the main regulatory authority in charge of fisheries and aquaculture development. Their mandate involves enforcement of fishery laws, managing private lease rights and cooperative uses of enclosed wetlands and river fishing. Fishers in the study area thus interact with two major 'institutions': the state fisheries department and the gangs. Here, a brief discussion is imperative on the terms used to differentiate "bandits" or "dacoits" from the current gangs of "free-booters", as indicated by Hobsbawm (1969). Social banditry of the kind that Hobsbawm (1969) describes in his classic work *Bandits* arose in this region around the turn of the 19th century in a major way, following peasant oppression and destitution. Over time, the image of such bandit-rebels, hailed locally as heroes and avengers once, has undergone some major shifts. The means and modes of operation of "bandits", who can be considered as anti-state resisters, appear to have been different from "dacoits" who typically would be ambivalent when it came to the targets (not only state actors but other economically powerful elite functionaries). The highly organized operations of these gangs must be differentiated from relatively unorganized or random acts of outlawry or freebooting, according to Hobsbawm. In recent decades, gangs have exploited the laxities of law and the difficulties of policing the floodplain terrain (see Slatta 2004, Cayli 2018 who comment on the 'frontier' spatial aspects of banditry). The gangs have now focused on accumulating economic profits through violence and exploitation of fishers trespassing their territories along river floodplains (Chaubey 2006, also see chapter 6 of the thesis). Due to the scope for formalized extraction and management of territories, these gangs, in collusion with politicians, now act as an organized "mafia", becoming non-state regulators of fishing access and activity.

In this context, I have considered "mafia gangs" as an "informal institution" based on Helmke and Levitsky's definition (2004), as an outcome of "socially shared, unwritten rules created, communicated, and enforced outside of officially sanctioned channels". In my study, I 1) mapped river channel course changes over time to understand overlaps between institutional boundaries and fishing areas, 2) compiled narratives of fishery conflicts from detailed interviews with different institutional representatives (between 2008 and 2018), and 3) analysed conflicts over the intersections of river-floodplain boundaries and institutional boundaries, fishery rights, access, and legal conditions.

Methods

Study Region

The Ganga, Kosi, and Gandak river floodplains (Bihar, India; Figure 3.1) are biologically productive floodplain riverscapes (Sarkar *et al.* 2000, Vass *et al.* 2010a,b). All rivers have monsoonal flooding for four months every year, and glacial inputs to summer flows preceding the monsoon (Philip *et al.* 1989, Swamee and Parkash 2004). High sediment erosion-deposition rates, river discharge, and neo-tectonic activity from the still rising Himalayas are known to cause unpredictable and abrupt channel course changes in river-floodplains of the Gangetic plains (Wells and Dorr 1987, Swamee and Parkash 2004, Singh *et al.* 2007, Roy and Sinha 2018). Channel course changes are manifested through transverse sub-surface (basement) faults that indicate geological interactions between the Himalaya and the Gangetic plains (Valdiya 1976, Goswami 2012). River discharge, sediment loads, and active faults are linked to channel morphology and stability in Western (tectonically stable) and Eastern (tectonically unstable) Gangetic rivers (Roy and Sinha 2018). Based on channel sinuosity and avulsion rates, the Ganga is classified as a meandering river, the Gandak as a braided river, and the Kosi as a complex braided + meandering river course (Sinha and Friend 1994). Meander cut-offs, oxbow lakes, side-channel inlets, and chutes are common floodplain channel features (Sarkar *et al.* 2000, Hooke 2007, Camporeale *et al.* 2008). Channel movement rates are the lowest for the Gandak (80 km in 5000 years, but with alternating flows between river braids) and the highest for the Kosi (120 km in the last 250 years), with intermediate meandering in the Ganga (Philip *et al.* 1989). Flood discharges range from 6500-8000 $m^3.s^{-1}$ (Gandak and Kosi) to 60,000 $m^3.s^{-1}$ (Ganga). Sediment fluxes are high during the flooding season 4-5 months from July to November, and from December onwards the waters recede till May-June (discharges lie between 200 and 4000 $m^3.s^{-1}$; Sinha *et al.* 2005). Human-induced habitat alterations (e.g. agriculture, embankments, transport, rural-urban infrastructure, etc.) have also affected geomorphological processes (Sarkar *et al.* 2000, Swamee and Parkash 2004, Bhargava 2007, Singh 2014), rendering channel changes furthermore unpredictable (Mishra 2009, Chakraborty *et al.* 2010).

Fishing caste groups, communities, and river-floodplain fisheries

In Bihar, over half a million people are estimated to be directly or indirectly dependent on river-floodplain fisheries as a full-time or part-time livelihood activity (Payne *et al.* 2004, Vass *et al.* 2010b, Kelkar 2014a). Traditional fishing and boat-ferrying communities in the river belong to the *Mallah* and *Nishad* caste-groups (Jassal 2001, Doron 2013), and comprise socially marginalized, economically poor, and mostly landless people (Kelkar 2014a,b; Kelkar and Krishnaswamy 2014, Choudhary *et al.* 2015). These communities are categorized as Other Backward Classes (OBCs) and some identify as *Dalit* groups. They fish over 50 species of freshwater fishes (Ray 1998, Sinha *et al.* 2009). Fish catches and effort peak in the summer, post-monsoon, and flood-recession periods (Payne *et al.* 2004, Montana *et al.* 2011). Regular fishing methods involve gillnets, basket-traps, cast nets, seine-nets, mosquito nets, carpet gears, brush-pile traps, and hook-lines in the main river, side-channels, and floodplain wetlands (Ray 1998). Significant declines in fish production have been noted after barrages were constructed on the Gandak and Kosi (in the 1960s) and the Farakka barrage on the Ganga in 1975 (Shetty and Malhotra 1983, Payne *et al.* 2004, Vass *et al.* 2009). Barrage effects on flows and fish production were succeeded by impacts of local river pollution, embankments, over-exploitative fishing practices, and degradation of fish spawn (Jhingran and Ghosh 1984, Vass *et al.* 2010b), along with recent threats from industrial waterways projects (Kelkar 2016). Over 60% of freshwater fish demand in the Ganga-Gandak-Kosi region is now met from cultured carp in Andhra Pradesh and West Bengal (Kelkar 2014a).

Selection of case studies

The five case studies presented here draw from observations and fieldwork between 2008 and 2018. The extents of cases ranged over many institutional scales: from within fishing areas to state-drawn sub-district blocks, to inter-district, to state and international borders. Historical conflicts over access to fishing areas formed a common thread, but present conflict narratives and outcomes also varied across studies. Figure 3.2 maps the case studies as per river channel movement rates per year, and the scales and hierarchy of administrative boundaries that they overlap.

Mapping river channel course changes: remote-sensing studies

Multi-temporal satellite images and old topographical maps of river channels of interest were obtained for selected years between 1920 and 2018. In the period from 1972 to 2018, satellite images from the MultiSpectral Scanner (MSS), Thematic Mapper (TM), LandSat (1-8), and Sentinel-2 series were acquired from the United States Geological Survey (USGS) Earth Explorer web portal (www.usgs.earthexplorer.gov). I obtained topographical maps from the Texas AMS map database (USA) for the period from 1920 to 1940. All images were accurately geo-registered to ensure perfect matching of overlapping extents of fishing areas and institutional boundaries of interest. River channels and floodplain water bodies were classified with unsupervised image classification (accuracy range: 85% to 97%) in the software IDRISI TerrSet (ClarkLabs). Vector overlays were made in Quantum GIS 2.4.0 to monitor channel width, meandering or braiding indices, cut-offs, and flooding extent over time, for each case study (Sinha and Friend 1994; Hooke 2007, 2011).

Delineating institutional boundaries

Spatial mapping of institutional boundaries was based on ground surveys and participatory mapping exercises involving fishers, state department representatives, and other key informants (traders, cooperative members, mafia gang associates) involved in river fishing activities. For mapping, I recorded geographic coordinates as waypoints and tracks in a Garmin GPS device, and digitized polygon boundaries of regular fishing areas, areas of operation of mafia gangs, and block jurisdictions of state fisheries departments (and other departments) in Quantum GIS 2.4.0. I overlapped block boundaries in each district with time-varying river floodplain boundaries over which jurisdictions of fishery cooperatives extended. From these data, I qualitatively assessed the overlaps between moving river channels, fishing areas, and different institutional boundaries.

Interviews and focus group discussions

I conducted semi-structured interviews and informal group discussions with: 1) full-time/part-time fishers using gillnets (regarded mostly as ‘traditional’), 2) part-time ‘non-traditional’ fishers using mosquito-nets, seine-nets, and basket nets/traps with mosquito nets, 3) members of local fishery cooperatives, 4) fish traders, 5) state

fisheries department officials and associated respondents, 6) members or affiliates of criminal gangs controlling fishing, and 7) other relevant institutional representatives and key informants. Interviews focused on understanding the views of respondents about 1) their memory and perception of historical and current control, and resulting conflicts in river fisheries, 2) involvement of state fisheries department and mafia gangs, 3) river channel changes, and 4) strategies used by fishers to navigate conflicts. Responses were triangulated and validated by independent observations, documented evidence (e.g. govt. records), and key informants. Table 3.1 provides sample sizes of interviewees and background information to case studies. Pseudonyms or designations of respondents are used wherever their responses are quoted verbatim or paraphrased, with their permission.

Textual analyses from policy documents and notifications

I analyzed state government policy documents, legislative articles and court proceedings on relevant cases of river fishery conflicts in Bihar, to study the legal contexts in which different respondents negotiated conflicts over fishing rights and access. I reviewed all relevant fisheries acts and analyses of those acts (e.g. Bengal Ferries Act 1885, Doss 1891, Indian Fisheries Act 1897, Ghose 1930, Bihar Fish Jalkar Management Act 2006, with amendments until 2018). Specifically, I extracted information on legal bans on fishing access or gear use, and provisions for deciding institutional jurisdictions of fisheries management.

Analysis of conflict narratives

Interview responses (narratives, opinions, oral histories, perceptions) specific to issues of conflicts over access and rights were qualitatively analysed. Dominant, recurring, specific, and isolated themes that emerged from responses on conflicts were coded and analysed with reference to institutional arrangements and their overlaps with changing river channel boundaries. I summarized information on the positions, mandates, and motivations of the main institutional representatives, as reported by respondents from the fisheries department, mafia gang-associates, and others. I analysed responses to identify any specific institutional strategies to the dynamic boundaries of river fishing areas. This was done to identify 1) modes of conflict negotiation over access and fishing rights, 2) interactions between and understanding

of socio-legal practices by fishers and state/non-state institutions. The analysis yielded insights on factors constraining fishers trying to adapt to conflict situations.

Results and insights from case studies

Case study 1. Uncertain fisheries in the treacherous riverscape of the Ganga: Barari, Bhagalpur.

Bhagalpur was the site of the *Panidari* or *Jalkar Zamindari* in Bihar, with one family controlling the fishery on 100 km of the Ganga River (Sultanganj to Pirpainti) from 1604 to 1991 (Reeves 1995, Sharma 2006, Verghese 2007). The Ghosh family that owned this fishery was conferred a private fishing grant in 1604 during the Mughal period, and the grant was later sublet to other families (e.g. see court cases in chapter 2 for details). All lessees had had a share of 50% to 75% in all daily catches made by river fishers in this stretch. Even as rights to 'public fisheries' on navigable river waters were applied under English law in colonial Bengal (Doss 1891), lessees still extracted rents through coercive measures (Verghese 2007).

The *Ganga Mukti Andolan*, a fishers' movement to free the river from the clutches of private control in the 1980s succeeded in overthrowing the oppressive *Panidari* regime in 1991 (Gupta 1993, Sharma 2006), after which an open-access regime on all flowing rivers in Bihar has prevailed (Kelkar and Krishnaswamy 2014). Since then mafia gangs have held control, by allowing "destructive" fishing gears such as mosquito nets, and poisoning of river side-channels to take place under their protection. According to the Bihar Jalkar Act (2006), these destructive fishing acts and the use of nets below 40 mm mesh size are illegal (mosquito nets, seine nets, and gillnets<40 mm). The legality of different methods has polarized conflicts over access between full-time and part-time fishers using gillnets, and fishers using mosquito nets and other small mesh-sized nets. Gillnet fishers think of mosquito nets as destructive to fish populations, because they harvest large catches of small-sized fish species, and larvae or spawn of larger fishes.

The governmental property rights template over which these conflicts unfold is the separation of the navigable, active flowing river channel from '*jalkar*' sections. River *jalkars* comprise river side-channels and inlets (*kols*/*dhabs*) managed under seasonal contracting, wherein the fisheries department of a block leases *jalkar*s to

bidding members from fishery cooperatives or independent private contractors or bidders, for the dry season (November-April). Such leasing applies only to *dhabs*, which are water-bodies (e.g. oxbow lakes) cut-off from the active river channel as floodwaters recede. According to the Bihar Fisheries Act, *kol* areas, which are side-channels or inlets connected to the main navigable river channel having a width of at least 100 m at the channel junction, can be accessed for fishing by anyone (Govt. of Bihar 2006). *Kols* are productive capture fishery zones for wild fishes through the year. Fish in *dhabs* or *damas* are harvested intensively and contractors also carry out minor fish culture. This is done after flood-recession when *dhab* boundaries become apparent. Figure 3.3 shows an illustration of different fishing areas in the Ganga-Kosi river floodplain. The state fisheries department generally focuses on developing *dhabs* for fish culture and not on the *kols*. This is because *dhab* boundaries are relatively clear and rights easy to assign, with straightforward contract terms and procedures for fisheries dept. officials. However, just before flood-recession, delineating *kol*s and *dhab*s is not easy. At this time, mafia gangs take control of both, and force or persuade fishers to run large mosquito nets and other intensive fishing practices in *kols* to make quick profits in their half- to one-year lease periods.

For a regular fisher, to get a lease to any such *Jalkar* through the cooperative system means that arrangements or collaborations may have to be attempted with gang operatives controlling these fishing areas. Thus, many fishers cannot access productive *kol* areas without paying hefty rents or facing threats. The Jamunia channel (*kol*) that met the Ganga near the Bhagalpur Bridge in 2007-08 has been extending in its length after the river started moving northward by 2015-16 (Figure 3.4). Embankments built to contain river meandering from Raghopur to High-Level (Hylebul), and intense river dredging for waterways may have accelerated sediment erosion and rapid silt deposition at Barari. From 2015 onwards, the tongue of the floodplain peninsula in the river is expanding eastward, extending the length of the *kol* beyond Mahadeopur Ghat (over 3 km downstream of the original *kol* mouth). Bage Mandal witnessed in 2016-17 that, as the sand bar enclosed the *kol*, goons from the Ariya Mandal gang extended their territory. They also extorted his fish catch by declaring the *kol* end as their new *jalkar* boundary. After this sandbar's expansion, the Barari fishers had to stop fishing in the 2018 dry-season. "It is exhausting to turn around the sand bar tip everyday to access the main channel of the river, and return afterwards. The trip takes us three more hours than earlier days when this *kol* had not

been formed. All kinds of *badmaash* (criminal) people are around and threaten us." In 2017-18, desperation pushed the family of Ramu Mahaldar to collaborate with Tarakeshwar Mandal (a local gang 'boss'), whose gangs had illegally obtained a contract on a part of this *kol* from the Bhagalpur Fisheries office. Soon after, Ramu was duped and then threatened. "They did not share the 35% profit that was promised after the intensive fishing period from October to December. I got cheated and also earned the tag of being involved in illegal activities," he lamented.

Groups that fish with large, barricading mosquito nets and traps own or at least tend temporary landholdings as peasant sharecroppers. These groups are regarded as 'non-traditional', and their practices as destructive, greedy, and ignorant by traditional and full-time gillnet fishers, most of who are landless. The illegality of using mosquito nets also pushes fishers towards seeking the protection of mafia gangs rather than approach the fisheries department for legal recourse over fishing rights. Mafia gangs provide protection for their *ilaaka*s (territories) in return for the labour of marginalized fishers. The control of gangs is exercised not only through the use of force, threat, and violence. Contractors from gangs also closely monitor the river-floodplain through the flood-recession period, and identify areas where new inlets may form, and the timing when the inlets can be "captured" based on the rate of water recession. They then easily shift control to such areas by obtaining leases to inlet channels (*kols*) and *dhabs* (Figure 3.4). Mafia gangs thus appear to be fairly adaptive, with their use of violence against river fishers allowing for stable control.

The traditional identity of fishers may buffer them from penalties on their regular use of nets below 40 mm mesh sizes. Most regular gillnet fishers (60% to 70%) use illegal mesh-sizes lower than 40 mm (usually 20-35 mm) to catch fish. Many traditional fishers (Sorahiya and Nishad), from Naugachhia on the northern bank of the Ganga, also come to Barari through the dry-season to employ massive river-seine nets or *Kachal jals*. Teams of 15-20 people haul these 10-15 mm mesh nets across *kols* and harvest huge catches (to the tune of 50-80 kg per haul per day). Bengali fishers (settled since the 1970s in the refugee colony at Bhagalpur) use large dragnets with mosquito net mesh and other multi-mesh filaments in the side-channel. Ironically, these are 'traditional' fishers specializing in the use of these 'illegal' nets for generations. In part due to the illegality of the nets as per fishery laws, these fishers pay mafia gang leaders and strongmen to allow them to fish. Notwithstanding conflicts among fishers over the use of seine nets or mosquito nets, how and whether

these illegal nets actually affect fish stocks is not clear. Management options are controversial under such uncertainty: whether just catching small fish (high selectivity), or catching too many small fish (excessive effort), is the issue at hand (see Garcia *et al.* 2016, Pauly *et al.* 2016). This is studied in thesis chapter 5. The fact that there is no systematic monitoring of legal/illegal fishing gears, catches, and fish stocks underlies similar enforcement problems.

How does the state view these problems? The responses of fisheries department officials at both the state-level (Patna) and the division-level (Bhagalpur) are interesting in this regard. "The issue of governance of river capture fisheries is complex because rivers are 'national property' and hence centrally regulated. The state government is thus not empowered to take any decision on fisheries directly". (Deputy and Assistant Director, Dept. of Fisheries, Patna Headquarters, Bihar). Further, as river fisheries are free in Bihar, there is no revenue to the government – "the fishers take all that they can get, and do not pay any taxes from whatever their earnings are. River fishing is part of 'unorganized sector' activities not to be interfered with." Officials at Patna confirmed that cooperative management of fisheries extends to all river stretches within a block, which is their smallest administrative unit. So according to them the official control of fisheries department was not restricted to ponds, tanks, mouns, or ox-bow lakes. This is contradictory for them, as rivers cannot at once both be national and under state control. Contrary to Patna officials, Bhagalpur officials said that their mandate was limited to pond and wetland fisheries, and did not apply to rivers. Or did they? If the rules of cooperative society application and membership are followed: "to obtain the grant of a *Jalkar*, a certificate has to be furnished by interested members of the block cooperative society. Each society can then apply for lease or grant of the *Jalkar* nearest to the residence of that committee member" (Divisional Fisheries Office, Bhagalpur). Is the Ganga River included in the *Jalkar*? The answers lie all over the place.

Bhagalpur is a 'special case' for river fisheries management in Bihar, according to officials at Patna. This is because of the sanctuary for river dolphins in the river in Bhagalpur district. "Large tracts of that district are active, shifting floodplain land, and there are lots of problems due to the big meandering and siltation caused by the river. There is a lot of confusion between *Jalkar* boundaries. Today the river is in one block, tomorrow in another. And then there is the sanctuary, so river fishing is technically not allowed in Bhagalpur district. But people fish all over the

area; in fact they fish wherever they can. They are backward, illiterate, and poor, so I allow some fishing, but based on an identity card system" (Fisheries Department official, Bhagalpur, 2018).

Traditional and non-traditional fisher groups are listed in the government gazette. The Bhagalpur fisheries department has "tried to curb illegal fishing by non-traditional fishers, and increased awareness about the impacts of using banned fishing gears and mesh size regulations on fish stocks among traditional fishers". Nearly three hundred traditional fishers of the Mallah and Nishad castes in Bhagalpur district received identity cards when the scheme was on between 2005 and 2010. These "*nihshulk shikaarmaahi* cards" (free fishing cards) were given after the Ganga river fisheries were freed in Bihar (made open-access in 1991). The Bhagalpur division officials believe that due to improved awareness, illegal and destructive fishing techniques like poisoning of river channels are now on the wane. When asked whether auction-leases applied both on *kols* and *dhabs*, official responses were highly variable. At Bhagalpur the officials were sure that river areas were not leased to anyone, not because of the open-access regime, but because fishing was banned in Bhagalpur district due to the river dolphin sanctuary on the Ganga. But it is well known that river fishing continues in the sanctuary, with no settlement of fishing rights ever done (Kelkar and Krishnaswamy 2014, Choudhary *et al.* 2015, Kelkar 2018). The intervention of the forest department, in charge of protecting river dolphins, further burdens fishers. Forest dept. ground staff, fishers allege, routinely target weaker gillnet users and extract legal fines or seek bribes, but do not ban illegal gears from operating (Kelkar and Krishnaswamy 2014, Choudhary *et al.* 2015). Importantly, the sanctuary overlaps a large part of the past *Panidari*-controlled stretch, which compounds historical conflicts over access (Figure 3.1, 3.4). Confusions over the sanctuary boundaries between the forest and fisheries departments also created barriers to their acknowledgement of fishing problems. Many fishers believe that the river dolphin sanctuary was created in place of the *Panidari* as a trick to refuse them access to fishing areas. Fishers perceive various impacts of the dolphin sanctuary, both real and imagined. There is a strong fear that the sanctuary laws would curb open-access fishing, though this has never happened. Fishers living in settlements outside the sanctuary (e.g. Janghira, Bariyarpur) report that more armed bandit and dacoit gangs occupy territories within the sanctuary than outside. The sanctuary is

regarded as a dangerous space, due both to its history and present confusions on access, which are seen to favour control of fisheries by gangs.

Fisheries department officials felt that river fisheries' productivity and livelihoods had deteriorated from the 1980s due to water pollution and siltation. They candidly admitted that no concrete steps have been formulated to address such threats. They also knew that since 1975, Hilsa yields had declined to nearly zero, post the Farakka barrage. In Bhagalpur, fisheries officials are aware of complexities in operationalizing their mandate: "We are an understaffed department. Every fisher wants to first fish freely all over the district's rivers – everyone wants identity cards. Then the meandering of the Ganga confuses the system every year, as new inlets, impoundments, wetlands appear over the floodplain in November. Then contractors start approaching us for leases. Due to flood action it is impossible to physically verify where ponds or *kols* and *dhabs* have formed. The Jamunia *kol* is now flowing on the boundary of Jagdishpur and Kharik blocks: then who should lease it out for fishing? It is so difficult to know the block area under which Jalkar the boundary of the lease falls." (Fisheries department officer at Bhagalpur, November 2017)

Interestingly, none of the responses from fisheries officials mentioned illegal fishing or mafia gangs (with their members often being "contractors") taking control of the river's fishery. This omission could have been due to denial or naiveté about the river fisheries scene. Unsurprisingly, fishers regularly pointed towards nexuses between local politicians, strongmen, mafia gangs, and widespread corruption in the state fisheries department. But for fisheries department officials, gang representatives staking claims to lease *dhabs* or *kols* are only 'contractors'. However, there seems to be tacit acknowledgment, without formal disclosure on the informal institution of the mafia. As shown before, mafia-backed contractors are far more alert and responsive than the fisheries department, to the shifting riverscape and opportunities that emerge. The system of control by mafia gangs is adaptive to seasonally changing *kol* and *dhab* configurations unlike the state department's rigid 'block-level' management of the fisheries. Areas of operation of gangs keep shifting with the changing courses of the Ganga. This shows that oppressive regimes are adaptive and also stable and resilient. Fishers using illegal nets mostly work under mafia gangs and local strongmen. In return, they pay hefty rents to gangs or forge temporary and often loss-making collaborations. Through a combination of adaptively shifting fishing areas, and threat of violence, mafia gangs have actively formalized and expanded their control. They

have not remained rent-seeking or marauding goon parties. Gillnets users with memberships to block-level cooperatives can seek recourse against this regime, but can they? With the expansion of mafia gangs and an endangered fishery, the involvement of the state fisheries department in riverine fisheries is zilch. The 'hands-off' approach and neglect by the state, and the control of gangs on river fisheries have thus aggravated conflicts over access and rights for Barari's fishers in an uncertain and treacherous regime.

Case study 2. The Ganga river in Kahalgaon and Gopalpur, Bhagalpur district, Bihar.

Kahalgaon and Gopalpur are towns in the Bhagalpur district of Bihar, to the south and north of the Ganga River (Figure 3.4, 3.5). They are also the respective names of two fishery blocks under the Bihar state fisheries department. When these blocks were demarcated in the 1960s (Figure 3.4), the Ganga river used to flow in the Kahalgaon block. The *Banpar* fishers of Kagzi Tola (fishing settlement in Kahalgaon) regularly fished the river stretch from the Bochaiya village upstream of the three rocky islands in the Ganga at Kahalgaon, till Bateshwar Sthan, which was about 7 km downriver from Kahalgaon. At this time, fishers paid rents of over half of their regular fishing catches or incomes to the *Panidars* of Bhagalpur, in exchange for continuing to fish in their 'private' river fishery. Kagzi Tola's identity is inseparable from the *Ganga Mukti Andolan*, a movement that overthrew the *Panidari*. Kahalgaon's fishers had worked the hardest to make the river free for all to fish in, toiling for years, until they emerged victorious (Gupta 1993, Bharti 2014, Sharma 2006, 2017). Prior to the fishery becoming open-access in 1991, the Ganga's northward meandering in the 1980s had been one source of severe conflicts. This meandering saw the river move away from the Kahalgaon block into the Gopalpur block (Figure 3.5). From the 1980s to date, over 50 fishers lost their lives to gangs operating in the river from the Gopalpur side. In nearly all cases, fishers had refused to part with their fish catches on extortion demands from gang members, but had to pay with their lives (Sharma 2006). Such violence continued post open-access at a lower frequency, and unfortunately continues till date.

The present boundary of the river abuts Kahalgaon but the river, along with all neighbouring fishing areas, lies in the Gopalpur block (Figure 3.5). The Gopalpur

fishers are mostly Gangota and Yadav, regarded as 'non-traditional' and destructive by the Kagzi Tola fishers, for using mosquito nets that kill immature fish. Fishers from the villages of Bochaiya and Tintanga place series of small mosquito nets opposite to and along embankments constructed over the eroded banks carved by the growing meander of the Ganga. Gear conflicts here are identical to those in Barari (Bhagalpur), only here they can be more dramatic and violent. Gangs dominating the stretch in Gopalpur block regularly threaten and extract rents from Kahalgaon fishers if they enter their block boundaries to fish. Whether the Ganga river channel flowing through a block comes under the ambit of the fishery cooperative remains unknown to fishers, as it does for the state fisheries department officials who give widely varying responses (see above). Kagzi Tola fishers fish mostly in the river, but nearly all active fishers have procured identity-cards and memberships of the Kahalgaon block fisheries co-operatives, which gives them an opportunity to bid for pond leases for culture fisheries in the dry-season. With neither income nor interest to place bids for pond fishing, fishers turn to the river that has been their traditional fishing place, and conflicts over laws, rights and jurisdictions continue.

The history of Kagzi Tola and their contribution to the *Andolan* now appear like ghosts of the past. It is possibly the last settlement with a significant number of households still wanting to continue river fishing, and remaining active in politics, litigation, and state confrontation over their rights. Kahalgaon fishers, unlike most others, range far and wide across rivers of the state, managing to fish and hunt turtles (which they regard as their birth right) all over the rivers of Bihar. As they do so they have to get their way by paying bribes and forging ties with mafia gangs and other anti-social elements spread over large fishing areas. But village elders do not necessarily approve of this behaviour. Interview respondents often enumerate court cases and legal representations over all the conflicts, either pending or in progress, in the Bhagalpur court. Kahalgaon, according to them, has turned into a tired, listless fishery. "People fight now over petty matters. I have been trying to keep the fight against the gangs going, but I can see that there is no future. I have failed – but our past contribution to the movement does not even allow us to admit its failure openly," (Ramraj Sahni, veteran fisherman and local *Andolan* leader, Kahalgaon). In 2016, the fish traders' union at the Kahalgaon station market protested against buying catches from mosquito net fishers. This led to an increase in the number of minor fish marts across the floodplain, that now directly sell to distant markets. The conflict has thus

likely led to diffuse and more excessive fish harvesting. In 2016-17, gillnet using fishers of Kagzi Tola requested the forest department to destroy mosquito nets in the river, including even small bankside basket-nets and stake-nets placed by 'traditional' *Bind* and *Sorahiya* fishers in the stretch from Kahalgaon to Kursela-Patthartola. According to Kahalgaon fishers, illegal netting must be banned in the whole Ganga River, whether it is by traditional or non-traditional fishers, and even non-traditional fishers can be allowed to fish in the river provided they use selective and legal nets. This is a 180-degree turn from the position the same fishers had earlier, when they bitterly opposed fishing by non-traditional castes. These developing narratives convey significant compromises, but are important new ideas implicit in current and future political and institutional rearrangements. These are studied further in chapter 6.

Case study 3. Fishing in the Gandak River: braiding through three institutional regimes

The Gandak River, originating from the Dhaulagiri mountain ranges of the Greater Himalayas, flows through Nepal for 300 km before entering India at Valmikinagar, Paschim Champaran district, Bihar (Mohindra *et al.* 1992). The river course below the Triveni barrage on the Indo-Nepal border at Valmikinagar is the basis to demarcate the boundary of the Indian states of Uttar Pradesh (UP) and Bihar. After entering India, the river again flows along the Nepal-India border and enters Nepal for a few kilometres till Susta (about 15 km from the barrage by river), before entering Bihar again. The Gandak braids throughout its course, flowing in multiple and shifting channel threads from year to year (Figure 3.6). Maps of the Gandak reveal a slow but consistent oscillating west-east movement of the river course from 1925 to present (Figure 3.6). In response to how monsoon floods shape channel movements, one braided channel might flow within Bihar and one in UP, or sometimes a single channel thread can flow along their border. Braiding complicates access to fish, providing a complex and interesting context for horizontal and vertical interplay between three distinct institutional regimes that sit in close proximity. In Nepal, community-based institutions manage river fisheries. In Bihar, active channels are fished open-access (like the Ganga, some stretches of the Gandak were also privately controlled in the Mughal and colonial periods: Khan 1985). In Uttar Pradesh, river stretches are allotted to private contractors for fishing each year, under

a state government controlled auction-lease system (Reeves 2002). Fish thus become privately owned or common property depending on where we are. If a channel braids into two threads, one each in UP and Bihar, the UP channel is controlled by private contractors. They use threat to ward off 'trespassing' fishers. Any flowing channel in Bihar remains free-for-all. If that whole channel moves to UP, Bihari fishers in the nearby settlements may temporarily lose access to those fishing areas (Figure 3.6). Local villagers recognize the boundaries of the two states despite regular channel movements and keep track of the changing channel lengths under auction (in UP).

A fisherman from Bihar wanting to fish in the channel flowing along the UP braid has to enter an informal labour-contract with the lessee and contractor/owner of that channel's fishery. But a UP fisher can enter the channel in Bihar without barrier to entry. The dynamics of the braided channels also imply that contractors cannot get leases extending beyond six months of the dry-season (December-May). In the Gandak, fishing intensity and activity are lower than the Ganga. Fishers' choices to enter into contract fishing or to stay in the open-access regime directly influence their perception of risk or conflict. My assessments indicated that daily catches of 20 mm and 24 mm gillnets and castnets, the most commonly used fishing nets, did not differ (both ranged between 1 to 2 kg per day) between the UP and Bihar channels for individual fishers. Hence, returns from fishing in either regime may not affect individual fishers' choices. I was told at Bagaha (Bihar) by local fishers that they prefer open-access fishing in their channel. Here they are free to do as they wish, so long as they stay off the "UP-side" of the channel. In the river stretch near Susta in Nepal (disputed territory between Nepal and India), fishers have their own informal arrangements with Nepalese fishers to secure access to fishing areas. In this stretch, fishing of loaches and cold-water barbs for the aquarium trade has become a lucrative business opportunity, which fishers from all three regimes try to exploit. Differing motivations behind subsistence fishing for food, and aquarium fishing for commerce, are likely to precipitate different conflicts. The ability to navigate potential conflicts over access is an important driver of fisher decisions to choose from the above options. Despite the variable institutional regimes in which fishing is carried out in this area, the relatively low intensity of fishing appear to have limited the intensity of fishery conflicts in the Gandak river.

Case study 4. Palaeo-channels, floodplain wetlands, and poison in the Kosi floodplains of Supaul and Araria.

The Kosi River in eastern Bihar forms one of the largest inland alluvial fans for any river in the world. Called the "Sorrow of Bihar" for its notorious flooding, this river is prone to dramatic channel avulsion and shifts over several kilometres (Wells and Dorr 1987, Singh 2008). The constantly shifting courses continue to influence life along the vast alluvial floodplains, with flood displacement and temporary settlements being a common feature of the landscape. For over two centuries, colonial and postcolonial states have attempted to confine the river within embankments that run along hundreds of km of the river in Saharsa and Supaul districts (Ray 1954, Mishra 2009). The Birpur barrage on the Indo-Nepal border was completed in 1963 for flood control as well as canal irrigation. Since then, the frequency of heavy flooding has been controlled, but risk from extreme floods has increased. Embankments that are subject to frequent breaching and collapse during high floods are a major reason for vulnerability to floods (Singh 2008, Mishra 2009). Here I discuss fishery conflicts specific to the shape-shifting mosaic of palaeo-channels, floodplain wetlands and oxbow lakes in the Kosi floodplain (Figure 3.7a). As per the Bihar Fish (Jalkar) Management Act of 2006, flowing waters in the state are free-for-all to fish in, and all ponds are leased out to co-operatives of which fishers are supposed to be members. However, the Kosi palaeo-channels or *dhaars* do not fit these categories easily. Palaeo-channels are river channels that once belonged to the erstwhile main course. As the river moved west, these channels got cut off rapidly and dried up soon. In subsequent floods, e.g. in 2008, these channels get reactivated temporarily and flow for some distance. As the season starts drying up, these channels become isolated. They are thus stagnant - but also flowing - water bodies over large distances (Figure 3.7a). So the immediate confusion is about whether one can get a lease to fish in these channels through an auction conducted by the block-level or village-level fishery cooperative. The history of riparian rights in the Kosi (see Hill 1990, 1997) and in eastern India's rivers in general (Doss 1891) has had a bearing on river or wetland access for fishing, to date. If palaeo-channels fall within private estates they are fished with the help of labourers recruited by landowners from nearby settlements. Some parts of the channel are leased out based on the blocks they cut through, while others remain open-access (where they adjoin state-reclaimed floodplain *diara* lands).

However, there is generally no notice, or any government *kaagaj* (document) on which these arrangements may be implemented. Gangs that work for upper caste landowners effectively use the uncertainty to exploit fishers and take ownership of floodplain wetlands in their names. If Mallah or Nishad fishers still manage to get titles and fishing rights over ponds, these gangs often poison ponds, in revenge.

In the Supaul and Saharsa districts, distinct palaeo-channels are found in the eastern Kosi basin. They are locally named the *Haiya dhaar, Sanjha dhaar, Kushkapur dhaar, Sitapur dhaar, Ahiya dhaar*, and the "main" *Kosi dhaar* (currently active channel). *Dhaar* nomenclature changes over short distances. There is widespread confusion on the ground about which channels the villages recognize as the main channel of the Kosi, around who controls them, and who can fish in them. "I lost nearly 1.5 lakh rupees that I invested in a fishing lease on a pond close to a channel fragment" (Bairagi Malla, fisherman, Bhimnagar, Supaul). This respondent claimed that, because of other interests in the pond, he could never do any fishing there – it was poisoned frequently, and armed men had extorted fish catches from his fishworkers once. Then the *dhaar* changed its course and his wetland got included in that channel fragment – and he was told by the cooperative that his lease was now invalid. A state fishery department official in charge of the co-operatives, also highlighted the problem of the palaeo-channels as a quirk of fate: "In the Kosi, wetland fishing is profitable and growing in its potential. But some water-bodies have a mind of their own." Officials familiar with the Kosi's flooding know how large floods (as in 2008) can activate palaeo-channels and flow like the main course. At Nauhatta, one fisherman explained, "there are not one but many *Kosis* here. What you call the main *dhaar* may not be the main *dhaar* tomorrow. It might run away. I will also move if fishing in some new wetland is possible."

Case study 5. The curious case of Koskipur, at the confluence of the Kosi and Ganga rivers, Bihar.

Koskipur is a village located right at the junction of the Bhagalpur, Purnia, and Katihar districts (Figure 3.7b). The village has 175 households of Mallah fishers (from the Gonrhi or Mahaldar sub-caste) who own 150-200 boats that they ply on the Kosi and the Ganga near the Kursela Bridge at the confluence of the rivers. These fishers fish for 3 to 4 months a year, targeting the rising flood and receding flood

periods from June-July to October-November. The remaining nine months, they either migrate to Punjab and Haryana to work as farm labourers, or work on sharecropped lands around their own village, where they grow tobacco. Being landed is an important asset these fishers enjoy, unlike many families living along the Ganga. But when they are fishing, even seasonally and occasionally, the challenge of channel boundaries affects their lives. Bandali Singh (Mahaldar) who fishes both in the Kosi and Ganga, remarked that he had to pay Rs. 2,200/- last year to the local strongman Bihari Yadav, who threatened to beat him and take his boat away. Fish grabbing is also regular. "Part of the problem is our location itself. Look where we are… the *kuchcha* road next to the house under construction is the Bhagalpur-Purnia border. We are now in Purnia. But the Kosi is flowing in Bhagalpur district. If we try to fish in the river, or in side-channels or floodplain wetlands, goons harass us because we are not from their district." (Bandali Singh, fisherman, Koskipur). His son adds that they also face difficulties selling their fish catch to the nearby market at Kursela in October and November, because Kursela lies in Katihar district. The market contractors there blame the Koskipur fishers for interfering in their *ilaaka* (territory) and recently there have been some fights too. While most fishers have moved on or make do with farming activities, those who cannot exit from fishing still suffer. "We wish sometimes that we relocated or that district boundaries were not used to decide our status. I am a member of the Purnea district fishery cooperative, and some of us managed to become members of the Katihar cooperative. But all ponds nearby are in Bhagalpur, and we cannot access other ponds in our district easily because they lie in private land. Our Rupauli block office is 18 kilometres from here. Going there to get any lease information means losing a whole day of work. For the fisheries department, the same distance is easier to travel, but nobody has visited Koskipur yet." (Bandali Singh).

Discussion and Conclusion

The case studies discussed here yield important insights about conflicts over fishing rights and access in the Gangetic plains of Bihar. To synthesize across the cases, we can hark back to Young's framework of institutional fit, scale, and interplay. River boundaries never obey boundaries, so institutional and administrative jurisdictions and boundaries need to adapt to the extent of river channel dynamics, in

order to "fit" relatively better in terms of the managing fisheries at the right scales. This never seems to happen, and as systemic confusion and uncertainty are commonplace, mafia gangs can exploit them to corner fishing areas, markets, or leased ponds. There is interplay between rates and magnitudes of river course change and spatial scales of management across rivers (see Figure 3.2), which may indirectly affect conflict events. For example, inter-state or international boundaries overlapping with the braiding Gandak channels limit interactions between fishers who wish to avoid potential conflicts. Trajectories of fishing activity in rivers also play a small role. In the Kosi, where wetland fishing is the mainstay and river fishing is low, violent conflicts are witnessed over rights and leases to ponds, but not so much over river course changes. The memory of historical conflicts over access to fisheries had a strong bearing on current fisheries management and conflicts in diverse settings. These histories and state management policies have co-produced similar outcomes and shared experiences of conflict across the five cases I studied, even though they varied in context and magnitude. Horizontal interplay is seen between state institutions (forest vs. fisheries) and between state departments (fisheries, police, etc.) and mafia gangs, while vertical interplay makes management actions inconsequential when mandates overlap across administrative levels within the state machinery (the Ganga as a national river and state fishery).

Due to such institutional interplay and confusion, and weakened community institutions, the emergence of criminal control by gangs and rapid exit of fishers denote the shrinking space for fishers to demand for rights and stakes. Formal state institutions simply do not seem able to get a foot in riverine capture fisheries, as they fail to come to grips with a dynamic riverscape. Ambiguities over fishing areas cannot be managed under existing cooperative and private auction-lease structures. Why is this the case? The state's lack of interest is in part due to the revenue that they cannot fiscally channelize from these open-access fisheries. Rather than being an arbiter, the state itself is a weak and ineffectual party to the conflicts. Surprisingly, there seems to be no attempt by the state to create new revenue channels or monitoring and management systems. The rigid "terrestrial" block boundaries of state institutions, in a dynamic riverscape, incapacitate adaptive fisheries management. Such rigidity has its origins in part, within the "agricultural" vision for fisheries. Historically, fisheries has been treated just as subsidiary issue to agriculture, with even the fisheries department once being part of agricultural ministry and departments. As shown

before, this also explains why the primary interest of the fisheries department is in aquaculture – which can be managed like agriculture in a fixed, intensive way.

In contrast, mafia gangs adaptably rework and change their boundaries, rules, and operations, to extend and consolidate control over fishing areas over time. Their control over the fishery very well accounted for uncertainties in river channel movements. These observations confirm how mafia institutions are efficient and adaptive, in ways almost similar to a "shadow" state, operating with authoritarian, undemocratic, and violent ways (Giordano 2017). Mafia gangs show signs of having substituted formal state control and regulation (Helmke and Levitsky 2004, Giordano 2017). Such control of fisheries has been noticed in inland fisheries of SE Asia (Sneddon 2007). Mafia gang members, by entering the fishery, are now the new "contractors": citizens who form the "shadow" state that dictates the terms of river fisheries. In the absence of monitoring, illegal fishing becomes profitable, as the marginal value of harvests far exceed the costs of fines and sanctions (Charles *et al.* 1999). The mafia regime built upon appropriation of fishers' labour is an economically profitable but exploitative and socially undesirable outcome (Hirshleifer 1988). Formalization of control by mafia gangs explains why remaining fishers try to enter illegal fishing when they can, than exiting completely (Daw *et al.* 2012). Catches per individual fisher involved in illegal fishing are generally higher than for individual gillnet fishers, making it worthwhile despite the dangers of getting exploited. Under such a regime the functions of official or formal state cooperative institutions are diminished (Deacon 2012), and can undermine principles of public trust, landing cooperatives in a democratic deficit (Birchall 2004). The legitimacy and authority of co-management institutions in India have frequently been undermined by elite capture and local politics (Blair 1996, Davis and Bailey 2008). The lack of transparency and fairness in cooperative lease allocations are 'open secrets', but the controllers are perhaps too powerful for regular fishers to challenge directly. Further, territorial conflicts and contract rivalries prevail between different gangs, as seen in the Kosi cases. These conflicts aggravate risks of violence, with fishers becoming easy targets in the crossfire.

In this situation, an easy way out for the state fisheries department is perhaps to remain indifferent about whether rivers "come under" their block or not (perhaps they even wish that rivers were not part of their blocks). Official responses vary significantly, but the dominant narrative is that co-operatives are meant only for

ponds where fish can be cultured. At their end, river fishers have secured cooperative memberships, identity cards provided by the Cooperative Fisheries Federation (COFFED-Bihar), and use them to access government schemes for housing or education for their children. While these benefits may not bring about security of work and livelihoods *within* capture fisheries, they can be used to securely exit a threatening fishery (Kelkar 2018, and chapter 6). These observations suggest that issues of equity, human rights, and dignity are more important than profit-maximization, efficiency, or income security in small-scale fisheries management (Allison *et al.* 2012, Bene *et al.* 2010, Blair 1996, Ruddle and Davis 2013).

The failure of state regulatory mechanisms and the restricted mandate of the fisheries department to only managing ponds is clearly an escape from the 'madness' of river-based capture fisheries. This lack of interest in river fishery matters is also identified by Narayanan (2016). Official renderings and representations of these issues often indicate a sense of inevitability. "What can be done about problems of river fishing? Not much. The situation is very complex in Bhagalpur, as it is a flood-prone *diara* region." (Fisheries Department clerk, Bhagalpur division). Such justifications are generic and are used to explain almost anything, even by local people – the poor condition of roads, railway delays, flood embankment failures, violence, corruption, … the list goes on. So far, investigations on institutional management of riverine fishery conflicts in Bihar have been limited to descriptive studies or are 'frozen in time'. For instance, Katiha *et al.* (2013) give an interesting comparison of institutional arrangements in the Gangetic plains. They review the effectiveness and outcomes of one cooperatively managed, one open-access, and one private auction-lease fishery in the Yamuna, Ganga, and Ghaghra rivers. Despite a useful comparative analysis of policies, benefits, and fish catch returns across these regimes they do not recognize the control of informal or illegal institutions on river fishing. But Kelkar (2014a) documented violence, threat, and other forms of criminal control are now pervasive influences on almost all rivers of the Gangetic plains, irrespective of officially recognized regimes. Katiha et al.'s analysis remains cursory as it lacks information on baseline fisheries productivity for the three rivers compared – and more importantly – historical insights on how conflicts have changed remain beyond their scope. Nonetheless, they recognize that local fishers need to be strengthened by cooperative arrangements to overcome conflicts. They believe this will help fishers adapt better to fish declines accelerated by private ownership of river

fisheries. The importance of cooperative and co-management paradigms is being recognized for many small-scale fisheries (Ovando et al. 2012). Cooperative management, if implemented effectively, could help fishers secure harvesting rights, conditional on which incentives for conservation and sustainable management may be easier to create (Ovando et al. 2012, Kalikosi and Franz 2014, d'Armengol et al. 2018). However, in the Gangetic plains, despite a few positive efforts on the above lines, cooperation in capture fisheries is very limited.

At their level, fishing people employ their local knowledge and diverse practices, and keep shifting strategies to adapt to the uncertainty and dynamism of the river-floodplains. But in the absence of meaningful community institutions and lack of agency, such 'everyday' adaptation remains weak. This weakness does not enable collective resistance by fishers to overcome conflicts and secure their fishing rights. The limited imagination and capacity of fishers to create community-based institutions to secure fishing rights is of concern for the future of capture fisheries livelihoods (Scott 1993, Hilborn *et al.* 2005) in the Gangetic plains. This lack of organization, dialogue, and coordination *among* fishing communities is puzzling, especially if we see the same fishers' past involvement in movements for fishing rights (but see chapters 2 and 6 for a critical analysis). Kelkar (2014b) noted how fishers in Bihar had started perceiving the open-access fisheries as worse than even the oppression they had faced for over 300 years under the *Panidari*. Fishers believed that those who once fought against the *Panidari* had no larger vision for their community or even the river beyond that specific movement. Instead they had only consolidated their own political power as community 'leaders'. From the vantage point of 'water tenure' (e.g. FAO 2016) in community-based management, the lacking effort of communities to organize action appears surprising (Kellert *et al.* 2000). Open-access regimes without any arrangements to manage tenure or access can make fishing areas more prone to takeover by anarchic elements, as shown in my work. In other words, can open-access really persist without the risk of conflicts, when local self-organization by communities is wanting? For these reasons, common property theory and management principles decry "open access" and argue for community-based institutional structures for local governance of fisheries (Scott 1993). However, Sharma (2017) argues that for marginalized communities, open access may likely be of immediate importance than alternative visions of local organization. Arthur (2020) has argued that issues of agency of communities involved in open access small-scale

fisheries are often downplayed or overlooked. For the resources they fight to access, open access brings freedoms more valuable than formal-rational benefits of institutional management, and might allow communities the power and confidence of not being berthed underneath the weight of state-controlled or elite-controlled institutional structures (Davis and Bailey 2008, Baird 2010, Arthur 2020). This insight proposes one reason why the willing participation of the most marginalized castes in standard formats of community organization for resource management may be difficult to solicit (Stringer *et al.* 2006, Reed 2008). However, without community-organized management, the danger of defaulting to earlier power structures and free-rider situations remains.

The other reason is of entrenched social inequalities in access to resources, stemming from caste conflicts and agrarian violence that have scarred Bihar over the last six decades (Prasad 2014). Irrespective of the rivers' biophysical dynamics, caste conflicts and inter-settlement conflicts remain a constant across my case studies. Thus, the present confusions and compromises with the risks of open-access need to be understood in terms of Bihar's caste politics (Kumar 2009). I discuss this in detail, in chapter 6 of my thesis. The major source of caste conflicts is related to the mafia gangs, typically formed by the Gangota (Mandal) and Yadav caste-groups. The emergence of Yadav gangs was after their political rise in the 1990s, which made them 'upper backward castes' as they replaced previously dominant castes in the power hierarchy (Robb 1979, Mendelsohn 1993, Kumar 2009). But for the Gangotas, a floodplain-dwelling caste, violent crime has been part of practice from some time. Rajesh (1995) has linked Gangota violence in Bhagalpur to past agrarian distress and oppression by upper-caste landlords. Other communities in Bihar also witnessed transitions to crime as a means of resistance (Chaubey 2006). Gangota leaders are making their presence felt today in the caste politics of Bihar, much the way Yadav leaders did in the 1980s and 1990s, through secular and caste alliances, and with increasing political patronage and links to criminal control (Chakrabarty 2008, Kumar et al. 2008, Ankit 2018). Their new political clout in the region has a strong bearing on the gradual legitimization or normalization of fishery control by gangs. Gangotas also got themselves enrolled as 'traditional fishing castes' in 2014. Mallah castes are also making steady but similar inroads in regional caste politics. However, conflicts at the sub-caste level *within* fishers also prevail. The call for political organization of fishers might still exclude the more marginalized communities. This was evident in

the responses of Bind fishers I interviewed, who belong to one of the most marginalized and "low" fishing sub-castes. These fishers said that their rights and access to fisheries were suppressed not only by *Gangota* and *Mandal* gangs, but also by opposition from "higher" fisher sub-castes (e.g. *Banpars* from Kahalgaon). Thus there are conflicts over fishing rights both within and between caste groups.

Here it is worthwhile to ask why fishing communities appear unable to organize, in spite of what seem to be enabling factors for local institution formation: at the settlement level, or by group identities and memberships based on caste or tradition. It is likely that, being trapped between the threat of violence by the mafia and the irrelevance of inept state institutions compels individual fisher families to focus on scratching out their day-to-day existence, than investing time in community organization or participation. This lack of agency is probably worsened by poverty and widespread corruption in the citizen-state interrelationship in Bihar. Due to the existing arrangements of allocating rights to water bodies, issues of recognizing and securing community rights is important. The assumption is that the benefits fisher communities may get from cooperatives are similar to benefits they may have enjoyed from their individual rights (Kelkar & Krishnaswamy 2014). This is a problematic assumption, because the government system seems to have no guidelines to formally recognize community rights to river stretches. For this, confusion on river-based cooperative jurisdiction needs to end. Community rights can be given to locally resident fishers along rivers, with rules to govern access by other fishers through nominal fees or tickets. But it is unlikely that the free-for-all system can be "enclosed" as clubs in this way without significant opposition. The retreat of community rights is as strongly linked to the internal fragmentation of fisher community relationships, as it is to unhelpful state policy frameworks. When fishers have tried to organize, the threat of gangs and self-interests of community leaders involved in individual political gains have also thwarted these attempts.

Conflicts for access and rights also intersect law, culture, and traditional knowledge when we look at differences in fishing practices (Charles 1992, Taylor and Garcia-Barrios 1995, Klug 2002). The conflict between what is traditional and legal/illegal is interesting; usually these categories are assumed to be synonymous in fisheries management (Bennett *et al.* 2001). But the cases of Bhagalpur and Kahalgaon prove otherwise (see chapter 5 for a thorough analysis). Fishing small fish with small meshed nets is not new in the region (at least not as new as mosquito nets)

and was in fact a 'traditional' fishing practice in Bengal, carried out through customary arrangements of access negotiated with landowners (Hunter 1874, Day 1877, Sen 2015). But colonial administrators of fisheries found these practices unsustainable and declared them illegal (see Hamilton-Buchanan 1812, Day 1873). See chapter 2 for details on how these perceptions gave an impetus to private and state control, and disallowed space for community-based management of fisheries. Importantly, despite years of researches on river fish production biology in India, the current view is no different. Though these practices are admonished for being illegal, their actual impact on fishery yields is not studied. The narrative of destructive fishing and declining yields rubs off on fishers' perceptions and deepen conflicts (Abbott and Campbell (2009) report a similar example in the Zambezi).

The current state of affairs has magnified the risks of river fishing, leaving behind limited and uncertain livelihood options. This uncertainty and pessimism deepen community perceptions of scarcity (linked to the analysis in chapter 4). The option of moving into pond-based fish culture is limited by financial constraints that prevent them from securing pond leases against more powerful bidders (Katiha *et al.* 2013, Kumar *et al.* 2014). Obtaining *Jalkar* areas (*dhabs* in river side-channels and temporary floodplain wetlands) on leases is possible if fishers work with or under mafia gangs through makeshift arrangements (e.g. by paying bribes or protection money, splitting catches, collaborating for contracts, etc.). But these arrangements are insecure and keep fishers vulnerable to continued exploitation. Now, whereas most young fishers have moved away from fishing to seek opportunities through education and skilled work, middle-aged fishers who were actively fishing are now exiting the fishery and migrating for labour work in farms or urban construction (Punjab, Delhi, Haryana, or Mumbai or Bangalore; Singh *et al.* 2011). Distress migration comes with its own major compromises and new vulnerabilities.

The above complexities call for approaches based on principles of plural management, to recognize and accommodate different modalities of customary access, formal tenure, and fishing rights (Edwards 2003, Bavinck 2005, Bavinck and Jyotishi 2015). Involvement of democratic and cooperative state institutions in capture fishery matters is important in this regard, to enable community-based institutions, social learning, and revive knowledge-systems and co-management (Faust 1998, Krause and Glaser 2003, Pahl-Wostl 2006). Fostering capacities for hybrid forms of co-management at different socio-ecological scales needs to be a

priority (Allison and Badjeck 2004, Abbott *et al.* 2007, Armitage et al. 2008, Nguyen *et al.* 2016). Recognizing community rights needs to go beyond being a legal or institutional objective, toward becoming a social and political priority, through which greater awareness of rights and leadership can be fostered (Gutierrez et al. 2011). Across the Gangetic basin, biodiversity and fish stocks are declining, as anthropogenic threats and extremes of climate variability increase (Vass *et al.* 2009, Welcomme *et al.* 2010). In this context, adaptive capacities of fishers to sustain fishery-based livelihoods need to be supported by local community institutions and recognition of community rights (Allison and Badjeck 2004, Smith *et al.* 2005, Armitage *et al.* 2008, Allison *et al.* 2012, Nguyen *et al.* 2016).

Tables

Table 3.1. Location details, interview respondent information, and the main issues of fishery conflicts are summarized for the five case studies. Numbers of interviews/group discussions conducted with fishing groups (with sub-caste names) and other institutional representatives are provided.

Case study and river	River stretch and districts covered	Nature of fishery conflicts studied	Details of interviews conducted
1 (Ganga)	Barari (Bhagalpur, Bihar)	Conflicts over access to *kol*s (river side-channels) for fishing; use of illegal fishing practices; harassment of fishers by mafia gangs	Fishing groups: *Mahaldar* (*Gorhi*) fishers (n=30) *Gangota* fishers (n=6) *Sorahiya* fishers (n=2) *Nishad* fishers (n=5) Bengali (refugee) fishers (n=2) *Banpar* fishers (Kahalgaon, n=3) Institutional representatives: Bhagalpur division of state fisheries department (n=2), Bihar state department of fisheries headquarters, Patna (n=3) Gang associates and members (n=3), Bhagalpur division of Bihar department of environment and forests (n=6) Co-operative members (n=2)
2 (Ganga)	Bochaiya to Kahalgaon (Bhagalpur, Bihar)	Conflicts over access to main river channel by Kahalgaon fishers. The river flows through the Gopalpur block, where Kahalgaon fishers are treated as trespassers and harassed by local gangs. Use of illegal fishing practices by fisher settlements in Gopalpur block is also a reason for conflict.	Fishing groups: *Banpar* fishers (n=25), *Bind* fishers (n=3), *Gangota* fishers (n=3) *Sorahiya* fishers (n=4) Institutional representatives: State fisheries department (n=2) Fish traders (n=5) Gang member (n=1) Co-operative members (n=2)
3 (Gandak)	Susta (Nepal), Bagaha (Paschim Champaran, Bihar), Paniyahwa (Kushinagar, UP)	Minor conflicts over access to braided river channels alternating between open-access in Bihar, and private contract fisheries in Uttar Pradesh.	Fishing groups: *Sorahiya, Khulwat, Banpar, and Tharu* fishers (n=10) Institutional representatives: UP fisheries department (n=1) Bihar fisheries department (n=2) Local farmers (n=7) Private fishery contractors (n=2) Cooperative members (n=1)
4 (Kosi)	Kosi river, floodplain wetlands, palaeo-channels (Supaul, Saharsa, Bihar)	Conflicts over accessing palaeo-channels for fisheries through auction-lease schemes for cooperatives	Fishing groups: *Mallah* and *Mukhia* fishers (n=10) Institutional representatives: Fishery cooperative members (n=3) Bihar fisheries department (n=3) Local farmers (n=2) Cooperative members (n=1)
5 (Kosi)	Koskipur village in the Kosi-Ganga interfluve belt (Purnia, Katihar, Bhagalpur districts, Bihar)	Conflicts over access to floodplain wetlands, river channels, and markets, issues of membership in fishing cooperatives	Fishing groups: *Mallah* fishers (n=10) *Bind* fishers (n=3) Institutional representatives: Cooperative member (n=1) Kursela market (n=3)

Figures

Figure 3.1. Map showing the Ganga, Gandak, and Kosi river-floodplains in Bihar, India, indicating the locations of the five case study areas.

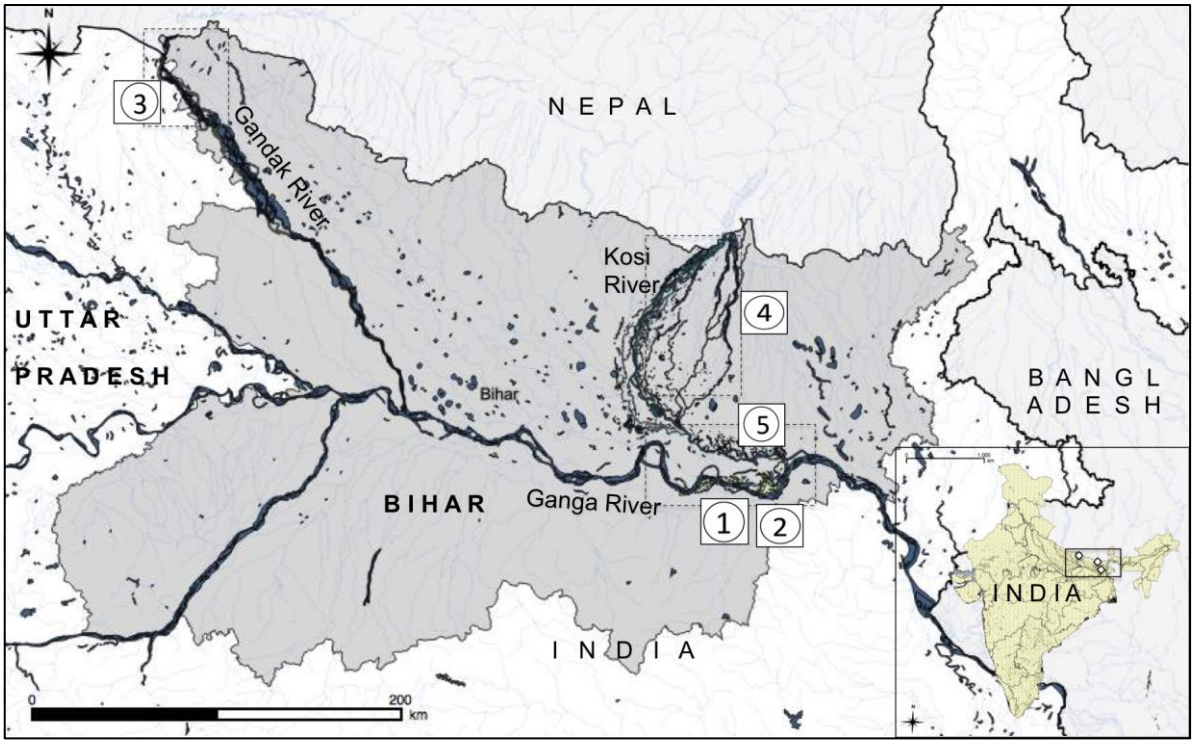


Figure 3.2. The five case study locations plotted to show channel movement rates across the scales defined by the hierarchy of institutional boundaries, over which fishery conflicts have precipitated.

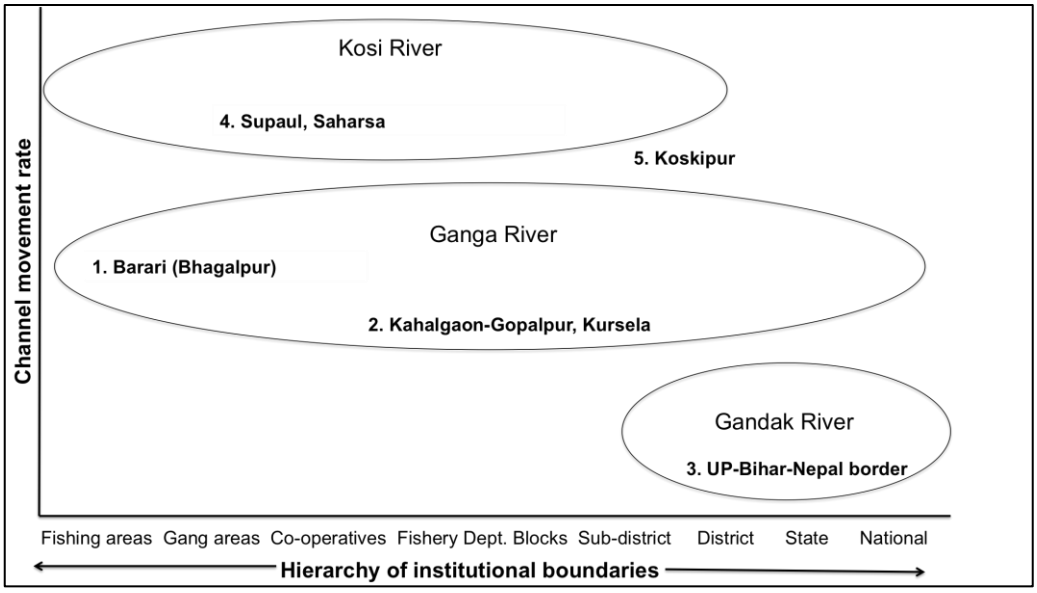


Figure 3.3. An illustration of the diversity of different fishing areas on the river-floodplain in Bhagalpur district, Bihar. Local words for different habitats: *diara* region, *kols*, *dhabs*, are also indicated.

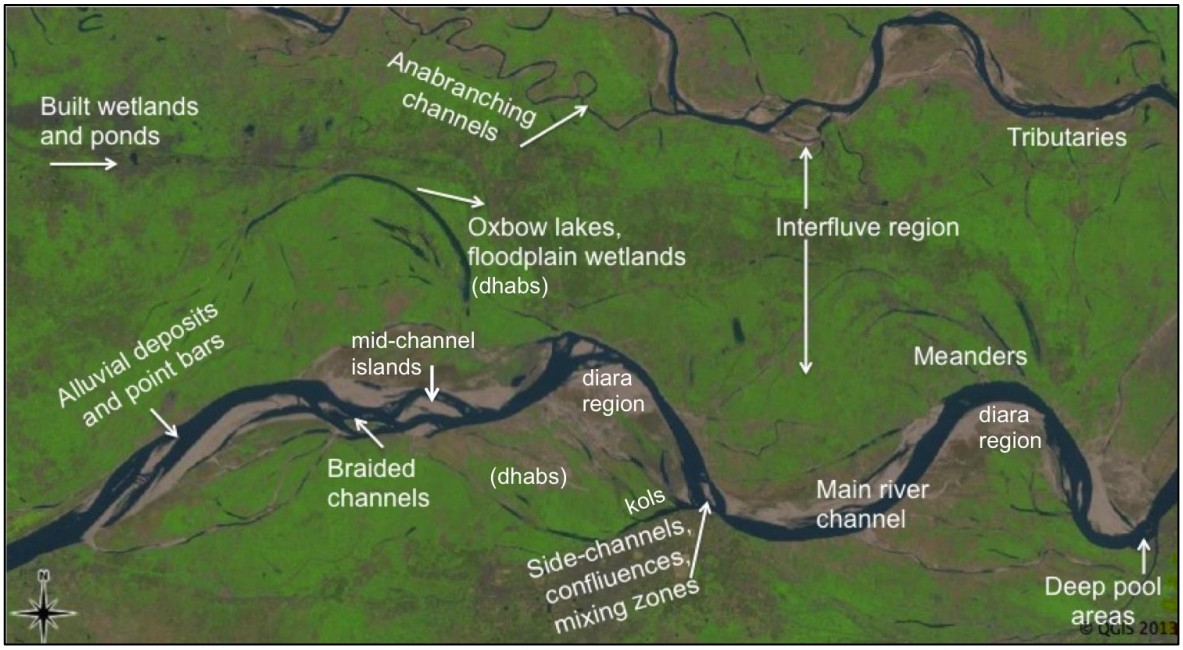


Figure 3.4. The Ganga River at Barari, Bhagalpur district (case 1). (a) The Ganga river (1989-2018) flows in large meandering loops at Barari, (b) the 100 km stretch from Sultanganj to Pirpainti, over which *Panidari* existed from 1604 to 1991, (c) state fisheries department blocks were delineated in the 1960s in all districts of Bihar (when *Panidari* continued), (d) the Vikramshila river dolphin sanctuary was notified from Sultanganj to Kahalgaon in 1991, the same year when *Panidari* ended, and (e) the subsequent control of mafia gangs on different stretches along the Ganga river. Channel course changes from 1937 to 2018 are shown in the lower panels with annotations.

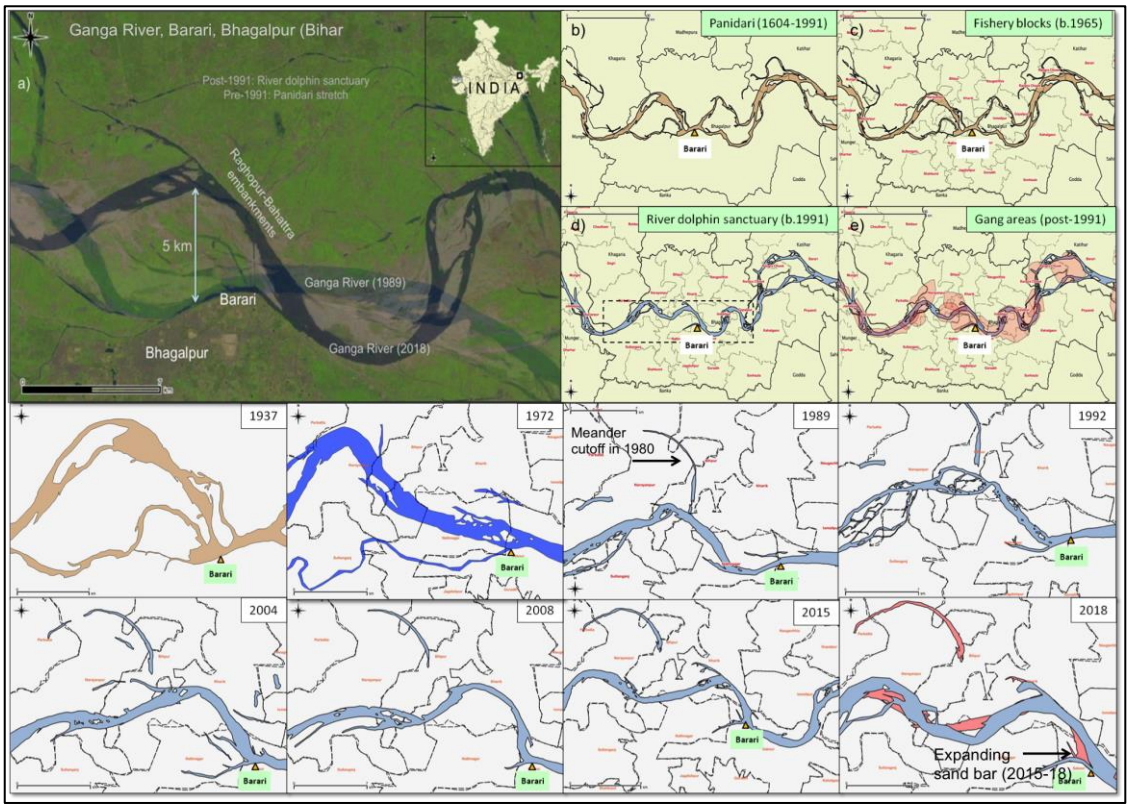


Figure 3.5. Changes in the course of the Ganga River (case 2) along the Kahalgaon-Gopalpur block boundary (large inset). In 1937, the Ganga flowed along two large meandering channels. Meandering of the Ganga after the 1980s saw the main channel move gradually northward into the Gopalpur block from the Kahalgaon block. In the 1980s, gangs murdered nearly 30 fishers in this stretch of the river. Conflicts over access to fishing areas have continued hence. The river at present flows almost entirely in Gopalpur block. Refer to Figure 3.4 and Table 3.1 for details.

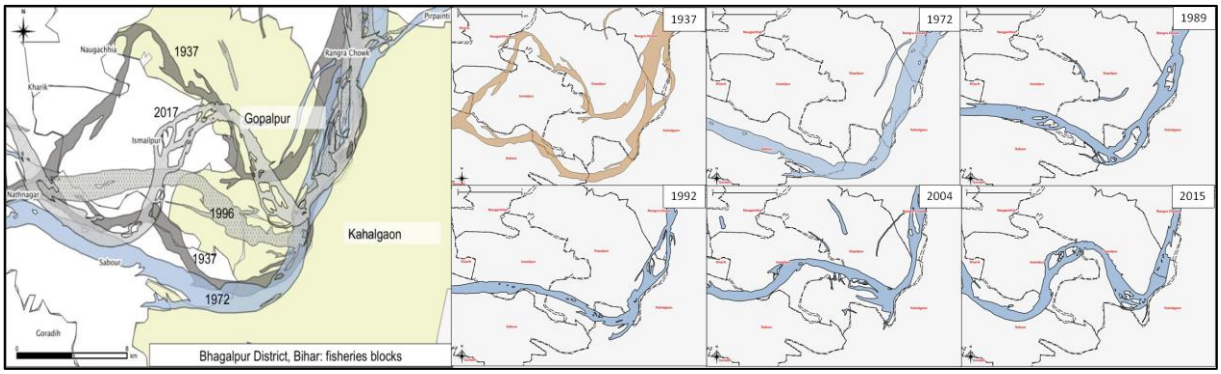


Figure 3.6. The Gandak River (case study 3) traversing through Nepal, Bihar and Uttar Pradesh (UP), below the Triveni barrage on the India-Nepal border (inset 1). From 1972 to 2017, reduction in river flows and increased sinuosity is noted (insets 2 and 3). The Gandak moved westwards immediately below the barrage, and eastwards further downstream. With its movements along the three borders, river braid channels overlap three fishing regimes (private contract fishing in UP, community-based fishing in Nepal, and open-access in Bihar). The red arrow indicates dynamic braiding and channel movements between 1925 and 2017 (top, small insets).

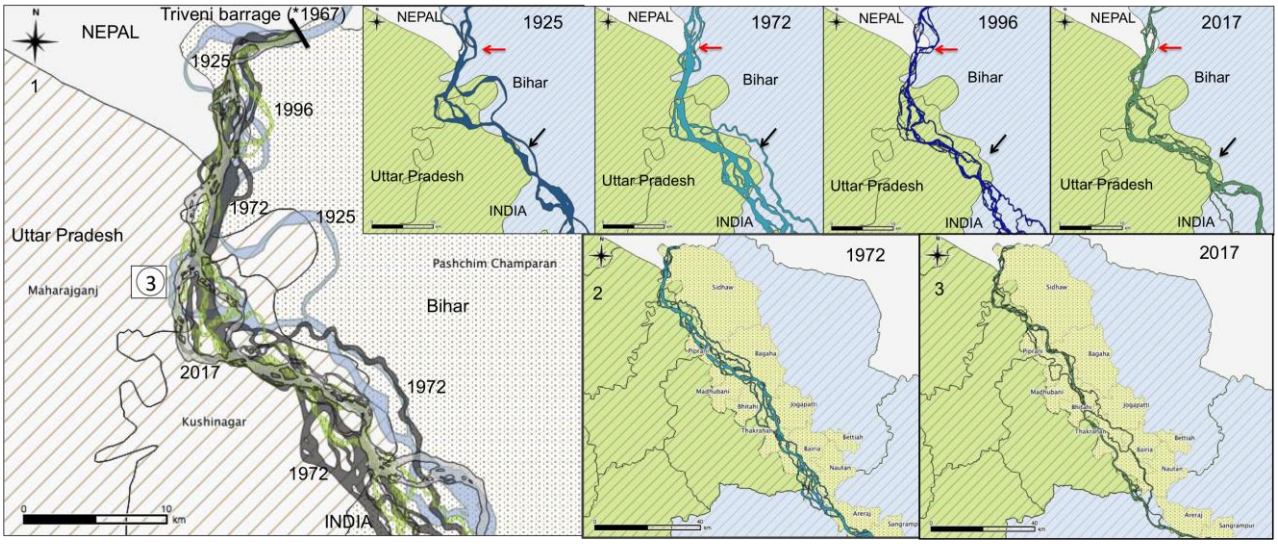
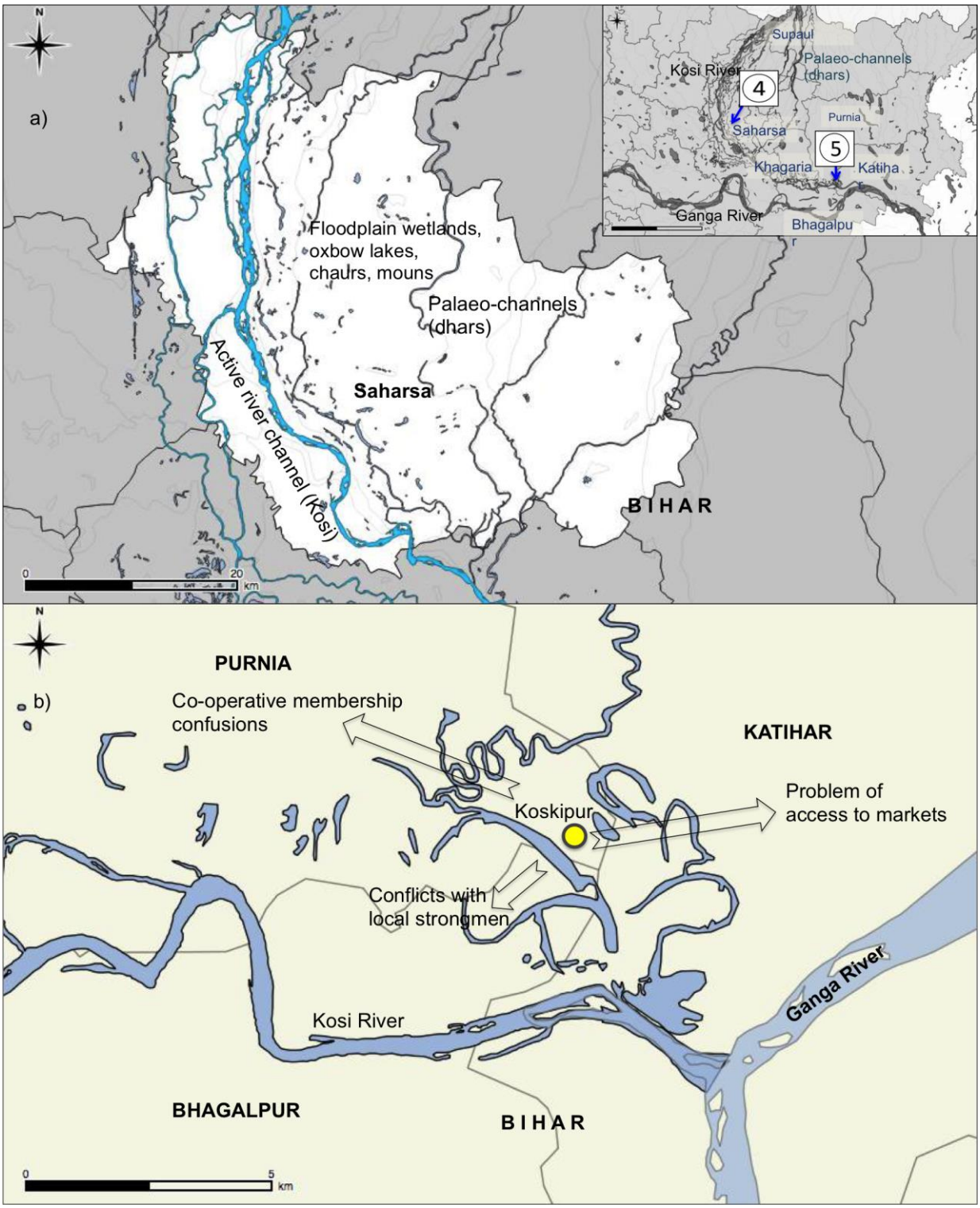


Figure 3.7. (a) The Kosi river-floodplain in Saharsa district, Bihar (case study 4). Floodplain wetlands, e.g. *mouns* and oxbow lakes are managed under block-level cooperatives, the main Kosi River is fished as open-access, but access to palaeo-channels has frequent conflicts. (b) Fishers of Koskipur (case 5), because of its location at the junction of Bhagalpur, Katihar, and Purnea districts, face various hurdles in accessing markets, cooperatives, and fishing areas on the floodplain.



Chapter 4. Fish traits determine the relative impacts of environmental variability and fishing practices on resource conflicts along the Ganga River

Introduction

Narratives of resource scarcity commonly underpin conflicts over river water and fisheries (e.g. Gleditsch *et al.* 2006). Ideas of scarcity mostly originate from two sources. The first is the "Malthusian overfishing" narrative, that suggests that increasing numbers of fishers in a waterscape, operating as independent individuals and without incentive to fish sustainable, leads to declining fish yields (Pauly 1994). Typically, catch rates show declines in emerging small-scale fisheries with limited barriers to access (Hilborn and Siebert 1982), and fishing is usually identified as causing resource declines (Welcomme *et al.* 2010). The second source is environmental variability and the pulsed behaviour of hydrological and climatic drivers of productivity of riverine capture fisheries (Allan *et al.* 2005, Dudgeon *et al.* 2006). Scarcity can emerge periodically in riverine capture fisheries, with time lags, creating 'scramble competition' and subsequently to conflicts (Welcomme 2001, Welcomme *et al.* 2010, Badjeck *et al.* 2010).

There are problems with both ideas. The Malthusian overfishing narrative neglects complex social and political drivers, and the institutional structures and social stratification that could lead to overfishing and resource loss, by affecting fisher folk and their fishing practices (Sneddon 2007, Finkbeiner *et al.* 2017). The scarcity of fish alone may not cause conflicts, as the Malthusian narrative insists. Instead, technological changes, economic choices, governance decisions, and social marginalization of fishing communities could affect fish resources, even when effort or fisher populations do not change significantly (Finkbeiner *et al.* 2017). Environmental variability creates temporary periods of scarcity, which are commonplace in any fishing activity. Fishers routinely modify their fishing practices and investments of effort with respect to hydro-climatic variability and pulsing, resulting in 'good years' and 'bad years' (Dudgeon *et al.* 2006, Rodriguez *et al.* 2007, Dey *et al.* 2019). Fishers otherwise adapted to pulsed and seasonal flow variability (Welcomme 1985, 1995; Welcomme *et al.* 2010, Lynch *et al.* 2016a) may not be able to respond to high anthropogenic perturbation of 'normal' environmental variability.

However, while appealing as an idea, 'normal' environmental variability is coming increasingly under scrutiny, as evidence mounts of non-stationarity and non-linearity in hydrological and climatic systems (e.g. seen in extreme events, regime shifts, etc.; see Park and Rao 2014, Bayazit 2015). Shifting ecological baselines can further aggravate impacts of fishing practices (Humphries and Winemiller 2009, Barnett *et al.* 2017, Jade Bladon *et al.* 2018, Ngor *et al.* 2018). Extreme climatic or altered hydrological variability can thus impair fisheries productivity and have implications for conflicts in fisheries (de Graaf *et al.* 2015, Myers *et al.* 2017).

Given how strongly resource conflicts affect marginalised fishing communities, understanding how environmental variability and fishing practices interact is critical in informing sustainable fisheries management and possibilities for adaptation. Fisheries science is dominated by studies documenting the impacts of fishing on fish catches, and environmental variability may or may not always be integrated with fishery analyses (Keyl and Wolff 2008, Gamble and Link 2009). Most studies look at these factors in isolation. Environmental drivers of primary productivity and fish abundance dynamics influence fishing effort and investments (Ahmed *et al.* 2005, Hilborn *et al.* 2003). Impacts of fishing on fish biology, demographics, and ecology affect the responses of fish species to changing environmental factors (Jennings *et al.* 1998, Baran 2006, Das *et al.* 2013a, b; Sarkar *et al.* 2017, 2019). Feedbacks between environmental variability and fishing pressure are complex, and can be additive or synergistic (Fulton *et al.* 2005). In river systems with active capture fisheries, unravelling the interactions of fishing pressure (effort and practices) and environmental change (Jul-Larsen *et al.* 2003, Gamble and Link 2009) is complicated by the degree of anthropogenic modification of river-floodplains (Humphries *et al.* 1999, Tockner and Stanford 2002). River flow regulation and fragmentation by dams, barrages, embankments, etc., alteration of sediment fluxes, and changes in water chemistry by pollution and modified flow regimes make it very hard to identify the "natural flow regime" of most rivers (Agostinho *et al.* 2005, Dudgeon 2000, 2005; Dudgeon *et al.* 2006, Humphries *et al.* 2013). River floodplains are also experiencing climate change, from warming temperatures, increased snowmelt, reduced rainfall, etc. (Bera 2017, Masood *et al.* 2015, Whitehead *et al.* 2015, Anand *et al.* 2018). Lagged effects of climatic extremes, which may persist even up to several years also alter social and ecological "memory" of fisheries (Lehodey *et al.* 2006, Dudgeon *et al.* 2006, Badjeck *et al.* 2010, Dudgeon 2011,

Myers *et al.* 2017). River fish responses to these multi-scale changes may also be altered (Agostinho *et al.* 2005, Baran 2006). These factors are key concerns for riverine fisheries management.

A few studies from tropical river systems have shown that present fishery impacts on fish production are linked to long-term declines in hydro-climatic and ecological conditions (e.g. Sinha *et al.* 1999, Halls *et al.* 2006, Vass *et al.* 2010a, Castello *et al.* 2011). In most tropical and sub-tropical river-floodplain regions, long-term data on fish catches collected with consistent sampling procedures are unavailable (FAO and WorldFish Center 2008, Bartley *et al.* 2015), with notable exceptions in the Amazon, Mekong, Zambezi, and a few other river systems (Baran 2006, Baran and Myschowoda 2008, Campbell 2007, Castello *et al.* 2011). Although government data on fishery yields exist, they are often unavailable in the public domain for analysis, and may not always be accompanied by adequate metadata on sampling procedures and methodological detail (Bartley *et al.* 2015). Often, large-scale sample data collection is restricted to market surveys of fish catches, and aggregate approaches usually lack information on fishing effort and spatial distribution of fishing (FAO and WorldFish Center 2008). It is hence rare to find long-term fish catch and effort data from specific areas collected using the same sampling frameworks.

In the Indian subcontinent, these data gaps for river-floodplain fisheries have been long lamented (Dudgeon *et al.* 2000, Bartley *et al.* 2015). The Gangetic plain is one of the most intensively used river basins in the world, and supports millions of artisanal fishers and their livelihoods even today. Yet it remains wanting of studies on interactions between environmental changes and fishing effort. The Gangetic plains have a diversity of fish species and fishing practices, which respond to the annual hydrological cycle. River discharge usually starts increasing from June/July with the arrival of monsoon rainfall. The peak flooding pulse from August to late September/early October is followed by a long period of recession from November to May, during which fishing activity is most concentrated (Payne *et al.* 2004, Sarkar *et al.* 2012, Das *et al.* 2007, 2013a). The flood-pulse period is the main breeding season for most tropical riverine fishes, dependent on water level and temperature cues for fish spawning, migration, and dispersal movements of larvae between river channels and adjacent floodplains (Junk *et al.* 1989, Tockner *et al.* 2000, Baran *et al.* 2001, King *et al.* 2003, Payne *et al.* 2004, Vilizzi 2012, Das *et al.* 2016, Walton *et al.* 2017).

Fish species not only physiologically adapt through responses to these changes, but can also pre-emptively act to maximize fitness in dynamic and fluctuating environments (Bernhardt et al. 2020). Flood pulse variability is also associated with multiple ecological changes that may be coupled or decoupled with flooding, e.g. water temperature, lateral connectivity with floodplain wetlands and oxbow lakes, soil moisture, access to nutrients and contaminants from floodplain land-uses, etc. (Junk *et al.* 1989, Tockner *et al.* 2000, Baran *et al.* 2001, Graham and Harris 2005, Dudgeon *et al.* 2006, Cloern 2007). Glacial melt is also an important contributor to river flow in the peak summer (April). Monsoonal variability is influenced by complex and non-linear interactions between climatic forcing at continental scales, and regional hydrological effects from river flow alterations and land-use change (Rjinsdorp *et al.* 2009, Das *et al.* 2013a, 2016, CIFRI 2015, Sarkar *et al.* 2017). Perturbations in hydro-climatic variables thus directly influence fisheries productivity (Hilborn *et al.* 2003, Welcomme *et al.* 2010, CIFRI 2015).

Earlier investigations have typically attributed a general declining trend in fish landings to hydrological changes (Jhingran and Ghosh 1978, Talwar and Jhingran 1991, Ray 1998, Payne and Temple 1996, Sinha *et al.* 1999, Payne *et al.* 2004, Vass *et al.* 2009, 2010a,b; Das *et al.* 2016, 2019, CIFRI 2015). Vass *et al.* (2009) reported monotonic decline in fish yields at Allahabad on the Ganga River, from 1959 to 2004, which they largely attributed to construction of dams, river pollution, reduction in rainfall, and intensive spawn collection of commercially valued carps (also see Datta Munshi *et al.* 1979, Vass *et al.* 2010a). However, few studies exist from India's rivers, which together analyse the effects of environmental variability and river fishing on yields and catch rates (but see Das *et al.* 2013a,b; 2016).

This chapter's primary objective is to analyse the interacting effects of hydro-climatic, ecological, and fishing effort-related drivers on observed long-term fish yields and catch-rates in the Ganga River at Bhagalpur, Bihar, from 2000-2018. For this, I adapt the framework on fish production and harvesting patterns provided by Vert-Pre *et al.* (2013) for marine fish stocks, to include environmental variability. The authors outline four hypotheses: 1) the abundance hypothesis where production is proportional to population abundance, 2) the regimes hypothesis where production shifts between regimes in ways unrelated to abundance, 3) the mixed hypothesis where production shifts between regimes and their relationship with abundance is irregular, and 4) the random hypothesis which postulates random behaviour in

fisheries production. In addition, I hypothesize that the impacts of environmental and hydro-climatic variables and fishing effort on catch-rates and yields will vary with fish species' life-history traits. My specific predictions are that: 1) in years with strong flood-pulses, yields and catches will both increase, due to higher productivity and higher fishing effort; 2) in years with poor flood-pulses, yields will decline due to lower productivity, and fishing effort will determine catch-rates, and 3) in average years, yields and catch-rates will vary as per interactions between hydro-climatic forcing and fishing behaviour.

As described above, the monsoon flood pulse is the strongest driver of fish yields and production in the Gangetic plains. In a natural flood pulse, the river discharge increases by >300% over the dry-season flow within a matter of 1-2 months, with similar magnitudes of increase in sediment loads and water temperatures (Junk *et al.* 1999, Tockner *et al.* 2000, Dudgeon *et al.* 2006). Flood pulses can thus be characterized in terms of waveforms according to the "River Wave Concept" (Humphries *et al.* 2014), in terms of the wave's amplitude, period, duration, and rise/recession rates. The fish life-history traits that I analyse include body size at different stages, growth rates, reproductive characteristics (breeding seasonality, fecundity), dispersal/migration (along river, river to floodplain, sea-to-river, etc.), and habitat preferences (Welcomme *et al.* 2005, Winemiller 2005, Mims and Olden 2013, Chea et al. 2020). Functional group analyses allow for intuitive, generalizable, and robust analyses of fish community responses to environmental fluctuations (Wang et al. 2019). I also test the effects of temporal variations in dry-season flow and flooding events on fish yields, in relation to climatic indices. Fishing effort is the primary fishing-related variable included in all analyses, and the responses of different fish species (grouped by life-history traits) to fishing pressure and environmental change are examined through estimates of natural mortality and fishing mortality. Finally, I identify the implications of variability in fish yields and catches for fishery conflicts. How fishers deal with the localized effects of their own fishing effort and behaviour and the large-scale effects of hydro-climatic variability could be critical for future conflicts and adaptation. I also discuss future possibilities and scenarios for ecological declines, resource availability, and fisheries management, which could buffer or aggravate fishery conflicts in the Ganga River.

Methods

Study Area

Our study area was the Ganga River in Bhagalpur district, Bihar, India (Figure 4.1). This region has historically had an active river-based capture fishery, with about 500 families of full-time, resident fishers belonging to the Mallah or Nishad caste-group. They are recognized as traditional fishers, with fishing as their principal livelihood (Choudhary *et al.* 2015, Kelkar 2018). Fishing practices mainly involve the use of gillnets, stake-nets, traps, seine-nets, and mosquito nets (Payne *et al.* 2004, Montana *et al.* 2011, Sinha and Sinha 2013). Most fishers are landless, live in poverty, and have witnessed severe conflicts over fish resources (details in Choudhary *et al.* 2006, 2015; Kelkar 2018, Dey *et al.* 2019). These conflicts have originated from a privately controlled and oppressive fishery. Its aftermath led to an open-access system (from 1991 onwards), with increasing control of the fishery by mafia gangs, who regularly harass fishers and extort fish catches (Kelkar 2014a, Kelkar 2018).

Mean (30-yr) annual river discharge is 8736 (SD 4845) $m^3.s^{-1}$, with peak flood-season discharges ranging from 16,500 to 60,000 $m^3.s^{-1}$ in August and September, and mean dry-season discharges between 3000 and 5000 $m^3.s^{-1}$ in March-April in this region (Central Water Commission, Govt. of India). Mean annual rainfall is around 1200 mm (Indian Meteorological Department, Govt. of India). The river-floodplain is characterized by strong monsoon flood-pulses, straight and actively meandering river channels, tributary confluences, side-channels or chutes, meander cut-offs, oxbow lakes, floodplain wetlands, and river palaeo-channels, and is characterized by strong inputs from tributaries and high sediment discharges (Singh *et al.* 2007). The Farakka barrage on the Ganga River is located approximately 160 km downstream of Bhagalpur, and has had significant negative impacts on river hydrology and fisheries productivity (Ray 1998, Adel 2001, Kawser and Samad 2016, Rahman and Rahaman 2018).

Data collection

Interviews and group discussions with fishers and key informants

Fishers' perceptions about conflicts and their relationship with fisheries decline were recorded through semi-structured interviews, informal discussions during landing surveys, and focus group discussions with about 100 fishers and fish-traders at Bhagalpur, Kahalgaon, Naugachhia and Sultanganj (Bhagalpur district, Bihar). Detailed methods of interview data collection, compilation, and verification are provided in Dey *et al.* (2020). Fishers with whom we had a long association, and who had an experience of at least 30 years with the fishery (n=20) were our key informants. During informal interactions, responses of fishers were noted ad libitum in field notes, running notes, and audio recordings (in some cases), with their prior consent. From the interview responses, I specifically attempted to identify if 1) fishers linked experiences of conflict to water availability and climatic change, and 2) how perceived fish declines were associated with the experience of conflict risk by fishers. To do so, I first estimated the fishers' perceived extent of decline and the primary factors that fishers identified as responsible for fish decline and conflicts (see Dey *et al.* 2020). For data analysis, I used qualitative methods of thematic/content analysis to interpret the emphasis and recurrence of particular events, drivers, and seasonal variables that fishers perceived to be of key importance.

Past fish yields and landings data

The Central Inland Fisheries Research Institute, Govt. of India, has reported fish landings data from the 1950s onwards from Bhagalpur, among multiple other sites (Talwar and Jhingran 1991, Payne *et al.* 2004). However, the available data are coarse in taxonomic and temporal resolution. I present summaries of aggregate fish landings data and fish spawn collection data for Bhagalpur from Ray (1998), Sinha *et al.* (1999), and other sources from 1958 to 1997 (listed in Appendix S6 of thesis). These datasets were based on snapshot surveys in specific years and detailed methodologies for yield estimation was not available. Hence, from the available data, I only assessed long-term trends in estimated total yields (1958-1983) for Hilsa *Tenualosa ilisha*, and in percentage of yields for carps, catfishes, hilsa, and other fish species from the 1950s to date (including data from our own monitoring, 2000-2018) at Bhagalpur (see below).

Fish catch-effort data from landing sites and market surveys

Fisheries monitoring data were collected from 2000-2018 by Dey (1999-2000 onwards) and Kelkar (2007-08 to 2018). To my knowledge, this is the longest time-series dataset on fisheries in the Ganga River compiled through informal monitoring by a non-governmental source, in spite of some gaps and missing years (see Dey *et al.* 2019). Inferences made here do not necessarily relate to the decades before 2000, when these fisheries witnessed multiple impacts from dams and barrages, pollution, excessive spawn collections, etc. Further, I used fishery-dependent data in the absence of fishery-independent assessments of fish productivity. I used aggregated yield and CPUE data as response variables after suitable corrections to indices of total effort, spatial distribution of effort, and seasonal variations in numbers of fishers, fishing boats, and nets used (Sparre and Venema 1998, Lorenzen *et al.* 2006, 2016; Maunder and Deriso 2003, Welcomme 1985, 2003; Jul-Larsen *et al.* 2003, Bishop 2006, Maunder *et al.* 2006, Maunder and Punt 2014). Shared and complementary information in chapters 4 and 5 is denoted wherever needed.

I analysed daily and monthly variations in fish catch (production) obtained from Bhagalpur and Kahalgaon on the Ganga River in Bihar. Monthly data were collected from landing sites and fish markets on fish catches, yields, and gear-specific effort for 90 species at Bhagalpur from 2000 to 2017. I used monthly sampling data (n=30557 records, i.e. recorded catch of fish species by day and individual fisher) for 60 fish species (after excluding rare species) from 2000 to 2017 (with some gaps in 2002, 2009, 2010, 2012, 2014, 2015 due to logistical issues). At Kahalgaon, I compiled daily fish catch and effort data (n=34820 records) from 2009-10 to 2018 (with a break from 2010 June to 2012 October), from which data on 34 species were analysed. I compiled these data from market logbooks provided to us by fish traders upon request. The logbooks contained fisher-specific information of daily catches, which helped us estimate fishing effort in terms of fisher trips per day. The numbers of hours invested in these gear operations were also recorded. I also independently verified logbook data with opportunistic fish landing and market surveys to ensure the accuracy of the recorded information. Together, the Bhagalpur and Kahalgaon data yielded approximately 70,000 catch records with effort data (measured in catch per fisher-day or catch per fisher-hour), but data for both sites were analysed separately.

To calculate net-day-wise effort, I first compiled a database on fishing gears and practices employed in the fishery (2000-2018). Data were collected on gear-specific variables (net width, height, mesh size) and fishing operation variables (preferred locations, method of deployment of gears, number of fishers involved, soak hours, start and end timings) during landing site surveys. From this data, I assigned effort metrics to catch data from landing sites. General sampling methods used for landing site and market surveys are described in Montana *et al.* (2011), who analysed aggregated fish catch data from Bhagalpur (for 2001-2007) to assess changes in yields and fish composition, but did not use data on fishing effort. I ensured that my sampling coverage was similar across seasons in relation to the actual effort (measured from boat-based surveys), to avoid any systematic seasonal or inter-annual biases in aggregated and spatial sampling of catch data (Pope and Willis 1996, Bishop 2006, Lorenzen *et al.* 2006, Johnson *et al.* 2017). Details of collected data, sample sizes, methods of collection, and analyses, are presented in Table 4.1. A taxonomic list of species analysed is provided as an index (Supporting Information S4.1) based on the latest updated taxonomic names provided by Fricke *et al.* (2019) and FishBase (Froese and Pauly 2019). Supporting Information Figure S4.2 shows an "ichthyograph" indicating fish spawning preferences in relation to river discharge and water temperature, and Figure S4.3 shows the seasonal fish catch calendar with reference to the study area (based on Dey *et al.* 2020). This species index is to be used as reference to species analysed in the thesis. Graphical data summaries of aggregated fish yield data are shown in Supporting Information S4.4 and S4.5 (for Bhagalpur and Kahalgaon), with trends in major environmental variables.

River flow data

Selection of satellite-based discharge data sources was made after review and trials of available datasets (based on advice by Bjerklie *et al.* 2005, Musa *et al.* 2015, Sichangi *et al.* 2016). Daily discharge data were obtained for the 1998-2018 period from the River Watch 3.5 module of the Flood Observatory, Colorado (www.floodobservatory.colorado.edu; Brakenridge *et al.* 2017). The estimation of daily discharge is based on a calibration between the microwave reflectance data collected from an AMSR-E satellite-gauging pixel and the predicted flow from a WBMSed model (Brakenridge *et al.* 2017). Satellite-based discharge data and relative trends were used to estimate long-term temporal responses of fish species to the

magnitude and variability of river discharge. I used satellite-gauged discharge data from 25.334^{o}N, 86.175^{o}E (upstream of Munger, Bihar) for this study. I calibrated satellite-gauged data for dates (n=10) with direct measurements conducted between 2008 and 2017. Field measurements were conducted from a boat, and river discharge estimated from cross-section data using the Manning's equation (Chow 1959, Williams 1978). I incorporated uncertainty about the riverbed slope (~6 cm/km), from reported literature for the same stretch of the Ganga River (Singh *et al.* 2007). To estimate the Manning's **n** (alluvial roughness coefficient) I used an iterative procedure to calculate the sensitivity of estimated discharge to different **n** values, allowed to vary between 0.03 and 0.04 (Arcement and Schneider 1989, Yagecic 2016), and the correspondence of estimates within known bounds of river discharge (e.g. from public-accessible bulletins of the Central Water Commission). From my own field measurements, a stage-discharge curve was first estimated for Kahalgaon as $Q = 661.43*e^{0.0915*S}$ ($R^2=0.81$, $p<0.001$). Recorded stage-values from the above data sources and field measurements were converted into discharge values. I then ground-verified the satellite-based discharge (SR) estimates with the equation: $\log_e(Q) = 6.48 + 0.25*\log_e(SR)$, ($R^2=0.864$, $P=0.0003$, $F=44.38$, $df=1,9$). Additionally, long-term annual trends in river discharge and water levels were obtained for selected sites (Hathidah, Munger, Bhagalpur, Kahalgaon, Farakka) from published literature (Dai and Trenberth 2004) and satellite altimetry-based water level data sources for points close to these sites (e.g. Theia Hydroweb, http://hydroweb.theia-land.fr/, the DAHITI database: https://dahiti.dgfi.tum.de/en/, and the MOSDAC: https://www.mosdac.gov.in/). The relationship between discharges at these sites and at my study sites was checked for additional calibration. Daily data on flood-season river discharges and water levels was also available from the Flood Management Information System (FMIS) website of the Govt. of Bihar (www.fmis.gov.in) from 2013-14 onwards. From the above datasets, I also derived characteristics of flood-pulses in terms of amplitude, variability, smoothness of pulse, start and recession dates (in Julian day of year), and duration of flood-pulse (Humphries *et al.* 2014). Different years were characterized in terms of flood-pulse "wave" characteristics, to assess flood-pulse impacts on fish catch.

Water temperature data

I obtained monthly water surface temperature data (2000-2018) from unclassified data provided by the Water Resources Department (WRD), Bihar for Hathidah station (25.366°N, 85.987°E). These data were obtained as part of the MoES-NERC funded CHANSE project on water management in the Gangetic plains. I estimated a positive relationship between water temperature and air temperature data that was available from the Indian Meteorological Department for districts in the study area. I also used available water temperature data for the Ganga, from publications (Payne *et al.* 2004) to calibrate WRD water temperature data with an independent source.

Discharge estimation from river channel width

Following Pavelsky (2014) and Sichangi et al. (2018), I predicted dry-season river discharge from river channel width, which was estimated from LandSat, MSS, and TM satellite images from 1972 onwards (www.usgs.earthexplorer.gov). I used the Global River Widths Database (Yamazaki et al. 2018) and the Global Surface Water Explorer datasets (Pekel et al. 2016) to check the consistency of channel width measurements. This indicated potential for seamless application of satellite-derived discharge to impute past gaps in discharge data, and to also construct robust long-term time-series datasets for Gangetic floodplain rivers. I predicted past discharge values based on channel width measured from satellite images available from 1972 onwards, when discharge data were unavailable or not accessible, to detect trends in dry-season river discharge.

Rainfall data

I obtained monthly rainfall data (in mm) for Bhagalpur and surrounding districts from the Indian Meteorological Department (IMD) website, from 2000-2018. To assess long-term trends, district-level rainfall data was also obtained from 1901 to 2018 for Bhagalpur district. Rainfall data was also divided into monsoon rainfall (June-Sept.), winter rainfall (Oct-Dec.), and dry-season rainfall (January-May), for further analysis of trends.

Climatic indices

Climatic variability and atmospheric tele-connections are known to affect the intensity, inter-annual variability and magnitude of summer monsoon rainfall, winter rainfall, and droughts, and in turn, river flows and flood-pulses (Ward *et al.* 2010, Pervez and Henebry 2015). To test responses of fish yields to inter-continental climatic oscillations and solar cycles, I collected monthly data on multiple indices. Monthly indices of the El Niño Southern Oscillation (ENSO) were collected from the NOAA website: https://www.esrl.noaa.gov/psd/data/climateindices/list/. The NINO4 index representing sea surface temperature (SST) anomalies over the Central Tropical Pacific region was chosen (https://climatedataguide.ucar.edu/climate-data/nino-sst-indices-nino-12-3-34-4-oni-and-tni). Positive SST anomalies (anomalies above or below 0.5^{o}C sustained over 5 months) are regarded as El Niño phases and negative anomalies as La Niña phases. Complex interactions between ENSO, the Indian Ocean Dipole (IOD), and SST polarity are known to affect summer monsoon strength, inter-annual variability, and extreme rain events across India's Gangetic plains (Pokhrel *et al.* 2012, Mishra *et al.* 2012, Krishnaswamy *et al.* 2015, Pervez and Henebry 2015). In general, the El Niño anomalies cause temperature warming and the La Niña are associated with cooling, leading respectively to weakening and increase in Indian summer monsoon rainfall. Positive IOD phases interacting with El Niño can lead to drought-like, low-rainfall conditions, and negative IOD-La Niña coincidences cause greater rainfall (Ashok and Saji 2007). Indian Ocean Dipole (IOD) data (Dipole Mode Index: DMI) were collected from https://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/DMI/.I also obtained data on the Multivariate ENSO Index (MEI) from https://www.esrl.noaa.gov/psd/enso/mei/. MEI is a bi-monthly averaged index that combines SST data with meridional and zonal winds, surface pressure, and radiation indices. MEI was multiplied by -1 and recoded as a composite La Niña Index for analysis (following Krishnaswamy *et al.* 2015). Monthly data on sunspot activity (solar cycle; Roy and Collins 2015) was collected from the WDC-SILSO, Royal Observatory of Belgium, Brussels. Both stations provided slightly different metrics so both MEI and NINO4 were included as predictors in models of responses of fish yields, but never together, since they were positively correlated. For consistency of interpretation, in all graphs, the sign of

NINO4 was also reversed to read as "fish yield responded positively or negatively to La Niña phases" of the ENSO.

Data analysis

Long-term changes and trends in fish catch composition (1950s onwards)

I graphically examined long-term trends in catches of Hilsa (1958-1988), and % carp, % catfish, and % other fish (using data from 1958-1997 from Ray 1998, and from 2000-01 onwards from our data from Bhagalpur and Kahalgaon). I also used other data sources (Sinha *et al.* 2007, CIFRI 2015) to understand the primary drivers of long-term trends. I identified relationships between observed percentages over time and rainfall data (source: Indian Meteorological Department, Govt. of India, district-level data), using general linear regression models.

Effects of climatic indices and solar activity on fish catches and river flows

To test the effects of climatic and solar cyclicity on river discharge and riverine fisheries, I used a spectral likelihood analysis with parametric empirical Bayesian estimation (Bretthorst 1988) on discharge data from Farakka (1948-2004, Dai *et al.* 2009), and fisheries catch time series from Allahabad (most upstream site for which data were available, Vass *et al.* 2009). These datasets were used as a proxy data for long-term variability in fish catches along the Ganga River (1959-2004; Vass *et al.* 2010) in relation to the Quasi-Biennial Oscillation (QBO, 2-3 years), El Niño Southern Oscillation (ENSO, 4-7 years), and the sunspot cycle (11-13 years) (Roy and Collins 2015, Hassan *et al.* 2016). Spectral likelihood analysis helped estimate the relative influences of the sunspot and ENSO cycles on cyclical variations in fish yields (at Allahabad) and river flows (at Farakka). Maximum likelihood estimates were obtained for each of the different cycles. Additionally, for river flow data at Farakka, I used time-series data to assess if the effects of ENSO and solar activity were different before (1948-1974) and after (1975-2004) the barrage was constructed in 1975.

Long-term hydrological trends

I analysed trends in river flow by conducting time-series analyses, and Seasonal and Trend decomposition using Loess functions (STL) for the period 1998-

2018 (Theodosiu 2011). Changes in flood-season and dry-season flows over time were analysed for four seasons, which were the monsoonal flooding period (June-September: JJAS), the post-flood recession period (Oct-Dec: OND), winter (Jan-Feb: JF) and summer (March-May: MAM). I also estimated correlations between flood pulse variables and climatic variables.

Seasonal trends in fish yields

Trends in different fish groups (carp, catfish, clupeids, other, and shrimps) were graphically examined for each month, in the sampling period from 2000-01 to 2017-18. For each species, I analysed monotonic trends across four defined seasons (JF, MAM, JJAS, OND) using a seasonal Mann-Kendall test (Yue *et al.* 2002), in the "trend" package in R 3.2.1 (R Core Team 2018).

Responses of fish yields to hydro-climatic variability and fishing effort

I analysed the responses of individual species to environmental (hydro-climatic) variables using general and generalized linear regression models (McCullagh and Nelder 1989, Harrell 2015). Hydro-climatic variable selection for individual models was based on time-series cross-correlations and collinearity checks between different predictor variables. I did not combine predictor variables with Pearson's correlation coefficients $|R|>0.30$ in the same models. For Bhagalpur and Kahalgaon, I analysed responses of monthly fish yields from 2000-2017 to hydro-climatic variables (river discharge or flow, water temperature, air temperature, rainfall, climatic indices, sunspot number, and electrical conductivity) using linear and log-linear regression models. Model selection was based on careful examination of the trade-offs between fit (pseudo-R^2 or R^2) based on the residual and null deviance (Williams 1987) and model complexity (number of parameters). I identified the simplest possible models of fish yield as response variable for each species, with the highest achievable explanation of response to covariates, over null models. I then analysed aggregated species-level responses of monthly fish yields and CPUFD (catch per unit effort in fisher-days) to river flow and fishing effort, using high-resolution (daily) data available for the Kahalgaon fisheries (2009-10 to 2017-18). I empirically estimated time-series cross-correlation between fish yields, river flow, and fishing effort for each species, to estimate lags in responses to these variables (Harrell 2015). For all analyses, I used linear models with time-series components for "Trend" and

"Season", and STL decomposition (Theodosiu 2011, Cleveland *et al.* 1990). Along with the trends in STL, I also interpreted changes in the seasonal cycle and the remainder (noise) over time. All analyses were conducted in the R software (R Core Team 2019).

Trait-based grouping of river fish responses

After estimating species-level responses to hydro-climatic and fishing effort variables, I grouped these estimates according to different trait-based groups in which the fish species were classified. Trait-based grouping criteria included taxonomic groups and groups based on life-history traits mainly related to reproductive behaviour, seasonality, migration and local dispersal, use of river-floodplain habitats, etc. (Prabhu 1956, Welcomme 1979, 1985, 2003, Jennings *et al.* 1998, Welcomme *et al.* 2005, Winemiller 2005, Elliott *et al.* 2007, Zeug and Winemiller 2007, Mims and Olden 2013). Taxonomic grouping criteria included fish family and common names (e.g. carp, catfish, etc.). Grouping criteria based on life-history characteristics were whether fish were of the Equilibrium, Opportunistic, or Periodic type (Zeug and Winemiller 2007, Mims and Olden 2013). Reproductive criteria were based on spawning periodicity (spawner types, as per Prabhu 1956, Qasim and Qayyum 1959), breeding season and catch-season (from Dey *et al.* 2019), fecundity (absolute and relative), age- and length-at-maturity, etc. Life history data can be found in the Appendices S1-S5. Appendix S6 lists the literature sources from which life-history trait data and numerical estimates of demographic parameters were compiled for fish species. Other criteria included migratory behaviours (Baran 2006), adult use of different river-floodplain habitats (Welcomme *et al.* 2005), whether fish larvae utilized floodplain wetlands during the first year of their lives, and the use of water column by fish species (surface, mid-column, or bottom-dwelling; Welcomme *et al.* 2005). Local ecological knowledge of fishers was also strongly integrated into the definitions of trait-based groups (see Dey *et al.* 2019, Silvano *et al.* 2008). All 60 fish species were classified into guilds based on multiple criteria.

Modelling catch-effort-yield relationships

Surplus production models

I used dynamic surplus production models (Laloë 1995, Sparre and Venema 1998, Halls and Welcomme 2004, Halls *et al.* 2006) to assess impacts of fishing effort

and harvesting patterns on standardized CPUFD and fish yields. Surplus production models need only catch and effort (fishery-dependent) data, and can be used for multi-gear fisheries (Bishop 2006) without the need for catchability and age-structure data. They are thus simple and effective to use provided their assumptions are reasonably for the system (density-dependent fishing, catches proportional to biomass, local stock stability, etc.). The models estimated biomass and fishing mortality at limited reference points of maximum sustainable yield (B_{msy}, q, and F_{msy} respectively). Model runs followed guidelines and reference points provided by different sources, for standardization and interpretation of estimates (Caddy and Mahon 1995, Arreguin-Sanchez 1996, Cadrin 1999, Salthaug and Aanes 2003, Campbell 2004). I compared regression fits and statistical significance of parameter estimates of Schaefer and Fox models (Fox 1970) of CPUFD change with effort (Jensen 2005, Halls *et al.* 2006). Estimation procedures were run using dynamic non-linear model fitting in the TropFishR package in R 3.4.2 (Mildenberger *et al.* 2017, R Core Team 2019).

Fishing behaviour and hyperstability

To assess the response of yield (biomass) to changes in CPUFD, I estimated the linear regression slope between the natural logarithms of total fish yield, catchability, and CPUFD. Statistically significant slope values (beta<0.6) were treated as a strong signal of hyperstability, while beta values between 0.75 and 1.00 were treated as indicative of proportionality between yield and CPUFD (based on Erisman *et al.* 2011). Factors related to the spatial distribution of fishing effort, seasonal behaviour, and spatial location use, were identified from field observations of individual fishers (see Hilborn and Walters 1992, Lorenzen *et al.* 2006). With hyperstability, the interpretation of fishery-dependent yield data is complicated, because changes in CPUE remain insensitive to changes in overall productivity. Due to this complication, hyperstability signals estimated from CPUFD-yield relationships, and surplus production models, helped in qualitatively differentiating responses of total aggregate yields and CPUFD to different variables.

Phase-shifts and stability regimes in the fisheries

To graphically interpret shifts in fishery yields over time, I plotted phase diagrams based on Holling's (1973) theoretical descriptions of stability regimes in complex systems. Holling's phase diagrams can be used to interpret stability of productivity regimes in fisheries and any shifts from equilibrium states of the system

over time. I used annual yield data (from Bhagalpur, 2000-2016) compiled for low, moderate, and high trophic-level species, and reproductive guilds (e.g. spawner-types) for the phase diagrams. For example, in a phase plane for high- and low-trophic species, I plotted yields with their time-trajectories to interpret overall system behaviour. Stability regimes observed from phase plots were interpreted in relation to inferences from time-series analyses.

Putting it together: exploring environmental and fishing impacts

Species-specific total mortality (Z) was estimated from catch-at-age data and catch curves computed from catch-effort data for 60 fish species (Maunder and Deriso 2003, Aanes *et al.* 2003, Smith *et al.* 2012, Trenkel *et al.* 2012, Ogle 2016). I empirically estimated species-specific natural mortality (M) using Pauly's method and Hoenig's method (based on Linf, tmax, average water temperature, and growth coefficient K; (Pauly 1983, Then *et al.* 2015, 2018). From Z and M, I obtained empirical estimates of F (=Z-M) and compared them with modelled estimates of Fmsy. I then plotted the ratio F: Fmsy against F: M, to estimate relative impacts of fishing mortality with respect to natural mortality (Jorgensen and Holt 2013). Following Rouyer *et al.* (2012), I assumed natural mortality to be driven mainly by environmental variability (including biological processes). These metrics were analysed to explore the interacting effects of hydro-climatic and fishing impacts.

Results

Fishers' perceptions of fish decline and conflict

All interviewed fishers unequivocally reported that the catches of most commercially valued fish species had declined in the last 30 years. Fishers cited overfishing and destructive fishing (by the use of mosquito nets) as the main drivers of fish declines. Relative to overfishing impacts, environmental variables were not thought to be as important in influencing conflict risk. However, fishers mentioned that in "good years" with strong flood pulses, the resulting high productivity provided fishers with a buffer to cope with risks of conflict, through more space use options. Fishers could access a greater diversity of habitats other than channel inlets (kols), due to better flows in the main channel. As shown in chapter 3, the kols get auctioned off to fishery operations worked under mafia gangs who set large mosquito net

barricades to capture fish through the flood-recession period until November. In poor flooding years (weak or erratic flood-pulses, low floodplain inundation), fish productivity declined, and, for a given fishing effort, fishers clustered at fixed spots, leading to higher local competition. Fishers also said that differences between winter and summer temperature mattered for specific species' yields during the dry-season.

Historical trends in fish catches and local rainfall (Bhagalpur)

After the construction of the Farakka barrage in 1975, a dramatic decline in hilsa was seen (Figure 4.2). Minor reduction in % carp (mainly due to decline in Indian Major Carp (IMC) species) corresponded with a clear increase in % catfish and a minor rise in % other (all non-carp, non-catfish) fish species-groups (Figure 4.3). Reduction in spawn production of IMC from 80% to 30% (out of total spawn collected) between 1961 and 2004 and pollution were noted as major causes of decline. Per cent catfish production out of total catch increased in response to the reduction in summer monsoon (JJAS) rainfall (Table 4.2). Per cent carp did not respond to long-term trends in monsoon (Table 4.2).

Long-term hydro-climatic trends

JJAS rainfall reduced (JJAS: Sen's slope: -2.67, i.e. decrease of 2.67 mm/yr over 50 years ($CI_{95\%}$: -1.68, -3.61) especially from 1959 onwards (Pettitt's test for single change-point detection: K=2021, P<0.0001), and up to 2009. The reduction in monsoonal rainfall at Bhagalpur became especially consistent from 1970-71 onwards (in part explaining the decline in river discharge). A weakly increasing but more variable trend in JFMAM rainfall was noted from 1975 onwards (Pettitt's test: K=757, P=0.22). OND rainfall remained largely stable (Pettitt's test: K=547, P=0.64). Overall, the ENSO cycle was dominant in long-term river flows. Fish yields at Allahabad showed cycles in response to both ENSO and solar activity. From 1948-1975, the ENSO cycle appeared to be the dominant influence on river flows at Farakka. But from 1975-2004, i.e. after barrage construction, the influence of the solar cycle appeared stronger.

A strong regression relationship was estimated between channel width (W) and natural log of discharge Q, as $Q=\exp(7.36 - 0.0023*W)$; $R^2=0.81$, $p<0.001$, $F=30.07$, $df=1,7$). I found a declining trend in the estimated dry-season river

discharge from 1972 onwards from the estimated discharge values: Q_{year} = exp(67.725 – 0.029*year); R^2=0.67, P<0.0001; F=34.16, df=1,17). This translated to a rate of declining discharge at 2.86% per year, for dry-season months.

From 2000 to 2018, increased variability in dry-season and flood-season river flow was recorded for the Ganga River (Figure 4.4a-b). The increase in dry-season as well as flood-season river flow was seen after the 2010 El Niño event. Bi-phasic behaviour was noted in ENSO-related indices and sunspot number (Figure 4.4c-f). The sunspot cycle (of 11-13 years) showed two major phases during this period, a decline from 2000-2007-08, and rise again in 2012-13. Air temperatures remained stable, while rainfall variability increased for the dry-season months (JFMAM, OND) (Figure 4g-h). Total rainfall increased in monsoon months from 2010 onwards (JJAS rainfall: Sen's slope=51.05 mm/yr increase). Reduction in river surface temperature and electrical conductivity (used as a proxy for inorganic productivity) were seen over time (Figure 4.4i-j). Stronger flood pulses were typically smoother (Figure 4.5a). Flood amplitude (strength) was the highest in moderate La Niña years but reduced with the strengthening of the ENSO cycle (Figure 4.5b). However, the intra-annual seasonal variability in river discharge was the highest during very strong El Niño years (Figure 4.5b). From 1998 to 2018, there was an increase in the variability of flood amplitudes (Figure 4.5c) and advancement in flood rise timings (Figure 4.5d-f).

Long-term seasonal trends in fish species' catches (2000-2017)

Of the five major fishery groups (carp, catfish, clupeids, others, shrimps), clupeid and shrimp yields showed clear declines over time (Figure 4.6). Total fish yields at Bhagalpur generally declined until 2006-07 and then increased after 2010 in years with large floods, exhibiting strong fluctuating behaviour (Figure 4.6). Total yields remained stable in the post-monsoon (OND) and winter (JF) seasons, but some groups showed declining trends in the monsoon (JJAS) and dry-season (MAM). At the species level, similar patterns were observed (Figure 4.7), with declines mainly in the peak dry-season (MAM), and of some species in the post-monsoon season (OND). Fish species are listed in their taxonomic order in Figure 4.7. Many fish species' catches showed increases in the monsoon season (JJAS), of which two notable and high-value species were the carp *Gibelion catla* and the mullet *Rhinomugil corsula*. Only one species, *Cabdio morar* (Danionidae) showed a clear and significant trend of

increase in all seasons (Figure 4.6). The two species that showed unambiguous and sharp declines in all seasons included the carp *Labeo rohita* and shrimps *Macrobrachium* spp. At the family level, yields of catfishes of the Bagridae showed a relatively small magnitude of decline, while Cyprinidae, Siluridae, and Channidae showed stronger declines (Figure 4.7).

Trait-based responses of fish yields to environmental variability and fishing effort

Aggregate responses (across all species) of total yield, CPUFD, and fishing effort responded mainly to the variables year, river flow, water temperature, and La Niña/El Niño phases of the ENSO. All variables showed year-effects. Fishing effort and CPUFD responded to variability in river flow, and total yield to river flow and temperature, but CPUFD was also affected by El Niño phases (Table 4.3, Figure 4.8). CPUFD increased during positive ENSO anomalies (El Niño) but did not change with fishing effort. Complex interactions were seen between fishing effort and seasonal river flows. Typically, at low river flows, fishing effort predicted yields, while at higher flows the effect of fishing effort on yields was weaker (negative interaction effect) (Table 4.4). STL decomposition of time-series trends of fish species showed that while trends generally showed qualitative declines, there was a general increase in "noisy" or flashy (extremely fluctuating) dynamics in terms of yields. For 34 species analysed in this regard, increasing noise was estimated in the CPUFD and yield of 8 and 20 species respectively. Increased flashiness appeared to be due to increasing variability in river flows and recurrent El Niño events (e.g. 2010 and 2015-16 were strong events and poor summer fishing, but were followed by extreme floods in 2011 and 2016 that led to bumper yields). Flashy species (e.g. *Silonia*, *Ompok*, *Hemibagrus*, etc.) occurred in catches only or mostly during years with severe floods, but were otherwise not regularly present.

Year-effects (yearly trends) were the most consistent across species. All species showed a decline and the mean effect size of year was -0.16 (range -0.77 to -0.04). Most species showed a positive response to river flow availability, whose mean effect size was 0.646 (range -0.22 to 3.734). For environmental variables, responses across species varied according to taxonomic groups and life-history traits. Life-history trait data for different species are tabulated in Appendices S1 to S5, and the

various literature sources for the data are enlisted in Appendix S6. Table 4.5 describes the broad results and Supporting Information S4.6 to S4.14 provides the statistically significant effect sizes of different variables on species-specific yields. Overall, river flow or discharge (and flood amplitude) was the primary environmental variable of importance in explaining monthly fish yields (43 of 61 species), followed by specific year (40), water temperature (27), rainfall (24), sunspot number (24), air temperature (13), climatic indices (La Niña (10), ENSO (9), DMI (6)), and electrical conductivity (8). River flow had a positive effect on all families' yields, especially the Cyprinidae (carps), Siluridae (rheophilic catfishes), Notopteridae (featherbacks), and Mastacembelidae (spiny eels). The only exception was that of Palaemonid shrimps, which were negatively affected with greater river flows in the immediate pre-monsoon period, when they enter the fishery. Water temperature and flood discharge were strongly coupled, with water temperature tracking the monsoon-driven flood-pulse. Water temperature decreased in the post-monsoon months (November-February) and increased when river flows were the lowest in summer (March-May). Water temperature had a positive effect on all fish families, barring the Aillidae and Pangasiidae. Water temperature and rainfall had a negative effect on Ailiidae (schilbeid catfishes), which responded positively to positive DMI (positive Indian Ocean Dipole) and La Niña phases. The large catfishes *Bagarius yarrellii* and *Pangasius pangasius* also showed similar responses. The clupeids *Gudusia* and *Gonialosa*, however, responded negatively to the La Niña phase, with higher yields recorded in summer during El Niño years. Warmer air temperatures also had a positive effect on yields of *Glossogobius giuris* (Gobiidae). Disparate groups such as Channidae (snakeheads), Siluridae, Tetraodontidae (puffers), Mastacembelidae, and Bagridae responded positively to La Niña phases. All catfish families also appeared to respond positively to sunspot intensities, whereas gobies, perciform fishes, clupeids, and cyprinids responded negatively. In terms of magnitude, effects of rainfall and electrical conductivity were the weakest.

A-type spawners responded positively to river flow, La Niña, and positive DMI, perhaps due to their strict flood-spawning behavioural cues of high rainfall and increased temperature. Responses of B-type spawners were similar but lower in magnitude than A-type spawners, and responded positively to water temperature (Supporting Information S4.6 to S4.14). C-type spawners showed a curious pattern in which they were positively affected by La Niña strength, but negatively by DMI –

perhaps due to their double spawning peaks in one year. D-type spawners did not show clear responses except that their yields were higher with greater river flow. Fish species whose larvae used the river floodplain for 1-2 years of growth, responded in a strongly positive way to river flows and water temperature. Rheophilic (eupotamonic) summer-breeding fishes responded negatively to rainfall, but positively to the La Niña index. Species strongly dependent on river flow, water temperature, and La Niña/DMI in their spawning peak period showed declines. Post-monsoon and spring-summer peaking fish species were also the most dependent on river flow and La Niña (correlated with monsoon rainfall). Bottom-dwelling, springtime fish species were most dependent on river flow and the most affected by El Niño phases, whereas surface-dwelling fish species responded positively to La Niña phases (Supporting Information S4.6 to S4.14).

Surplus production models: fishing effort and sustainable yields

The Fox surplus production model fit the catch-effort data best for 12 out of 34 species, and the Schaefer model fit for 5 species' data (Table 4.6). For 17 species, however, none of the models showed a clear fit (interestingly, for most Cyprinidae, Bagridae, and Siluridae, which formed the dominant fished groups). This indicated non-linear relationships with noise in catch-effort data for these species (Table 4.6).

Fishing behaviour and hyperstability

Hyperstability was observed in case of nearly half the species, whose CPUFD remained stable even as yields decreased (Appendix S5). Hyperstability appeared to be most in case of the Siluridae and Notopteridae, moderate for Ailiidae, Mastacembelidae, and Bagridae, and low for Cyprinidae, Danionidae, Mugilidae, and Gobiidae (almost indicating proportionality). None of the species showed typical "hyperdepletion" patterns. As I used fisheries-dependent data for estimating yields, it is important to note that for hyperstable species, observed catches could have masked "real" trends of decline to some extent. This could be the case for the Silurid catfishes (*Wallago* and *Ompok*) and Notopterid fishes (*Chitala chitala*). However, analyses of yields at multiple temporal scales (daily, monthly, seasonal) were able to unambiguously detect declines for these species as well.

Phase-shifts and stability regimes in the fisheries

Phase plots of high- and low-trophic level fish yields at Bhagalpur showed an unstable equilibrium with locally stable limit cycles (Figure 4.9). The 2008 and 2016 phases appeared to "reset" declining fishery yields to the initial 2000 state. Both were phases of strong flood-pulses following prolonged El Niño drought periods. The interpretation of the phase plots thus matched with other time-series analyses that indicated recent recovery in fisheries productivity after 2016.

Environmental and fishing impacts on fish yields

Out of 34 species whose yields were analysed to assess the relative impacts of environmental variability and fishing effort, 20 species (mostly small-sized, early-maturing, and low-value species) of environmental variability and 14 species (large-bodied, late-maturing, high-value species) were influenced by fishing (Figure 4.10). F: M ratios were positively related to length at maturity (linear regression: $F:M=0.325*\log_e(L_{mat}) - 0.152$; $R^2=0.187$, $p=0.002$, $df=1,46$). Ten out of the 20 species whose natural mortality estimates dominated fishing mortality also showed fishing near maximum sustainable levels of effort, and ten species showed long-term changes in yield only in response to environmental changes (Figure 4.10). Of the 14 species affected by fishing, 2 species (*Wallago attu* and *Gibelion catla*) showed potential for recovery in yields (Figure 4.10). These species were seen to respond positively to strong floods in recent years. The 12 species affected by overfishing included high-value species: the carp *Labeo rohita*, the Bagrid catfishes *Sperata* and *Rita*, the Ailiid catfish *Eutropichthys* spp., and Silurid catfishes *Ompok* spp., *Mastacembelus armatus* (spiny eel), and Rhinomugil corsula (river mullet).

Discussion

Overall, the effects of long-term environmental variability on fish yields were much more significant than the spatially localized effects of fishing pressure for most fish species. However, this varied considerably with fish life-history traits. The perception of fishers along the Ganga River, that overfishing is the ultimate cause of fish declines and conflicts, needs to be studied with more nuances. Environmental variability, represented by the steadily increasing trend in flooding intensity and complex tele-connections with the La Niña phase of the ENSO, is predicted to be the

major driver of fish yields. What about overfishing and conflicts, then? In this regard, there is scope for better understanding of what overfishing comprises, and whether its impacts are more severe than environmental impacts (Friend and Arthur 2012).

At an aggregate level, it is difficult to say from the evidence available, that the Ganga River is "overfished" at present. This may be because many fishers have exited the fishery permanently, out of fear and distress due to the scene of conflict. Fish yields might be responding more to environmental fluctuations more recently, as aggregate fishing effort has declined (Halley and Stergiou 2005, Lorenzen *et al.* 2016). Those who remain in the fishery have indeed intensified fishing effort in terms of numbers of gears, nets, and time spent fishing, especially in poor fishing years, in particular. We should be careful in addressing overfishing merely as a biological process – by comparing catches with production. This definition of overfishing, while tractable, is also narrow, for the social consequence of even one "bad year" might cause fishers to exit the fishery, or change their investment of effort. What may not be 'biological overfishing' might still become 'socio-economic' overfishing if fishing effort behaviour intensifies. Intensification of fishing effort, as a response to the high uncertainty involved in fishing, might also create and sustain resource declines and perceptions of overfishing. Seasonal regulations on fishing effort may be needed (Melnychuk et al. 2017). Future investigations of fisheries impacts needs to carefully look at whether fishing effort invested in poor years, irrespective of its impact, inflates the idea of overfishing furthermore. Importantly, fishers' decisions about investments in fishing effort are made in response to environmental variability. I showed that fishing effort typically increased when conditions supported high productivity, and exited during dry-season conditions with poor productivity. Impacts of fishing were thus correlated with environmental impacts on fish yields. Signals of recovery in some fish species were also detected in response to current climatic trends. Interestingly, larger species with slower growth and late maturity had higher ratios of fishing mortality to natural mortality, whereas small, early maturing, and fast-growing species had the opposite response. Larger species' declines were thus due to historical and current fishing pressures (through the capture of large breeding adults: e.g. Seth and Katiha 2001), whereas the smaller species (now the mainstay of the fishery) mainly responded to environmental variability (e.g. Sarkar *et al.* 2019). The stronger signal of environmental variability came from the dominance of small fish species in river fish catches.

This is probably the first study from India's rivers to quantify the effects of climate tele-connections (e.g. sunspot cycle) and eco-hydrological variables on riverine fish yields. El Niño and La Niña events, and Indian Ocean Dipole modes were identified as important drivers of fish yields. In the period from 2002 to 2007, fish catches from Bhagalpur declined steadily during the weak ENSO phase that persisted over this time. From 2007-08 onwards, though, fish yields picked up again, in response to flood-pulses increasing in amplitude and showing greater extremes of variability. Fish yields showed declines in 2014-15 and also responded negatively to the 2015-16 ENSO drought (regarded as the fourth worst in 100 years, Santoso *et al.* 2017). But the 2016 flood pulse appears to have "reset" the fishery to its 2000 state. Chea et al. (2020) have also noted such an effect of an extreme flooding event. By 2016-17, fish yields recovered significantly. However, recovery might be highly uncertain and noisy, in phases of high and increasing environmental variability (Kuparinen *et al.* 2014). The peculiar circumstances of flooding in the Ganga in 2016 were in part due to rapid and abrupt large flow releases from barrages on tributaries such as the Son and Gandak (https://sandrp.in). Long-term annual and seasonal rainfall (1991-2000) shows reductions (Yaduvanshi and Ranade 2015, Bera 2017), but more recent summer rainfall extremes and increases are becoming evident (Tesfaye *et al.* 2017, Mukherjee et al. 2018, Das *et al.* 2019), and winter rainfall has shown declines (Subash *et al.* 2011) over eastern Bihar and the lower Gangetic plains as well. The Son, in particular, has become an unpredictable and large contributor to flood-season discharges in the Ganga. This change could be driven by the extremes of rainfall in central India (Ajayamohan *et al.* 2010), where the Son originates. Local precipitation recycling across North and Central India (Pathak *et al.* 2014) can cause feedbacks between central Indian extreme rain events (Goswami *et al.* 2006) and irrigation-induced weakening of summer monsoon rainfall in the Gangetic plains (Agrawal *et al.* 2019). Further, an increase in fine aerosol buildup in the middle and lower Gangetic plains could alter rainfall intensity and magnitude (Gautam et al. 2009, Pandey et al. 2017, Kumar et al. 2018). This could aggravate tributary flood discharges (e.g. of the Son) into the Ganga River in Bihar and increase fluctuations in fish yield dynamics in the near future. The Son discharges into the Ganga at Patna, and combined with some backwater effects of the Farakka barrage (until Kahalgaon; Wiley, M.J.; pers. comm.) these appear to have aggravated flooding in Bihar in recent years (https://sandrp.in/2016/08/23/a-tale-of-two-dams-is-bihars-unprecedented-

flood-an-avoidable-man-made-disaster/). Mismatched timings of floodwater releases from the Farakka barrage and inflows from the Son and other tributaries could be causing large-scale impoundment along Bihar's floodplain region. Dai *et al.* (2009) had estimated long-term decline in river flows at Farakka until 2004, but this pattern may be changing.

Overall, the high-resolution data from 2013-2019 showed that fishery yields showed higher fluctuations in response to increasing extremes of river discharges between the flood-season and dry-season (Anderson *et al.* 2008). Such fluctuations may affect the fisheries in the near future because of increasing uncertainty about equilibrium yields, resulting in fishers reluctant to invest further effort (Stergiou 2002, Halley and Stergiou 2005). Complex ENSO-IOD interactions might have triggered these enhanced fluctuations. The frequency of severe droughts followed by severe floods in the Ganga in Bihar appears to be on the rise (Siderius *et al.* 2014). This pattern was noted in the four strongest ENSO years for which presently active fishers had memory: 1970-71, 1982-83, 1997-98, and 2015-16 (Santoso *et al.* 2017). The effects of ENSO strength and sunspot activity were identified to drive not only fish yields, but also fishing effort (during droughts) in our study area. With recurrences of El Niño droughts, effects of 11-13 year long sunspot cycles on fish species with spasmodic or irregular population recruitment dynamics might change (Caddy and Gulland 1983, Halley and Stergiou 2005). These important hydro-climatic trends bear upon the proximate environmental cues that fish track during different stages of their life (Keyl and Wolff 2008, Lehodey *et al.* 2011, Pinaya *et al.* 2016). Seasonal river discharges and water temperature exerted strong influences on fish breeding and recruitment patterns, underlying the importance of coupled flow-temperature regimes (Junk *et al.* 1989, Rolls *et al.* 2013). Dey *et al.* (2020), in their long-term study from the same area, found that non-flood or year-round breeding fishes like *Cabdio morar* (Danionidae) and *Eutropichthys vacha* (Ailiidae) had likely responded to such changes by modifying their reproductive responses to spawn multiple times every year. Evidence is emerging now that many species of the Gangetic plains are changing reproductive phenology, growth, and maturation patterns in response to climatic changes (e.g. Sarkar *et al.* 2017: catfishes). Palaemonid shrimps could be sensitive to increased flooding pulses because their abundances peak in May-June, with increases in algal and decomposing organic matter. Smaller species, such as minnows, however, seem to be climate-resilient (Sarkar *et al.* 2019). Species that

reproduce in the dry-season might not be affected by observed and future climate trends (Mallen-Cooper and Stuart 2003). Reductions in surface water temperatures over time point towards combined effects of increases in glacial melt water (Moors *et al.* 2011, Anand *et al.* 2018, Armstrong *et al.* 2019), greater discharges from barrage and reservoir storages on tributaries (esp. the Ghaghara, Gandak, and Kosi), or evaporative cooling in the dry-season (due to atmospheric warming; Moors *et al.* 2011). Air temperature, however, remained stable over the last 2 decades, indicating that local evaporative cooling was the weakest explanation for reducing surface water temperatures. Trends in dry-season river flow and water temperatures of the Gandak ad Kosi Rivers suggested an increase in dry-season flows, but temperatures were not significantly different from the Ganga River (from WRD Bihar data). Thus, higher glacial melt contributions likely explained the reductions observed in surface water temperature over time (Anand *et al.* 2018). Other curious trends were seen in electrical conductivity (decline) and pH (increase), and could be due to increased river pollution. But their effects on fish yields were weak in general.

Changing flow regimes, reductions in temperature, and climatic perturbations have altered fish species composition through complex processes of environmental trait filtering (Jennings *et al.* 1998, Keyl and Wolff 2008, Rjinsdorp *et al.* 2009). Given that fishing practices were not highly selective towards particular species or sizes (although larger sizes of *Sperata*, large *Labeo* spp., *Gibelion*, *Cirrhinus*, and *Wallago* were preferred), the impacts of fishing on fish composition and yields were estimated as proportional to stock abundances or as showing hyperstability (Castello *et al.* 2015, Alós *et al.* 2019). They were likely to follow, in interaction with increased environmental variability, a "mixed" or "regimes" hypothesis (Vert-pre *et al.* 2013). Due to the "pulsed" nature of river flows, and spatially non-random nature of fishing gear usage, CPUFDs did not show trends over time, but overall fish yields declined, indicating hyperstability. In hyperstability, catch-per-unit effort (CPUE) remains stable or increases as yields decrease, but CPUE decreases with stable yields in hyperdepletion (Erisman *et al.* 2011). Hyperstability has been commonly noted in marine, coastal, and inland fisheries, which have 1) diffuse fish stocks, as in many large rivers, and 2) stable fishing spots with non-random effort investment (Hilborn and Walters 1992, Welcomme 1995, Prince and Hilborn 1993, Rose and Kulka 1999). Aggregating, dispersing, or central-place space use by fish species could also affect these patterns (Erisman *et al.* 2011). Hyperstability depended on fishing behaviour

and the "concentration profiles" or densities of fish species, and it was seen that fishing spots stabilized in good years (Alós *et al.* 2019). In poor years, when effort investment became more random and scattered, patterns of proportional harvest were evident (e.g. for *Sperata* catfishes, which were fished year round, CPUEs were stable as yields declined). For species with prolonged spawning or repeated spawning bouts in a year (e.g. *Cabdio*), fishing effort was more or less uniformly distributed, and CPUEs became proportional to changes in yields. Fishing effort variation across years indicates a curious self-regulating effect of constraints on fishing investments that leads to "effort sorting" which appears adaptive to seasonally changing river flows (Hilborn and Walters 1992, van Poorten *et al.* 2016). Mobility of fishers in and out of the fishery is common, as they may seek to work as labourers elsewhere when returns become poor (Kelkar 2014b). They may return for six months following a normal or 'good' flood, because they are sure of making up for at least some of their investments. Usually, as fishing happens in dense clusters near fishing villages (see Figure 5.1), exchanges through local fishers' networks inform these decisions. Lagged effects of CPUFD at fixed fishing spots could lead to declining fish productivity in the subsequent dry-season, and aggravate conflicts. While this study identifies how aggregated fishing effort and yields responds to changing river flow regimes over time, fish responses can vary widely between different gear types, and across active (e.g. gillnets) and passive gears (fish traps, baskets, stake-nets, mosquito nets, etc.). A disaggregated analysis of how different gears interact with each other and produce gear-use conflicts is made in chapter 5.

Implications of environmental variability for conflicts and fisheries management

After the impact of the Farakka barrage led to a shifted baseline for fish catches after the mid-1980s, local overfishing is now one of the major causes perceived by fishers for increasing conflicts (Dey *et al.* 2019). The relative contributions of environmental degradation (exogenous factors) and fishing (endogenous factors) on fish yields hold great relevance to the way these fisheries conflicts have been expressed (Stergiou 2002, Jul-Larsen *et al.* 2003, McAllister *et al.* 1999). They also influence the livelihood security of fisher folk, and prospects for ecosystem conservation (Campbell 2007, Allan *et al.* 2005, Dudgeon 2011). Fisher

narratives of conflict and poverty might have implicitly recognized both sets of factors, but narratives of the experience of conflicts are dominated by how fishers have damaged their resources and community, through competition, selfish behaviour, jealousy, etc. (see Dey *et al.* 2020). Fishing effort also responded to seasonal river flows (Castello *et al.* 2015), facilitated by no barriers to exit or entry in the open-access fishery. In the dry-season of poor flow years, high fishing effort could have overwhelmed fisheries productivity and caused local overfishing (Carson *et al.* 2017).

In the post-monsoon period of "good years", fishers' catches also increase as per productivity pulses, and buffer them from the constant background threat of fish grabbing (see Kelkar and Krishnaswamy 2014). Better river flows increase the connectivity between side-channels and the main river, thus allowing increased access of fishers to productive fishing areas. In 'bad years', lateral disconnectivity and reduction in fish yields can not only affect fishers' catches, but also make them more vulnerable to the threat of grabbing by other actors in the river-floodplain (field observations). Local increases in fishing effort with improved river flow may be linked not only to greater resource availability, but also to tracking greater availability of fishing space, with less potential for conflicts. Inter-annual changes in fishery yields thus create locally dynamic conditions that underlie how conflict situations are negotiated and adaptive strategies developed (Keyl and Wolff 2008, Badjeck *et al.* 2010). Capture fisheries in the Gangetic plains seem to be moving towards hydro-climatic regimes with high uncertainty and erratic perturbations to productivity, affecting the nature and stability of fishing returns and risks of conflict. It is important for state fishery legislation and institutional management policy to recognize these implications. In this context, restoring and managing ecological flow regimes and near-natural flow conditions at the river basin scale may be crucial to support fisheries productivity and livelihoods (Dudgeon *et al.* 2006, Humphries *et al.* 2009, Arthington *et al.* 2010, Nguyen *et al.* 2016). Attempts at restoration to optimal flow conditions (Reeves and Duncan 2009, Humphries *et al.* 2009, Jade Bladon *et al.* 2018) can provide gainful returns for fishers and also help them better adapt to shocks and perturbations caused by increasing hydro-climatic variability.

Tables

Table 4.1. Details of data on fish species' yields, catch, effort, and associated variables for aggregate analysis in this chapter. Gear-wise analyses of CPUE and catch-effort relationships are conducted in chapter 5. # Data collected from long-term monitoring work by Mr. Subhasis Dey has been used with his consent. Mr. Dey will also be a co-author in the research outputs based on these data.

Data description	Monitoring sites	Temporal extent and resolution	Number of species, sample size (n)	Missing data	Data sources#
Landing site survey data on fish catches and gear-wise individual fishers' effort data.	Bhagalpur (Barari)	2000-2017, Monthly	86 species, of which 62 species' data used (n=30557 records)	Data unavailable from 2002, 2005, 2009, 2010, 2014, 2015	Long-term monitoring by Subhasis Dey and Nachiket Kelkar
Market survey data of aggregated fish catches	Bhagalpur (4-5 town markets) Kahalgaon (station market)	2000-2013, Monthly 2000-2004, 2013, 2015	86 species, n=1038 (c. 12 years) 86 species, data used to calibrate high-resolution daily data (see below)	As above. Not used for this study	Long-term monitoring by Subhasis Dey and Nachiket Kelkar
Total yield data (from landing and market surveys)	Sum of above	2000-01 to 2017-18; aggregated data	Sum of above	Overall missing years 2005, 2009, 2012, with minor gaps elsewhere	Long-term monitoring by Subhasis Dey and Nachiket Kelkar
Market survey data (fish catches, derived index of effort, fish price data, large individual fish noted)	Kahalgaon (station market)	Dec. 2009-Mar. 2018, Daily + opportunistic	52 species, of which 34 species' data used (n=38185 records)	Jun. 2010-Sep. 2012, Jun.-Aug. 2013, Nov. 2016-Feb. 2017	Data collection from Mr. Chandan Sahni and other fish traders by Nachiket Kelkar and Subhasis Dey
Net-mesh sizes and fish length data (across 20 mesh sizes and gears, 1 mm to 300 mm)	Bhagalpur, Kahalgaon	Opportunistic; 2000-2018	27 net types/ mesh-sizes (n=1563)	-	From direct field measurements and photographs to scale, taken by Subhasis Dey and Nachiket Kelkar
Fine-sized mesh nets' (<16 mm) catch data (by gear, location, and species)	Kahalgaon	Feb-May 2013; Oct 2013-Feb 2014; Daily	48 species, 8 net types (n=3365)	Provided by Mr. Chandan Sahni, fish trader, Kahalgaon. Used with net mesh sizes and length data to estimate proportional catch-at-age data and estimating total mortality	
Interview surveys	Bhagalpur, Kahalgaon, and surrounding areas	1999-2000 to 2016-17; Intermittent, purposive sampling	n=48 (Bhagalpur); n=35 (Kahalgaon); n=17 (others): total n=100 (+ repeat surveys, discussions)	Done by Nachiket Kelkar and Subhasis Dey	
Fish gear use locations (spatial mapping of fishing boats, net types)	Munger to Manihari (Figure 4.1)	2013-2019; Opportunistic	Approx. 400 locations, 20 net types, over 175 km on the Ganga river	Conducted by Nachiket Kelkar, used for fishing behaviour analyses and spatial effort monitoring	
Net measurements (length, breadth, mesh, deployment details)	Bhagalpur, Kahalgaon, and surrounding areas	2000-2018; Opportunistic	n=1563	Conducted by Subhasis Dey and Nachiket Kelkar, used for empirical estimation of catchability from area methods	

Table 4.2. Relationships of % catfish, % others, and % carp (out of total fish yield) with seasonal rainfall at Bhagalpur (1958-2017; data sources in Figures 4.2-4.3). Catfish showed a negative response to monsoonal rainfall but positive responses to dry-season rainfall, which contrasted with the response of other fish groups. Per cent carp did not respond to rainfall, but the per cent of other groups responded positively to monsoon rainfall but negatively to dry-season rainfall. The increase in % catfish in catches can be linked to reductions in monsoon rainfall from 1959 onwards.

Group	**JJAS rainfall**	**OND rainfall**	**JFMAM rainfall**
Catfish %	0.33 – 0.07*JJAS, R^2=0.41, p=0.034	0.335 + 0.068*OND, R^2=0.367, p=0.048	0.335 + 0.077*JFMAM, R^2=0.47, p=0.02
Others %	0.57 + 0.08*JJAS, R^2=0.52, p=0.01	0.57 – 0.07*OND, R^2=0.38, p=0.04	0.57 – 0.06*JFMAM, R^2=0.32, p=0.07
Carp %	14.04 – 0.0007*JJAS, R^2=0.0003, p=0.96^{NS}	15.05 – 0.015*OND, R^2=0.006, p=0.82 ^{NS}	21.99 – 0.07*JFMAM, R^2=0.117, p=0.304^{NS}

Table 4.3. Regression model parameter estimates showing the responses of aggregate fish yields, catch per unit effort/fisher-days (CPUFD), and aggregated fishing effort (Kahalgaon: 2009-10 to 2017-18) to environmental variables. A decline in yield and effort is seen with year, while CPUFD shows a marginal increase with year. River flow had a positive effect on total yields and fishing effort. Yields were higher in warmer seasons (high air/water temperatures). Strength of NINO index had a positive relationship with CPUE, indicating high-intensity fishing in El Niño phases.

Response	Parameter	Mean	SE	t	P-value	R^2	F	P	df
Total Yield	Intercept	289000	129000	2.24	0.0296	0.57	21.48	<0.0001	3,49
	β (Year)	-144.1	64.1	-2.25	0.029				
	β (River Flow)	0.073	0.0098	7.43	<0.0001				
	β (Temperature)	54.06	23.06	2.34	0.023				
CPUFD	Intercept	-451.06	116.49	-3.87	0.00026	0.25	10.7	<0.0001	2,63
	β (Year)	0.215	0.0573	3.75	0.0004				
	β (NINO)	0.707	0.225	3.14	0.0026				
Fishing Effort	Intercept	120900	36370	3.33	0.0015	0.54	36.24	<0.0001	2,63
	β (Year)	-60	18.06	-3.32	0.0015				
	β (River Flow)	0.029	0.0035	8.29	<0.0001				

Table 4.4. Effect sizes of river flow and fishing effort on CPUFD (Catch per Unit Effort in Fisher-Days) and monthly yields of fish species at Kahalgaon (2009-2018), estimated from the best-fitting time-series linear regression models. Most species showed strong positive relationships between yields and effort, but CPUFD responded more strongly by river flows. Interaction parameter estimates, where statistically significant, had signs opposite to the individual effects of river flow and fishing effort. This indicated that at higher river flows, fishing effort had a weaker effect and at lower flows, fishing effort had a stronger effect on CPUFD.

Species	Response	β0	SE (β0)	β (Flow)	SE (β (Flow))	β (Effort)	SE (β (Effort))	β (FxE)	SE (β (FxE))	Trend	SE (Trend)	R^2	P-value
Chitala chitala	CPUFD	3.575	3.04	-0.41	0.32	1.03	0.37	-0.09	0.033	0.045	0.02	0.265	0.033
Chitala chitala	Yield	-1.37	1.535			1.46	0.03					0.99	<0.0001
Clupeidae (Gudusia + Gonialosa)	CPUFD	1.86	0.384			0.025	0.006			-0.038	0.0186	0.326	0.001
Clupeidae (Gudusia + Gonialosa)	Yield	-31.25	9.38	0.00208	0.00053	2.58	0.2625					0.89	<0.0001
Setipinna brevifilis	CPUFD	0.7	0.23							0.02	0.01	0.11	0.04
Setipinna brevifilis	Yield	0.618	3.9			1.29	0.07					0.895	<0.0001
Gibelion catla	CPUFD	10.29	4.93	-0.73	0.522							0.05	0.169
Gibelion catla	Yield	30.51	6.46	-0.001	0.00039	2.147	0.192					0.83	<0.0001
Labeo calbasu	CPUFD	-0.8016	1.146	0.13	0.12	0.173	0.05	-0.016	0.005	0.01	0.0057	0.35	0.0057
Labeo calbasu	Yield	-1.45	1.65			0.98	0.046			0.123	0.07	0.93	<0.0001
Labeo rohita	CPUFD	NO FIT											
Labeo rohita	Yield	-4.246	3.406			4.123	0.177					0.9375	<0.0001
Cirrhinus mrigala	CPUFD	11.72	5.855	-0.83	0.62							0.047	0.19
Cirrhinus mrigala	Yield	-172.22	93.38	17.44	9.77	17.836	2.104	-1.53	0.204	0.9066	0.425	0.883	<0.0001
Bangana ariza	CPUFD	11.903	3.59	-1.016	0.37	-0.387	0.226	0.044	0.02	-0.028	0.018	0.277	0.026
Bangana ariza	Yield	1.44	2.7			2.095	0.177					0.795	<0.0001

Systomus sarana	CPUFD	-2.948	1.39	0.36	0.147							0.143	0.019
Systomus sarana	Yield	0.06	0.92			1.15	0.033					0.97	<0.0001
Crossocheilus latius	CPUFD	0.713	0.2025	-0.000014	0.0000083	0.027	0.0052					0.49	<0.0001
Crossocheilus latius	Yield	-2.507	3.013			3.112	0.11					0.96	<0.0001
Osteobrama cotio	CPUFD	4.27	1.25	-0.4156	0.133	0.08	0.017					0.47	<0.0001
Osteobrama cotio	Yield	-0.48	0.35			1.95	0.055					0.97	<0.0001
Puntius/Pethia spp.	CPUFD	NO FIT											
Puntius/Pethia spp.	Yield	2.86	3.42			1.29	0.198					0.54	<0.0001
Cabdio morar	CPUFD	41.685	10.68	-3.56	1.13							0.216	0.003
Cabdio morar	Yield	128.51	68.53	8.92	0.98	-0.008	0.0027					0.7035	<0.0001
Salmostoma spp.	CPUFD	0.356	0.193			0.1118	0.0268					0.3255	0.00018
Salmostoma spp.	Yield	-0.78	1.57			2.46	0.22					0.78	<0.0001
Hemibagrus menoda	CPUFD	-2.511	0.88	0.29	0.095	0.025	0.0128					0.45	<0.0001
Hemibagrus menoda	Yield	-0.875	0.49	0.000065	0.000025	0.807	0.0738					0.864	<0.0001
Mystus spp.	CPUFD	-0.86	2.41	0.18	0.248	0.087	0.038	-0.0079	0.0035	-0.0083	0.0126	0.1845	<0.0001
Mystus spp.	Yield	6.696	6.63			0.983	0.07					0.843	<0.0001
Sperata spp.	CPUFD	NO FIT											
Sperata spp.	Yield	10.76	7.55			1.19	0.055					0.928	<0.0001
Rita rita	CPUFD	-0.356	0.49	0.1377	0.05	0.006	0.002					0.318	<0.0001
Rita rita	Yield	-12.32	5.3	0.000226	0.000136	1.448	0.125					0.815	<0.0001
Ailia coila	CPUFD	0.092	0.518							0.017	0.011	0.06	0.145
Ailia coila	Yield	-0.4847	3.15			1.87	0.125					0.86	<0.0001
Clupisoma garua	CPUFD	-6.95	3.298	0.917	0.34	0.165	0.04	-0.014	0.004	-0.0315	0.0186	0.738	<0.0001
Clupisoma garua	Yield	-111.863	22.3			6.99	0.225					0.964	<0.0001
Eutropichthys vacha	CPUFD	-6.06	2.66	0.76	0.28	0.13	0.0485	-0.0128	0.0046			0.206	0.047

Eutropichthys vacha	Yield	-251.63	79.114	26.7	8.36	6.84	1.44	-0.56	0.14			0.81	<0.0001
Pachypterus atherinoides	CPUFD	0.1259	0.11			0.094	0.013					0.598	<0.0001
Pachypterus atherinoides	Yield	-3.56	2.18			2.419	0.257					0.717	<0.0001
Ompok spp.	CPUFD	0.126	0.03			0.002	0.0005					0.35	<0.0001
Ompok spp.	Yield	-0.73	1.525			0.549	0.03					0.909	<0.0001
Wallago attu	CPUFD	-6.03	3.0338	0.93	0.3165					-0.027	0.021	0.23	0.0098
Wallago attu	Yield	4.744	15.87	-0.002	0.0009	4.436	0.18					0.97	<0.0001
Bagarius yarrelli	CPUFD	11	10.366	-1.16	1.07	3.6	1	-0.32	0.099	0.085	0.047	0.56	<0.0001
Bagarius yarrelli	Yield	5.59	49.985	-1.04	5.31	41.845	4.86	-3.695	0.48			0.845	<0.0001
Gogangra spp.	CPUFD	0.45	0.13			0.076	0.02					0.27	<0.0001
Gogangra spp.	Yield	-0.028	0.507			1.275	0.08					0.875	<0.0001
Johnius spp.	CPUFD	0.67	0.155			0.018	0.0045					0.31	0.0003
Johnius spp.	Yield	5.204	5.2087	-0.001	0.00025	2.28	0.148					0.88	<0.0001
Glossogobius giuris	CPUFD	1.33	0.585	-0.147	0.06	0.115	0.02			0.013	0.005	0.7	<0.0001
Glossogobius giuris	Yield	-0.194	0.096			1.285	0.034					0.975	<0.0001
Channa spp.	CPUFD	-9.404	3.86	1.0266	0.4076	-0.027	0.015			0.062	0.021	0.27	0.013
Channa spp.	Yield	0.92	1.19			1.27	0.054					0.94	<0.0001
Macrognathus spp.	CPUFD	-1.301	0.755	0.16	0.08	1.07	0.147	-0.095	0.0134	-0.0065	0.004	0.787	<0.0001
Macrognathus spp.	Yield	7.023	3.186			1.328	0.106			-0.376	0.15	0.817	<0.0001
Mastacembelus armatus	CPUFD	0.828	0.156			0.003	0.0014			-0.019	0.007	0.2126	0.0152
Mastacembelus armatus	Yield	-2.36	1.236			0.9009	0.02					0.98	<0.0001
Rhinomugil corsula	CPUFD	1.126	0.448			0.1886	0.03			-0.04	0.02	0.545	<0.0001
Rhinomugil corsula	Yield	-2.55	3.03			3.78	0.33					0.784	<0.0001
Sicamugil cascasia	CPUFD	0.07	0.36			1.09	0.198					0.457	<0.0001

Sicamugil cascasia	Yield	-0.32	1.41			4.526	0.78			0.4825	<0.0001
Shrimps	CPUFD	0.26	0.07			0.033	0.0048			0.57	<0.0001
Shrimps	Yield	45.29	22.335	-4.466	2.31	2.52	0.15	-0.486	0.172	0.905	<0.0001

Key: All parameter estimates are shown as β values, where β0 is the intercept of the best models, FxE refers to an interaction between river flow (F) and fishing effort (E). SEs are the standard errors of all parameter estimates. Statistical significance values were based on α=0.15, but P-values close to this limit are also shown.

Table 4.5. Descriptive summaries of averaged guild-wise responses to hydro-climatic variables. Tile plots showing the averaged effect sizes of different variables are shown in supporting information figures S4.6-S4.14.

Hydro-climatic variable	Taxonomic group	Spawning periodicity	Catch season	Use of Water Column	Floodplain use by larvae and YOY	Life-history strategies
River flow	Cyprinidae (carps), Silurid catfishes, and Notopteridae (featherbacks) responded most positively to discharge. Only Palaemonid shrimps (Macrobrachium sp.) showed a negative response to river flow.	A > B, C > D, all positive	Post-monsoon to spring and summer breeders responded strongly to river flow (dry-season flow effect) and water temperature, than monsoon-breeders	Bottom-dwelling and mid-column fish species responded positively to river flow and water/air temperature, as opposed to the negative response of surface-dwelling species	Species whose larvae resided in floodplain wetlands, depended more strongly on river flow and water temperature than species with rheophilic larvae	Equilibrium, Periodic, and Opportunistic strategists responded to river flow and water temperature positively
Water Temperature	All groups, esp. carps and bagrid catfishes responded positively to water temperature, except for Ailiidae catfishes and *Pangasius* catfishes (negative).	B > A, C, D, all positive				
Air Temperature	Effects were generally small, except in case of minor perciform (gobies, belonids, etc.) which showed a positive response to air temperature	C > B > A, C and B responded positively but A negatively	Prolonged breeders (post-monsoon to summer) responded negatively, but pre-monsoon, monsoon and post-monsoon breeders responded positively to air temperature		Floodplain-dependent species responded negatively to air temperature, unlike non-dependent species	Positive responses to air temperature, except for Periodic species
Rainfall	Catfish, especially the Ailiidae, responded negatively to rainfall. Responses were weak or insignificant of all other groups	All species responded negatively	Dry-season breeders (post-monsoon to spring) responded negatively to rainfall	-	Non-dependent species responded negatively to rainfall and ENSO, but positively to La Nina/DMI	Periodic species responded negatively to rainfall
La Nina/ DMI/ ENSO	Silurid catfishes, Channidae (snakeheads), and Mastacembelidae (spiny eels), responded positively to both La Nina and DMI; Cyprinidae responded positively to La Nina but negatively to DMI; and Clupeids responded negatively to both. Clupeids responded positively during ENSO years, but catfishes and carps responded negatively.	A, B, C responded positively, D showed no effect, of La Nina. A responded positively to DMI and C negatively. A and B responded negatively to ENSO	Positive response of fish species to La Nina years and DMI. Only summer breeders responded positively to ENSO.	Strong positive response of surface-dwelling species to La Nina and DMI, weaker responses of mid-column and bottom-dwellers. Bottom-dwelling fishes showed strong negative responses to ENSO		Species' responses to La Nina were positive, but Opportunistic species responded negatively to DMI. Periodic species showed strong negative responses to ENSO
Sunspot number	Only catfish responded strongly and positively to sunspot intensity.	Only C responded negatively to sunspots	-	-	-	-

Table 4.6. Estimates of surplus production models for CPUE and effort for 33 selected species (2009-2018, Kahalgaon) from the dynamic fitting procedure in the R package TropFishR. Model estimates did not fit data for 17 species (pink-shaded species). The Fox model fit best for 12 species, and the Schaefer fit model fit best for 4 species. Statistical significance was tested at 90% (i.e. $P<0.10$). The parameter estimates β0 and β1 indicated the intercept and slope of the models.

Family	Fish species/groups	Best fit model	β0	SE (β0)	*P*	β1	SE (β1)	*P*	R^2	F
Notopteridae	*Chitala chitala*	NA	0.55	0.14	p=0.008	0.0003	0.0006	0.67	0.03	0.205
Clupeidae	*Gudusia, Gonialosa*	Sch	0.597	0.137	p=0.003	-0.0002	0.0001	0.185	0.235	2.153
Engraulidae	*Setipinna brevifilis*	NA	1.05	0.1	p<0.0001	-0.0003	0.0002	p=0.24	0.19	1.65
Cyprinidae	*Systomus sarana*	NA	1.524	0.425	p=0.01	-0.0037	0.004	p=0.45	0.09	0.64
Cyprinidae	*Crossocheilus latius*	NA	0.36	0.04	p<0.0001	-0.0001	0.0001	p=0.29	0.156	1.29
Cyprinidae	*Osteobrama*	NA	0.84	0.16	p=0.002	-0.003	0.003	p=0.44	0.1	0.677
Cyprinidae	*Labeo calbasu*	NA	0.76	0.07	p<0.0001	0.0007	0.0006	p=0.308	0.147	1.211
Cyprinidae	*Puntius, Pethia*	Fox	0.217	0.29	p=0.48	-0.006	0.003	p=0.09	0.35	3.74
Cyprinidae	*Bangana ariza*	Sch	1.93	0.35	p=0.005	-0.019	0.008	p=0.08	0.58	5.6
Cyprinidae	*Gibelion catla*	NA	0.19	0.23	p=0.45	0.002	0.002	p=0.37	0.2	1.01
Cyprinidae	*Labeo rohita*	NA	0.33	0.12	p=0.04	-0.0008	0.003	p=0.84	0.01	0.04
Cyprinidae	*Cirrhinus mrigala*	NA	0.78	0.125	p=0.003	-0.001	0.001	p=0.53	0.104	0.465
Danionidae	*Salmostoma*	Fox	0.196	0.217	p=0.40	-0.01	0.003	p=0.019	0.57	9.197
Danionidae	*Cabdio morar*	Fox	-1.47	0.21	p=0.0002	-1.31E-04	6.54E-05	p=0.08^	0.36	4.011
Bagridae	*Sperata*	Sch	0.306	0.061	p=0.001	0.0005	0.00018	p=0.03	0.495	6.87
Bagridae	*Hemibagrus*	Fox	0.466	0.18	p=0.08^	-0.0078	0.006	p=0.29	0.347	1.596
Bagridae	*Mystus*	NA	1.215	0.19	p=0.0004	-0.00057	0.0005	p=0.29	0.158	1.31
Bagridae	*Rita rita*	NA	0.902	0.8	p<0.0001	-0.00017	0.0002	p=0.43	0.09	0.69

Ailiidae	*Clupisoma*	Fox	-0.645	0.27	p=0.04	-0.00023	0.00012	p=0.09^	0.357	3.885
Ailiidae	*Eutropichthys vacha*	Sch	1.5	0.24	p=0.0005	-0.0014	0.0006	p=0.06^	0.4	4.62
Ailiidae	*Ailia coila*	NA	0.62	0.09	p=0.0006	-0.00017	0.0003	p=0.67	0.03	0.2
Horabagridae	*Pachypterus atherinoides*	Fox	0.46	0.18	p=0.04	-0.0056	0.002	p=0.03	0.57	8.075
Siluridae	*Wallago*	NA	-0.99	0.11	p<0.0001	-7.44E-05	6.57E-05	p=0.294	0.155	1.284
Siluridae	*Ompok*	NA	3.03	0.504	p=0.001	-0.0068	0.005	p=0.26	0.245	1.62
Sisoridae	*Gogangra*	Fox	1.12	0.11	p<0.0001	-0.004	0.002	p=0.06^	0.41	4.92
Sisoridae	*Bagarius yarrelli*	NA	0.14	0.025	p=0.0008	0.0001	0.0001	p=0.33	0.13	1.077
Mastacembeli-dae	*Mastacembelus*	NA	0.65	0.18	p=0.009	-0.0013	0.001	p=0.249	0.184	1.581
Mastacembeli-dae	*Macrognathus*	Fox	0.97	0.41	p=0.077^	-0.011	0.005	p=0.11^	0.5	4.04
Sciaenidae	*Johnius*	Fox	-0.376	0.128	p=0.0265	-0.0006	0.0001	p=0.02	0.61	9.539
Gobiidae	*Glossogobius*	Fox	0.69	0.13	p=0.006	-0.0176	0.006	p=0.05^	0.657	7.65
Mugilidae	*Rhinomugil*	Fox	0.00024	0.16	p=1	-0.0055	0.0008	p<0.001	0.8715	40.68
Mugilidae	*Sicamugil cascasia*	Fox	-0.48	0.35	p=0.22	-0.199	0.008	p=0.05^	0.49	5.775
Channidae	*Channa sp.*	NA	0.56	0.08	p=0.0005	0.0012	0.001	p=0.28	0.19	1.41

Figures

Figure 4.1. (a) The Ganga and Brahmaputra river basins, with the study area of the river floodplains in Bihar in focus (image source: Wikipedia creative commons). River flows in the lower sub-basins receive snowmelt, summer monsoon (JJAS rainfall), and winter rainfall (OND rainfall), and river channel courses change frequently due to sediment deposition-erosion dynamics and neo-tectonic effects. (b) The Ganga, Gandak, and Kosi river floodplains in Bihar are influenced by the Farakka barrage (on the Ganga), Triveni barrage (Gandak), and the Birpur barrage (Kosi). (c) The study area covers the Bhagalpur and Kahalgaon areas of the Bhagalpur district, from where fisheries data are used for this study.

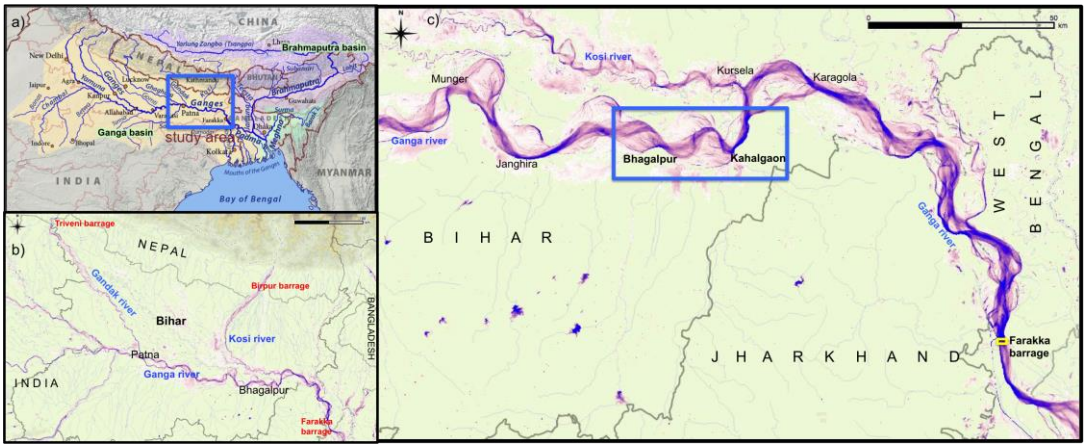


Figure 4.2. Long-term trends in catches of Hilsa (*Tenualosa ilisha*) at Bhagalpur, Bihar: after the completion of the Farakka barrage in 1975, catches declined as the barrage blocked the migratory route of upstream spawning Hilsa (data source: Ray 1998). From the 1980s onwards, Hilsa has been a very rare species in year-round catches at Bhagalpur.

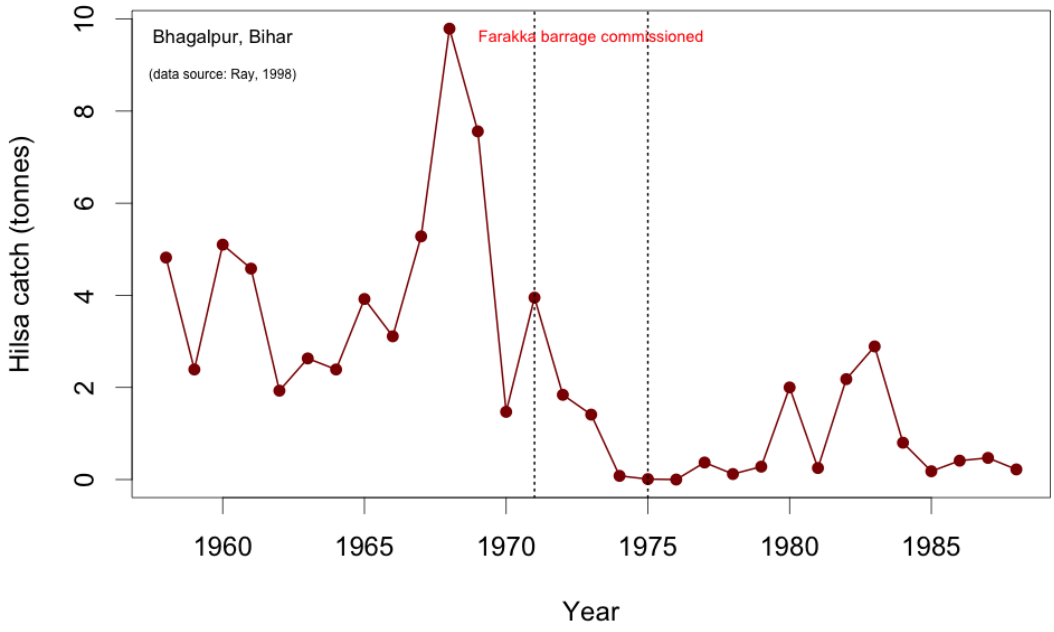


Figure 4.3. Long-term trends (1958-2017) in per cent catches of different fish groups out of the total fish landings at Bhagalpur, Bihar. White area covers data obtained from CIFRI data (from Ray 1998; see below), and the grey shaded area covers the data collected by the authors of this study (2000 onwards). A consistent increase in % catfish catches is recorded alongside a decline in carps.

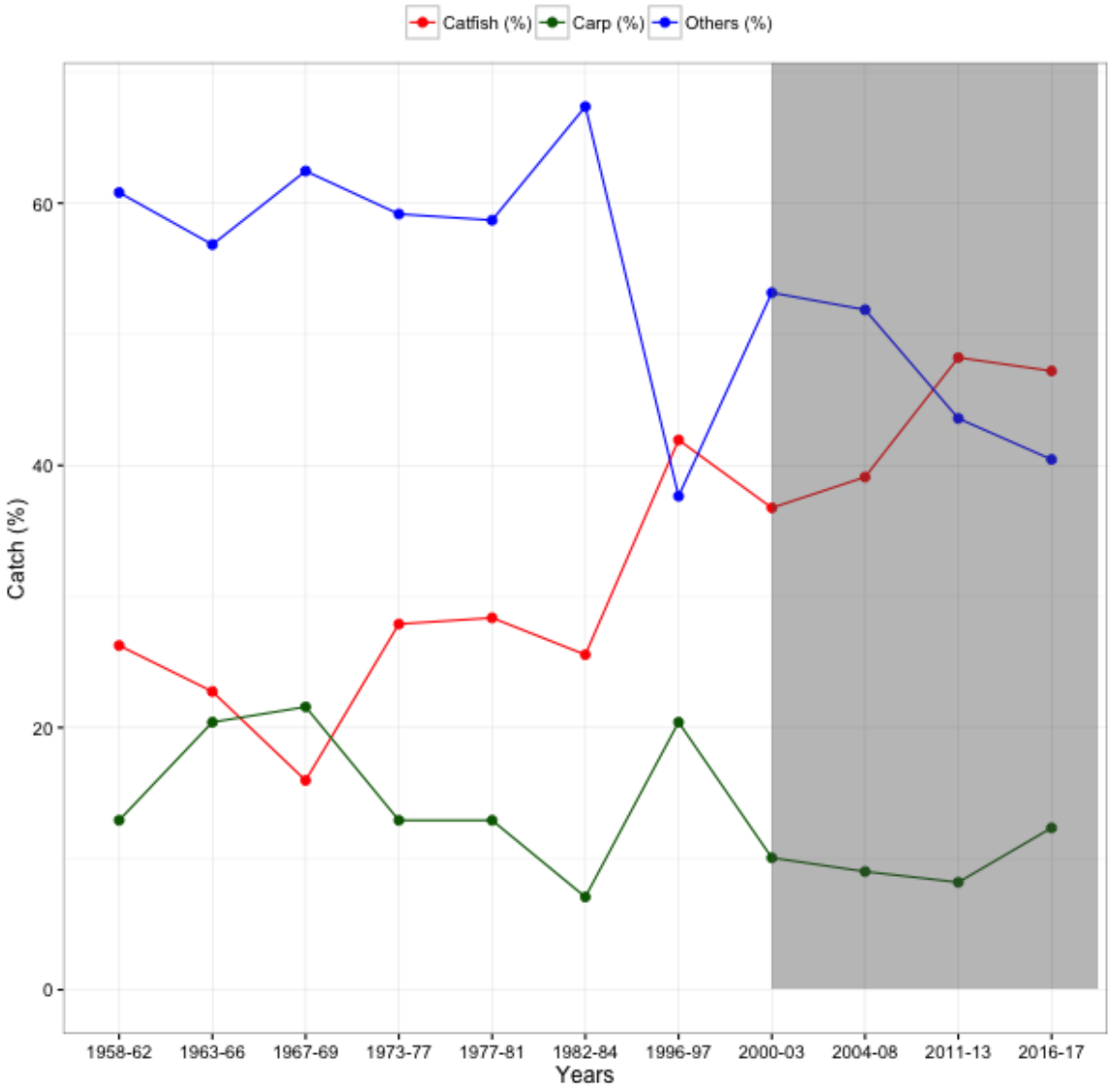


Figure 4.4. Long-term season-wise trends and differences in environmental, hydrological, and climatic variables (2000-2018). The trends noticed here are: 1) increased river flow variability over time (a-b), 2) bi-phasic behaviour of ENSO-related indices and sunspot number (c-f), 3) stable air temperature and local rainfall (g-h), and 4) reduction in surface water temperature and electrical conductivity (i-j).

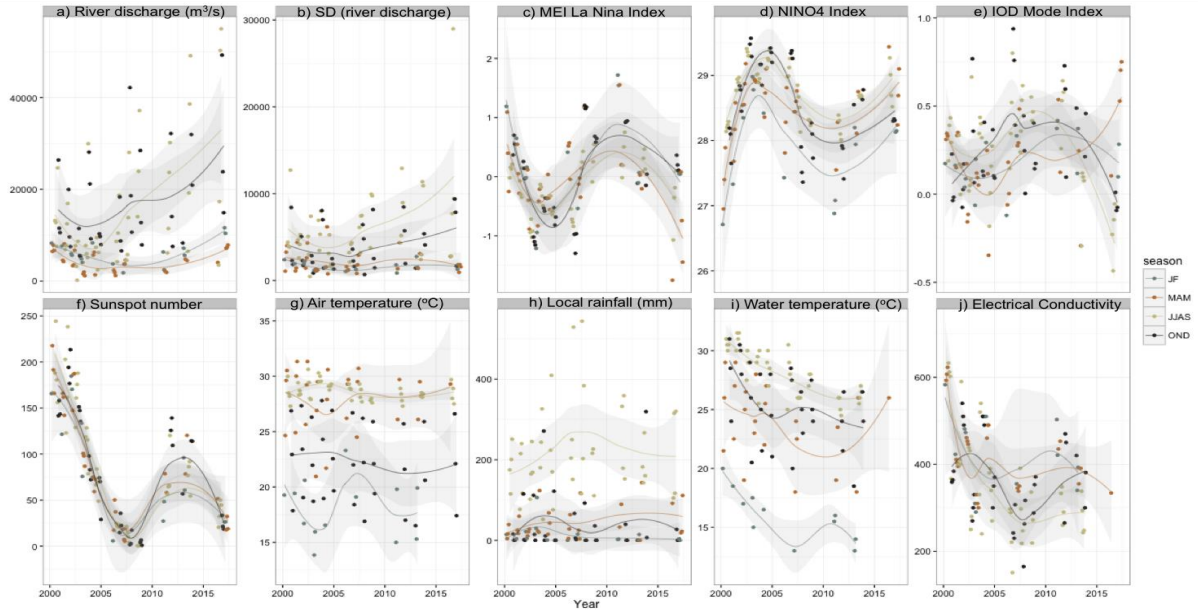


Figure 4.5. River flood characteristics and recent trends: a) flood strength (amplitude) was positively correlated with the smoothness of the flood-pulse, b) flood amplitudes were the highest in strong and moderate La Niña years (SLN, MLN) and reduced with strengthening of ENSO index (from weak La Niña: WLN to weak and moderate El Niño, but were highly variable in "very strong El- Niño" (VSEL) years, c) increase in the variability or "noise" of flood amplitudes (de-trended) over time from 1998-2018, d) Late-rising floods led to highly jagged flood-pulses (lower smoothness), e) a plot showing different years plotted with respect to timing of flow rise and total duration of flood-pulse, and f) at the beginning of the flood-season, timings of flow rises are advancing.

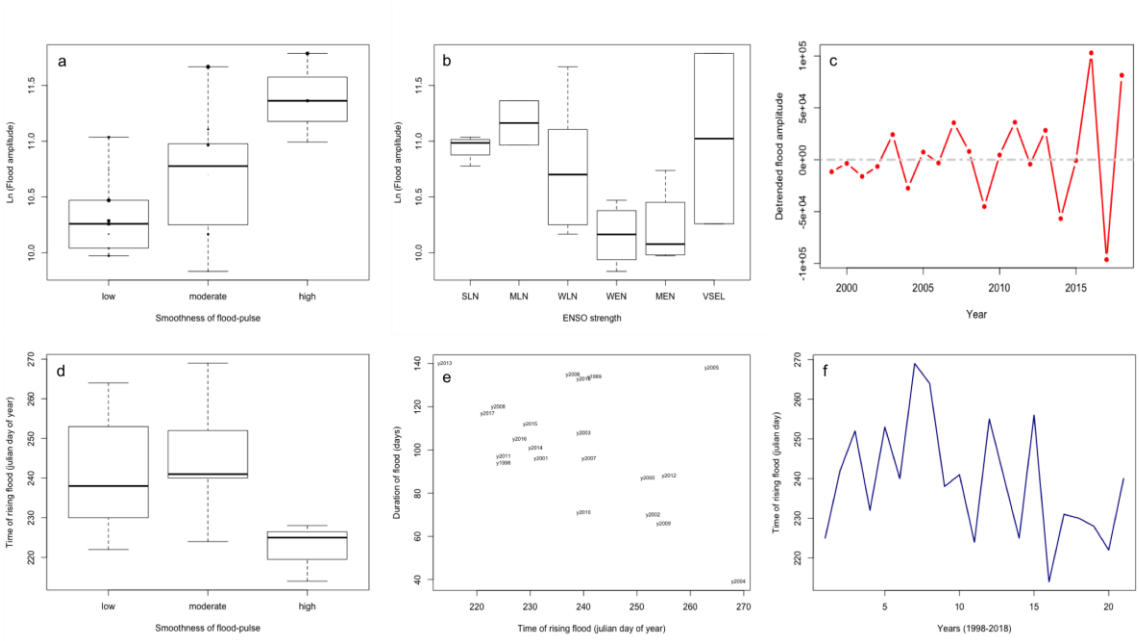


Figure 4.6. Trends in total yields of different fishery groups from 2000-2017 (Bhagalpur). Panels indicate the season JJAS, OND, JF, and MAM. While inter-annual fluctuations are noted for all groups, yields mostly remained stable, although species composition may have changed. Total yields of river shad (clupeids) and shrimps showed seasonal declines over time.

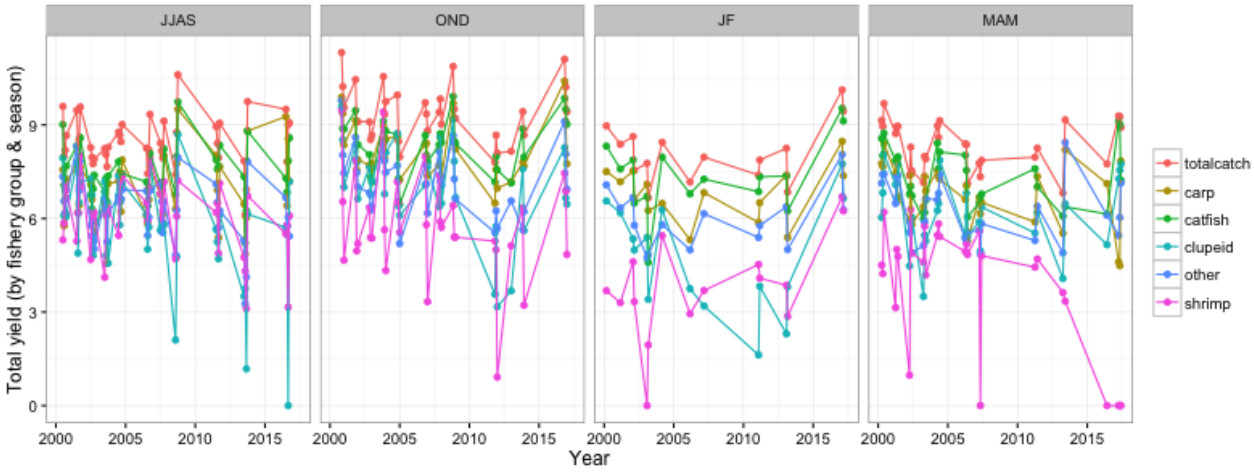


Figure 4.7. Seasonal trends in fished species' yields (2000-17). Coefficients of Seasonal Mann-Kendall tests are shown in the figure.

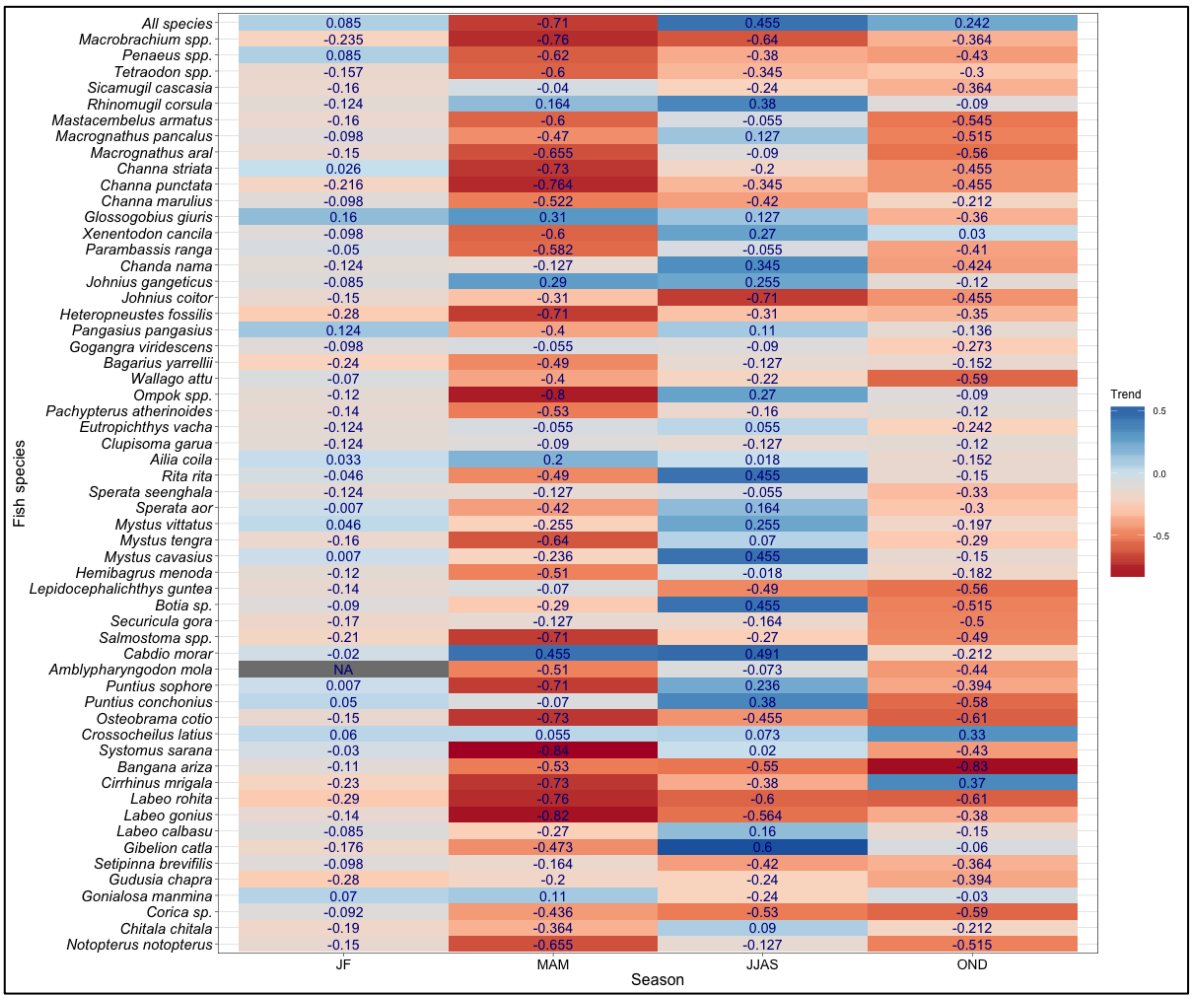


Figure 4.8. Positive interaction between number of active fishers and fishing effort (red dashed line) and river flows (blue solid line) in the Ganga River (2013-16), with effort linked to strong flooding, but delinked from poor floods in 2014 and 2015. Fishing effort was also high in the strong ENSO event in the dry-season of 2015-16.

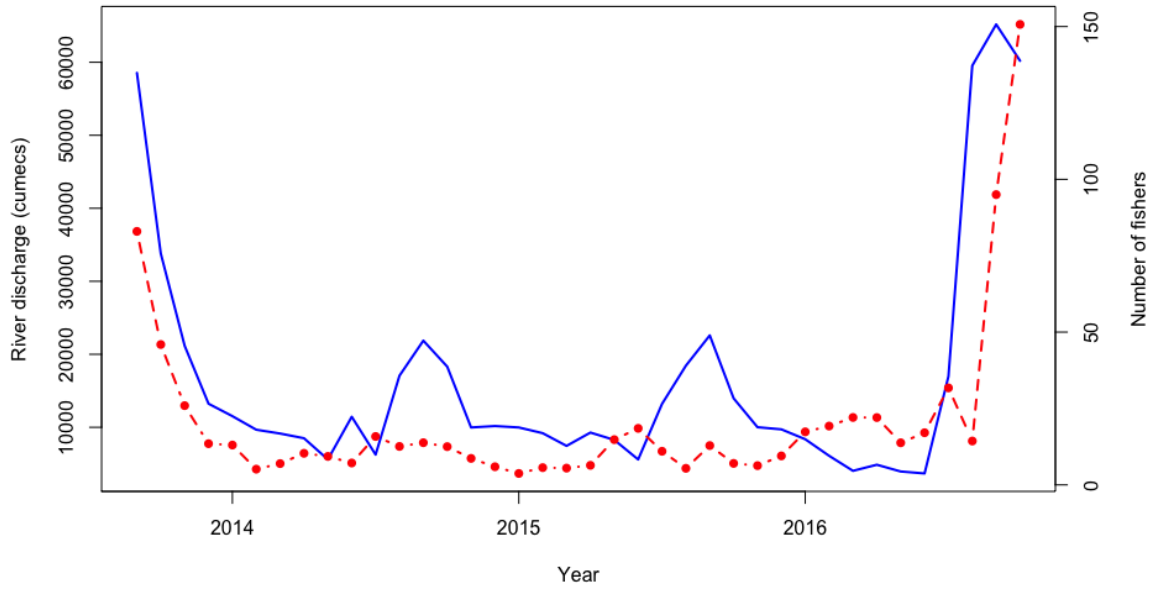


Figure 4.9. Phase shifts observed in yields of high and low trophic level fish species at Bhagalpur, from 2000 to 2016. Both trophic levels show similar shifts, and an unstable equilibrium with locally stable limit cycles, that appear to be defined by hydro-climatic trends. The 2008 and 2016 phases appear to "reset" declining fishery yields to the 2000 state. Both were phases of strong flood-pulses following prolonged El Niño drought periods. A similar regime was noted for moderate trophic-level fishes and all reproductive guilds.

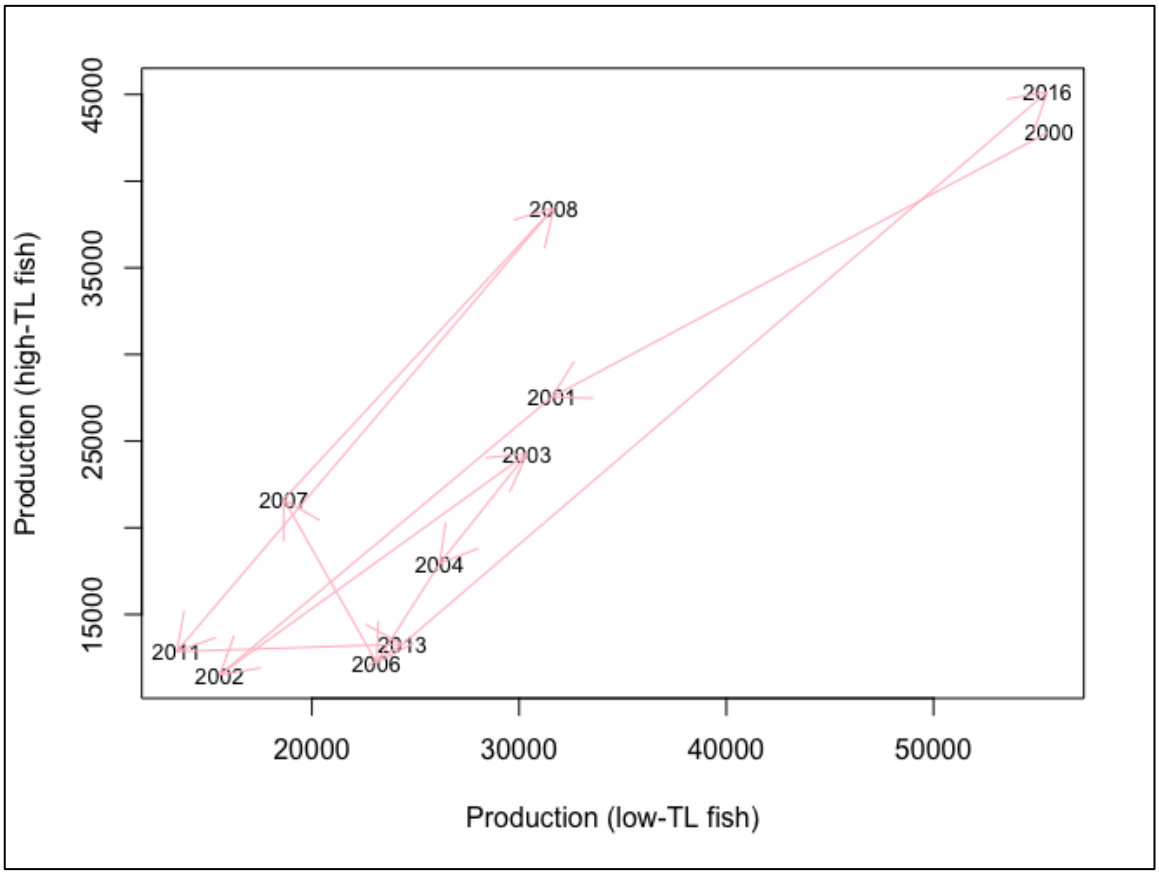
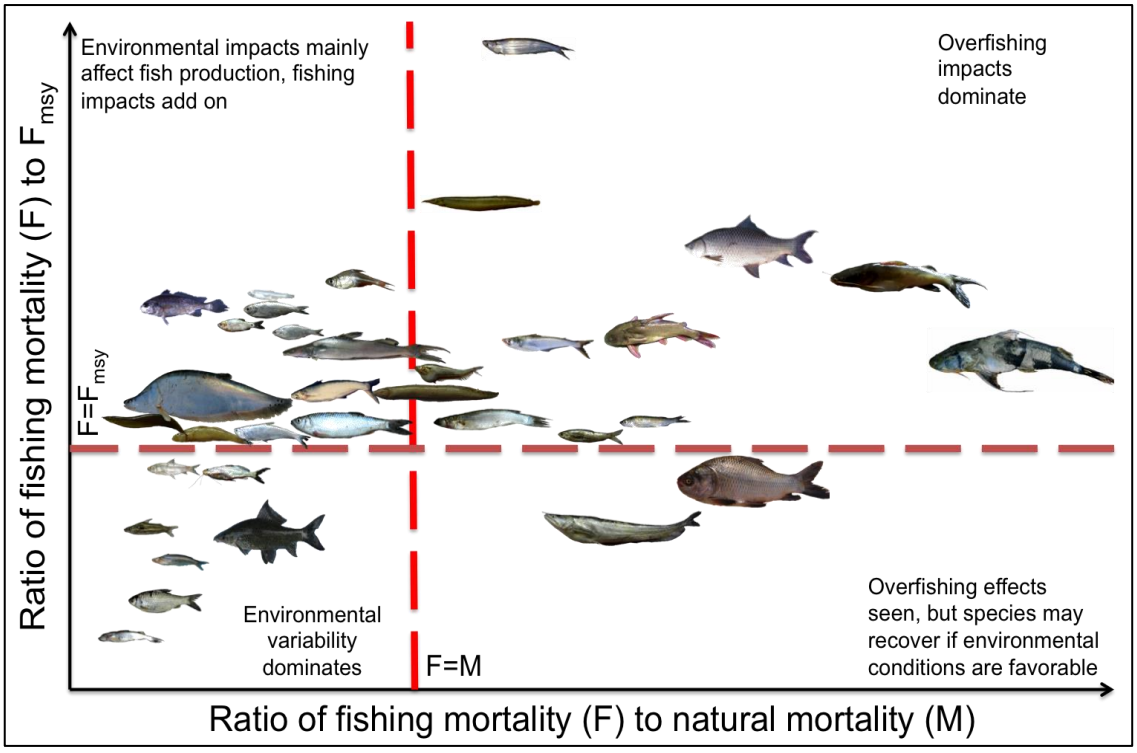
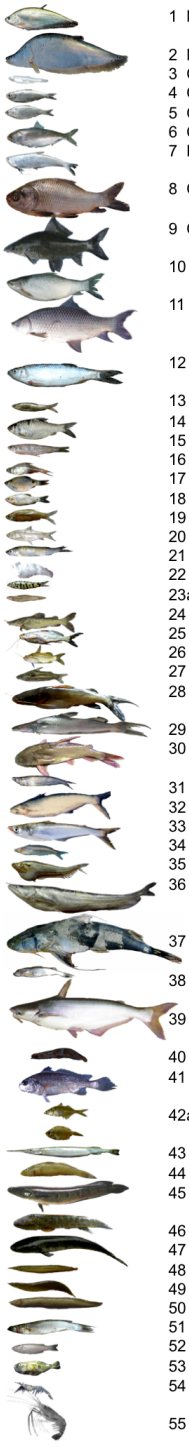


Figure 4.10. Plot describing interactions between 'overfishing' status (F: $F_{msy} > 1$) and the ratio of fishing mortality to natural mortality (F: M > 1 indicating the dominance of fishing over environment) for different fish species. Species are grouped according to whether overfishing impacts dominated (top right), environmental variability dominated (by influencing natural mortality; bottom left), or both effects acted together (top left and bottom right) on fish yields and catches. In general, it is observed that larger species' yields were more affected by fishing impacts, and smaller species' yields were driven more by environmental impacts.



Supporting Information

Figure S4.1. A numbered index of all the fish species/taxa analysed in the present study. The images and numbers can be used to identify the species plotted in the different graphs used. Common names of different fish families have been provided. Species-specific taxonomic details, author names, and ecological trait data can be found in Appendices S1-S6.



1 Notopteridae: *Notopterus notopterus*

2 Notopteridae: *Chitala chitala*
3 Clupeidae: *Corica soborna*
4 Clupeidae: *Gudusia chapra*
5 Clupeidae: *Gonialosa manmina*
6 Clupeidae: *Tenualosa ilisha*
7 Engraulidae: *Setipinna brevifilis*

8 Cyprinidae: *Gibelion (=Labeo) catla*

9 Cyprinidae: *Labeo calbasu*

10 Cyprinidae: *Labeo gonius*

11 Cyprinidae: *Labeo rohita*

12 Cyprinidae: *Cirrhinus mrigala*

13 Cyprinidae: *Bangana (=Gymnostomus) ariza*
14 Cyprinidae: *Systomus sarana*
15 Cyprinidae: *Crossocheilus (=Tariqilabeo) latius*
16 Cyprinidae: *Osteobrama cotio*
17 Cyprinidae: *Puntius conchonius*
18 Cyprinidae: *Puntius sophore*
19 Danionidae: *Amblypharyngodon mola*
20 Danionidae: *Cabdio morar*
21 Danionidae: *Salmostoma* spp.
22 Danionidae: *Securicula gora*
23a-b Cobitidae: *Botia* spp., *Lepidocephalichthys guntea*
24 Bagridae: *Hemibagrus menoda*
25 Bagridae: *Mystus cavasius*
26 Bagridae: *Mystus tengra*
27 Bagridae: *Mystus vittatus*
28 Bagridae: *Sperata aor*

29 Bagridae: *Sperata seenghala*
30 Bagridae: *Rita rita*

31 Ailiidae: *Ailia coila*
32 Ailiidae: *Clupisoma garua*
33 Ailiidae: *Eutropichthys vacha*
34 Horabagridae: *Pachypterus atherinoides*
35 Siluridae: *Ompok* spp.
36 Siluridae: *Wallago attu*

37 Sisoridae: *Bagarius yarrelli*

38 Sisoridae: *Gogangra viridescens*

39 Pangasiidae: *Pangasius pangasius*

40 Heteropneustidae: *Heteropneustes fossilis*
41 Sciaenidae: *Johnius* spp.

42a-b Ambassidae: *Chanda* spp., *Parambassis* spp.

43 Belonidae: *Xenentodon cancila*
44 Gobiidae: *Glossogobius giuris*
45 Channidae: *Channa marulius*

46 Channidae: *Channa punctata*
47 Channidae: *Channa striata*
48 Mastacembelidae: *Macrognathus aral*
49 Mastacembelidae: *Macrognathus pancalus*
50 Mastacembelidae: *Mastacembelus armatus*
51 Mugilidae: *Rhinomugil corsula*
52 Mugilidae: *Sicamugil* (=*Minimugil*) *cascasia*
53 Tetraodontidae: *Tetraodon* spp.
54 Crustacea: Penaeidae:: *Penaeus* spp., *Metapenaeus* spp.

55 Crustacea: Palaemonidae: *Macrobrachium* spp.

featherbacks

shads

anchovies

major carps

minor carps, barbs, minnows

carplets, hatchetfishes

loaches

catfishes

stinging catfish

croakers, drums

glassfishes

gars

gobies

snakeheads

spiny eels

mullets

pufferfishes

prawns, shrimps

Figure S4.2. An “ichthyograph” showing the spawning preferences of different fish species in relation to river discharge and water temperature of the Ganga River in the study area. The position of different species in relation to the monsoonal flood-pulse is approximate. Adapted from Dey *et al.* (2020).

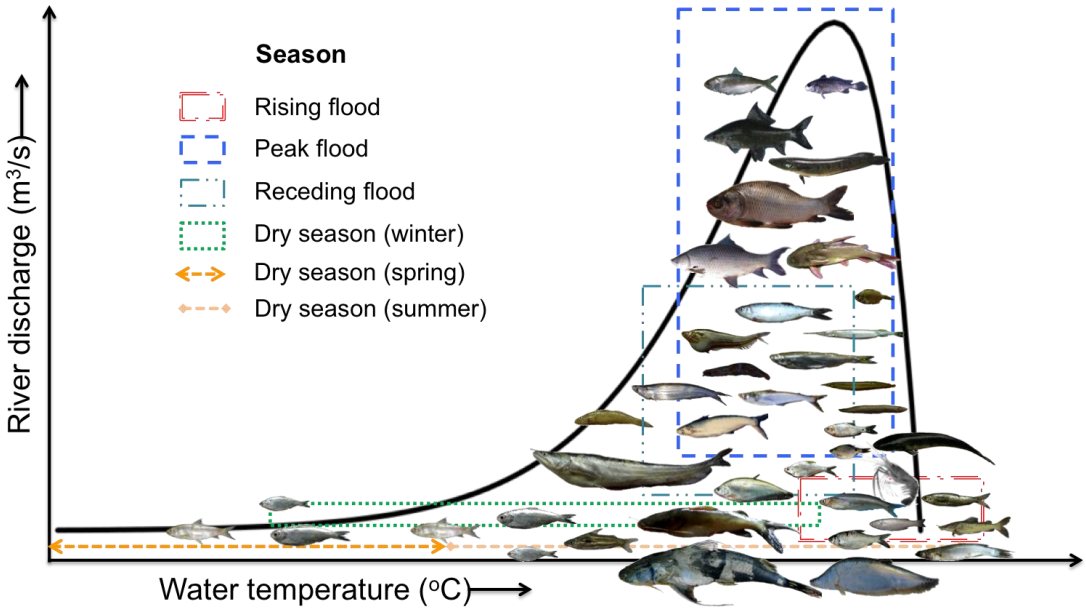


Figure S4.3. Rose-diagram indicating seasons in which catches of different fish species are the highest in the Ganga River in the study area. The peak fishing seasons are during the post-monsoon (October-December) and in summer (February to June). Fishing is low in the monsoon (July to September) and winter (December-January). Adapted from Dey *et al.* (2020).

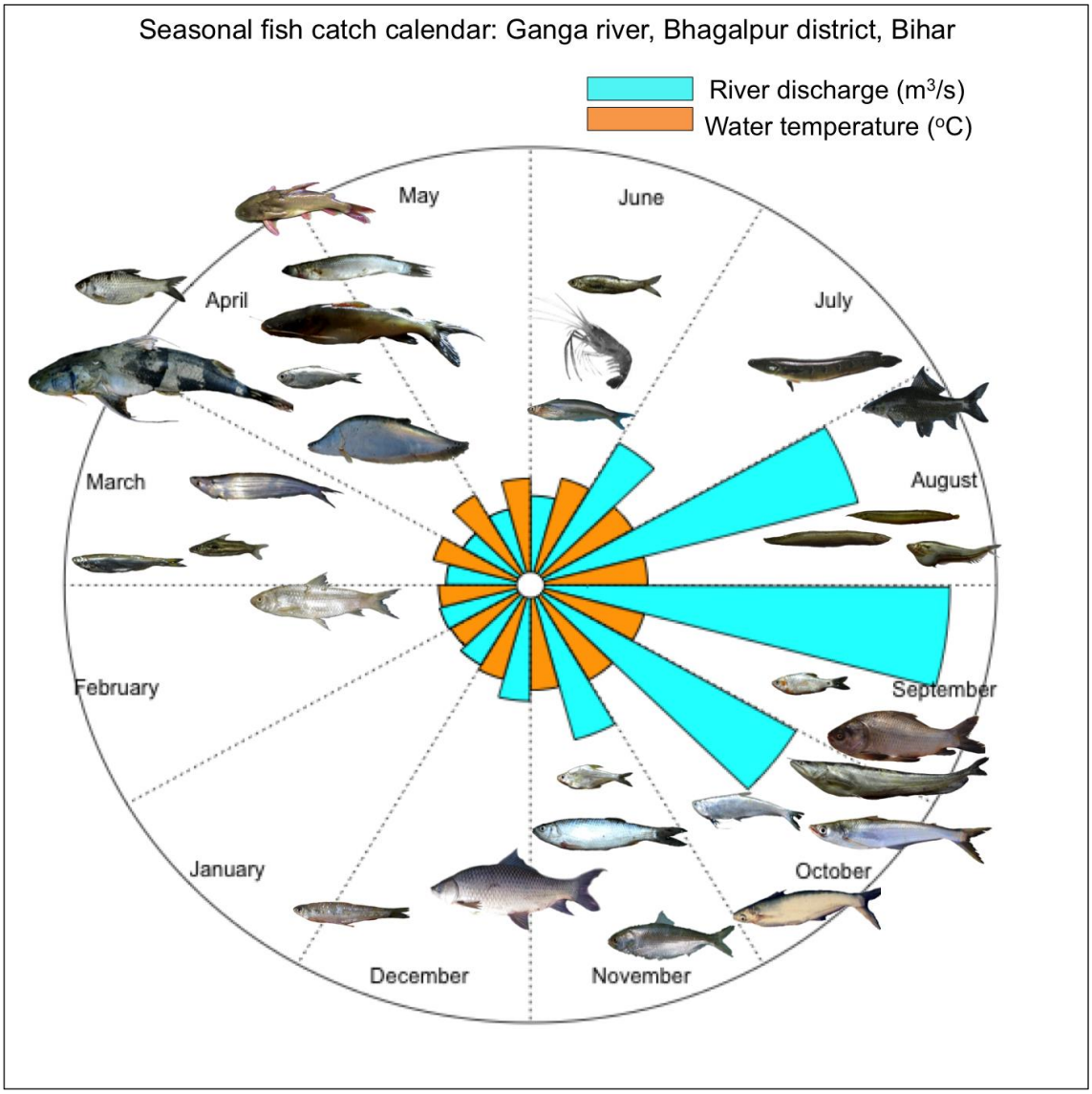


Figure S4.4. Long-term (2000-2017) monthly data of total yield of different fish groups at Bhagalpur (Barari), and the trend of river flow in this period (bottom panel).

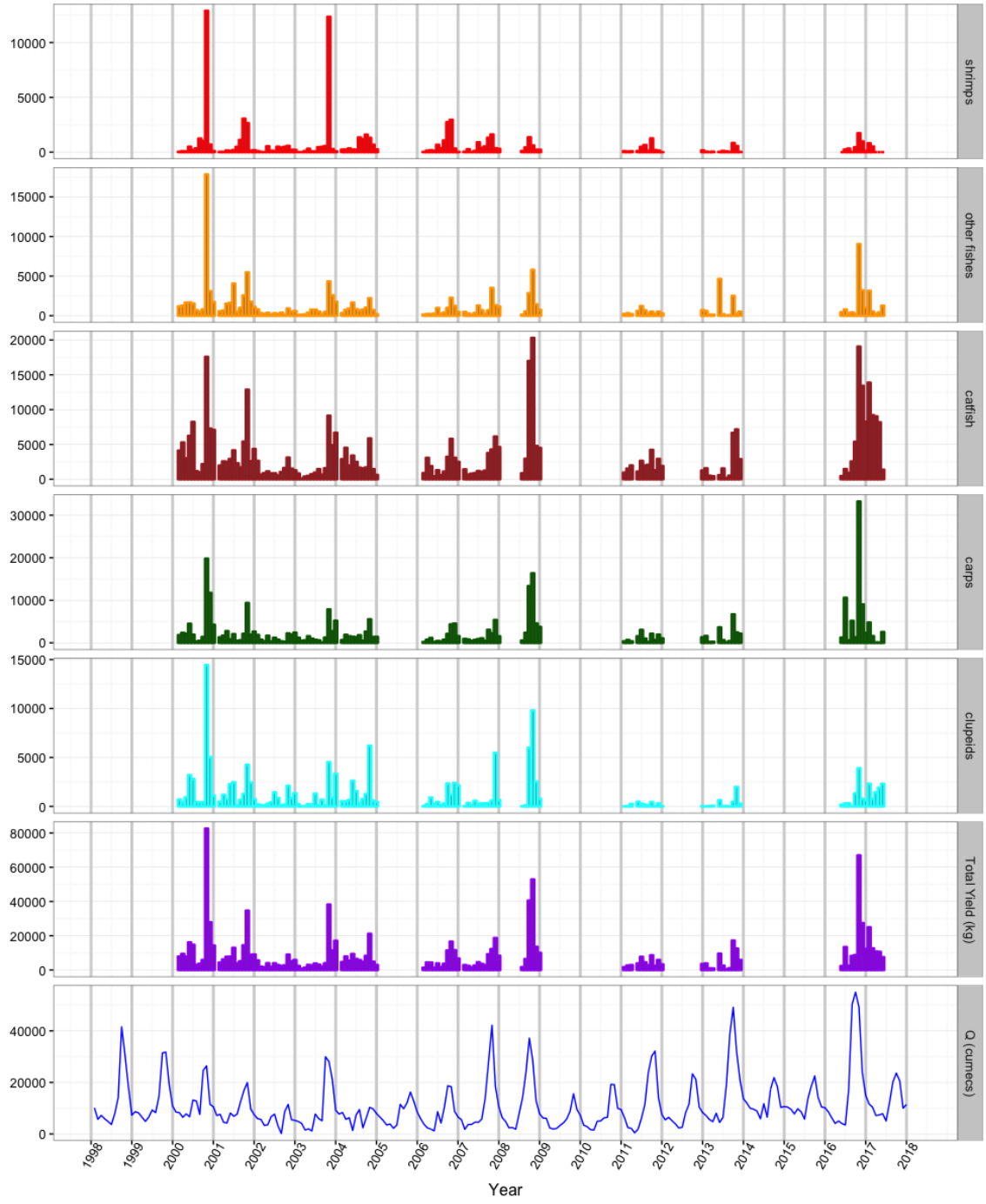


Figure S4.5. River flow (Q), La Niña Index (based on MEI data), and total yield, effort, and catch trend in Kahalgaon (2013-18). The year 2015-16 witnessed the fourth strongest ENSO event of the century. A response is evident in the low fish yields.

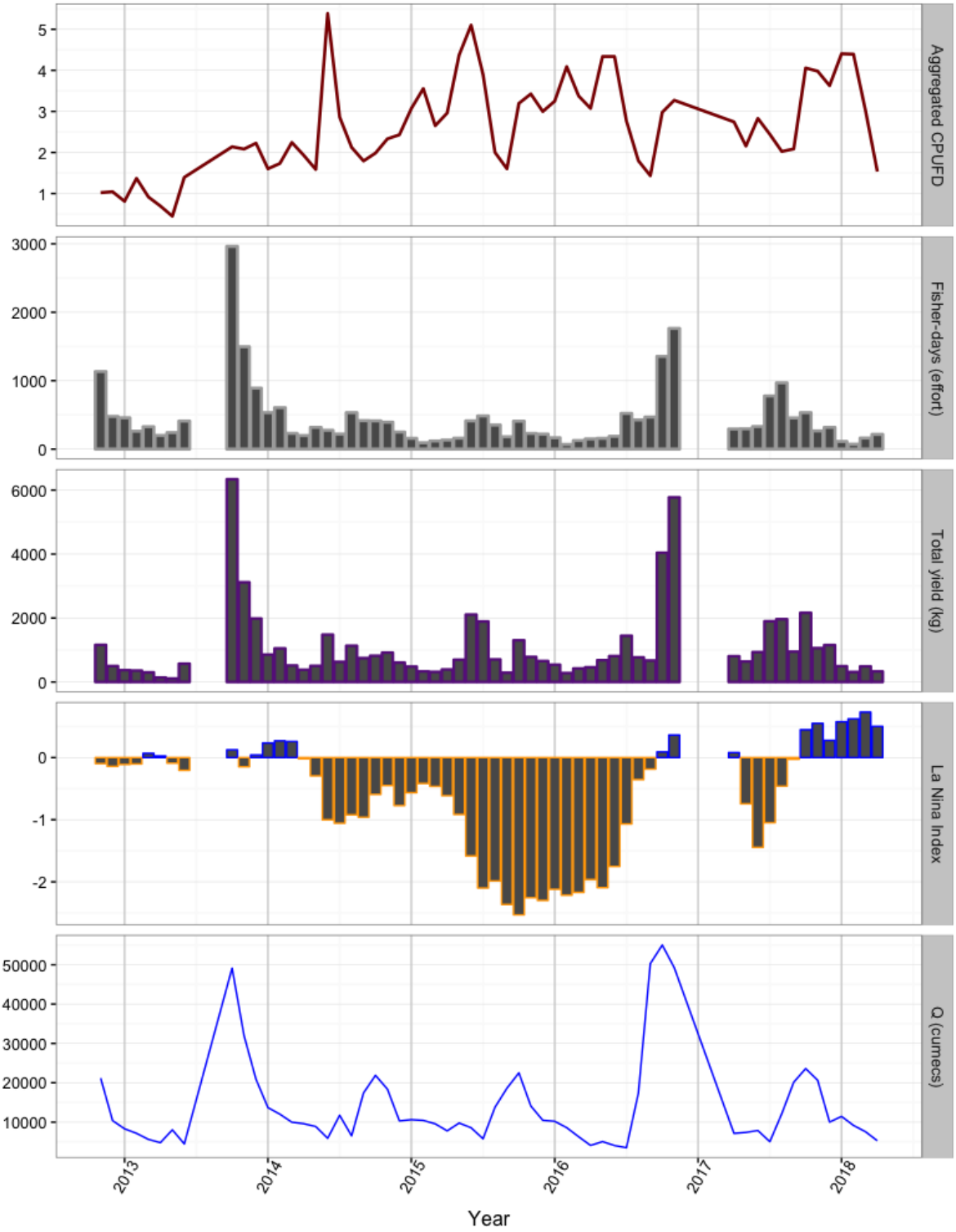


Figure S4.6. Tile plots showing responses of total yields of individual fish species/groups to hydro-climatic variables (effect sizes of environmental variables; Bhagalpur data).

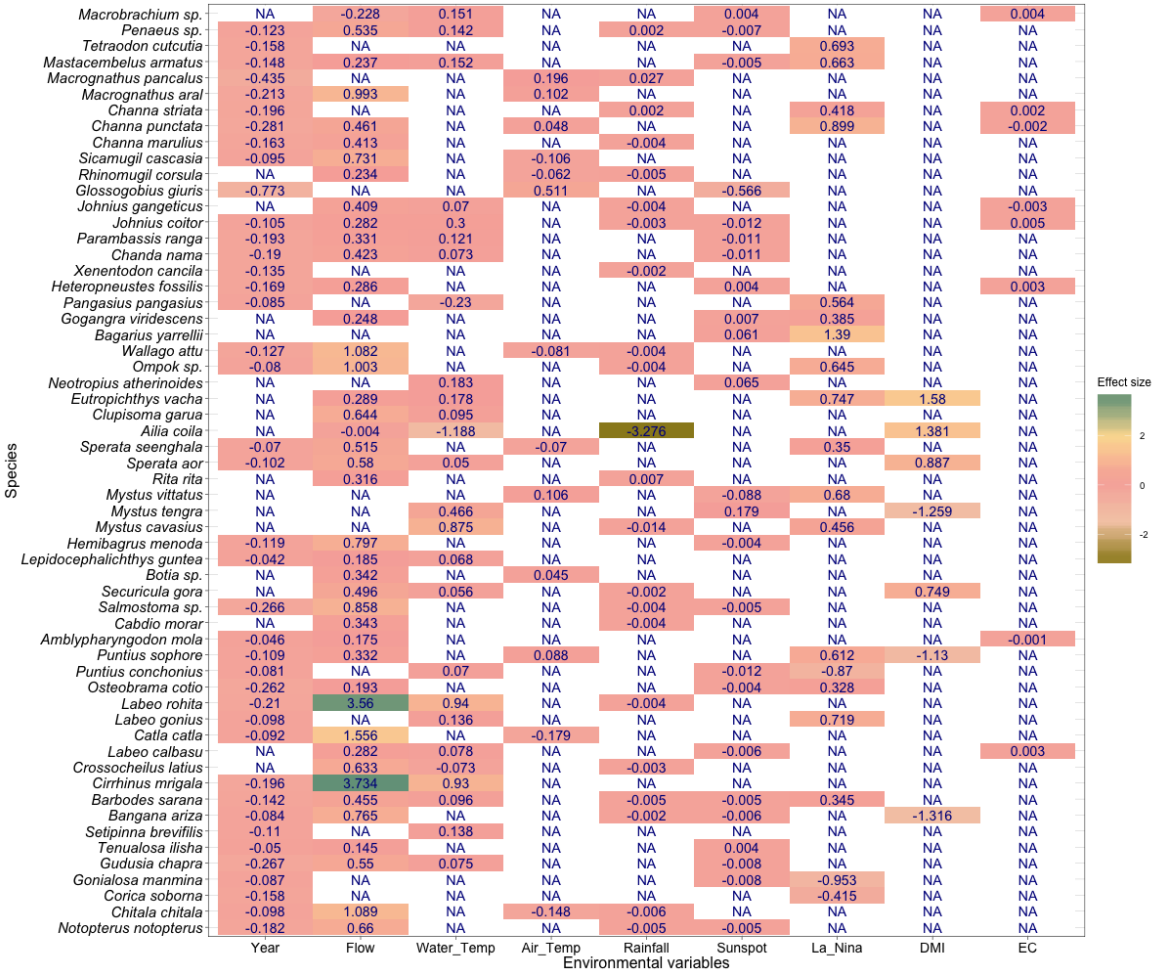


Figure S4.7. Tile plots showing responses averaged across fish families (shown alphabetically) to hydro-climatic variables (effect sizes of environmental variables; Bhagalpur data).

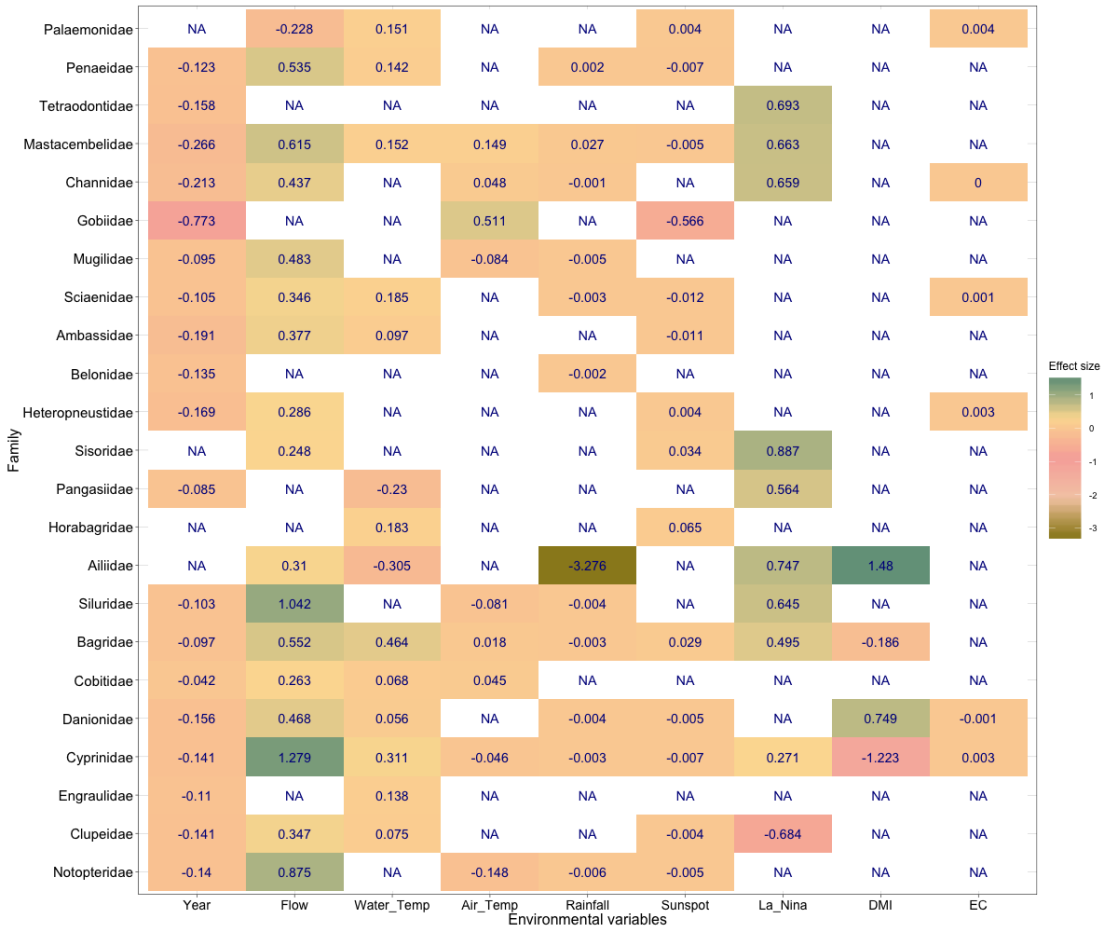


Figure S4.8. Tile plots showing responses averaged across fish groups based on their spawning periodicity, to hydro-climatic variables (effect sizes of environmental variables; Bhagalpur data).

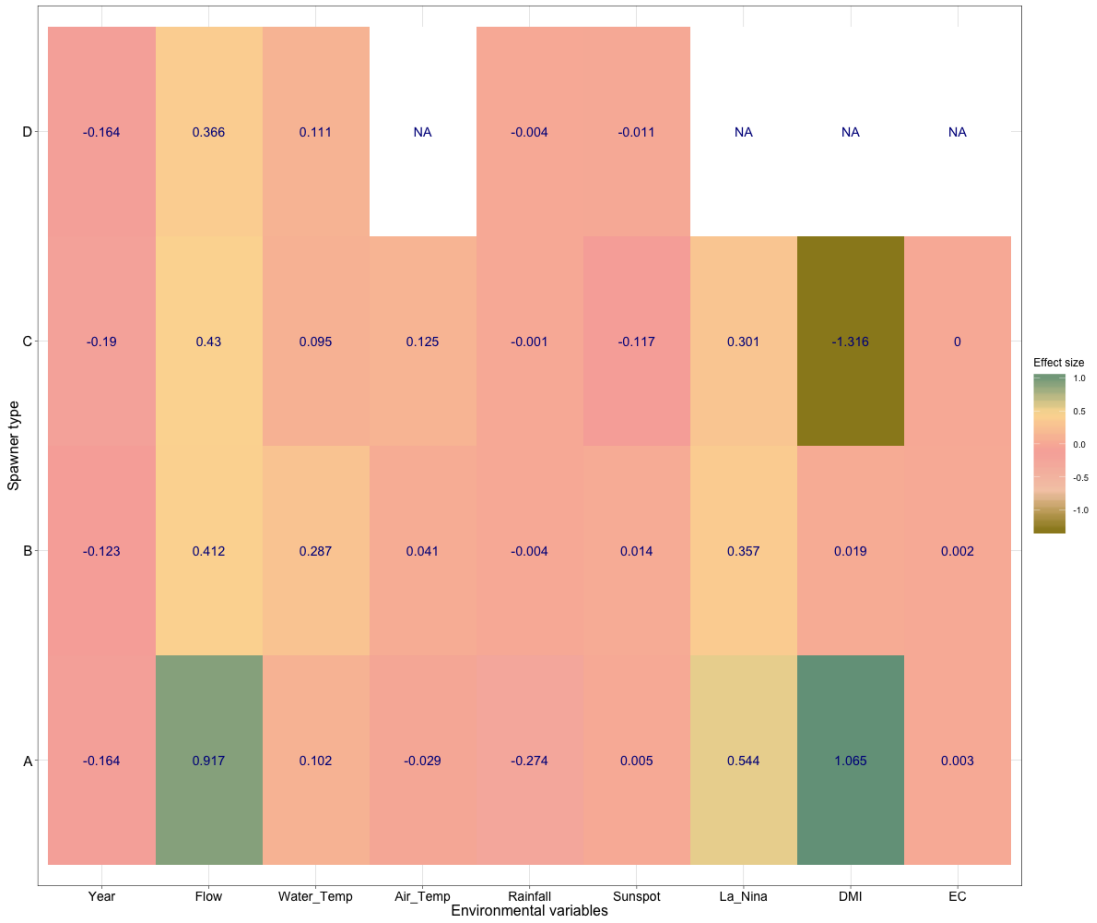


Figure S4.9. Tile plots showing responses averaged across fish groups based on floodplain-dependence for larvae and young, to hydro-climatic variables (effect sizes of environmental variables; Bhagalpur data).

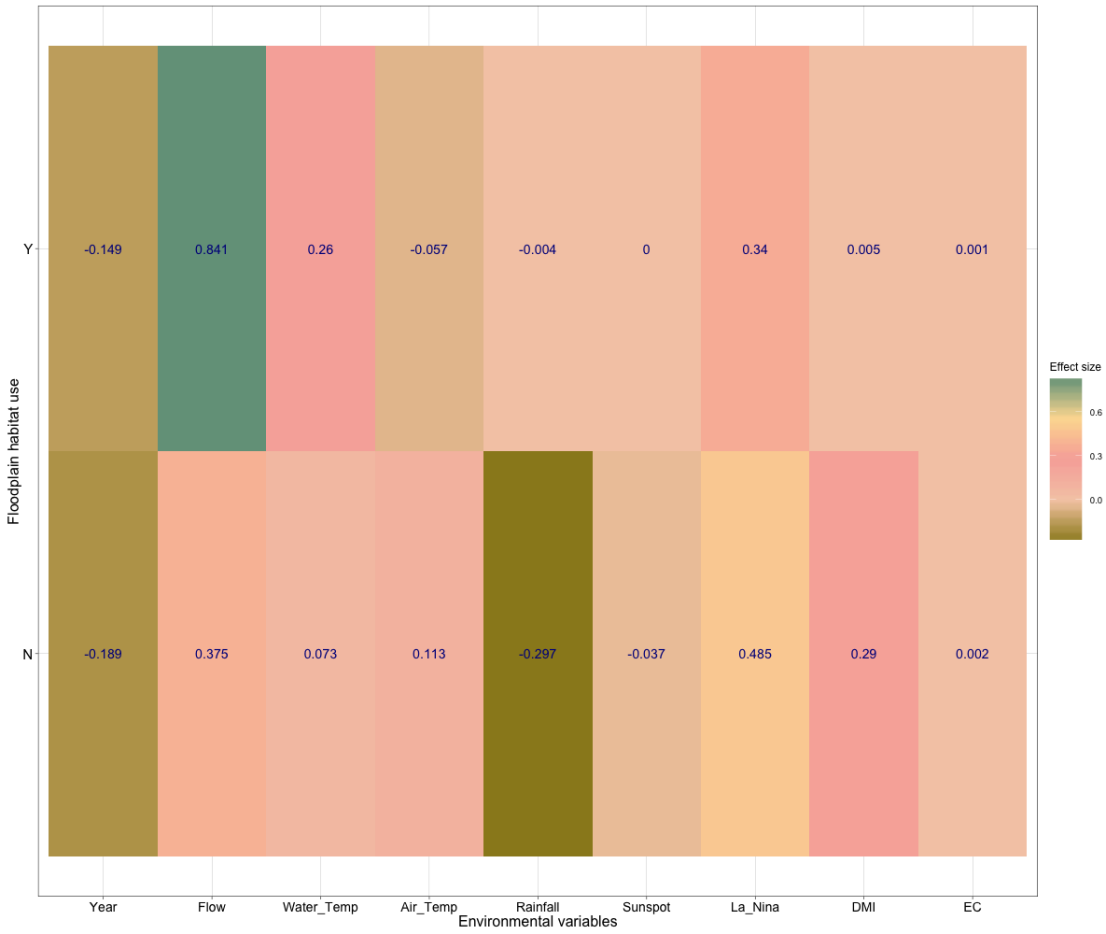


Figure S4.10. Tile plots showing responses averaged across fish groups based on life-history strategies (E=Equilibrium, O=Opportunistic, P=Periodic), to hydro-climatic variables (effect sizes of environmental variables; Bhagalpur data).

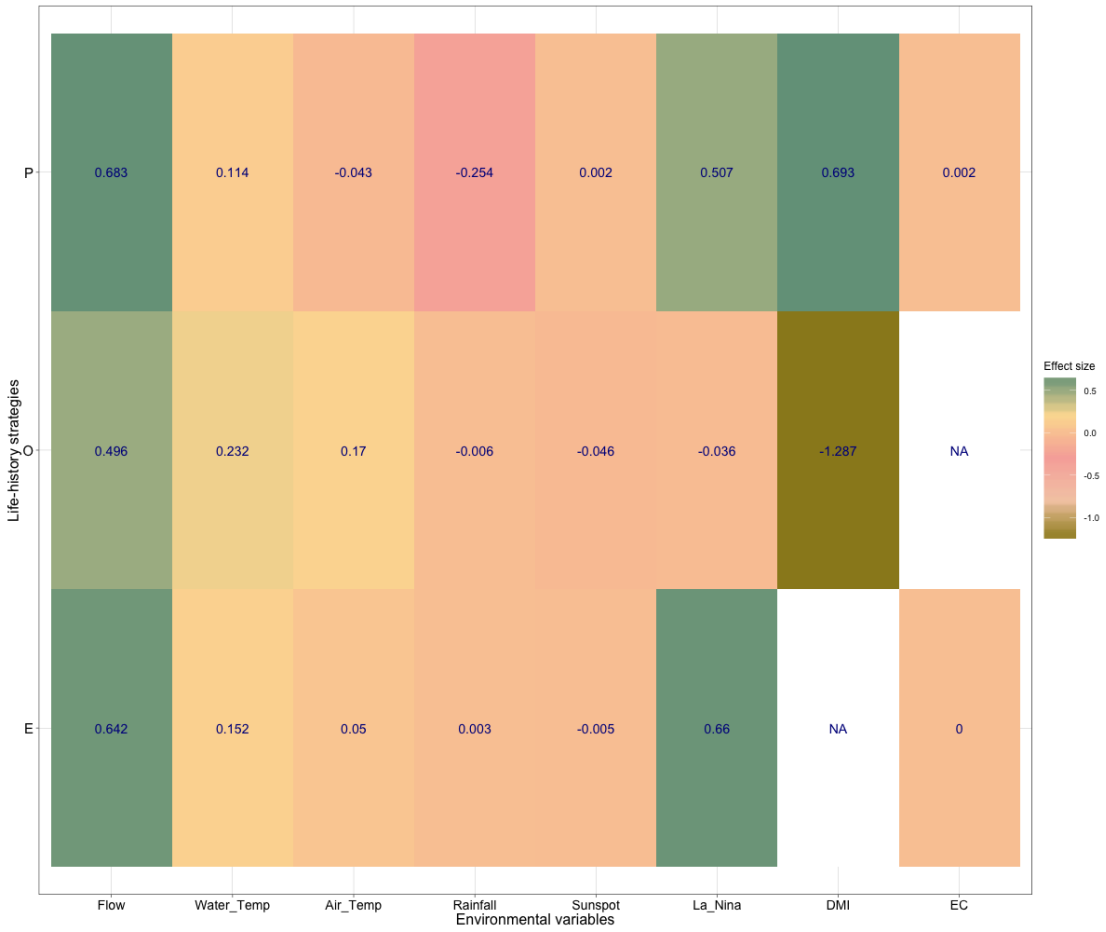


Figure S4.11. Tile plots showing responses averaged across fish groups based on peak catch-seasons, to hydro-climatic variables (effect sizes of environmental variables; Bhagalpur data).

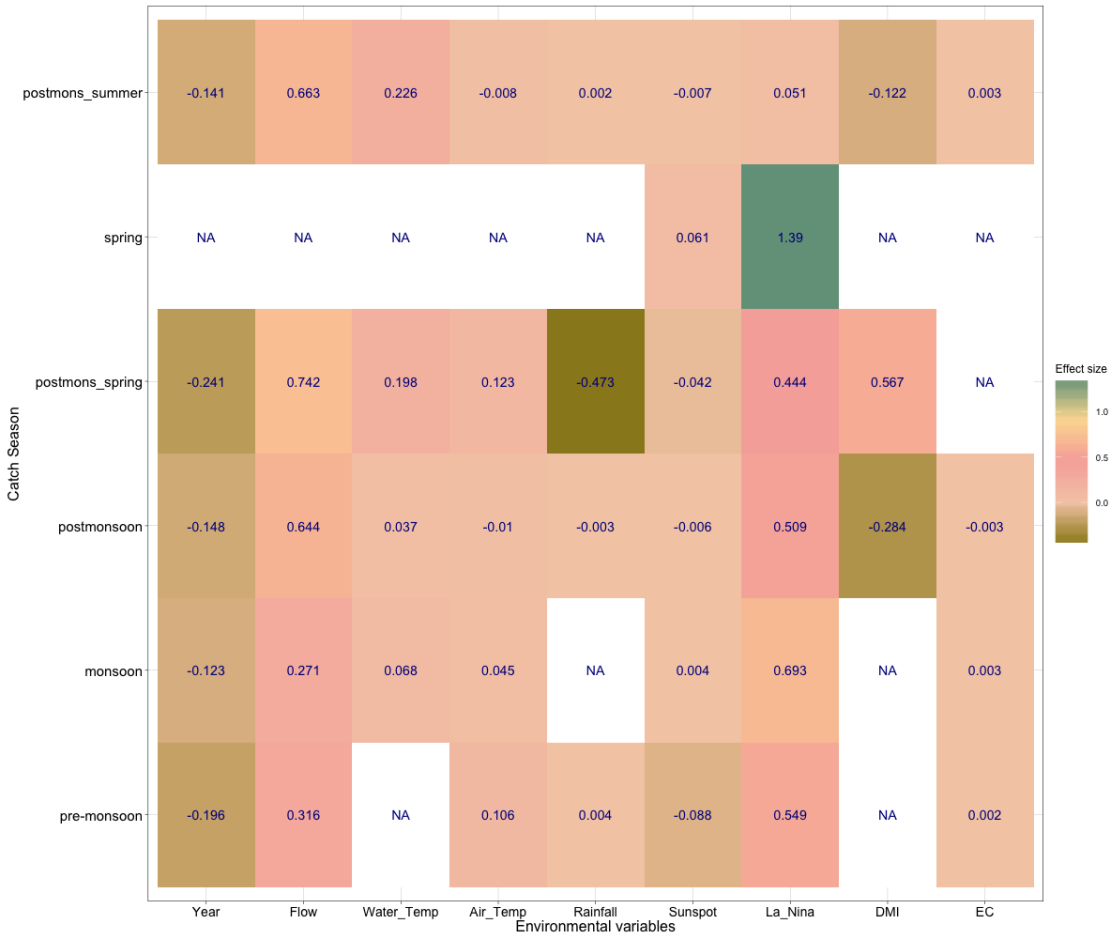


Figure S4.12. Tile plots showing responses averaged across fish groups based on use of river water-column, to hydro-climatic variables (effect sizes of environmental variables; Bhagalpur data).

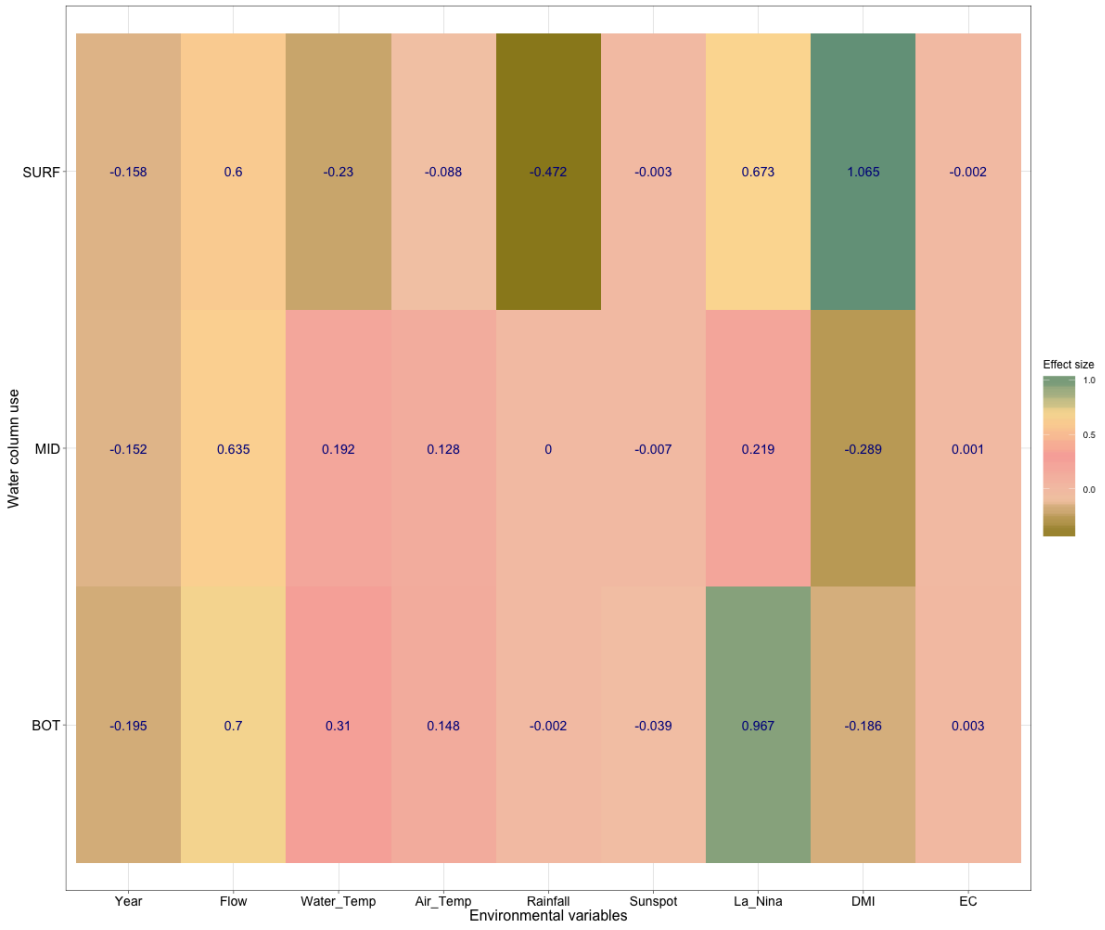


Figure S4.13. Tile plots showing responses of the total yields of individual fish species/groups to hydro-climatic variables (effect sizes of environmental variables; Kahalgaon data).

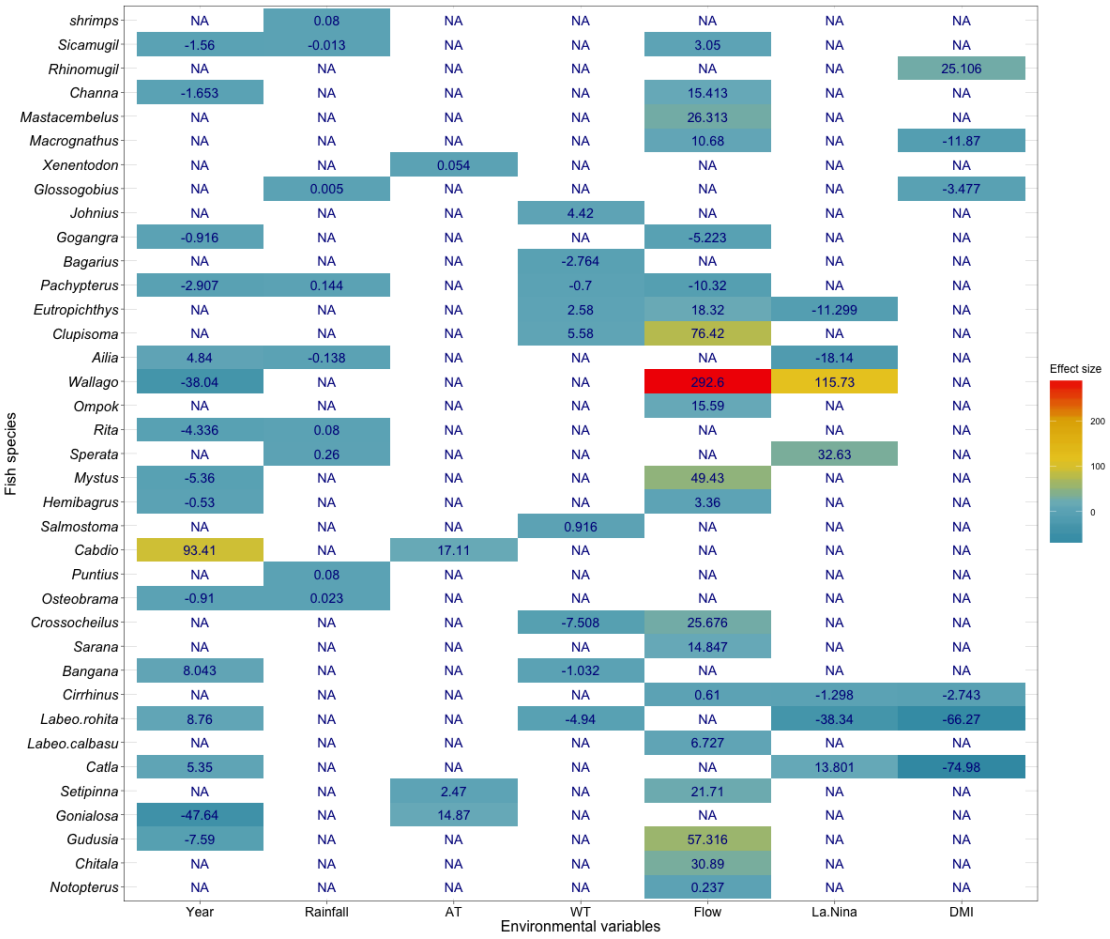
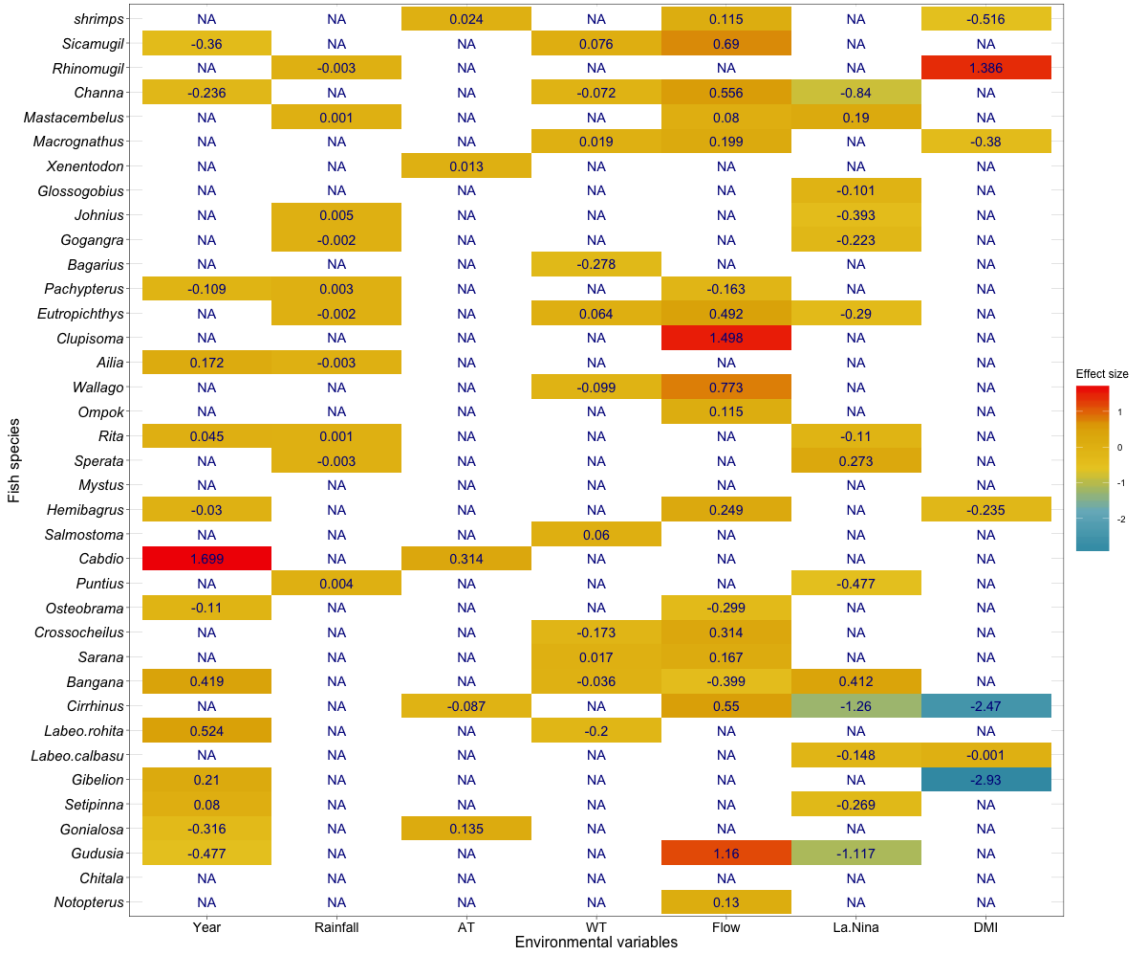


Figure S4.14. Tile plots showing responses of the total CPUFD (catch per unit effort (fisher-days) of individual fish species/groups to hydro-climatic variables (effect sizes of environmental variables; Kahalgaon data).



Chapter 5. Lives of small fish: disentangling ecological and social drivers of gear-use conflicts in Gangetic fisheries

Introduction

The impacts of selective and unselective fishing on fish yields are a complex issue underlying fishery conflicts over gear-use (Charles 1992, Pauly 1994). Narratives of overfishing by particular gears can trigger conflicts between user groups (Welcomme 1985, 1995, 2003) that differ with cultural practices, access to technology, etc. (Bennett *et al.* 2001, Santha 2008a, Cardinale and Hjelm 2012, Cadrin *et al.* 2016). Overfishing often constitutes subjective and contradictory ideas about levels of effort and fishing targets (Friend and Arthur 2017, Chiaravallotti 2017). Low selectivity, use of small mesh sizes, and high effort investment are widely regarded as characteristics of unsustainable fishing nets and gears (Carruthers *et al.* 2014, Kolding and van Zweiten 2011). Choices of fishing gear use are not just biological, ecological, and economic. They vary with market demand or seasonal variation in fish availability, legal restrictions, and traditional specializations (Sneddon 2007, Santha 2008a,b; Dey *et al.* 2019). Gear-use conflicts can affect the ecological sustainability and socio-economic value of fisheries, particularly in multi-gear, multi-species, and open-access fisheries, where diverse fishing practices can closely interact (Welcomme 2003, Tahvonen 2009). However, links between the biological processes operating in multi-gear interactions, fishery regulations, and narratives of gear-use conflict are not often clear and need to be better understood.

Both unselective and selective fishing can be detrimental to fish yields (Fenberg and Roy 2008, Castello *et al.* 2011, Vasilakopoulos *et al.* 2011, Ngor *et al.* 2018). Unselective fishing is not specific to the fish sizes harvested, whereas selective fishing captures particular ranges of sizes or species. Unselective fishing can lead to the capture of immature or juvenile, small-sized fish, and negatively affect fish yields (Vasilakopoulos *et al.* 2011). "Growth overfishing" refers to excessive harvesting of juvenile fish (arresting their growth to maturity), and "recruitment overfishing" is the overfishing of reproductive adults, preventing new recruitment into the population (Pauly 1983, 1994; Sparre and Venema 1998). Whether growth or recruitment overfishing has a greater impact on fish stocks is a major component of gear-use conflicts. Growth overfishing is generally thought to be worse than recruitment

overfishing because it reduces current yields and potential future recruitment (Diekert 2011, Ngor *et al.* 2018). Growth overfishing is also easier to detect than recruitment overfishing in small-scale fisheries (Pauly 1987). Environmental and physiological bottlenecks acting in addition to the fishing of juvenile/immature fishes can retard growth and maturation (Cetra and Petrere 2001, Stergiou 2002, Schiemer *et al.* 2003, Craig *et al.* 2004, Kasulo and Perrings 2005, Perez and Munch 2010). Growth overfishing can deplete forage fish for predators and affect trophic interactions (Froese *et al.* 2016, Shelton *et al.* 2014. Stergiou *et al.* 2007).

Classical fisheries theory emphasizes selective fishing of mature adult fishes to maximise yields, and dominates fishery regulations and management norms (Kolding and van Zweiten 2011). But selective fishing targeting larger reproductive adults could also lead to negative impacts on demography, productivity, truncation of the natural (unfished) age-distribution of fish, increased population fluctuations and advanced maturation of juvenile fishes (Walters and Kitchell 2001, Anderson *et al.* 2008, Zhou *et al.* 2010, Rouyer *et al.* 2011, Ohleberger *et al.* 2011, Shelton and Mangel 2011, Hsieh *et al.* 2014). Reductions in large-bodied fish species can also have ecosystem-level consequences from intensive size-selective fishing (Bayley 1981, Walsh *et al.* 2006, Campbell 2007, Audzijonyte *et al.* 2013, Kuparinen *et al.* 2016, McLean and Forrester 2017). Recruitment overfishing becomes a problem when levels of targeted fishing on reproducing adult fish exceed the population's capacity for new recruitment. Fishery harvest models need to consider mechanisms to avoid both growth and recruitment overfishing, such as by targeting specific optimal length ranges (Ahrens *et al.* 2020, Froese 2004). Younger adults, not mega-spawners, can still be targeted because of their lesser reproductive contribution (Birkeland and Dayton 2005).

The emerging theory of "balanced harvesting" challenges size-selective harvesting and its assumptions, and recommends moderate harvesting of fish (fishing mortality), distributed across the size-(age-)spectrum in proportion to their representation in populations (Kolding and van Zweiten 2011, 2014; Garcia *et al.* 2012, 2014, 2016). Balanced harvesting can also increase productivity even if the fishery targets juveniles and immature forage fishes (Engelhard *et al.* 2014, Jacobsen *et al.* 2014). This approach suggests that fisheries targeting small and immature size-classes may not affect overall fish yields, provided fishing effort is regulated (Zhou *et al.* 2019, Plank *et al.* 2016, Kolding *et al.* 2016a,b; Garcia *et al.* 2014, 2016). The

differences between these models could not be starker. Classical fishery concepts have their origins in large-scale, commercial fisheries, often with one or a few species caught with one or a few gear types (Hayes 1989, Clement *et al.* 2014). In contrast, balanced harvesting theory has been inspired by long-term observations of tropical multi-species, multi-gear small-scale fisheries, especially in African lakes, and rivers (see Kolding and van Zweiten 2014, Kasulo and Perrings 2005).

The balanced harvesting approach has been criticised for its interpretations about the selectivity of fishing gears, confounded effects of fishing mortality and minimum mesh sizes, likely negative trophic impacts by altering prey (forage fish) and predator fish stocks, inconsistent predictions about size-spectra of fish catches, and difficulties in its practical implementation (Breen *et al.* 2016, Froese *et al.* 2016, He *et al.* 2016, Kolding *et al.* 2016a,b; Pauly *et al.* 2016, Burgess *et al.* 2015). Many of these issues have had a continued discussion with evidence from small-scale fisheries mostly supporting balanced harvesting (Garcia *et al.* 2014, 2016; Kolding and van Zweiten 2014, Kolding *et al.* 2015, Zhou *et al.* 2019). There is a fundamental confusion of what constitutes selective and unselective harvesting. Zhou *et al.* (2019) clarify that fishing gear types, even if individually selective for different sizes, can lead to a balanced harvest across the community or fishing system. Small mesh gillnets also show high and unimodal length selectivity, mostly capturing immature fishes, which can prevent reproductive adults in the existing stock from being fished (Garcia *et al.* 2014, Wolff *et al.* 2015), compared to relatively unselective fishing methods such as seine nets or trawls (Wolff *et al.* 2015, Vasilakopoulos *et al.* 2011, Bayley and Herendeen 2000). But balanced harvesting need not involve allowing the unrestricted use of unselective fishing gears to capture "forage fish" (small-sized fish that are prey for larger fish) or cause trophic declines (Garcia *et al.* 2014, Breen *et al.* 2016, Jacobsen *et al.* 2014, Kolding et al. 2016, Zhou *et al.* 2019). Studies integrating environmental variability with fishery models have also shown limited evidence for connections between forage fish abundance and predator numerical responses (e.g., Kuparinen *et al.* 2014, Hilborn *et al.* 2017). Balanced harvesting or size-selective fishing can have variable effects on fish yields, depending on species' life-history traits, environmental or human-induced effects, and physiological constraints operating on different cohorts that are differentially prone to capture in fisheries (Miller *et al.* 1988, Houde 1997, Sogard 1997, Schiemer *et al.* 2003, Bjørnstad and Nisbet 2004, Naesje *et al.* 2007, Ohlberger *et al.* 2013).

In river-floodplain capture fisheries, there is also a spatial basis to fish growth and recruitment (de Graaf 2003, King *et al.* 2003, Halls and Welcomme 2004, Zeug and Winemiller 2007), which forms the template for interaction between selective or unselective harvests of larval fish, and usually selective harvesting of adults. In river systems, larval fish move from the river and floodplain wetlands during the rising seasonal flood-pulse, as these habitats get connected. They reside in floodplain water bodies for a few months to a year, returning to the river channel in subsequent flood recession periods (Copp *et al.* 1988, Junk *et al.* 1989, de Graaf *et al.* 1999, Lyon *et al.* 2010). Demographic studies show that river fish recruitment and juvenile survival depend on life-history traits and environmental variability (Miller *et al.* 1988, King *et al.* 2003, Gamble and Link 2009). These factors are critical in multi-species fisheries, in determining species' reproductive and growth capacity, and resilience to harvesting effects (Winemiller 2005, Zhou *et al.* 2012).

Overfishing narratives related to selective or unselective fishing deserve a critical look in small-scale multi-gear and multi-species capture fisheries in river ecosystems (Welcomme 1995, Kasulo and Perrings 2005). Gear-use conflicts in such systems are located at the centre of the larger debate over size-selective fishing and balanced harvesting. In river-floodplain fisheries, gear-use conflicts are widespread and very much "current", in spite of a long history of fishing with diverse types of gears (Kosamu 2015, Burgess *et al.* 2015). In the Mekong, Friend and Arthur (2012) have shown that overfishing narratives stem from state-driven projects to control fisher behaviour than from what is directly observed in the fishery. Additionally, fishers' reliance on ecological knowledge systems, notions of ethnicity, agency, and identity, also strongly influence conflict narratives. In the Zambezi River, Abbott and Campbell (2009) show how ethnic conflicts often translate into conflicts over the perceived sustainability of fishing with mosquito nets versus gillnets. Fishing groups thus seem to stake their positions and define "worldviews" by internalizing legal-administrative discourses to accentuate pre-existing cultural divides. Together, these factors can translate into strongly polarised conflicts over selective or unselective (and sustainable or unsustainable) fishing.

Concerns about the increasing global use of mosquito nets in fishing are connected with the balanced harvesting discourse (Gurung *et al.* 2015, Short *et al.* 2016). There are potential trade-offs in the provision of subsidised mosquito nets for malaria control and fishery consequences of the increasing use of these nets

worldwide (Short *et al.* 2016, Fiorella *et al.* 2017, Larsen *et al.* 2018, Jones and Unsworth 2019). Bush *et al.* (2017) reported negative perceptions about mosquito nets from African lakes and rivers, but also noted that the impacts of mosquito nets on fish yields had not been assessed. Mosquito nets might also offer social safety nets for livelihood security and subsistence to rural poor in many countries, and emerging conflicts over their use have implications for social justice (Abbott and Campbell 2009, Larsen *et al.* 2018). Mosquito net studies have unfortunately overlooked well-reported cases of gear-use conflicts in the Gangetic plains (e.g. Sinha and Sinha 2013, Kelkar and Krishnaswamy 2014, Kelkar 2018), and almost no empirical investigations of the problem are yet available. With this background, I emphasise the need for a nuanced understanding of gear-use conflicts in riverine capture fisheries of the Gangetic plains.

In this chapter, I examine evidence in relation to the perception of fishers using gillnets (GNFs), that fine-meshed mosquito nets and seine nets (fine-sized mesh nets: FSMNs) destroy young larval fishes, which reduces fish yields (Kelkar and Krishnaswamy 2014). I also examine the counter-narrative of mosquito net fishers, who say that gillnet fishers selectively harvest reproducing fishes, and are responsible for overfishing (Kelkar 2018). These allegations are easily translated into testable predictions of growth and recruitment overfishing by FSMNs and GNFs respectively. To test these predictions, I used statistical analyses and age-structured population models to assess the relative impacts of FSMNs and GNFs on fish yields and gear-wise catch-per-unit-effort (in fisher-days, CPUFD) of 60 species captured in 25 gear-types (2000-2018) in Bhagalpur district, Bihar, India. I have shown in chapter 2 that historically, the use of fine-meshed nets was widespread in the Gangetic plains (Hamilton-Buchanan 1812, Day 1873, 1877; Gupta 1908, Southwell 1915, Hornell 1924, Reeves 1995, Pokrant *et al.* 2004). Minimum mesh-size rules entered fishery acts and laws from the 1870s onwards (Day 1873), and bear upon gear-use conflicts in riverine fisheries even today. In Bihar's fishery regulations, mesh-sizes of FSMNs and GNFs below 40 mm are considered illegal. Further, FSMNs are mostly used with the support of "mafia" gangs, who threaten poorer GNF fishers. There is thus an element of social conflict underlying conflicts over gear-use. I discuss my results on the social and ecological drivers of gear-use conflicts in relation to predictions of balanced harvesting and conventional fisheries management. I then discuss the

interplay between fishery regulations, tradition, issues of social justice, and fisheries sustainability in precipitating gear-use conflicts.

Methods

My methods analysed fishers' perceptions and narratives of gear-use conflicts with respect to observed fish yields in the study area from 2008 to 2018. I analysed temporal trends in fish yields, catch-effort, and fish size data for a range of fish species, evaluated the size- and age-selectivity of 25 different types of FSMNs and GNFs, and correlated catch trends of interacting gear types to assess their impacts on each other. I then analysed the similarities of fish life-history data and observed catch-at-age patterns, with size-selective fishing or balanced harvesting predictions. I further validated these predictions with age-structured fish population models (with model parameters for 18 selected species) that simulated relative impacts of harvesting immature and mature fishes on overall yields.

Study Area

I studied gear-use conflicts in the Ganga river-floodplains of the Bhagalpur district, Bihar, India (Figure 5.1). The Ganga river-floodplain in Bihar is extensive, and the river shows strong meandering (Singh *et al.* 2007) with channel movement rates of 300-400 m/year. Annual discharge ranges from 16500 to 60000 m^3/s and annual rainfall is about 1200 mm (public data sources: WRD, Govt. of Bihar, and IMD, Govt. of India). The Bhagalpur district has about 1000 fisher families that depend on the Ganga River for subsistence. Details of the study area can be found in Choudhary *et al.* (2006, 2014), Kelkar and Krishnaswamy (2014), and Dey *et al.* (2019). Side-channels, chutes, meander cut-offs, oxbow lakes, are some of the distinctive river channel features of the Ganga in this area. FSMN and GNF locations were in close proximity and their effective areas overlapped spatially (Figure 5.1).

Fish catch and effort data collection

Data on fish catch, yields, and effort were obtained from a long-term fisheries monitoring program that covered the landing and market sites at Bhagalpur (25.2425° N, 86.984° E) and Kahalgaon (25.263° N, 87.237° E) towns along the Ganges, from 2000 to 2018 (with missing years, see Dey *et al.* 2020 for details). I demarcated

fishing areas of fishers at both locations through field surveys and participatory exercises. Chapter 4 provides details on fish catch and effort data collection, monitoring methods, and timelines. Tables 5.1 and 5.2 summarise the concepts, statistical approaches and indicators, and the data used in this study, with sample sizes of fish catch-effort data from landing and market sites.

Perceptions of impacts of net and gear use

To understand fisher perceptions of the various impacts of net and gear use, I conducted formal and informal group discussions and semi-structured interviews with 110 fishers across the Bhagalpur district (Table 5.2). Details of interview methods are described in chapters 2, 3, and 4 of the thesis. Interviews were conducted in Hindi and with the full consent of fishers, after openly sharing the purpose of the study. I interviewed fishers belonging to fishing castes locally regarded as "traditional" (e.g. *Gonrhi, Banpar*, and other sub-castes from the *Mallah* and *Nishad* caste-groups). Traditional fishers mainly used drifting and fixed gillnets with a range of mesh sizes (16-330 mm), hook-lines, cast nets, basket traps, scoop-nets, small trammel nets, and brush-pile traps (*Sirka Jal*) (Ray 1998). I also interviewed fishers using seine nets (Kachal Jal: mesh sizes 10-16 mm, also regarded as traditional *Sorahiya* caste fishers), and other fishers locally regarded as "non-traditional" or at least "non-regular" fishers (*Gangotas*, *Yadavs*, Bengalis, Muslims). The so-called non-traditional fishers used large and small mosquito nets, barricading mosquito nets, stake-nets, drag-nets, multi-mesh nets, and traps with mesh size ranges of 1-2 mm. For this chapter, I assessed different fishers' perceptions of how gear types and their use affected fish mortality and fish yields in the Ganga River. Table 5.3 provides details of different fishing gears and nets assessed in this study, along with trends in their overall yields, catch-rates, effort, and information on seasonal use, preferred locations, and modes of operation.

Legal restrictions on mesh size use and their implications

I noted the current minimum mesh size limit stipulated by the Bihar Fish Jalkar Management Act (2006, with amendments till 2018). Based on this mesh size restriction, I classified different fishing gears as "legal" or "illegal". I linked the use of

legal (GNFs) and illegal gears (FSMNs and GNFs) by fishers to their perceptions about existing regulations.

Fisheries data analyses

Selection of fishing gears

The study compared daily and monthly fish catch data over time for the net types described in Table 5.3. FSMNs included mosquito nets (mesh size 1-2 mm), boat-drawn river seines used in side-channels (10-16 mm), and small-mesh (15-20 mm) carpet gears used as shore-seines (Payne *et al.* 2004). GNFs included small-mesh gillnets (15-40 mm), medium-mesh gillnets (40-100 mm), and large-mesh gillnets (>100 mm). Mosquito nets included three major types: 1) nets dragged in side-channels similar to seine nets, 2) barricading nets used to completely block channel confluences and inlets, and 3) small fish traps and box nets set along shorelines (Blowfield and Haque 1995). All GNFs had meshes made of nylon (or occasionally, plastic) monofilament (Montana *et al.* 2011).

Long-term trends in fish catch per unit effort for selected gears

Monotonic trends in month-wise average catches (catch per unit fisher-day: CPUFD) and effort for major gear types were assessed with the non-parametric Theil-Sen estimator (Sen's slope) and Mann-Kendall tests (Yue *et al.* 2002), at both sites from 2000 to 2018. Effort units were defined as fisher-days for all gear types (Bayley 1988, Gray *et al.* 2005, Bishop 2006, Lorenzen *et al.* 2006, Maunder *et al.* 2006, Wilberg *et al.* 2010, Laurence *et al.* 2015). CPUFDs for individual gear types were generally proportional to total yields (Maunder *et al.* 2006). Analyses were conducted in the 'trend' package in the R software (R Core Team 2018).

Local interactions between gears: cross-correlation analyses

I used cross-correlation analyses to test if GNF CPUFDs and FSMN catches were correlated, based on statistically significant lag-correlations, with a maximum lag period of 10 days. For this, I used high-resolution daily data on catches from FSMNs and gillnets at Kahalgaon from two seasons of 2013-14 (Feb-May 2013, Oct-Feb 2014: see Supporting Information Figure S5.1). The detection of significant negative correlations at different lags until 10 was interpreted as a negative effect of

FSMNs on GNF catches. Positive correlations were interpreted assuming that FSMNs and GNF catches would both show similar responses to environmental effects (e.g., productivity pulses from floodplain to river). Cross-correlation analyses were conducted separately for the two seasons in the software R 3.2.1 (R Core Team 2019).

Correlation of species ranks in FSMNs and GNFs and trends in fish catches

I compared the composition of fish catches between fine-meshed nets and gillnets by plotting rank differences of fish species in GNFs and FSMNs against their ranks in FSMNs. Positive rank differences indicated species that were caught mostly in FSMNs, negative rank differences were species mostly caught in GNFs, and rank differences near zero (-5 to +5) were species that were caught in both FSMNs and GNFs at similar levels. Species that were regularly harvested by both FSMNs and GNFs were selected for detailed analysis (Figure 5.2). I also chose other species that were harvested only by FSMNs and only by GNFs, whose catches did not occur in both nets (Figure 5.2). I used Spearman's rank correlation to test if ranks of species in FSMNs and GNFs were correlated with ranked seasonal trends in yields observed for the species from 2000 to 2018. The four seasons were defined as JJAS, OND, JF, and MAM as per methods used in chapter 4. Statistically significant rank correlations indicated FSMN or GNF catches influencing seasonal trends of different species.

I categorised long-term trends in CPUFDs of FSMN and GNF gear-types (mesh-sizes: 1-300 mm) as "decreasing (D)", "fluctuating (F)", "increasing (I)" and "stable (S)", to identify correlated trends in catches of size-based (age-based) cohorts (Bjørnstad and Nisbet 2004, Jorgensen and Holt 2013, Botsford *et al.* 2014). This was done for different fish groups (cyprinids, catfish, clupeids, perciform fish, others, shrimp) and gears with adequate sample sizes, for which gear-specific size-selection was estimated (see below). I checked if different size-based cohorts in different nets showed similar or related trends, and whether relative capture rates in FSMNs or GNFs or both (based on rank differences) were related to trends in gear-wise CPUFD. If rank differences decreased in the order D-F-I-S, then FSMNs had a negative impact, but if they increased, then GNFs had a negative impact, on CPUFDs.

Gear selectivity and captured age-lengths

I plotted length distributions across different mesh sizes and net types, and estimated age-distributions for each different gear type from these data. Selectivity of each mesh size was analysed graphically through violin plots, boxplots, and ridge-plots (Sparre and Venema 1998, Saberin *et al.* 2013, Clement *et al.* 2014, Laurence *et al.* 2015, Alba *et al.* 2016, Collins *et al.* 2017). I calculated the variance of length distributions for each gear type, checked for assumptions of normality, and used linear regression to estimate the relationship between net mesh size and mean fish standard length (n=1563). Fish standard length (from mouth tip to caudal-fin base) was used, to avoid aberrations from long and variable fish tail-lengths. For fish species, the parameters $L\infty$ (infinite length) and K (a proxy for growth rate) were estimated for von Bertalanffy models of age-length relationships (King 2005, see Supporting Information 4.2). Approximate age-classes captured in each gear type and mesh size were calculated from the von Bertalanffy models (Maunder *et al.* 2006, Catalano and Allen 2010, Punt *et al.* 2014).

Data on ages and lengths of fish at maturity (90%) were compiled from literature and compared with the distributions of fish std. lengths captured in different gears (Supporting Information Figure S5.3, and Tables 5.1 to 5.3). From data on fish catch biomass and length distributions observed in different mesh sizes, I extracted a variable called "FSMN % catch" to denote the percentage of total catches of individual species captured in FSMNs. I also calculated per cent of mature fish, percentage of fish at optimum length for capture, and per cent of mega-spawners in overall catches, based on Froese (2004). Observed percentages were compared to Froese (2004)'s desirable criteria: 1) proportion of mature fish at 100%, 2) proportion of mature fishes harvested in an "optimal" length band at 100%, and 3) proportion of mega-spawner fishes at 0% (protection of experienced adult females).

Catch-at-age data, selection patterns, and estimation of mortality

Fish catches at different ages, captured in different FSMNs and GNFs were tabulated from size-selectivity data across different types of nets, from a cross-sectional survey of all gears and nets in 2013-14 (Ogle *et al.* 2016). These data were converted to proportional catch-at-age data (Fournier and Archibald 1982, Aanes *et al.* 2007, Linton and Bence 2011) for all species. We classified catch-at-age

distributions according to fishery selection patterns categorised by Brunel and Piet (2013), Sampson (2013), and Punt *et al.* (2014) (Table 5.1). Catch-at-age data were used to estimate total mortality Z (Ogle 2016, Smith *et al.* 2012). I then obtained averaged estimates of natural mortality (M) and stage-specific survival for fish species from five estimators (Alverson and Carney 1975, Pauly 1980, Hoenig 1983, Gunderson and Dygert 1988, Jensen 1996), based on data available for different species/groups (Jorgensen and Holt 2013). From these estimates of total mortality (Z) and natural mortality (M), I directly calculated fishing mortality (F) as F = Z-M. To validate the demographic method for calculating F, I also used an area-based method to estimate catchability of fish for different net types (Arreguin-Sanchez 1996, Salthaug and Aanes 2003, King 2005, Wilberg *et al.* 2010). F was estimated from net-wise fishing effort, length, width, mode of operation, and effective swept area (net area/total area available) (n=1241).

Fish life-history traits, FSMN catches, and fishing mortality

Fish reproductive, growth-linked, and life-history traits of 60 (58 fish and 2 shrimp) species-groups were correlated with their observed trends in FSMNs and/or GNF catches. I compiled data on age-length relationships, spawning periodicity, absolute and relative fecundity, egg diameter, longevity, lag between breeding and catch season, use of floodplain by adults and larvae, etc., from published studies (Prabhu 1956, Qasim and Qayyum 1959, Froese and Luna 2004, Welcomme *et al.* 2005, Winemiller 2005, Zeug and Winemiller 2007, see Table S5.1-S5.3, Appendices S1-S6). Trait data were first explored to check for life-history trade-offs in fish species (Froese 2005), as such trade-offs could affect the vulnerability of species to capture in FSMNs and GNFs. I then examined correlations between life-history traits and "FSMN % catch". Based on Kolding and van Zweiten (2014), I plotted the F/Z ratio (fishing mortality to total mortality) against the length at maturity (cm) of fish species. A F/Z ratio > 0.5 was considered indicative of overfished species. This indicator of overfishing was assessed in relation to the lengths of different fish species, and the major gears in which these species were captured.

Effects of fishing immature fish on growth to maturity: lag analyses

FSMN and GNF fish catch data for 18 selected fishery groups (17 fish and 1 shrimp species were correlated by lags defined by the species' age-at-maturity (Supporting Information Tables S5.1-S5.4). For example, if GNF catches of a fish species maturing in 1 year were negatively correlated with FSMN catches of this species from 1 year ago, it would indicate a negative effect of harvesting immature fishes by FSMNs.

Effects of harvesting immature and mature fishes: age-structured population models

From data on age at maturity, spawning frequency, and fecundity of these species, I first simulated stable age distributions of fish populations for the 18 selected species (Catalano and Allen 2010, Fujiwara and Diaz-Lopez 2017). Age-specific probabilities of survival and transition into new age-classes were calculated for when population growth rate stabilised at zero. Survival probabilities were assigned conservatively (lowest bounds of range) for age-classes from index estimates in the literature (Houde 1994, 1997; Letcher *et al.* 2008, Tahvonen 2009) and verified with intrinsic rates of population increase (from FishBase: Froese and Pauly 2019) prior to running models. I used a Beverton-Holt formulation for density-dependent survival for younger fish ages in the model (Tahvonen 2009). Population model runs were based on changing input parameters for fishing mortality (F_{tot}) for FSMNs and GNFs targeting young and immature size-classes (F_{imm}) or mature, adult size classes (F_{mat}). I estimated the response of harvested fish populations at different values of F_{imm}, F_{mat}, and the ratio F_{imm}/F_{mat} (based on Vasilakopoulos *et al.* 2011, Halls and Welcomme 2001, Welcomme 1999, Burgess *et al.* 2016). Estimated F_{imm} and F_{mat} levels were compared with derived estimates of F from catch-at-age data and empirical reference points for fishing mortality on individual species (Brooks *et al.* 2010, Zhou *et al.* 2012, Burgess *et al.* 2016). In all models, environmental variability was held fixed as an external variable affecting fish recruitment. As a proxy for environmental variability, I used data on flood pulse amplitude (chapter 4) as fixed conditions for a 25-year period, including a positive effect on recruitment. The modelling exercise helped estimate levels of fishing mortality of different fish stages under scenarios of

selective and unselective fishing of juveniles and adults, which best matched the observed trends in overall yields of fish species (Jul-Larsen *et al.* 2003).

Effects of preferential and selective fishing of reproductive adults

I used linear regressions to check if market selling prices of fish (INR per kg) were size-dependent (on fish standard length) or not (Zimmermann and Heino 2013, Tsikliras and Polymeros 2014), for a 10-year period (2009-2018). A positive relationship would indicate fishing pressure to be higher on larger fish sizes, whereas a neutral response would indicate that fishing intensity was indifferent to size and age-classes (Zimmermann and Heino 2013). A negative response was not expected because of the nature of fishing effort and prevailing preferences. I also checked temporal trends in the mean maximum size (maximum standard lengths) of individuals of some large catfish and carp species. Decreasing maximum lengths were considered indicative of selective fishing on larger individuals. All the above results were then interpreted in terms of the relative impacts of FSMNs and GNFs on different fish species and the overall fisheries in the Ganga River.

Results

Fishers' perceptions and positions in gear conflicts

Fishers using GNFs and FSMNs had contrasting perceptions. GNF users maintained that FSMN users were responsible for the severe decline of fish yields because their harvests did not allow fish to grow to maturity. FSMN users felt that GNF users were actually affecting fish stocks more by selective harvesting of reproductive fish, while their nets only harvested small fish, which would anyway die. FSMN users provided various arguments justifying their use of mosquito nets or seine nets. The *kachaal jal* is a traditional river-seine net with mesh sizes of 10-15 mm, and operated by groups of 8-12 people dragging it from two boats. Here is how a *kachaal* net fisher described its advantages: "*Kachaal nets catch many fish in a short time, and also catch fish of different sizes. It is thus profitable. Not only that, many fishers need to work together to operate the kachaal, and one net operation feeds 20 labourers and their families, as they get nearly INR 800 per month (USD 12). As an owner I earn a total of almost 80,000 INR (1200 USD) in 5-6 months per year of fishing with the Kachaal Jal.*" When asked about the impacts of *kachaal* nets alleged by gillnet

fishers, a typical response was as follows: "*In the dry-season of the Ganga, the water levels in the river are extremely low, especially in the last 10-15 years. Pollution from the Bhagalpur town has affected fish species very badly in the last 30 years. Kachaal nets are used only in shallow side-channels and inlets, and not in the main channel of the Ganga River because of difficulties of dragging the nets in deep waters. So we are not interfering with the catches of gillnet users. Low water levels in the Ganga have affected both gillnet fishers and Kachaal fishers in similar ways. But fishers are only blaming each other. There is a lack of unity even among traditional fishers, and the conflict over net use is only because of jealousy. Individual gillnet fishers earn a lot more than the kachaal net labourers, and they also target larger reproductive adults of many fish species. Hence, gillnet fishing has a much bigger impact on fish stocks than Kachaal nets*."

Kachaal fishers also wanted only fishing castes to be permitted to fish in the river, and all non-traditional (non-fishing) castes to be arrested if found fishing (esp. Yadav, Mandal (Gangota), Dusadh, Muslims). Mosquito net fishers also expressed similar views. An important difference between fishers using mosquito nets and *Kachaal* nets was that large mosquito nets were used mostly by fishers regarded as non-traditional or non-local (Bengali fishers), whereas smaller mosquito nets were regularly used by many fishers in small traps, stake-nets, and screens placed along shallow river banks.

Gillnet fishers strongly opposed the justifications about the advantages of mosquito and seine nets. "*The kachaal net was meant for Jalkar ponds where you can manage fish stocks. But they use it in the river, where all fish are wild. So they are just extracting tiny fish without any limits. Kachaal fishers have the option of pond fishing, we do not.*" (Gillnet fisher of the Gonrhi sub-caste, Barari, 2016). Gillnet fishers stated that FSMNs of all types harvested small-sized fish in large numbers, which then could not grow to maturity, and that in turn impacted the later recruitment of young-of-year and 0+ aged fishes to the main river channel (growth overfishing). Smaller fish returning after a season of growth in floodplain wetlands were harvested from the peak flood-recession period onwards. These fishes take refuge in the stable flows of side-channels where they needed less energy expenditure. Gillnet fishers were most strongly against the use of mosquito nets and barricades. "*Entire river channels are barricaded by these nets in the post-monsoon season, and nowadays from the flood-season itself. How will small fish even enter the main river to grow*

bigger? Haven't you seen that every single inlet and bank is blocked by mosquito nets!" (Ramraj Sahni, veteran fisherman, Kahalgaon). Gillnet fishers often blamed non-traditional farming and other floodplain-dwelling castes resorting to fishing and "destroying" their fish stocks, as summed in this response: *"Farmers have land and many livelihood options. Gillnet fishers are traditional fishers. We are also landless, and our only hope to survive is from river fishing. Why should they even deny us this one right that we have?"* (Gillnet fisher, Barari, 2017). Further, FSMNs are operated under the patronage of antisocial elements that practice extortion, grab nets, and beat up other fishermen. Fishers using gillnets compensate for lost potential catches due to FSMNs, by using more and more nets while fishing in the river. This has led to intensive gillnet fishing and increased competition between GNF fishers working nets in the main river channel.

Legal and management implications of using FSMNs and GNFs

According to the Bihar Fisheries (Jalkar) Management Act (2006 and with subsequent amendments), fishing nets with less than 40 mm mesh sizes were illegal. Thus, most gillnets and FSMNs (almost 70%) being regularly used at present were illegal. Illegal nets were being used as large fishes had declined in the river, and only smaller meshes could provide fishers with adequate catches for daily effort. The near-absence of any monitoring and enforcement of fishing regulations allowed the use of illegal nets. Both FSMN and GNF fishers said that they had no choice but to use nets with smaller mesh-sizes than the legal cut-off of 40 mm, to ensure that they caught something. The general perception was that the minimum mesh size regulation was arbitrary. A *kachaal* net user remarked: "*What does the law know? They just put a number of 4 cm out of nowhere. The kachaal net is being used for generations.*" Interestingly, *kachaal* fishers have I-cards provided by the Bihar State Fisheries Department, based on their traditional caste status, even when they openly operated 'illegal' nets as per the law.

There is also a ban during the monsoon for 3 months (July-September), on the fishing of reproductive adults in the peak spawning period. The 40 mm minimum mesh size also disallows harvest of small and juvenile fishes. But not all species have spawning periods that overlap with the monsoon ban period. High-value species like large carps and catfishes typically enter the fishery about 2 months before the peak

spawning period, when catching them is legal. Fixed fishery regulations like these, are complicated when multiple species with highly variable sizes, life histories, and maturation phases, are fishery targets. Thus both legal and illegal fisheries can lead to the potential for recruitment or growth overfishing, which is the main concern of gear-use conflicts.

Long-term trends in fish catch per unit effort in FSMNs and GNFs

FSMNs (Anta jal traps, stake-nets, mosquito nets, seine nets), and small-meshed gillnets (mesh-sizes from 20 to 48 mm) showed weak trends of decline in CPUFD (Table 5.3). But CPUFD of large-meshed gillnets (65 to 155 mm) showed weakly increasing trends (Table 5.3). Catches in barricading mosquito nets showed major increases over time. Overall, variability in CPUFD had increased over time for all nets. Effort invested (hours) did not show any clear trends (Table 5.3), but was higher in years with higher productivity.

Local interactions between FSMNs and GNFs: cross-correlation analyses

In the dry-season (February-May 2013), FSMN and GNF catches had a weak negative correlation (0 to 2 day lags from -0.22 (negative effect) to 0.26). In dry-season periods where GNF fishing intervals ranged from 1 to 5 days, i.e., fishing was not done regularly, and lag correlations indicated that FSMNs could have reduced GNF catches to a minor extent. In the post-monsoon, FSMNs and GNF catches both responded positively to flood-recession (October 2013-February 2014), with lag correlations ranging from 0.23 to 0.38 (0 to 6 days).

Gear selectivity

Most nets and gears were unimodally size-selective. Relatively unselective nets were seine (*kachaal*) nets (10-16 mm), nets with 40-60 mm meshes, and nets above 200 mm mesh sizes (Figure S5.3a). Mesh sizes up to 60 mm showed a somewhat asymptotic relationship with fish standard length but above 60 mm. Fish standard length was linearly related to mesh size (std. length (cm) = *0.703*mesh size (mm) – 4.15; R^2=0.76, p<0.001, F=5012, df=1,1563; Figure 5.3b*). Age-class

distributions estimated from catches of FSMNs and GNFs below 60 mm showed that most species had catches with immature fishes.

Correlation of species ranks in FSMNs and GNFs and trends in fish catches

Seasonal trends of fish species' yields and their abundance-ranks in FSMNs and GNFs were not correlated (Table 5.4). Trends in CPUFDs of size-specific catches of different gears also did not show clear signals of effects of FSMNs or GNFs, across different species groups (Figure 5.4). CPUFDs of FSMNs and GNFs declined for some high-value catfishes and carps (e.g., *Sperata*, *Labeo rohita*). But overall, declines of species in larger meshed gillnets were more common than for FSMNs, with intermediate sizes being mostly stable. Rank differences across trend categories (decrease, fluctuations, increase, stable) showed no clear effects of FSMNs or GNFs on total yields for Bhagalpur (Figure 5.5). However, for Kahalgaon, negative effects of FSMNs on overall yields were identified. Negative effects of FSMNs were seen on CPUFDs of carpet nets (16-20 mm) and gillnets (33-38 and 115-130 mm; Figure 5.5). Negative impacts of GNFs were seen on CPUFDs of 9 gear classes, including mosquito nets, stake-nets, and gillnets of 24-28, 40-48, 76-86, 135-220 mm (Figure 5.5). No effects of FSMNs or GNFs were seen on the remaining 10 gear classes.

Effects of age-wise catches and fishery selection patterns

"Productivity" type selection patterns were noted for most species' long-term catches (almost 82% of the analysed species, Figure 5.6). Across species, proportions of immature fishes and mature fishes were highly variable, but younger fish (of 0+ and 1+ age-classes) dominated catches in general. The proportions of mature fish varied widely from 1% to 82.5%. Species with per cent mature fish from 1% to 41% showed variable trends in long-term yields, ranging from declines to increases. Catches of *Sperata* and *Rita* (Bagridae), *Pangasius* (Pangasiidae), and *Bagarius* (Sisoridae) had significant proportions of mature adults in catches (24%-82%), but these species showed varying trends. Yields of *Rita* showed an overall increase, *Bagarius* yields were stable, while *Pangasius* yields declined (see Chapter 4). Long-term trends in yields of fish species thus had no relationship with the proportion of juvenile fish, immature fish, or mature fish harvested. Lengths at first capture for most

species ranged between 3 and 10 cm, with most species were captured in FSMNs at 0+ (first year). There were some exceptions (e.g., *Cabdio*, *Gudusia*, *Mystus*, etc.) whose young (0+) spent their first year in floodplain wetlands and became available for capture in the second year (Figure 5.6). Trends in the yields of these species were stable, perhaps because of their fast life histories, and due to being caught near mature sizes even in FSMNs. Yields of species for which proportions of mature fish did not differ from proportions of immature fishes, also showed stable long-term trends in yields. These included examples like *Labeo calbasu* (Cyprinidae), *Channa* (Channidae), *Chanda*, *Parambassis* (Ambassidae), *Chitala* (Notopteridae), *Mastacembelus* (Mastacembelidae), and *Rhinomugil* (Mugilidae). Other than the dominant "productivity" selection pattern, some large catfishes were harvested only at adult or mature sizes: these included *Bagarius yarrelli*, *Rita rita*, and *Pangasius pangasius*, which showed "knife-edge" and "flat" selection patterns (older individuals were selectively harvested, Figure 5.6), but their yields declined over time. Large carps (*Gibelion catla, Labeo bata, Cirrhinus mrigala, Systomus sarana*) and other large catfishes (*Sperata*, *Wallago*) were intensively harvested across all age-classes and had declining long-term yields.

Trade-offs between fish life-history traits and fishing impacts

Fish relative fecundity was negatively related to egg diameter and length at maturity (Figure 5.7). This indicated life-history trade-offs between the quality and quantity of eggs produced. Larger fish had lower relative fecundity but higher egg survival than small species (Figure 5.7). Further, opportunistic species and year-round or multi-season spawners (C and D-type) had higher relative fecundity (Figure 5.7) than periodic and equilibrium species, and single-season spawners (A and B-type). Relative fecundity increased with total mortality (as a function of natural mortality) but had no relationship with F/Z (ratio of fishing mortality to total mortality, Figure 5.7). These trade-offs were related to per cent catches in FSMNs. FSMN % catches were dominated by small-sized, multi-season spawning (C and D), fast-maturing, and surface-dwelling fish species (Figure 5.8). FSMNs captured most species at very short intervals after their breeding season, as seen from the negative relationship between FSMN % catch and the lag between breeding and catch seasons. But no clear relationships were found with other life-history traits, such as the use of floodplain by

adults or life-history strategy (Figure 5.8). FSMNs also captured the larvae of large-bodied fish species, but in lower proportions than small-sized and fast-maturing species. There was no relationship between FSMN % catch and % of mature fish. FSMNs mostly had species with high total mortality and growth coefficients (Figure 5.8). But there was a negative relationship between F/Z and FSMN % catch, indicating that species with the highest per cent of their catches in FSMNs had lower fishing mortality as compared to their natural mortality (Figure 5.8).

F/Z ratio increased with an increase in length at maturity, across species. F/Z was greater than 0.5 (indicative of overfishing) for large catfishes and carps (*Sperata, Wallago, Gibelion, Labeo rohita*), intermediate catfish (*Eutropichthys, Ompok*), shrimps, the mullet Rhinomugil, and the carplets *Salmostoma* and *Bangana,* that were captured in both medium-large GNFs and FSMNs (Figure 5.9). Only two species, *Bagarius* and *Rita,* were captured mainly in hooklines and large gillnets. Species mostly captured in FSMNs and small GNFs, and those captured mostly in hook-lines, had F/Z < 0.5, and were not overfished (Figure 5.9). Overall, these results indicated that GNFs had a relatively greater negative impact on FSMNs.

Effects of fishing immature fish on growth to maturity: lag analyses

Of the 18 selected species for lag analyses, only 5 species (*Pachypterus, Sperata, Gibelion, Gudusia, Cirrhinus*) may have declined because of harvesting of immatures by FSMNs (Table 5.5). Of these five, only *Pachypterus* and *Cirrhinus* showed statistically significant declines. The remaining species did not show a response post-lag, to their previous FSMN catches, which meant that they were not affected by harvests of small/immature fish. One species, *Cabdio morar*, showed a positive relationship between FSMN catches and gillnet catches (Table 5.5).

Effects of harvesting immature and mature fishes: age-structured population models

Age-structured population models showed that many species (61%, 11 of 18) could maintain stable trends (also see Figure 4) at high levels of F_{imm}, greater by 2 or more times than F_{mat} (Table 5.5). Of the other 7, three species could maintain stable trends at F_{imm}: F_{mat} ratios between 1 and 2. For four species (shrimp, the mullet *Rhinomugil*, the catfish *Ailia*, and the carplet *Osteobrama*) the condition was F_{imm}<

F_{mat}. These estimates of F_{imm} and F_{mat} assumed a natural larval survival rate of 1% in all models, irrespective of minimum fecundity.

Decline in mean maximum size of large fish species

Among large carps *Gibelion catla, Labeo rohita, L. calbasu,* and *Cirrhinus mrigala,* a decline in mean maximum size was not observed only for *L. calbasu* and *L. rohita* (Figure 5.10). Overall yields of *L. rohita* and *C. mrigala* showed strong long-term declines, while *G. catla* yields showed high fluctuations with environmental variability. *L. calbasu* was the least affected species in terms of maximum sizes and yields. Clear declines in mean maximum sizes of *Chitala chitala* (Notopteridae), *Sperata aor*, *S. seenghala* (Bagridae), *Wallago attu* (Siluridae), and *Channa marulius* (Channidae) were observed (Figure 5.10). *Wallago* and *Channa* yields declined, but *Chitala* and *Sperata* showed strong fluctuations in yields.

Effects of preferential harvesting of large, reproductive adults on yields

Selling price was related positively to fish standard lengths for *Gibelion, Cirrhinus, Chitala, Sperata, Wallago,* and *Channa* species that showed a decline in mean maximum sizes (Table 5.6, Figure 5.10). Size-dependent pricing was not seen in other species, for which fish catches had also not declined (Table 5.6). All the species I analysed were large, A-type spawners (with one well-defined peak from late summer to peak monsoon), except *Channa* (two spawning peaks per year). In small-sized species, common species like *Gudusia*, *Cabdio*, etc. did not show much variation in prices with respect to size, but an exception was the bagrid catfish *Mystus cavasius*. Irrespective of size-dependent pricing, stable trends were noted for yields of common small-sized species.

Discussion and Conclusions

My analysis of the impacts of FSMNs and gillnets combined trend analyses of fish catch-effort data with age-structured population models, and estimation of gear selectivity, catchability, and fishing mortality. Estimation of fishing mortality was dependent on empirical estimation of total mortality from catch-curves, and time-varying estimates were not calculable. In spite of this limitation, the combination of modelling insights and observed trends provided consistent evidence to show that

gear use impacts varied across species widely. Overall, the use of larger gillnets had more negative impacts on large-bodied catfish and carp species than FSMNs. FSMNs might have affected a few species, including some large carps, but had no clear effects on yields of most species, especially small-sized fish. This evidence suggests that, at current levels of fishing effort and mortality, FSMNs and gillnets might together maintain the fisheries in a state of 'balanced harvesting', with fishing mortality being proportional to productivity across age-classes (see Figure 5.7). These findings allow a nuanced understanding of a gear-use conflict issue that has been painted in black and white so far. Dey *et al.* (2020) showed that gillnet fishers perceived FSMNs as a primary cause for fish declines. But there was no evidence suggesting that CPUFDs of gillnet fishers reduced because of FSMNs capturing immature fish.

We can understand the issue of gear conflicts in Bihar's fisheries first through the lens of legal versus illegal fishing. The preponderance of illegal (FSMN and small-GNF) fishing points to poor law enforcement, possibly due to the high costs of monitoring large river-floodplain regions (Charles *et al.* 1999). The enforcement task is also complicated by the fact that most poor fishers use illegal nets at some time of the year (Kelkar 2008, this study). Here I show that size-selective fishing of immature and mature fish by different illegal and legal fishing gears may together be allowing for "balanced harvesting" (Breen *et al.* 2016, Zhou *et al.* 2019), rather than driving alleged growth or recruitment overfishing patterns. Planck *et al.* (2016) demonstrated that individual, uncoordinated decisions in unmanaged fisheries could equally result in balanced harvesting as planned management. Fishing with FSMNs and GNFs might thus inadvertently maintain local high-productivity states in this fishery. These insights have relevance for freshwater fisheries across the world, where the use of mosquito nets and other fine-meshed gears is increasing (see Tilley et al. 2020). Interpretations of balanced harvesting effects continue to be divergent across different fisheries, based on the socio-ecological variables and modelling approaches or assumptions involved (see Froese *et al.* 2016, Zhou *et al.* 2019). This study probably makes the first empirical contribution from India to the debates on "balanced harvesting" and size-selective and "unbalanced" conventional fisheries management.

Based on the above findings, I argue that the minimum mesh size regulation deserves to be revisited. The importance of specifying maximum mesh size regulation or "length-slots" for harvesting particular sizes of different species needs to be emphasised (Froese 2004, Mullon *et al.* 2012, Ahrens *et al.* 2020). There is a ban on

fishing during the monsoons in all coastal states, and even in Bihar's Fisheries Act, which assumes to be protecting fish that are breeding in the monsoon. The monsoon ban is a convenient one for most fishers to follow because the conditions of the sea or river are risky for fishing anyway (see Gunakar and Jadhav 2017). In the Ganga, small fish are captured in passive bank-side traps through the monsoon, or hook-lines are used, while boat-based gillnet fishing is avoided until September or October. Even then, the monsoon ban on catching breeding fish is not adequate to protect mega-spawner large adult fishes, which often enter the fishery before the ban, and are anyway harvested in the peak summer and pre-monsoon (Montana *et al.* 2011). Seasonal restrictions on minimum and maximum mesh sizes can help achieve fishing in optimal size ranges, thus protecting mega-spawners as well as juvenile fish (Froese 2004). But more attention is needed to protect large reproductive adult fishes from harvesting, as shown here (Birkeland and Dayton 2005, Fenberg and Roy 2008, Barnett *et al.* 2017, Tilley et al. 2020). For smaller fishes, the existing system might maintain balanced harvests but restrictions on fishing effort (fishing mortality) would still remain critical (Engelhard *et al.* 2014, Kolding and van Zweiten 2014, Plank *et al.* 2016, Garcia *et al.* 2016). From a biodiversity conservation viewpoint, a combined system of minimum and maximum mesh size regulations could reduce bycatch of endangered species (Raby *et al.* 2011). For endangered Ganges river dolphins, mortality by entanglement in gillnets (bycatch) is a significant threat (Braulik and Smith 2017). But most mortality of river dolphins is recorded in legal fishing gears (Kelkar and Dey 2020)! These observations challenge the premise of continuing with minimum mesh size regulations, even though these regulations are upheld in status reports on fisheries (e.g. Vass *et al.* 2011).

Historically, declines in fish yields at Bhagalpur have been blamed on impacts such as the Farakka barrage (Ray 1998, Payne *et al.* 2004, Dey *et al.* 2020). More recently, environmental factors are the main contributors to the variability in yields. For the same fishery, an earlier study by Montana *et al.* in 2011 (using data from 2000-2007) found stable fish species composition and significant coupling between fish yields and monsoon rainfall. The main indicators of fishing impacts have been reductions in sizes of large-bodied catfish and carp species and age-truncation, causing increased fluctuations in the yields of most species, and especially of those caught in FSMNs. But catch-per-effort, yields, catch composition, and incomes have in fact remained generally stable. Stable but fluctuating yields could maintain

productivity, but also increase the natural mortality of smaller fish (Jacobsen and Essington 2018). This can increase the sensitivity of their yields to external perturbations from extreme flooding or climate-linked droughts (Kuparinen *et al.* 2014). Over time, there has been a decline in the use of large-meshed gillnets, as many traditional fishers have exited the fisheries permanently. River fishing practices are thus becoming more part-time and sedentary, as seen in the increased use of fixed fishing gears corresponding with the declining use of large gillnets. This means that smaller fish species are now being harvested more intensively than larger species, strengthening the perception of growth overfishing (Pauly 1987). Small fish harvests also have market demand, which indicates that excessive depletion of small fish could bring about trophic downgrading of fisheries (Alder *et al.* 2008, Kuparinen *et al.* 2016). These trends can potentially shift the fishery towards growth overfishing (Diekert 2011) and also hyperdepletion (Alós *et al.* 2019). Fixed fishing gears are known to show hyperdepletion, i.e. they have CPUFDs that change more rapidly in response to the rate of declining yields. This might lead to a pessimistic view of overall declines in fisheries. In open-access fisheries yielding no revenue and with already low catch-rates (Hilborn and Siebert 1988), processes of hyperstability or hyperdepletion might not be self-regulating, and can cause complex changes and fluctuations in yields and catches harvestable by fishers at different points of time.

The increased harvest of small fish will still need institutional interventions and greater state involvement in riverine fisheries management and monitoring, even while allowing the fisheries to continue open-access, as a livelihood safety net (Hossain and Afroze 1991, Kasulo and Perrings 2005, Arthur 2020). Asche et al. (2018), based on a global review, have shown that providing access rights and harvesting rights to fishers can increase the sustainability and compatibility of desirable social, economic, and ecological outcomes as compared to open-access. They show that in open-access fisheries, socio-economic benefits and productivity may be achieved, but tradeoffs between social and ecological outcomes are likely. Small-scale fisheries in the Gangetic plains need management for rural incomes and benefit distribution than for commercial targets (de Melo Alves Damasio *et al.* 2016). Fishery targets that have changed over time require adaptive management in response to environmental variability (Jul-Larsen *et al.* 2003, Kasulo and Perrings 2005). Globally, a clear positive relationship between fish diversity and fishery yields has been identified (Brooks et al. 2016). Diversity of fishing target species can buffer

fisher revenues and incomes, as seen in multi-species tropical fisheries (Robinson *et al.* 2020). At present, intermediate catfishes, small carps, clupeids, and spiny eels are the main high-value elements of Gangetic fisheries, as larger and prized fish species have declined. FSMNs or smaller gillnets might not have a major impact on many of these species due to their gear-specific size-selectivity (Millar 2000), but other intensive methods (e.g., baited hooks, fishing with dolphin oil), which are not analysed here, might have caused declines (Lennox *et al.* 2017). The use of such targeted and intensive fishing practices will need new and specific regulations. Gear use conflicts are not merely technological and ecological battles, but political battles affecting social identities (Abbott and Campbell 2009, Béné and Friend 2011, Kelkar 2018). They also involve institutional and monitoring failure (Béné 2003, Béné and Friend 2011, Kosamu 2015) and not just ecological competition or diversification of practices. Thus, the uncertainty about the effects of gears, even among fishing communities, is likely to persist and remain contested, and can offer a complex challenge to further ecological investigation and for informing policy. An example of this is problem is seen in recent policies promoting harvests and consumption of "Small Indigenous Freshwater Fishes" or SIFFs for rural nutrition and poverty alleviation (Kumar 2010). This is paradoxical, for SIFFS are caught with nets and mesh sizes considered illegal under most state fisheries acts. In turn, as almost nobody follows those laws, SIFFs are being harvested and eaten in any case.

In this regard, it is also interesting how the legal and illegal nature of gear use has been realigned with traditional versus non-traditional caste identities involved in fisheries (Kelkar 2018, Dey *et al.* 2019). As my historical analysis has shown, claiming that FSMNs are non-traditional fishing gears is dubious, because they have also been in use for hundreds of years. Ironically, the FSMNs and GNFs that are classified as "illegal" might allow for balanced harvesting and thus be relatively sustainable than "legal" gillnets selectively targeting the larger fish. But FSMNs are often worked under the protection of mafia gangs (Kelkar 2018), that have threatened poorer fishers using GNFs. Gear-use conflicts have their roots in social injustice and livelihood insecurity of gillnet fishers, who have been articulating it in the form of ecological and sustainability concerns of gillnet fishers about the use of FSMNs (Kelkar and Krishnaswamy 2014, Choudhary *et al.* 2015). From the 1950s, intensive spawn collection of major carps in the Gangetic plains by state agencies like the Central Inland Fisheries Research Institute (CIFRI) was conducted for the

development of freshwater carp aquaculture (David 1959, Datta Munshi *et al.* 1979). Later, CIFRI itself identified excessive spawn collection by fine-meshed nets as a major threat to yields of major carps (Jhingran and Ghosh 1978, Sinha *et al.* 1999). These discourses appear to have reinforced the declensionist narratives of gillnet fishers (Dey *et al.* 2020), that overfishing of various kinds, river pollution, or changing river flows, had doomed all fish. Not a single fisherman thought, no matter which camp he belonged to, that some species' yields had remained stable despite the impacts of different fishing practices.

My study shows, importantly, that concerns of social justice may not always be aligned with concerns of ecological sustainability. While the latter concern forms the content of the fishers' worldview and positioning in the gear-use conflict I describe, the core pressing issue is the former concern. This example demonstrates that sustainable fisheries might exist even in a highly inequitable, unjust, violent, and insecure regime of access. Exploring the underbelly of gear-use conflicts has tremendous political implications for future management of Bihar's open-access fisheries. Apart from identifying the institutional limitations in addressing these gear-use conflicts, the study also holds a word of caution for standard discourses of conservation and development that tend to valorise or demonise communities based on their traditional identity or compliance to law (Kelkar 2018).

In gear-use conflicts involving regular violence and threat to human life, the top priority of fishery managers will have to be providing basic security to fishers. GNF fishers depend critically on capture fisheries for their livelihoods (Funge-Smith and Bennett 2019) and must be secured from the threat of mafia gangs. If a balanced harvesting approach is to be implemented for equitable and productive fisheries without criminal control, then the need to revisit the current minimum mesh-size regulations becomes key (see Plank *et al.* 2016). However, the implementation of new regulations, with control of excessive fishing effort and adaptive management, will need stronger local, community-level institutions for decision-making. New fishing regimes need to sustain productivity through systems similar to balanced harvests and also allow for the restoration of depleted fish stocks (Béné and Friend 2011). Reducing selectivity and effort regulations on fishing practices could help in the recovery of exploited species' stocks (Aramayo 2015, Melnychuk et al. 2017). To overcome dangers and threats in accessing fishing areas, gillnetting fishers have employed creative and convincing ecological narratives of size-based overfishing.

Riverine fisheries in Bihar are open-access and do not contribute revenue to the state. However, in spite of existing threats, several fishers are maintaining their livelihoods at a minimum level, with meagre but stable incomes. This system continues in the absence of state management. The neglect of riverine capture fisheries in the Gangetic plains become evident in the current state of affairs if we compare them with other fishery systems in South Asia. My study provides some insights to understand conflicts based on contradictions between modern laws (Klug 2002) and their linkages with history, ecology, and the cultural politics of fisheries management. It highlights the need for critical engagement by fishery managers with the binaries of legal versus illegal, traditional versus non-traditional, and sustainable versus unsustainable. The resulting complicated trade-offs between social justice and ecological sustainability objectives need to be acknowledged in multi-objective management of small-scale capture fisheries.

Tables

Table 5.1. Definitions of the concepts that explain size-dependent overfishing by FSMNs and GNFs, with the metrics used to test their impacts.

Impacts of fishing gears	Interpretation	Indicators	Results
Local interactions of FSMNs and GNFs	Catches of one gear type respond to catches of other	Spatial interactions, cross-correlation and lag analysis of gear-wise catch data	Figure 5.1, Figure S5.2
Trends in CPUFD and effort of different gears	Increasing effort and decreasing CPUFD would mean declining fish size-classes specific to gear	Temporal trends in effort (hrs/day) invested in use of different gears, and catch per fisher-day (CPUFD)	Table 5.3
Seasonal declines in species yields	Harvest levels in FSMNs and GNFs are related to trends in species yields	Correlation between ranks of fish (based on biomass harvested) in FSMNs and GNFs with seasonal trends in yields across species	Table 5.4
Selective/unselective fishing	Ability to target and capture specific sizes (~ages) by a particular gear. Contrasts with unselective fishing that catches a range of fish sizes.	Relationship between net mesh sizes and standard lengths of fish captured in different net types. Unimodal selection curves for different nets indicate selective fishing across size-classes	Figure 5.3
	Selection patterns	Catch-at-age data (whether particular age-classes are more harvested)	Figure 5.4
	Life-history traits influence fishing impacts on species caught in FSMNs or GNFs	Per cent captured in FSMNs in relation to life-history traits (length, habitat use, maturation, growth, mortality, etc.)	Figures 5.7, 5.8
Growth overfishing (allegedly by FSMNs)	Fish are caught before they realise biological growth and economic potential, i.e. caught as juvenile or young	Catches of immature fish reduce catches of mature fish after lags=age-at-maturity	Table 5.5
		Decrease in mature size-cohorts relative to smaller size-cohorts, trends in catches and species ranks in FSMNs and GNFs	Figure 5.5, 5.6
Recruitment overfishing (allegedly by GNFs)	Reproducing fish are selectively caught; new potential recruitment to population is reduced. Age-distribution truncated to lower maximum sizes	Decrease in small size-cohorts relative to large size-cohorts, trends in catches and species ranks in FSMNs and GNFs	Figure 5.5, 5.6
		Reduction in maximum sizes of fish caught, when preferential and selective fishing of large adult fish.	Table 5.6, Figure 5.9
Fishing mortality	Population death rate due to fishing	Estimates of total fishing mortality F_{tot} (Z=M+F). $F_{tot}=F_{imm} + F_{mat}$; F_{imm}/F_{mat} ratio estimated for which population models predict declines in fish yields	Table 5.5
Balanced harvesting	Moderate fishing mortality distributed proportional to productivity of age classes (small to large), across FSMNs and GNFs	"Productivity" selection patterns, and F/Z ratios < 0.5 indicate overfished species. F/Z ratio plotted against length at maturity: higher F/Z of larger fish indicate selective fishing, similar F/Z (<0.5) across fish sizes would indicate effects of balanced harvesting	Figures 5.4, 5.10

Key: Selection patterns (Brunel and Piet 2013): 1) flat: selection constant across ages, 2) current: selection based on recent fishing mortality, 3) knife-edge: selection only above an age where maximum biomass is attained relative to growth, 4) protect old: like current but limits on maximum ages captured, and 5) productivity: selection scaled to natural productivity across different ages. F_{imm}/F_{mat} ratios are based on Vasilakopoulos *et al.* (2011), and F/Z ratio analysis based on Kolding and van Zweiten (2014).

Table 5.2. Details of data on fish species' yields, catch, effort, and associated variables, collected in this study.

Data description	Monitoring sites	Temporal extent and resolution	Number of species, sample size (n)	Missing data	Data sources[#]
Landing site survey data on fish catches and gear-wise individual fishers' effort data.	Bhagalpur (Barari)	2000-2017, Monthly	86 species, of which 62 species' data used (n=30557 records)	Data unavailable from 2002, 2005, 2009, 2010, 2014, 2015	Long-term monitoring by Subhasis Dey and Nachiket Kelkar
Market survey data of aggregated fish catches	Bhagalpur (4-5 town markets)	2000-2013, Monthly	86 species, n=1038 (c. 12 years)	As above.	Long-term monitoring by Subhasis Dey (SD) and Nachiket Kelkar (NK)
	Kahalgaon (station market)	2000-2004, 2013, 2015	86 species, data used to calibrate high-resolution daily data (see below)	Not used for this study	
Total yield data (from landing and market surveys)	Sum of above	2000-01 to 2017-18; aggregated data	Sum of above	Overall missing years 2005, 2009, 2012, with minor gaps elsewhere	Long-term monitoring by SD and NK
Market survey data (fish catches, derived index of effort, fish price data, large individual fish noted)	Kahalgaon (station market)	Dec. 2009-Mar. 2018, Daily + opportunistic	52 species, of which 34 species' data used (n=38185 records)	Jun. 2010-Sep. 2012, Jun.-Aug. 2013, Nov. 2016-Feb. 2017	Data collection from Mr. Chandan Sahni and other fish traders by NK and SD
Net-mesh sizes and fish length data (across 25 mesh sizes and gears, 1 mm to 300 mm)	Bhagalpur, Kahalgaon	Opportunistic; 2000-2018	27 net types/ mesh-sizes (n=1563)	-	From direct field measurements and photographs to scale, taken by SD and NK
Fine-sized mesh nets' (<16 mm) catch data (by gear, location, and species)	Kahalgaon	Feb-May 2013; Oct 2013-Feb 2014; Daily	48 species, 8 net types (n=3365)	Provided by Mr. Chandan Sahni, fish trader, Kahalgaon. Used with net mesh sizes and length data to estimate proportional catch-at-age data and estimating total mortality	
Interview surveys	Bhagalpur, Kahalgaon, and surrounding areas	1999-2000 to 2016-17; Purposive sampling	n=48 (Bhagalpur); n=35 (Kahalgaon); n=25, other sites see chapter 3 for details of respondents	Done by NK, SD	
Fish gear use locations (spatial mapping of fishing boats, net types)	Munger to Manihari (also see Figure 5.1)	2013-2019; Opportunistic	Approx. 400 locations, 20 net types, over 175 km on the Ganga river	Conducted by NK, used for fishing behaviour analyses and spatial effort monitoring	
Net measurements (length, breadth, mesh, deployment details)	Bhagalpur, Kahalgaon, and surrounding areas	2000-2018; Opportunistic	n=1563	Conducted by SD and NK, used for empirical estimation of catchability from area methods	

Table 5.3. Description of the different fishing gears and nets used in the study area, over the use of which severe conflicts are perceived and articulated by different groups of fishers. Fishing methods such as hooks and lines, use of oils in fishing, are also practiced, but are not part of the study. Rows with the salmon pink background are illegal nets, of which the purple font denotes FSMNs, and the blue font denotes GNFs. Black text with white background denotes legal gillnets. Statistics for nets showing significant (at alpha=0.15) monotonic trends are underlined: FSMN CPUFDs declined for mosquito nets and seine-nets, but increased for fixed FSMN traps and carpet gears (Chatti Jal). For gillnets, the only significant trends were of weakly decreasing CPUFD for mesh sizes from 29-48 mm, and increases in CPUFD for mesh sizes from 65-75 mm, and from 95 to 155 mm.

Net-gear group (mesh-size range in mm)** and fish length mid-points in cm [mean, range]	Seasonality of use	Areas fished, control regimes, operations	Mean effort hours (SE), trend (number of nets used)	CPUFD Mean (SD)	CPUFD trend: Sen's Slope, Mann-Kendall test statistics
Mosquito nets (Kapda Jal), traps and fixed gears: Anta, Arsi, Bahuwa (0-2) [4, 1-5] (MOS, TRP, STK)	Seasonal / part-time, used through the dry-season (6-7 months, October to May)	Side-channels and shallow banks along main river channel. Often used under the protection of anti-social elements or "mafia", in side-channels obtained on lease via auctions	13.55 (6.49) for fixed traps Increase in effort and number of nets used, 7 times increase from 2000 levels 5.24 (4.7)	Anta 2.03 (2.40) Arsi 146.87 (194.62) Bahuwa 10.26 (12.99) Kapda Jal§ 56.15 (79.04)	Anta S_{t-s}=0.002 S=1782, *P*=0.087 Arsi St-s= -15.425 S=-64, *P* =0.004 Bahuwa S_{t-s}=N.E. S=-6, *P* =0.74 Kapda Jal§ S_{t-s}= -0.28 S=-935, *P* =0.005
Mosquito *baris* or barricading nets (0-1) [4,1-8] (BAR)	Seasonal / part-time, used in the dry-season (6-7 months Oct-May)	Side-channels, shallow banks along main river channel, used by gillnet fishers and other fishers	Increase in numbers of barricading mosquito nets used.	Bari 188.61 (301.04)	Bari S_{t-s}=13.27 S=32, *P* =0.03
Seine nets# (10-15) [8, 1-50] (SEI)	Seasonal (Oct- May)	Side-channels, impoundments, floodplain wetlands, under mafia control	5.38 (0.40) No trend in intensity of use	Kachal 115.76 (102.47)	Kachal S_{t-s}= -0.49 S=-586, *P* =0.076
Cast nets or *Bhirka Jal* (multi-mesh nets, 20-65)	Seasonal (mid-monsoon to spring)	Used by individual fishers usually near banks or in shallow water	2-4	Castnet 4.57 (3.20)	Castnet S_{t-s}= 0.225 S=99, *P* =0.009
Carpet gear (16-22) [8, 3-23] (DRG)	Seasonal / part-time, used mostly in the dry-season (Feb -May)	Shallow bankside areas, side-channels, operated by 4-6 fishers standing in shallow water	4.00 (0.25) Increase after 2013	Chatti Jal 7.67 (6.99)	Chatti S_{t-s}=0.11, S=2069, *P*<0.0001
Brush-pile traps#	Seasonal, used specifically to catch mullet *Rhinomugil corsula*	Along banks of channel inlets and confluences	-	Sirka Jal 18.49 (17.40)	Sirka Jal St-s= -0.69 S=-71 p=0.045
Gillnets^ (small, 16-23) [10, 5-15] (GNF)	Full time (8-12 mo/yr), except peak flooding time	Main channel, side-channels	10.28 (3.12) Increase after 2013	gillnet 16-19 2.35 (2.91) gillnet 20-23 4.237 (5.46)	gillnet 16-19 S_{t-s}=0.002 S=75 p=0.735 gillnet 20-23 S_{t-s}=0.008

					S=8822 p<0.0001
Gillnets^ (small, 25-32) [13, 3-30] (GNF)	Full time (8-12 mo/yr), except peak flooding time (this range of mesh sizes is modified according to target sizes, esp. for *Cabdio* and *Mystus*)	Main channel, side-channels	10.05 (2.3) Increase after 2013, above 30 mm no change	gillnet 24-25 2.80 (2.23) gillnet 26-28 2.14 (2.36) gillnet 29-32 2.44 (3.67)	gillnet 24-25 S_{t-s}= -0.0001, S=-1768 p=0.48 gillnet 26-28 S_{t-s}=-0.0015 S=-1765 p=0.16 gillnet 29-32 S_{t-s}=-0.007 S=-1608 p=0.007
Gillnets^ (small, 33-38) [20, 12-40] (GNF)	Full time (8-12 mo/yr), except peak flooding time	Main channel, side-channels	9.89 (2.23) No change	gillnet 33-38 2.01 (2.83)	gillnet 33-38 S_{t-s}= -0.005 S=-466 p=0.15
Gillnets^ (small, 40-48) [24, 11-40] (GNF)	Full time (8-12 mo/yr), except peak flooding time	Main channel, side-channels	10.54 (2.35) No change	gillnet 40-48 2.39 (3.76)	gillnet 40-48 Sts= -0.0025 S=-1444 p=0.08
Gillnets^ (medium, 50-75) [35, 21-55] (GNF)	Full time (8-12 mo/yr), except peak flooding time	Main channel, side-channels	10.65 (3.59) increase after 2013, 1.24-1.64 times	gillnet 50-60 1.61 (1.71) gillnet 65-75 2.76 (5.01)	gillnet 50-60 S_{t-s}=-0.0007 S=-117 p=0.75 gillnet 65-75 S_{t-s}=0.0094 S=5387 p<0.0001
Gillnets^ (medium, 75-86) [60, 25-65] (GNF)	Full time (8-12 mo/yr), except peak flooding time	Main channel, side-channels	10.97 (3.87), No change	Gillnet 75-86 2.10 (3.38)	gillnet 75-86 S_{t-s}=0.0017 S=335 p=0.45
Gillnets^ (medium, 95-115) [68, 25-120] (GNF)	Full time (8-12 mo/yr), except peak flooding time	Main channel, side-channels	11 (3.5), No change	Gillnet 95-115 2.32 (2.46)	gillnet 95-115 S_{t-s}=0.0185 S=498 p=0.015
Gillnets^^ (large, 135-155) [85, 45-130] (GNF)	Full time (8-12 mo/yr), except peak flooding time	Main channel, side-channels	10.35 (4.10), No change	Gillnet 135-155 5.29 (7.34)	gillnet 135-155 S_{t-s}=0.052 S=160 p=0.107
Gillnets^^ (large, 160-240) [110, 80-155] (GNF)	Used in peak dry-season	Main channel	9.32 (3.06), Decrease	gillnet 160-180 10.70 (11.099) gillnet 200-240 10.665 (7.05)	gillnet 160-180 S_{t-s}=0.375 S=28 p=0.34 gillnet 200-240 S_{t-s}=-0.154 S=-64 p=0.26
Gillnets (GNF)^^ (large, 250-300) [140, 95-200]	Used in peak dry-season	Main channel	6.77 (3.96), Decrease	14.60 (12.61)	S_{t-s}=-0.175, S=-48 p=0.29

Notes: ** Nets with mesh sizes less than 40 mm (4 cm) are illegal according to the Bihar Fish Jalkar Management Act, and related guidelines. § I refer to Kapda Jals as large mosquito nets used by dragging or drifting them in water from boats, in side-channel areas. #Large seine-nets are used by traditional fishers usually in floodplain wetlands/ponds, and side-channels, often under the protection of "mafia" or criminal elements, because the nets are illegal but catches are high, many people are employed, and gangs contract and take significant shares of large catches obtained by hauling nets across channels by 15-20 fishers from 2 boats. ^All gillnets are operated by individual fishers or by small groups of fishers (3-4), either by setting them or occasionally by drifting along the river (especially in the dry-season, to increase catches). ^^ Large gillnets are operated by small groups of fishers (6-8) by dragging, drifting, or hauling methods along deep-cut riverbanks and mid-channels. #Brush-pile traps (Sirka) are used to specifically target the river mullets *Rhinomugil* and *Sicamugil* and can capture any size range. Size ranges for cast nets are not available.

Table 5.4. Correlations between season-wise trends and ranks of the top 20 species caught in FSMNs and GNFs. Major FSMN and GNF species and their seasonal trends did not show any statistically significant correlations. Species less common in GNFs had stronger declines in MAM (weakly significant negative correlation).

Season	**Spearman's rank correlation (FSMN vs. trend of decline)**	**Spearman's rank correlation (GNF vs. trend of decline)**
JJAS	S=2451.6, rho=0.057, P=0.786	S=2058, rho= 0.21, P=0.317
OND	S=2443.7, rho=0.06, P=0.775	S=2847.8, rho=-0.095, P=0.65
MAM	S=2777.8, rho= -0.068, P=0.745	S=3326.3, rho= -0.28, P=0.176^
JF	S=2700.7, rho= -0.04, P=0.85	S=2941.9, rho= -0.13, P=0.53

Table 5.5. Predictions of population models based on 6 different life-history profiles under scenarios of 1) fishing of juveniles and immature fish only, 2) fishing of matures and adult fish only, and 3) fishing of both immature and mature fish. Cross-correlations with lag analyses and empirical results about fish stock trajectories based on model predictions. Fishery selection of these species followed a "productivity" pattern, except *Gudusia* and *Gonialosa* (Clupeidae), *Cabdio* (Danionidae), and *Osteobrama* (Cyprinidae), which were most caught in the second year of their lives.

Fish species	**Age at maturity (months); lag in breeding peak and next catch peak (months)**	**Lag analysis parameter estimates**	**Statistical significance p-values**	**Regression model fit**	**Estimated Fimm, Fmat**	**Fimm: Fmat threshold level**
CLUPEIDAE *Gudusia chapra, Gonialosa manmina*	9; 3.5	0.75 (1.72) -0.178 (0.57)	0.68^{NS} 0.77 ^{NS}	R^2=0.02 F=0.098	Fimm<0.3 Fmat>1	< 2.0
ENGRAULIDAE *Setipinna brevifilis*	15; 1	0.31 (1.50) -0.11 (0.58)	0.84 ^{NS} 0.85 ^{NS}	R^2=0.006 F=0.037	Fimm 1.2, Fmat 0.7	< 2.0
DANIONIDAE *Cabdio morar*	18; 1	1.276 (0.28) 0.36 (0.10)	0.003*** 0.008**	R^2=0.65 F=13.01	Fimm=1.5 Fmat=1	≈1.0
CYPRINIDAE *Gibelion catla*	24; 3.5	1.33 (0.02) -0.006 (0.01)	0.0003*** 0.64 ^{NS}	R^2=0.128 F-0.293	Fimm=1.2 Fmat=0.5	2.5-3.0
Cirrhinus mrigala	24; 5.5	2.54 (1.95) -0.41 (0.87)	0.28 ^{NS} 0.67 ^{NS}	R^2=0.07 F=0.22	Fimm=1.2 Fmat=0.5	2.0-2.5
Labeo calbasu	24; 3	N.E.	N.E.		Fimm=1.2 Fmat=0.5	2.5-3.0
Osteobrama cotio	15; 0.5	-0.17 (0.29) 0.21 (0.20)	0.59 ^{NS} 0.33 ^{NS}	R^2=0.187 F=1.146	Fimm = 0.2 Fmat = 0.6	0.5-1.0
Puntius sp.	12; 0	-0.036 (0.45) 0.438 (0.28)	0.94 ^{NS} 0.18^	R^2=0.32 F=2.39	Fimm = 0.2 Fmat = 0.6	0.5-1.0
BAGRIDAE *Sperata sp.*	42; 4.5	0.19 (0.99) -0.23 (0.50)	0.86 ^{NS} 0.67 ^{NS}	R^2=0.05, F=0.21	Fimm=1.1 Fmat=0.5	< 2.0
SILURIDAE *Wallago attu* *Ompok sp.*	11; 2.5 24; 2.5	0.94 (0.47) 0.01 (0.13) non-log 0.27 (0.19) -0.048 (0.046)	0.09^ 0.94 ^{NS} 0.24 ^{NS} 0.35 ^{NS}	R^2=0.0009; F=0.005 R^2=0.22 F=1.13	Fimm=1.4 Fmat=0.9 Fimm<0.3 Fmat=0.1	1.5-2.0 < 3.0
AILIIDAE *Pachypterus atherinoides*	15; 0.5	1.10 (0.54) -0.32 (0.17)	0.11^ 0.136^	R^2=0.46, F=3.47	Fimm=0.45 Fmat=0.20	2.0-2.5
Eutropichthys vacha	27; 3.5	N.E.	N.E.	N.E.	Fimm 1.3 Fmat 0.5	> 2.5
Ailia coila	30; 7	non-log 0.506 (0.53) 0.01 (0.025)	0.38 ^{NS} 0.58 ^{NS}	R^2=0.05 F=0.349	Fimm<0.2 Fmat 0.3	≈1.0
AMBASSIDAE *Chanda nama, Parambassis spp.*	9; 0.5	0.87 (0.25) -0.25 (0.16)	0.01* 0.16^	R^2=0.298 F=2.54	Fimm = 0.4 Fmat = 0.2	> 2.0
MUGILIDAE: *Rhinomugil corsula* *Sicamugil cascasia*	30; 1.5 11; 3	0.71 (0.80) 0.27 (0.33) non-log 1.55 (0.93) -0.07 (0.07)	0.54 ^{NS} 0.56 ^{NS} 0.09^ 0.41 ^{NS}	R^2=0.41 F=0.70 R^2=0.35 F=1.07	F imm=0.3 Fmat >1 Fimm=0.5 Fmat=0.06	0.5-1.0 >3.0
CRUSTACEA: *PALAEMONIDAE* *Macrobrachium sp.*	5; 0.5	non-log 1.31 (0.93) -0.33 (0.298)	0.22 ^{NS} 0.31 ^{NS}	R^2=0.20 F=1.25	Fimm<0.1 Fmat<0.5	<< 0.5

Table 5.6. Relationships between fish prices (INR per kg) and sizes targeted, for selected large fish species (Kahalgaon: 2009-18). Species with size-dependent pricing showed steeper declines (**bold**) than species without size-dependent pricing. This indicated negative effects of selective fishing of large, mature fish species by GNFs. In case of the major carps *Gibelion catla*, *Labeo rohita*, and *Cirrhinus mrigala*, regression parameters were not estimable due to limited data, but their recent trends showed hints of recovery (possibly due to reduction in the use of large-meshed nets).

Species	Bhagalpur (2000-2017) Size-trend (Theil-Sen estimator for monotonic slope)	Kahalgaon (2010-2018) Size-trend (Theil-Sen estimator for monotonic slope)	Size-price relationships (linear regression models)*
Chitala chitala	$S_{t\text{-}s}$= -0.374 S= -1374, p<0.0001	$S_{t\text{-}s}$= 0 S=1499; p=0.55	a=68.09 (7.72); p<0.0001*** b=1.627 (0.158); p<0.0001***
Gibelion catla	$S_{t\text{-}s}$= 0.154 S=4008; p<0.0001***	N.E.	N.E.
Labeo calbasu	$S_{t\text{-}s}$= 0.06 S=1542, p=0.013	$S_{t\text{-}s}$= -0.51 S= -308; p=0.0008	a=160.29 (25)***, p=0.26 b=8.61 (2.31); p=0.0006 *** b(I^2)= -0.06 (0.017); p=0.001**
Labeo rohita	$S_{t\text{-}s}$= 0.249 S=349; p=0.077	N.E.	N.E.
Cirrhinus mrigala	$S_{t\text{-}s}$=0 S=203, p=0.585	N.E.	N.E.
Sperata aor	$S_{t\text{-}s}$= -0.335 S= -1096, p=0.0001	$S_{t\text{-}s}$= -0.012 S = -29254, p<0.0001	a=82.39 (4.62); p<0.0001*** b=1.607 (0.078); p<0.0001***
Sperata seenghala	$S_{t\text{-}s}$= -0.0445 S=-747, p=0.225		
Rita rita	$S_{t\text{-}s}$=0, S= -72, p=0.78	$S_{t\text{-}s}$= -0.257 S= -252, p=0.04	a=230.79 (57.73); p=0.0002*** a=1.64 (1.04); p=0.12^
Wallago attu	$S_{t\text{-}s}$= -0.058, S=-1129, p=0.10	$S_{t\text{-}s}$= -0.039 S= -4056; p=0.0038	a=19.35 (10.26); p=0.06^ b=1.574 (0.146); p<0.0001***
Bagarius yarrellii	$S_{t\text{-}s}$= -0.126, S=-194, p=0.41	$S_{t\text{-}s}$=0.026 S=296, p=0.566	a=128.08 (15.84); p<0.0001*** b=0.03 (0.14); p=0.83 NS
Pangasius pangasius	$S_{t\text{-}s}$= -0.39 S=-143, p=0.164^	N.E.	N.E.
Channa marulius	$S_{t\text{-}s}$= -0.2975 S= -343, p=0.03**	$S_{t\text{-}s}$= -0.227 S= -789; p=0.0003	a=19.00 (18.60); p=0.31 NS b=1.61 (0.308); p<0.0001***
Mastacembelus armatus	$S_{t\text{-}s}$= -0.038 S= -214; p=0.298	N.E.	N.E.

Key: a and b in all regression models are the intercept and slope parameters of linear regression fits, where b indicates the effect of fish standard length (size) on prices; N.E.: parameters not estimable.

Figures

Figure 5.1. Fishing intensity and use of different fishing gears across the study area (top), and major FSMN areas and GNF areas at Bhagalpur and Kahalgaon (images 1 and 2 in inset B, bottom). FSMNs and GNFs show close spatial interactions and overlap in their effective areas. Base map source: Global Surface Water Explorer, Pekel et al. (2016).

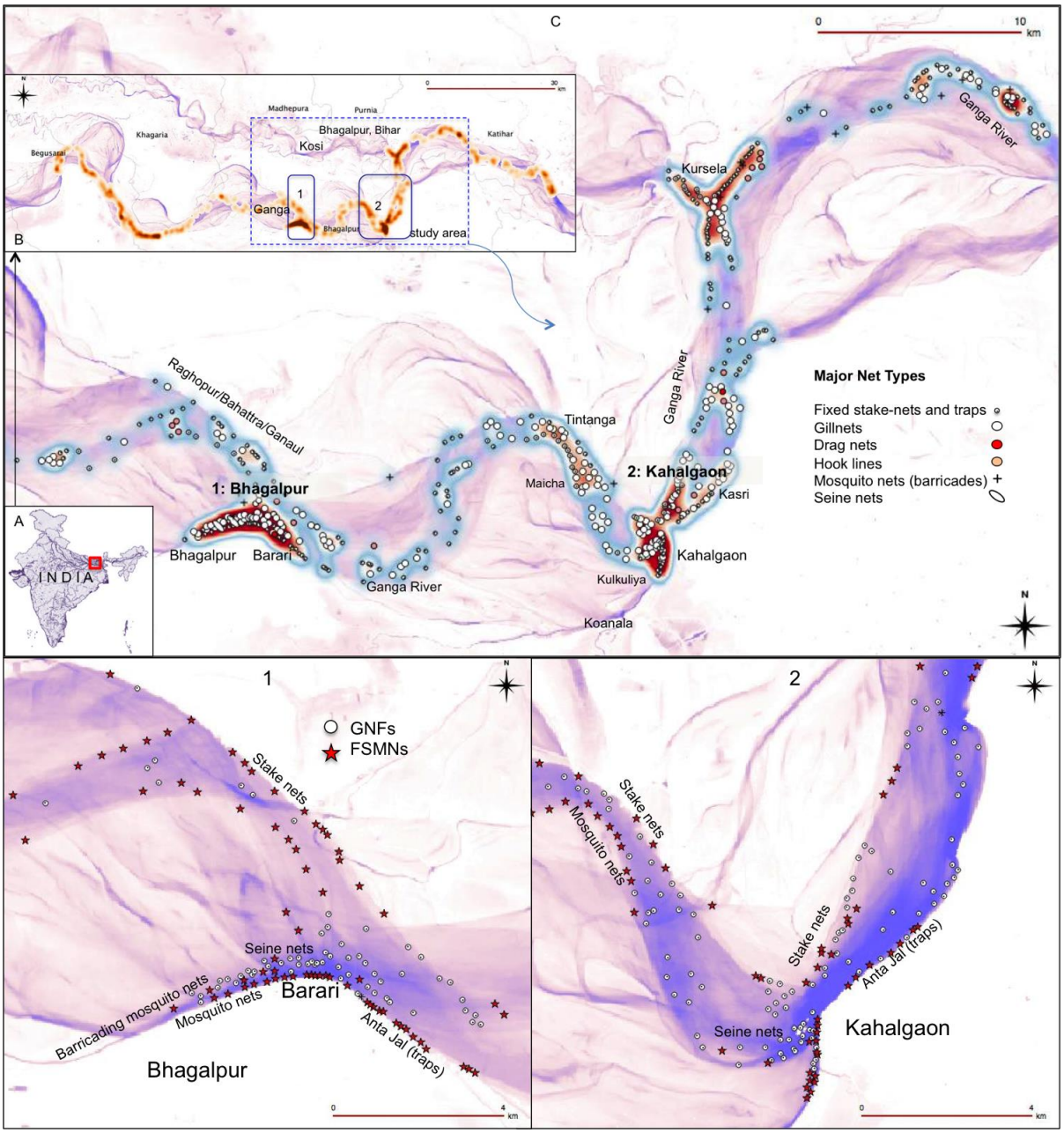


Figure 5.2. Plot showing differences in ranks of fish species captured in GNFs and FSMNs (Y-axis) plotted against ranks of species in FSMNs (X-axis). Ranks are based on relative biomasses of fish species captured. Species with high positive rank differences included those caught mainly in FSMNs (small-sized fishes), and those with negative rank differences were caught mainly in GNFs. Species with rank differences ranging from -10 to 10 were caught in similar relative biomass in both net types.

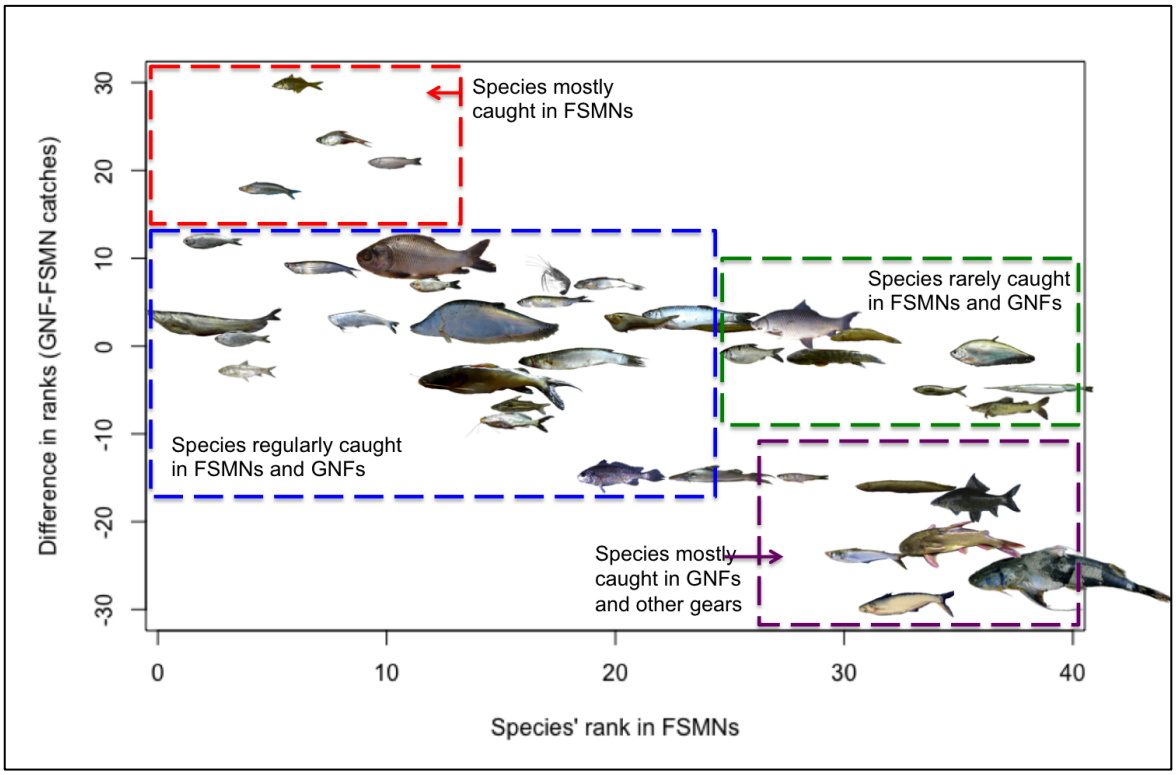


Figure 5.3. Graphs showing the distribution of fish lengths caught in different net mesh sizes (1-300 mm). Net-wise selection curves were unimodal from 1 to 60 mm, after which selectivity reduced with greater mesh sizes (a). A strong linear relationship was found between net mesh sizes and fish standard lengths captured in them (b).

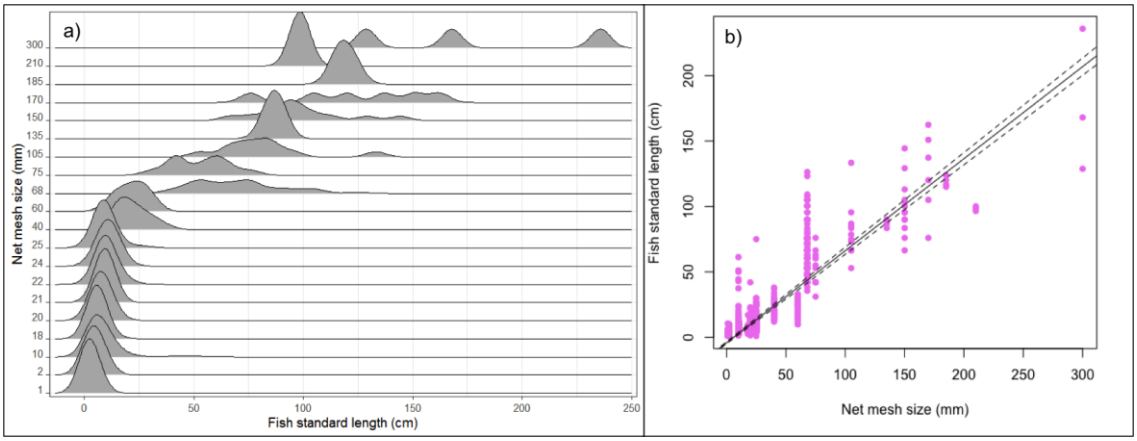


Figure 5.4. Trends in CPUFD for different FSMNs (MOS, BAR, TRP, STK, SEI, DRG) and GNFs (GNFs from 16 to 300 mm) for different fish groups (cyprinids, catfish, clupeids, perciform fish, shrimp, and other groups). Pie charts represent percentage of species with declining (D), fluctuating (F), Increasing (I), and Stable (S) trends across different size-cohorts and species groups. NE (Not Estimable: white areas) represented data gaps in the estimation of trends.

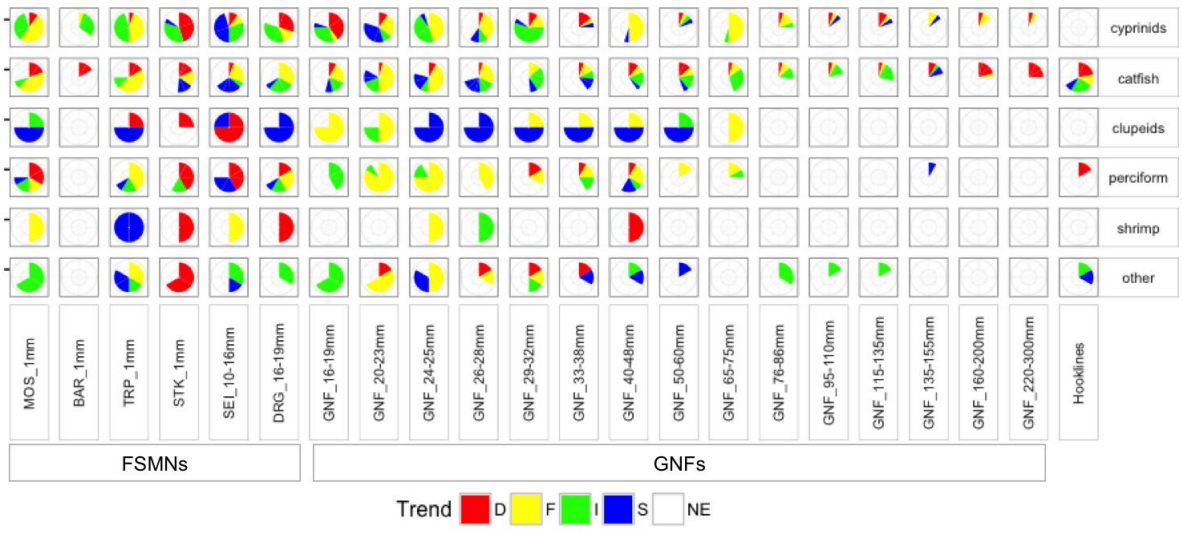


Figure 5.5. Differences in ranks of fish species in GNFs and FSMNs (Rank Difference) plotted against trends (decrease=D, fluctuations=F, increase=I, and stable=S) in catches of species in different nets. Positive rank differences indicate species caught mostly in FSMNs, negative differences indicate GNF caught species, and near-zero differences indicate a similar status of fish species in both GNFs and FSMNs. Decreasing order across trend categories indicates declines due to FSMNs (red), increasing order indicates declines due to GNFs (yellow). Blue plots indicate no clear effect of either FSMNs or GNFs. FSMN-linked declines were seen in total yields at Kahalgaon. But in general, impacts of GNF catches on declines were greater than the impacts of FSMNs.

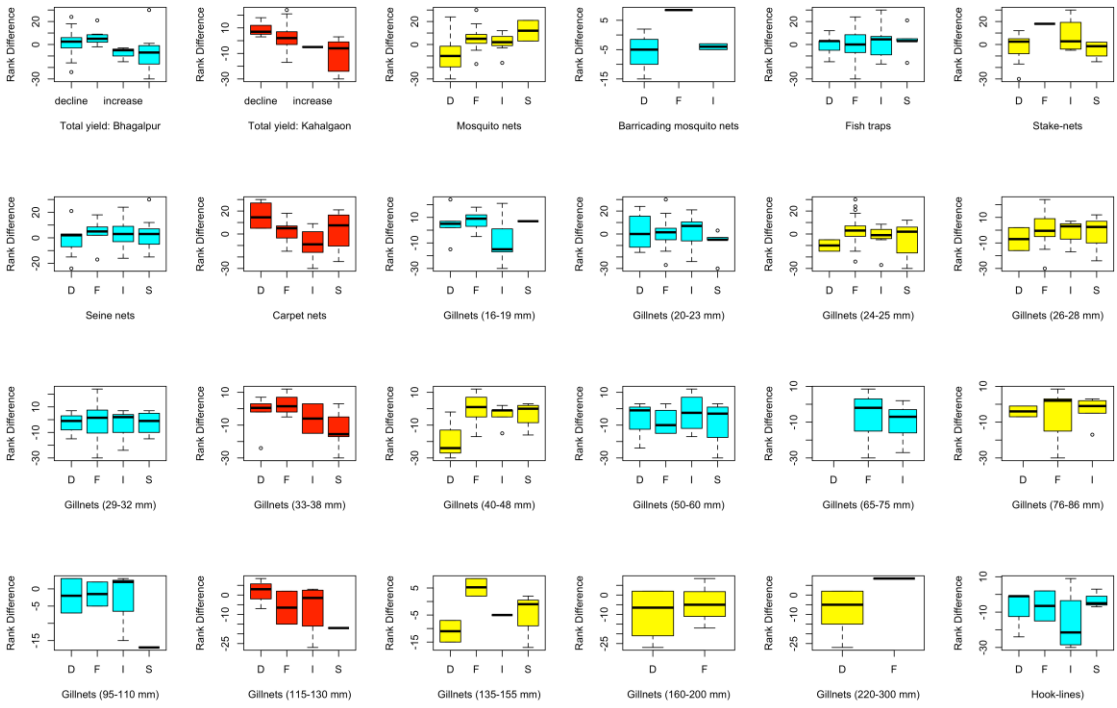


Figure 5.6. Species plots showing proportional catch-at-age data, with red lines indicating approximate age at maturity. Most species were observed to show a "proportionality" selection pattern, indicating a productivity-maximing or "balanced harvesting" pattern. Exceptions were *Rita*, *Pangasius*, *Bagarius* and *Gogangra*, which showed flat or knife-edge selection towards adult sizes in fishing gears. Note that these species are caught with hooks as well as by nets. The clupeids *Gudusia* and *Gonialosa*, the cyprinid *Osteobrama*, the danionid *Cabdio*, the Sciaenids *Johnius* sp., and the Bagrid *Mystus* sp. had the highest proportional biomass captured in the second year of their ages (post age at maturity).

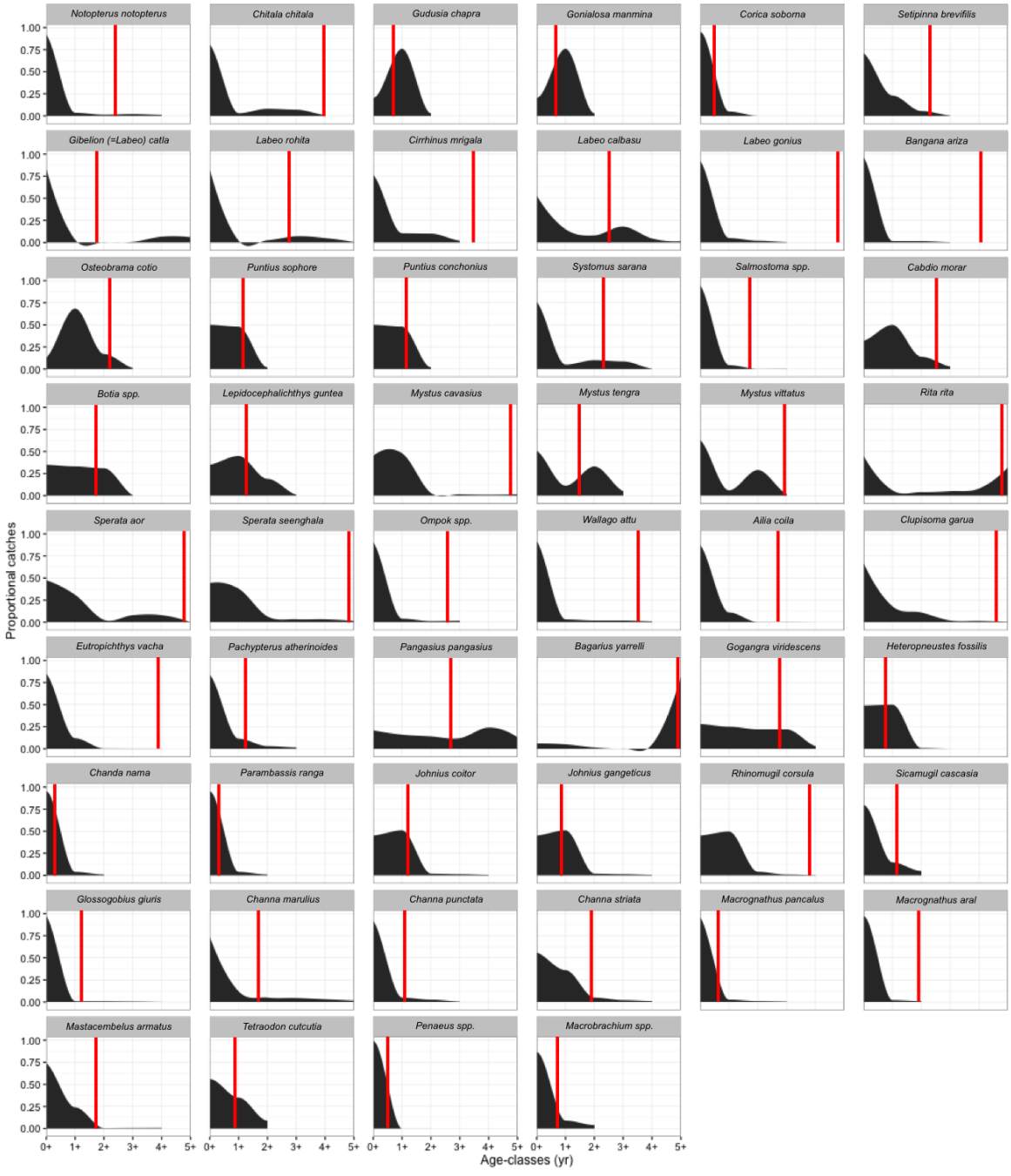


Figure 5.7. Trade-offs between relative fecundity of fish species and life-history traits. Late-maturing species with larger eggs have lower relative fecundity (1 and 2). C and D-type, and opportunistic spawners had higher relative fecundity than A or B-type spawners, and periodic or equilibrium species (3 and 4). Relative fecundity was positively correlated with total mortality, but not with the ratio of fishing mortality to total mortality (5 and 6). All variables are shown with log-transformed values, except categorical variables on X-axes.

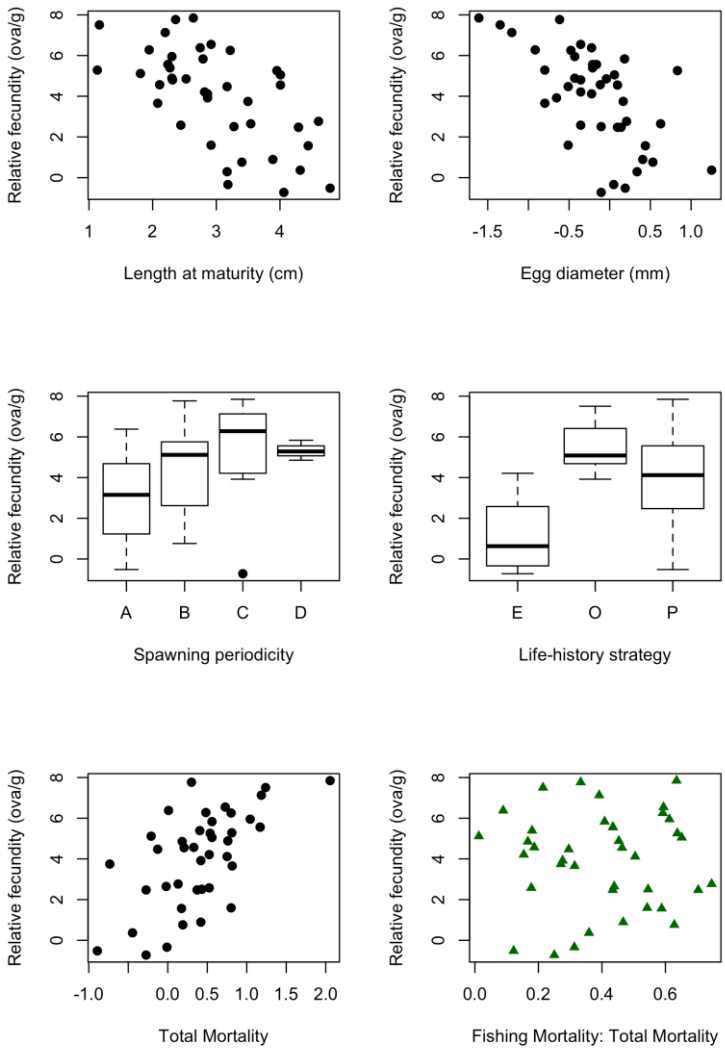


Figure 5.8. Percentages of fish species caught in FSMNs (FSMN % catch), in relation to different traits. Top: FSMN % catch was highly variable for spawning type, life-history strategies, and water-column and floodplain habitat use of different species. In general, surface-dwelling, eupotamic, and year-round, opportunistically spawning fish species were mostly caught in FSMNs. Middle: FSMN % catch was negatively correlated with lag between breeding to catch season (Pearson's r=-0.353, P=0.03), length at maturity (r=-0.60, P<0.0001), and length at first capture (r=-0.373, P=0.023). But there was no relationship between % mature fish and FSMN % catch (r=-0.145, P=0.39). Bottom: FSMN % catch was positively correlated with total mortality (r=0.45, P=0.006), natural mortality (r=0.61, P<0.001), and growth-coefficient K (r=0.66, P<0.001), but negatively correlated with the ratio of fishing mortality to total mortality (r=-0.344, P=0.046). These correlations showed that FSMNs mostly captured small-sized fish species with "fast" growth, maturity, and reproductive cycles. Impacts of fishing mortality were stronger on larger sized fish species. Length at maturity, Total Mortality, Natural Mortality, and K are log-transformed values.

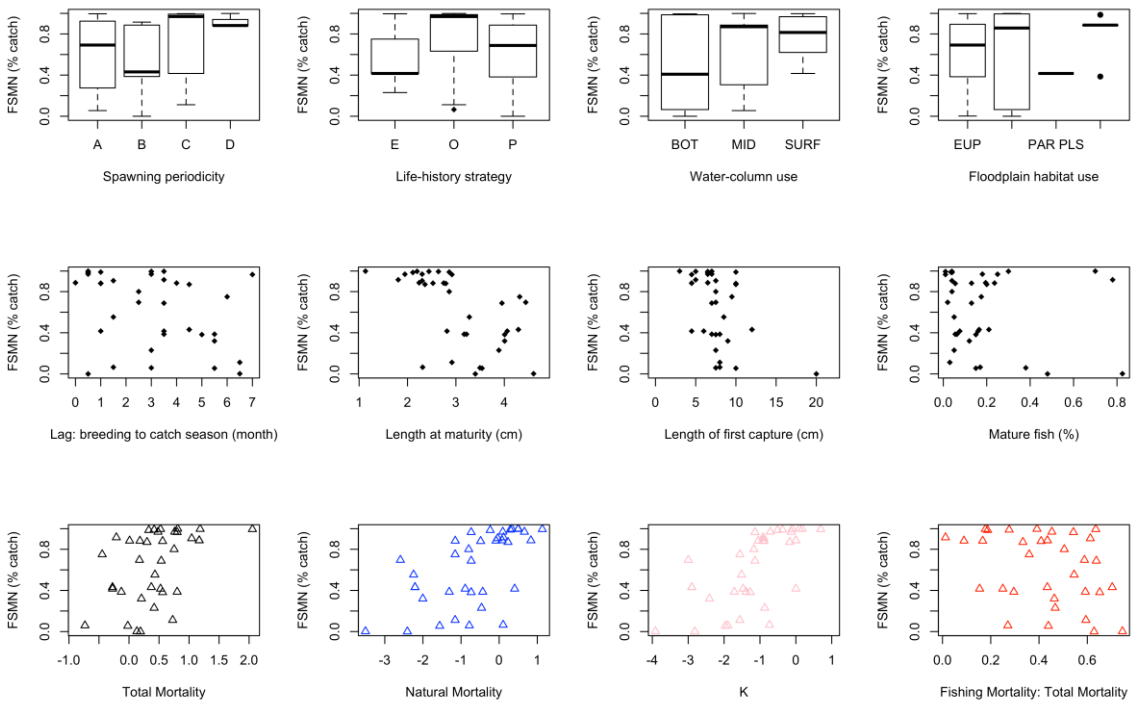


Figure 5.9. Ratio of fishing mortality to total mortality (F:Z) in relation to length at maturity of different fish species. F:Z > 0.5 (dashed red line) was considered an indicator of overfishing. Overfished species as per this criterion were high-value large carps and catfishes, along with a few intermediate carps, catfish, and shrimp. These species were caught with medium to large GNFs and their young captured in FSMNs. However, species mostly caught in FSMNs and small GNFs were not overfished, in spite of fishing effort and catches being concentrated in this size-range.

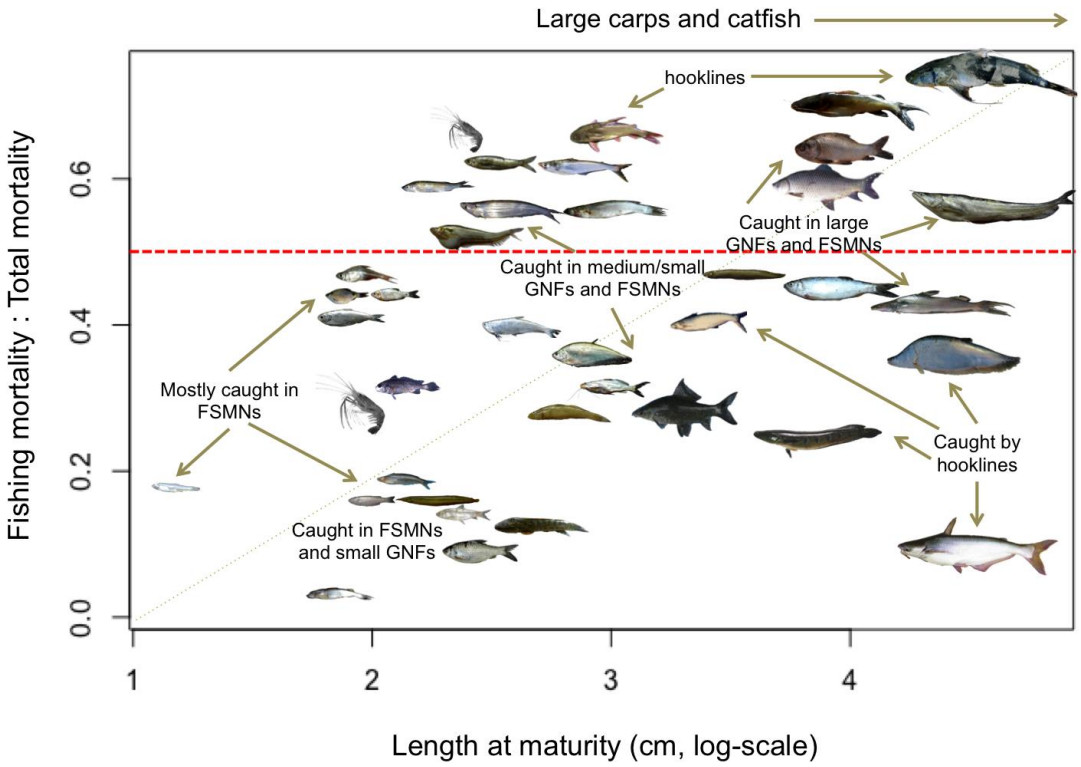
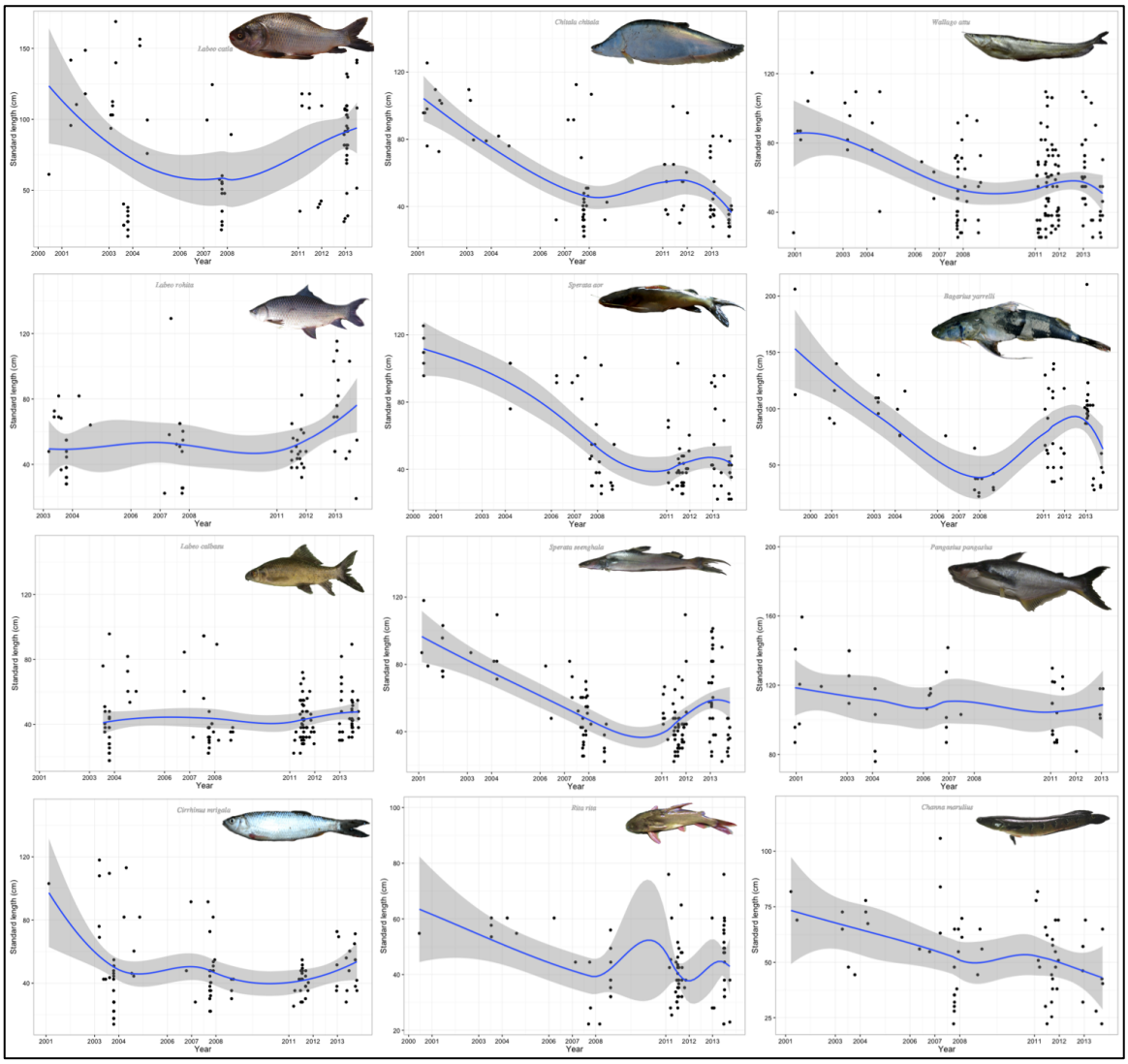


Figure 5.10. Declining trends in mean maximum lengths of large fish species, with the only exceptions being the *carp Labeo calbasu* and the migratory *Pangasius* catfish. In some species, recent weak recovery in maximum sizes was noted (e.g., *Gibelion catla, Labeo rohita, Sperata seenghala, Bagarius yarrelli*).



Supporting Information

Table S5.1. Maximum fecundity range, number of spawning events per year (superscripts), parameters of Von Bertallanfy equation ($L\infty$, K) used to estimate age-at-lengths, and the parameters a and b governing the length-weight relationships for the selected focal species.

Fish Species	**Max. Fecundity (number of spawning events/year)**	$\mathbf{L_\infty}$	**K**	**Length-weight relationship parameters averaged**	
				A	b
CLUPEIDAE *Gudusia chapra, Gonialosa manmina*	30,000-50,000[2]	14	1.19	0.0106	3.02
ENGRAULIDAE *Setipinna brevifilis*	<30,000[2]	27	0.41	0.004	3
DANIONIDAE *Cabdio morar*	<20,000[3-4]	21	0.35	0.0068	3.1
CYPRINIDAE *Catla catla*	>30,00,000[1]	115	0.32	0.009	3.06
Cirrhinus mrigala	<20,00,000[2]	102	0.09	0.0072	3.22
Labeo calbasu	450,000-800,000[2]	103	0.15	0.0117	3.03
Osteobrama cotio	<5,000[1]	16	0.49	0.0096	3
Puntius sp.	5000-8000[1]	14	1.00	0.0105	2.95
BAGRIDAE *Sperata sp.*	130,000-450,000[4]	168	0.055	0.0065	3
SILURIDAE *Wallago attu,*	65,000-450,000[2]	243	0.05	0.0065	2.9
Ompok sp.	2,000-20,000[1]	31	0.31	0.006	3
AILIIDAE *Eutropichthys vacha*	<200,000[1-2]	40	0.25	0.006	3
Ailia coila	600-1400[1]	31	0.32	0.0068	3
HORABAGRIDAE *Neotropius atherinoides*	<3000[1]	16	0.6	0.0063	3
AMBASSIDAE *Chanda nama, Parambassis ranga*	2,500-5,000[1]	10	1.1	0.0186	3
MUGILIDAE *Rhinomugil corsula**	9,000-17,000[1]	47	0.22	0.0102	3
*Sicamugil cascasia**		11	0.88	0.0115	3
CRUSTACEA: PALAEMONIDAE *Macrobrachium sp.*	80-300[1-2]	30	1.0	0.11	3.2

Table S5.2. Length data for focal fish species obtained from diverse sources (Appendix S6) for maximum length (Lmax), common length (Lcomm), and length at maturity (Lmat), from which age-at-maturity was estimated from age-length tables (see Table S5.3 and Figure S5.2). Data on natural lifespan of species were compiled from FishBase (Froese and Pauly 2019). Breeding seasonality data were extracted from Dey *et al.* (2019).

Fish species	**Lmax (cm)**	**Lcomm (cm)**	**Lmat (cm)**	**Age-at-maturity (yr)**	**Natural Lifespan (yr)**	**Breeding Season**
CLUPEIDAE *Gudusia chapra, Gonialosa manmina*	14-20	7-8	8-10	0.6-0.9	2.2-3	Mar-May, Sep-Oct
ENGRAULIDAE *Setipinna brevifilis*	30	15	16.3	1.5	6-11	All year, esp. Oct-Nov and March-May
DANIONIDAE *Cabdio morar*	20	8	12.5	2.2	8	Dec-Mar
CYPRINIDAE *Catla catla*	182	45	45-60	1.9-2	9	Jul-Aug
Cirrhinus mrigala	100	15	55	5.8	28	Jul-Aug
Labeo calbasu	90	30	33	3	19	Apr-Aug
Osteobrama cotio	15	7	10	1.3	5.7	May-Jun
Puntius sp.	14	7	9.4	1.5	5.4	May-Jun
BAGRIDAE *Sperata sp.*	150-180	45-55	57-90	8.9	41-48	Apr-Jun
SILURIDAE *Wallago attu,*	240	15-75	75-116	0.9	4.5	Jun-Sep
Ompok sp.	30	10-15	16-18.5	2.1	8	Jul-Aug
AILIIDAE *Eutropichthys vacha*	36	12-15	25	2.5	11	Jun-Aug
Ailia coila	30	12-15	18.5	2.8	11	Jun-Sep
HORABAGRIDAE *Neotropius atherinoides*	15	8-10	7.5-9	1.3	4.7	Jun-Aug
AMBASSIDAE *Chanda nama, Parambassis ranga*	8	3	3.1	0.3-1.4	3.8-4	All year except peak winter
MUGILIDAE *Rhinomugil corsula**	45	15	26.5	3	12.4	Jul-Sep
*Sicamugil cascasia**	10	5	7	0.9	3	Jul-Sep
CRUSTACEA: PALAEMONIDAE *Macrobrachium sp.*	26-30	7	14.2	0.39	2	Growth period (Feb-Jun) Breeding: Jul-Oct

Table S5.3. Age-length relationships of selected fish species from published literature sources (see Appendix S6). The age-classes 0+, 1+, 2+… refer to the first, second, third years, and so on, years of life of fish species. Shaded cells indicate mature age-classes of fish species.

Fish species	**0+**	**1+**	**2+**	**3+**	**4+**
CLUPEIDAE					
Gudusia chapra,					
Gonialosa manmina	5-7	10-11	13.5	14	-
ENGRAULIDAE					
Setipinna brevifilis	7.6	12.2	12.7	20-23	24-30
DANIONIDAE					-
Cabdio morar	2.9-6.8	6.9-9.3	9.4-10.5	10.6-11.5	
CYPRINIDAE					
Catla catla	<30	35-44	44-59	63-77	80-90
Cirrhinus mrigala	16.8-27.6	21.2-39.6	37.5-58.2	52 – 67.4	64 – 76.3
Labeo calbasu	20-22	30-34	36-43	49-52	56+
Osteobrama cotio	5-7	8-10	11-12	12-14	14+
Puntius sp.	2.1-3.6	3.7-5.1	5.2-6.4	6.5-7.9	8-9
BAGRIDAE					
Sperata sp.	19-20	49	70	85	95-100+
SILURIDAE					
Wallago attu,	44-50	75-85	100-110	115-125	125+
Ompok sp.	7-8	14-15	17-20	22	23+
AILIIDAE					
Eutropichthys vacha	18.6-19	26-27	30-34	34-39	40+
Ailia coila	7-9	10-15	17-19	20-22	24-25
HORABAGRIDAE					
Neotropius atherinoides	5-6.5	7-7.5	7.5-8.5	8.5-9.5	10-12
AMBASSIDAE					
Chanda nama,					
Parambassis ranga	2.6-3.5	3.5-4.2	4.3-4.8	4.9-5.4+	-
MUGILIDAE					
Rhinomugil corsula	6-10	11-22	23-29	27-32	32-37+
Sicamugil cascasia	4-5	6-8	9-10	-	-
CRUSTACEA:					
PALAEMONIDAE	17-20	21-27	28-30	-	-
Macrobrachium sp.					

Table S5.4. Table showing the age ranges of fish species that typically get captured in nets and traps of different mesh sizes, based on the observed data on fish age-lengths (Table S5.3) for different net types (n=1563). Mosquito nets and traps caught most species in the first year of their life, and seine nets were age-unselective. Gillnets captured a range of ages increasing in order with their mesh sizes.

	Net mesh size (mm)					
Fish Species	**Mosquito nets and traps (1-2 mm)**	**Seine nets (10-16 mm)**	**Gillnets (21-40 mm)**	**Gillnets (41-60 mm)**	**Gillnets (61-115 mm)**	**Gillnets and dragnets (>115 mm)**
CLUPEIDAE *Gudusia chapra, Gonialosa manmina*	R, 0+	0+, 1+	0+, 1+, 2+, 3+	1+, 2+	-	-
ENGRAULIDAE *Setipinna brevifilis*	R	0+, 1+	0+, 1+, 2+	1+, 2+	3+, 4+	-
DANIONIDAE *Cabdio morar*	R	0+, 1+	0+, 1+, 2+, 3+	3+	-	-
CYPRINIDAE *Gibelion catla*	R	R	0+	0+	1+, 2+	2+ and above
Cirrhinus mrigala	R	R	0+	0+	1+, 2+	2+ and above
Labeo calbasu	R	R	0+	0+, 1+	1+, 2+	2+ and above
Osteobrama cotio	R, 0+, 1+	0+, 1+	0+, 1+, 2+, 3+, 4+	1+, 2+, 3+, 4+	-	-
Puntius sp.	0+, 1+	0+, 1+, 2+, 3+, 4+	1+, 2+, 3+, 4+	4+	-	-
BAGRIDAE *Sperata sp.*	R	0+	0+	0+, 1+	1+	1+ and above
SILURIDAE *Wallago attu,*	R	0+, 1+	0+	0+	0+	1+ and above
Ompok sp.	R, 0+	0+, 1+	0+, 1+, 2+	1+, 2+	3+, 4+	-
AILIIDAE *Eutropichthys vacha*	R (X)	0+	0+, 1+	0+, 1+	1+, 2+, 3+	4+
Ailia coila	R, 0+	0+	0+, 1+, 2+	1+, 2+	2+, 3+, 4+	-
HORABAGRIDAE *Neotropius atherinoides*	0+, 1+	0+, 1+, 2+, 3+	0+ to 4+	4+	-	-
AMBASSIDAE *Chanda nama, Parambassis ranga*	0+ to 2+	2+, 3+	3+	-	-	-
MUGILIDAE *Rhinomugil corsula**	R, 0+	0+, 1+	0+, 1+	0+, 1+	2+, 3+, 4+	4+ -
*Sicamugil cascasia**	0+, 1+	0+, 1+, 2+	1+, 2+	-	-	-
CRUSTACEA*:* PALAEMONIDAE *Macrobrachium sp.*	R 0+	0+	0+	0+	1+, 2+	-

Figure S5.1. Daily time-series observations (from 2013-14) of catches in FSMNs and CPUFD in GNFs. Cross-correlation analysis showed that GNF CPUFDs lagged FSMN catches by 1-2 days. FSMN catches might have had a weakly negative effect on GNF CPUFDs.

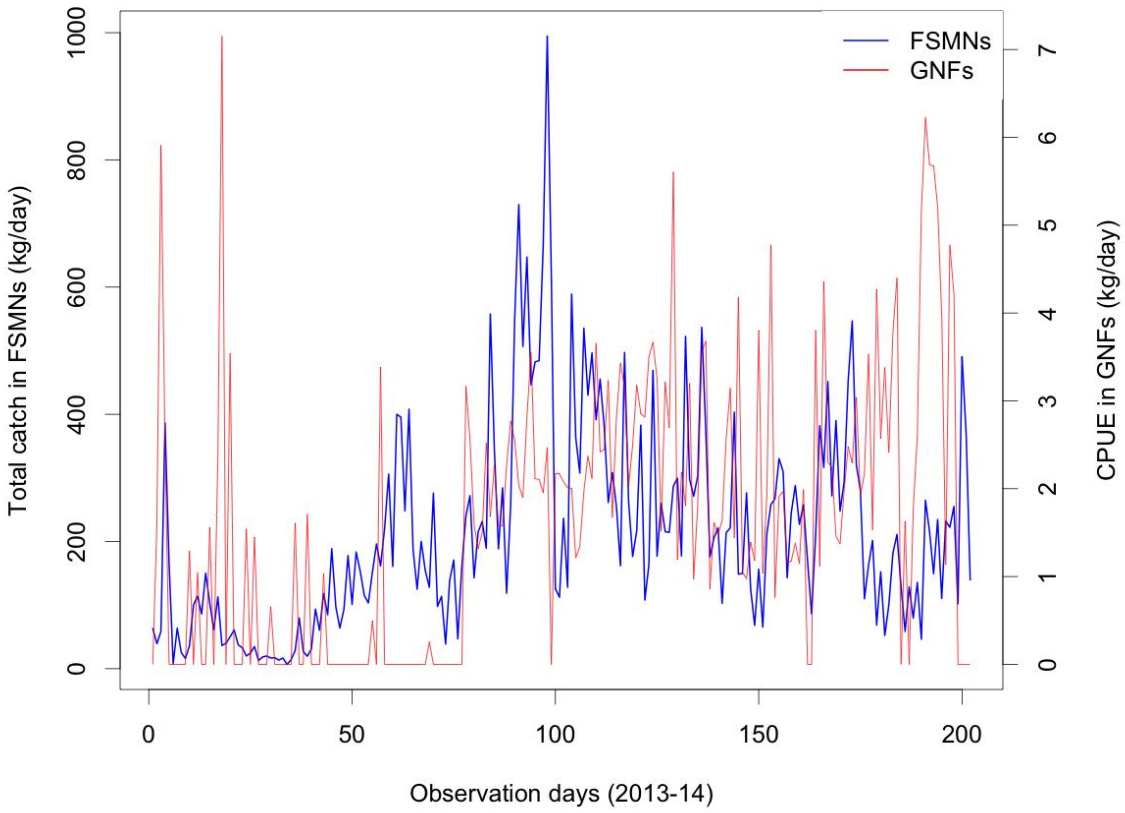


Figure S5.2. Relationships between age (yr) and fish standard length (cm) for selected fish species. These relationships were used to estimate proportional catch-at-age across the different net types and mesh sizes used.

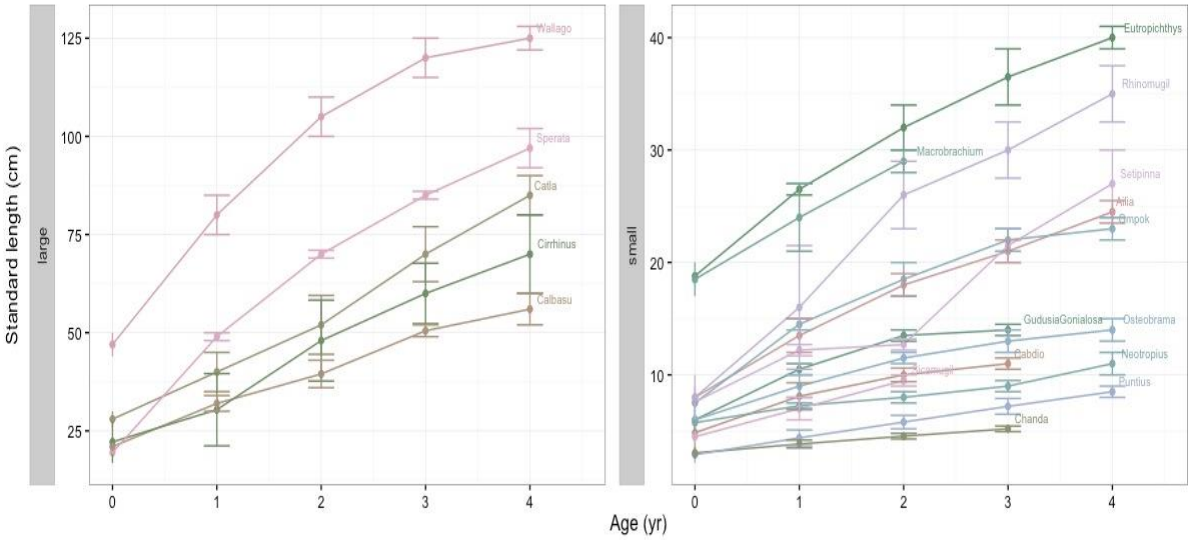
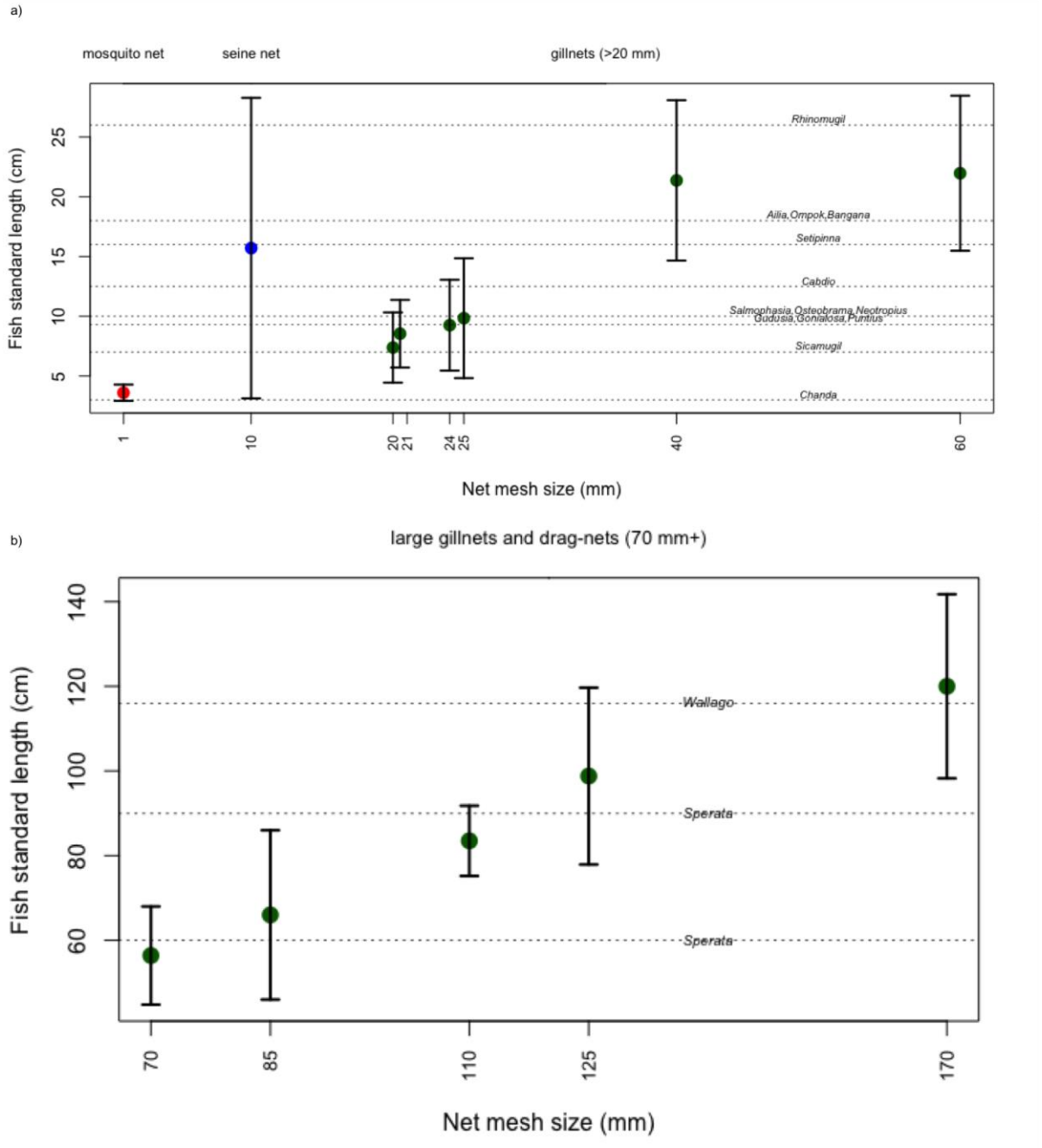


Figure S5.3. (a) Ranges and means of standard lengths of fish caught in net mesh sizes from 1 to 60 mm. (b) Ranges and means of standard lengths of fish caught in net mesh sizes from 70 to 170 mm. Horizontal lines indicate approximate lengths at maturity for the different fish species analysed. Nets catch immature fish when the corresponding standard lengths are below the horizontal lines.



Chapter 6. The resource of traditional identity: emerging identity politics and new conflicts in Gangetic fisheries

Introduction

Fishery conflicts in the Gangetic plains, over the last 5 years in particular, have entered the formal political realm of party politics based on caste identity. Here, identity politics can be indicatively described as politics of representation by groups organized around common cultural practices or affiliations to specific social, ethnic, or other cultural identification categories (caste, gender, or language identities; Harrison 1999, Bernstein 2005). In the case of Gangetic fisheries, caste-based identity politics is now seen to intersect in complex ways with conflicts over fishing rights and gear use. The core of new conflicts over identities is built around the issue of who should be recognized as "traditional" fisher castes. In Bihar, the burning questions of "who should be allowed to fish in the Ganga River?" or "who ought to fish?" trigger conflicts between fishers over 'traditional' and 'non-traditional' identity (Kelkar and Krishnaswamy 2014). Both groups cite caste affiliations, inter-generational knowledge systems, fishing practices and skills, adaptation to floodplain inhabitation, and major livelihood dependence on fishing, as evidences of being 'traditional'. A definitive shift is seen in fishery conflict narratives with the new wave of identity politics and caste assertion moving through the Gangetic plains.

As per my central thesis, conflict narratives shift between material and symbolic frames over time, mediated by technology, institutional interactions, and ecological change. In chapter 2, I showed that fisher identities have changed at various points in history, made and unmade by shifting regimes of institutional management of riverine capture fisheries under the colonial and post-colonial state. Fishers were relegated to a homogenous peasant class in the late eighteenth century, then stigmatized as criminal people in the 1870s, and later also recognized as traditional castes by recent policies and development interventions. The portfolio nature of riverine fishing activity always included shifts between fishers using their own labour, or selling labour service for farm work, boat ferrying, fish trading, or other labour-intensive wage jobs. Changes to fisher identities by caste-based or political groups, were linked to livelihood decisions under such constraints and choices, both enforced from the top, and internally.

In chapters 3 and 5, I showed that confusions and conflicts over property rights and access to fishing areas between 1) fishers and the state, and 2) between fisher groups over gear-use over fish conservation or legal concerns, are not delinked from issues of caste and identity. Gillnet-using 'traditional' fishers regard that mosquito nets and other fine-meshed nets are used only by 'non-traditional' fishers, and by corollary, these nets to be destructive to fish stocks. However, this perception is not fully supported by ecological assessments, or even by history. In fact, at least since the early 19th century, a diversity of fishing practices, including very fine-meshed nets with mesh sizes similar to today's mosquito nets, are recorded as routine fishing methods in the Gangetic plains (see chapter 2). These observations raise the question of what can even be called 'traditional practice' in today's fisheries, and with respect to what ecological, historical, or social baselines. However, gillnet-using fishers from weaker communities are facing threats from mafia gangs, under whose protection many fine-sized mesh nets are deployed. The control of gangs over fishing areas leads to curtailed access of gillnet fishers, leading them to lose out in the competition for harvesting small fishes.

In this context, the contrast between traditional and non-traditional identities as emphasized by different fishers, needs to be understood through careful engagement with the institution of caste. Benjamin Lindt's (2013) "comprehensive model of caste" proposes that caste is comprised of biological and economic elements and their rationalization. The biological element is based on recruitment by birth in endogamous kin groups, which forms the "essential" core of identity. This is further linked to social and economic identity, through functional and occupational divisions of labour. The economic and biological elements are rationalized through religion and tradition, which are the "ideational" aspects of caste according to Lindt. Further, these elements are important to determine caste hierarchies and power relations. Inter-caste power relations are linked to the reproduction of social and economic class divides (see Kothari 1995, Jeffrey 2002, Gupta 2005). Class-caste linkages are further influenced by economic interdependencies and inter-caste competition/jealousy, giving rise to new forms of corruption and alienation. Lindt suggests the nexus between tradition and occupation in caste has weakened in an age of relatively greater economic and social mobility, whereas the biological bases of caste remain strong and continue to be reinforced, due to their political, symbolic, and economic advantages.

This interesting idea can help begin our engagement with the cultural politics of fishery conflicts in the Gangetic plains, where tradition is being rearticulated in new narratives demanding political space as well as fishing rights. To understand the modes through which these narratives are emerging, it is worth discussing caste through the lens of some important works that show us relationships of caste with justice, economic entitlements, politics and ecology with sharp insights. Kothari (1995) shows that the tradition of caste in society and its 'modern' democratic articulation in politics makes caste a resource for competitive politics by "ascendant" castes. Caste persists and keeps changing in its political economic forms, which coexist with its social, symbolic, and ritual markers (Guha 2013). Guha (2013) also argues that the dynamics of power as well as cultural differences among caste groups contribute together to what he calls "instrumental" caste politics. Gupta (2005) has also argued that caste has not remained just a system of hierarchies, but is a competitive ground for appropriation of political space. Opportunities of democratic politics and economic access have retained the salience of caste as social identity, than as a social system underlying politics (Gupta 2000, 2005; Sharma 2019).

Mukul Sharma's *Caste and Nature* (2017) argues at length about how caste identities are maintained through the perpetration of systematic forms of injustice and deprivation. Sharma offers views of nature from the eyes of Dalits and other deprived groups, including fishers. He emphasizes that if we understood conservation and ecology from their positions, a radically different perspective of nature would emerge, with space for social justice at its core. David Mosse (2018) argues that caste, as a complex institution, provides for "opportunity-hoarding" for development, but also increases discrimination against the weakest, and reproduces past prejudices in spite of economic and political access (Mosse 2018). There are thus some paradoxes in the demand for political space by emphasizing caste identities, entitlements, and rights (Mosse 2018).

From the insights offered by these scholars, it is worth exploring the relationship of caste and identity politics that also have the subtext of "modern" socio-environmental discourses on conservation, justice, rights, and development. How have fishers in the Gangetic plains articulated their traditional identity during their lived experiences and interactions with conservation and development discourses of the state and civil society? What are the links between perceptions of conservationists and development agencies about 'traditional' fishing communities, and the latter's

own articulation of traditional identity? Finally, how does the fishers' own positioning in identity politics affect their stakes in future conflicts, fisheries management, and related outcomes for ecological sustainability? Drawing from conversations with fishers, conservationists, rights activists, and state policy-makers in this chapter, I attempt to address these questions by tracking emerging turns in identity politics in the Gangetic fisheries of Bihar.

Methods

I conducted interview sessions and focus group discussions in 12 fishing settlements along the Ganga, Gandak, and Kosi floodplains of Bihar. Semi-structured interviews with questions about the meanings of tradition, rights, and their historic caste-identities and cultural distinctions as fishermen were administered verbally to 100 fishers. I also used participant observation methods by taking running notes during meetings with government officials and fisheries/forest department officials about the rights, entitlements, and privileges of traditional versus non-traditional fishermen. Through repeated meetings with 'traditional' and 'non-traditional' fisher groups, key informants, and representatives of state/non-state institutions, I assessed why fishers perceived traditional identity as important. I also tracked how they articulated traditional identity to voice concerns about socio-economic issues, fishing rights, ecology, and so on. Long-term associations and informal interactions with fisher families in some settlements also allowed me to track fishers' behaviours, choices, and their changing political affiliations over time. Insights from my interviews and observations (e.g. Kelkar and Dey 2016) have yielded the material for this chapter. Names of individual fishers have been changed throughout the manuscript to ensure anonymity and for privacy.

Discussion

Theorizing tradition and identity

Rationalization of caste identity with tradition, and its articulation in conflict narratives, requires a sociological as well as cognitive understanding of identity theory. The fields of "identity theory" and "social identity theory" provide for a rich and expansive meta-theory (Abrams and Hogg 2004), by combining insights and conceptual generalizations on social interactions, conflicts, and politics. Stryker and

Burke (2000) describe two main contexts in which identities are formed and defined. These refer to the relationship of identity with social structures, and processes of 'internal self-verification'. They also indicate that often identity is equated with ethnicity and culture, without proper contextualization. Identity "tends to mean too much or too little", in the sense in which it is used (Brubaker and Cooper 2000). Turner and Oakes (1986) emphasize that social psychology needs to move from "individualist" cognitive-psychological concepts of identity towards interactionism, which could help understand individual-group relationships, the role of social influences, and inter-group polarizations. Hogg *et al.* (1995) posit that identity theory and social identity theory offer remarkable theoretical similarities about the relationship of the self-structure with social structure, but their application may vary with the level of analysis and context of relationships. In general, identity theory is assumed more useful as a construct to understand 'chronic identities' at the individual level, whereas social identity offers utility to understand group behaviours and inter-group dynamics in changing contexts (Tajfel and Turner 1979, Northrup 1989, Ashmore *et al.* 2001, Cook-Huffman 2008, Cuhadar and Dayton 2011, Hogg 2018).

Identities are thus inherited, imposed, and even invented. Caste identity may be a clear example of inherited and imposed (and reinforced) identities. It is important to remember that many caste identities were linked to social stigma and based on ideas of pollution or purity (as under the *Varna* system), reinforced by those with economic and political power (Dumont 1980, Gupta 2005, Lindt 2013). These factors also explain the need to perform identities in response to changing social stimuli (Goffman 1959; Owens *et al.* 2010). The stable biological or occupational core of caste identity can maintain inter-group boundaries reinforced by particular differentiated practices, symbols, and meanings (Howard 2000; Lamont and Molnar 2002; Callero 2003; Owens *et al.* 2010). Hobsbawm and Ranger (1983) in their book "The Invention of Tradition" highlight how shared identities around traditions are created. Invented traditions serve to unite group members, and can be employed to serve as tools of political resistance against dominant social authority (Scott 1998; Howard 2000; Polletta and Jasper 2001). Traditions are invented, but we must also abandon the view of invention of fixed traditional identities. Rather than being fixed features, later scholarship takes a dynamic and fluid view of traditional identity as strategically articulated positioning (Hall 2000). The dynamics of articulating traditional identity can vary to the tune of changing socio-economic interests,

conflicts, or political assertion (Hall and Du Gay 1996; Gergen 1999; Clifford 2000, Dove 2006). However, Brubaker and Cooper (2000) criticize the idea of fluid and plural identity, precisely because they may not explain conflicts that are produced by the "hardening and congealing" of identities. Therefore, in understanding long-term transformations of conflict narratives over tradition and caste, constructivist concepts of identity prove useful. For my analysis of conflicts, these ideas help explain both the hardened and fluid nature of diverse identity labels that fishers have lived with.

Similarly, traditional identities may be repeatedly invented over time, and even modified as per social contexts, as shown in earlier chapters. The strategic benefits of using traditional identity need to be linked to the adaptive responses of actors and institutions involved in fishery conflicts. Further, it is valuable to see when and how communities involved in protracted and continuing conflicts use the "symbolic resources" of chronic identities (Hogg *et al.* 1995) and contingent identities (Hall 2000) to demand rights, access, and entitlements (Harrison 1999). Social identity theory proves useful in the analysis of within-group and inter-group conflicts, especially in the context of emerging, formalized identity politics that I introduced above. To do this I will trace how the articulation and positioning of traditional identity (as per Hall's (2000: 17-20) framework) have changed or persisted as features of Mallah fisher identity in different ecological, economic, and social contexts, and their outcomes for both conflict and adaptation. These theoretical ponderings help confront complex questions of what tradition means in the particular sphere of fisheries conflicts in the Ganga River.

Constructing tradition and community: becoming Nishad and Mallah fishers

From many fishers, the immediate response I heard was that their claim of being traditional is due to the biological and occupational correlates of their caste or sub-caste (as shown by Doron 2013, Lindt 2013). Fish yields in the Gangetic plains have been declining in water quality and productivity over the last six decades (Payne and Temple 1996; Tsai and Youssof-Ali 1997; Payne *et al.* 2004; Vass *et al.* 2010a). According to fishers, fishery conflicts have been linked to this degradation, but conflicts within their community appear to have intensified post-1991, after river fishing became free for all. But today, an interaction with conservation and

development discourses may have led to a significant delinking of fishers from their relatively rigid past identities. Today, going by the responses of Mallah and Nishad fishers, many more push- and pull-factors are behind using traditional identity as strategy. At one level, it is their poor socio-economic condition; at another, it is a precise understanding of preferences within conservation and development paradigms towards 'traditional' people that they can negotiate and utilize.

'Tradition' is a widely used and also contested word in the politics of development and conservation. Some ecologists and conservationists equate the 'traditional' with the good and the right thing, worthy of conserving into eternity, often uncritically (Sobrevila 2008; Orlove and Brush 1996). The durable moral rhetoric of tradition implies that conservationists seek to form what they regard as mutually beneficial alliances with local people, identified as traditional or indigenous. This recognition implies as if by default, that traditional fishers will be ecologically benign in their ecological impacts, a perception often underlying community-based conservation programs (Brosius 1999; Leach *et al.* 1999; Kellert *et al.* 2000; Dove 2006; Brunckhorst 2010). In contrast, state-led discourses on human development and social justice treat 'tradition' in a more convenient way. They can regard traditional practices as primitive, technologically constrained, and in need of development intervention and empowerment, or as virtuous or wise in contexts such as conservation or granting rights (Blaikie 1995; Dove 2006; Torri 2011). The categories of 'traditional', 'indigenous' and 'local' are thus problematic and political as they tend to 'essentialize' or frame people, to fit ideal expectations of the advocates of conservation and development (Brosius *et al.* 1998: 165). Through this process, deeper inequalities within, and changing cultural self-beliefs of the so-called 'communities' are glossed over (Agrawal and Gibson 1999, Demo 2015). This homogenization eases the use of strategies of influence towards making "environmental subjects" out of local people (following Agrawal (2005: 162) and Foucault (1977)); and changing their identities in complex manners (Bonnes *et al.* 2006; Clarke 2008). In turn, people use their new identities to wrest economic opportunities, but also become victims of state surveillance calculations and increased visibility. Empowerment is burdensome in various ways (Scott 1998; Dove 2006).

The *Mallah* and *Nishad* caste-groups are regarded generally as castes traditionally practicing fishing and boat-ferrying livelihoods (Wise 1883, Risley 1892, Russell and Hira Lal 1916, Jassal 2001, Barman 2008). This widely held social fact

has helpd reinforce the use of this caste-group's identity as political currency in the Gangetic plains (Bayly 1999; Sahay 2004; Jha and Pushpendra 2012). Mallah/Nishad caste-groups are comprised of several sub-caste identities, of which an entire taxonomy exists, with complex interrelationships (Wise 1883, Risley 1892, Jassal 2001, Reeves 2003, Barman 2008). Sub-castes generally connote endogamous boundaries and more or less stable ranks in caste hierarchies. There are also synonymies, indicating that the same sub-caste is known by multiple names in different regions. These sub-castes are ordered usually as *Gonrhi, Sorahiya, Nishad, Kewat, Khulwat, Banpar, Chain, Bind,* etc. but these names, their ranks, and cultural attributions, vary across the Gangetic plains (Risley 1892, Jassal 2001). For fishers, traditional identity has been linked to micro-scale differences in cultural practices, customs, values, and know-how of fisheries (Haller and Merten 2003; Hitlin 2003; Nazarea 2006; Abbott and Campbell 2009; Kelkar 2014a). Many fishers use simple 'tests' of recognizing traditional folk from the rest, such as possessing the skill to 'weave and mend one's own net'. Many sub-caste boundaries and hierarchies have been determined by redundancies and minor differences in fishing, or net-weaving, or dietary habits and practices (Wise 1883). Amid these differences, the ecological knowledge of fishers about breeding and migratory habits of fishes, turtles, water birds, river dolphins, and flow dynamics of rivers form a uniting common thread. Such knowledge is aligned with caste and group identity in the test criteria for defining tradition (Deb 2015). Local knowledge shows signs of erosion today. As fishers claim, this knowledge once guided their practices of resource harvest, but now, poverty does not allow much choice in terms of practice. There is thus an intersection of class status with caste identity here. The persistence of certain social practices and caste-specific rituals underlie diffuse and conflicted versions of their own definitions of tradition. Traditional fishers mainly refer to floodplain cultivating and livestock-rearing castes such as Yadav, Kurmi, Koeri, and Gangota as 'non-traditional' and blame them for destructive fishing practices that have damaged river fish stocks. But traditional fishers themselves display wide variation in the way they understand their traditional identity to assess their own impacts on biodiversity conservation, or in responding to government regulations on fishing (e.g. fishing bans, mesh-size regulation, etc.) and in accessing development subsidies (e.g. housing schemes etc.), as will be shown later. Interactions of fisher folk with these interventions over time

have also enhanced the utility of traditional identity and its use to assert rights and claims to the floodplain ecology, and space within the caste politics of Bihar.

Mallah and Nishad fishers in Bihar have historically remained a community living in poverty, landlessness, marginalization and discrimination (Jassal 2001; Doron 2013, 2016; Kelkar 2014a). Despite being regarded as 'low-castes' and economically backward communities (BC-II category in Bihar), the Mallah are not treated as untouchables. This exception goes back all the way to a mythological episode in the *Ramayana* (details in Doron 2009a, 2013). The story in which *Kewat*, the chief of fisher-boatmen, and his crew ferry Ram, Lakshman, and Sita across the river, has been the most powerful source of legitimization for the community even today, as being dignified and commendable (Doron 2009a, Doron 2013: 169–170). This episode is portrayed in the Ramayana, with the *Mallah* boatman portrayed as having the initial air of a street-smart cunning and untrustworthiness. However, the emphasis of Mallahs in Uttar Pradesh (Doron 2013) is on the later portion of the episode where the boatmen are recognized as true devotees, whose service to Ram earned them the virtue of being "purified" by his contact. Colonial accounts (Russell and Hira Lal 1916) retell these legends as invention of tradition (of attaining purification) for mobilizing and uplifting Mallah identity to resist Hindu upper caste dominance. In other regions of Uttar Pradesh, the Nishad castes trace their link to Eklavya, the tribal prince and gifted archer who became a victim of upper caste prejudice in the *Mahabharata*. But Doron (2009b, 2010, 2013, 2016) argues that the exalting of Nishad identity as irreplaceable in older culture and tradition is not just resistance to upper caste injustices; rather it is used as a creative strategy by Mallahs to assert their own place within the *Bhakti* literature. This self-image forms the core of current Mallah identity in Varanasi and other sacred towns (Doron 2013) where they operate mainly as boatmen ferrying pilgrims to temples and ghats. Recent conservation discourse on 'saving' the Ganga River has tapped into the idea of the 'traditional fisher-boatman' as a *sevak* (servant) of *Maa Ganga*, their mother. However, the Mallah fishers in Bihar seem to have reconciled with a contradictory image. These fishers often portray themselves as simpletons, unlike the clever outsider. This is similar to other clichéd contrasts that they regularly use to assert themselves, of the urban and rural, or the rich and poor, in India. As another old story goes, Goddess Lakshmi lays the imprecation that because they are foolish, they will always remain poor, but also always be happy (Russell and Hira Lal 1916).

Under the British Raj, caste was viewed as an institution that maintained a certain social order and function, although views diverged between observers, legislators and administrators (Riser-Kositsky 2009). Unfortunately, even though they had seen the deep injustices of the caste system well, the British administration chose to avoid interference in what they regarded as 'traditional' and 'ages-old' institutions of Indian society, for the fear of disturbing that so-called order (Riser-Kositsky 2009). British views thus ended up reiterating the "inferiority" of fisher castes as they reflected the views of the upper castes, which were usually the landowners and revenue payers. Colonial depictions of the Mallah community were often as a lazy, foolish, or untrustworthy people, in part coming from the lack of trust in the contractual terms that officials formed with boatmen or "dandies" (Crooke 1896b; Sinha N. 2014). The Mallah were even enlisted in the 'criminal tribes and castes' of India under the Criminal Tribes Act in 1871 (revised in 1913-14), to the effect. However, not all sub-castes were included in this list. The relatively mobile and hierarchically lower sub-castes like the Chain and Bind particularly suffered from such criminalization (Reeves 2002). The constraints posed to the colonial control by the mobility of different groups formed a basis to ascribe criminality to them in the Gangetic plains (Sinha N. 2008). In colonial accounts, one also sees remarks cautioning the reader of the fishers' 'criminal tendencies', 'lowly' dietary habits, hygiene, etc. (Nigam 1990). In the current political discourse, fishers have offered correcting counter-narratives to this negative historical imagery (Doron 2016), employing traditional identity to undo the social stigma of being stereotyped and criminalised. Goffman (1968) showed that new identities are shaped by perceived threats from social stigmatization. Boundaries between people within and outside the stigmatized collective then become sharply contrasted (Major and O'Brien 2005). With this background, battles over traditional identity have helped appeal for and demand long-due fishing rights, and have been reiterated over the last three decades with different emphases.

History, resistance, and new conflicts

After India's independence, and especially from the 1960s to 1980s, movements of peasant resistance, resistance by *Dalit* groups, and the *Naxalite* movement across Bihar's villages spurred many struggles for subaltern mobilization

(Bayly 1999; Chaubey 2006; Sharma 2006, 2012; Jha and Pushpendra 2012; Mukherji and Mukherji 2012). Ankit (2018) traced a longer continuity of caste conflicts and struggles in Bihar since the 1920s, in response to social backwardness, agrarian distress, the national freedom movement, and land reforms in the 1950s. These struggles involved demands for rights, transnational and regional movements against dam building, flood embankments, pollution, farmers' rights and welfare, land-grabbing of rural agricultural lands, etc. against state and national governments (Sharma 2006, Mukherji and Mukherji 2012, Sinha S. 2014, Thakur 2014). Beteille (2012) argues that post-Emergency (1975-77), caste became more central to perceptions of social justice than class. The Mandal Commission report (1980) recommended caste-based reservations in government jobs in India, and was implemented in 1990, which spurred political parties and alliances based on caste identities. The subsequent "post-Mandal" wave of caste-based politics strongly influenced political strategies and alliances, especially in north India (Bagchi 2018). In Bihar and Uttar Pradesh, caste politics had witnessed a surge with the socialist movements through the 1970s and 1980s (Ankit 2018). But since the early 1990s, Uttar Pradesh saw a stronger effect of religious and Hindutva politics on Nishad and Mallah fishers as compared to Bihar (Doron 2016, Verniers 2016). In Bihar, the *Ganga Mukti Andolan* (GMA) that began in 1982 against private control of the Ganga River was led by floodplain dwellers, primarily fishers (Gupta 1993; Sharma 2005; Choudhary *et al.* 2006; Kelkar and Krishnaswamy 2014). One contributing factor was that within a decade of the construction of the Farakka barrage in 1975, stocks of many commercially valuable and migratory fish species had collapsed in the upstream reaches of the Ganga River in Bihar (Payne and Temple 1996; Adel 2001; Kelkar 2014a). The problem of poor fish catches was compounded by the fact that the Ganga River at Bhagalpur had been under the private control of an oppressive, feudal regime (*Panidari*) for nearly 200 years (Reeves 1995, 2002; Sharma 2006; Kelkar and Krishnaswamy 2014). "This situation was the last straw in triggering the Andolan," remarked Ramraj Sahni (name changed), an elderly fisher from the Kagzi Tola fishing settlement of Kahalgaon town, which was the epicentre of the GMA.

In 1991, following GMA agitations and protests, the state government decreed to remove the *Panidari* and made the river an open-access, free-for-all resource and space (vide Notification No. 39191, Vol. I-892). Despite this symbolic achievement, this change generated new and intense conflicts between fishers and other groups

(even farming and livestock-rearing castes that lived on the floodplain, and occasionally fished). Other marginal floodplain-dwelling groups also took efforts to fish in the now free waters of the main river channel (Choudhary *et al.* 2006, 2014). This shift did not meld the hitherto occupational and caste identities of floodplain people into a unified class of 'fishers'. Instead, it generated strong caste and sub-caste identities that fragmented the community. Ramraj Babu, himself a foot soldier of the GMA once, lamented that the free-for-all system actually backfired on the fishers (Kelkar 2014a). "The situation of free fishing is even worse than the *Panidari*. First, only traditional fishers like us could fish in the river because of the *jalkar* (private fishery), so we got at least some protection from intruders. But now look around you. Every other fellow has now become a fisherman." As I have shown earlier, the so-called 'free' fishery is controlled by mafia-style fishing rings or gangs formed by stooges of landlords, local gunmen, and politically patronised musclemen who lost out after the end of Panidari. Members of these gangs include 'non-traditional' fishing castes, and other castes with little or no historic link with fishing. The gangs have since 1991 controlled fisheries through extortion and grabbing of catches from any fishers, who have included mostly traditional, but sometimes even non-traditional fishers! Fishers have also lost their lives, or were brutally beaten up on many occasions, and their catches grabbed frequently, almost once in every few days or a week (Sharma 2006). The mafia also threatened fishers to work "destructive" fishing nets, mainly seines and mosquito nets, which they also invest in now. Fishing for the Mallah people and those who claim to have traditionally depended on river fishing has now become a risky and life-threatening task (see Choudhary *et al.* 2014; Kelkar and Krishnaswamy 2014; Kelkar 2014b for details).

Around the same time that the *Panidari* was terminated, a section of the Ganga River was declared as the Vikramshila Gangetic Dolphin Sanctuary by the Bihar state government (vide Gazette Notification S.O. 382, 7th August 1991; Kelkar and Krishnaswamy 2014). This section, between Sultanganj and Kahalgaon in Bhagalpur district, overlapped more than half of the Panidari-owned stretch. The declaration was met with bitter opposition and protest from fishers working with the GMA, who argued that the sanctuary was yet another form of state control, bent on depriving fishers of their fishing rights (Choudhary *et al.* 2014). Threats from the mafia, declining fish availability, and the declaration of the sanctuary, have since made fishing community leaders call for exclusive control of the fishery (especially

from leaders in Kahalgaon). According to them, unlike non-traditional fishers, traditional fishers "know how to fish sustainably, without damaging fish stocks". Traditional identity has been strongly reinforced by their (often justified) claims of having the right knowledge and skills to sustainably harvest fish resources. But in the last 10 years or so, their claim has been extended to state compatibility with dolphin conservation. The long-term interaction of fishers with river dolphin conservation awareness programs has played a clear role in this renewed articulation (Choudhary *et al.* 2014). But as we shall see soon, this is complicated.

The idea of traditional fishing has also changed from belonging to the Mallah caste alone, to becoming equated with fishing practices used, gear chosen and ecological knowledge about fishing, irrespective of any fishers' caste. The river dolphin conservation program that originated in 1999, through civil society efforts led by Prof. S.K. Choudhary from the Bhagalpur University and his team, has been sympathetic to a vision of the traditional fisher (Choudhary *et al.* 2014). This team has engaged keenly with issues of welfare of traditional fisher households, through involvement of fishers in river biodiversity conservation, outreach and education programs. One desirable outcome of this engagement has been that the deliberate killing of river dolphins for their oil probably reduced (Choudhary *et al.* 2006, 2014; Kelkar *et al.* 2010). For S. Dey, a river dolphin conservationist working closely with fishers for over two decades, the meaning of tradition used to mean that, "only traditional fishers should have fishing rights to the river because they do not use destructive gear, and possess great knowledge of fish breeding, migration and ecology. Traditional fishers are poor and landless people with no fallback options. This is unlike farming groups or criminals that own land and have so many options other than fishing. However, more powerful farming castes have entered and ruined the fishery with destructive means." These responses indicate the concomitance of caste and class identities in the representation of fishers and others. But these ideas have now changed for these conservationists over time, after witnessing the wave of identity politics.

The involvement of fishers in biodiversity conservation and monitoring programs has also perhaps led to a gradual shift towards positive attitudes towards river dolphin conservation – unlike the severe opposition and suspicion about the intent of the sanctuary in earlier years. Prof. Choudhary explains that: "the challenge before us was to reduce their strong antagonism to the sanctuary. Anyway people

have been fishing in the stretch even after the sanctuary was declared – so we had realised that the opposition was not exactly to the sanctuary's presence, but to do with 'who' fished there. The real opposition is now to the fact that destructive netting is going on in the river. But it is also true that it is becoming difficult to tell which fishing practice can be truly called destructive or sustainable."

Generally, conservationists are sympathetic to the socio-economic condition of fishers, but their alliance is not immune to suspicion and mistrust on both sides. Fishers and conservationists locked in a silent bargain and weighing of interests. At the same time, conservation discourses generally focus on legal morality, compliance, and conformity on the part of fishers (Honneland 1999). Interestingly, the state fisheries act (the Bihar Jalkar Fisheries Management Act 2006) prioritizes rights of "traditional fishers". Thus, combined influences of conservation and fisheries legislation end up legitimizing caste identity through the traditional categorization. The best instance of this is seen in the promotion by some conservationists of traditional fishing practices as ecologically low-impact and benign ones, and hence favourable for river dolphins, in comparison with supposedly destructive methods used by non-traditional fishers with the support of mafia gangs. As per the fisheries act, with amendments till 2017-18, fishing with nets of mesh size smaller than 40 mm is deemed illegal, irrespective of whether it is by traditional or non-traditional fishers (Kelkar 2014a, 2014b). At this threshold, nearly 80% of regular river fishing would still be high-impact and illegal. Thus, the legal focus of conservation discourse also divides fishers according to whether they abide with such laws or cannot. Even if the threshold were reduced to 24 mm mesh size (see Choudhary *et al.* 2006), over 60% of existing fishing practices would still be unsustainable. In fact, fishers themselves had negotiated for the 24 mm cut-off, as they would still get some fish catch, which would otherwise be impossible if meshes greater than 40 mm were used. In short, being able to catch something is a bigger concern for poor fishers now, than the impacts of using small nets. As I have shown in chapter 5, fishing with small-meshed nets, deemed as destructive by traditional fishers, do not seem to depress fish yields. Interestingly, mortality of dolphins due to by-catch appears to be higher in large-meshed and legal gillnets! Declining catches and the threat of extortion by gangs also compels fishers to fish more intensively nowadays (personal observations). These findings suggest that traditional practices, however positioned by conservationists and in turn by fishers, are not ecologically benign. Some fishing methods are only called traditional because

of their ancestral use and continued practice. Hence, equating them with sustainable practices is problematic. But by laying the blame for poor fishing returns on non-traditional fishers, traditional fishers have actually aligned their articulation with that of conservationists, to advance claims of 'sustainable traditions'. In this process, conservation discourses valorising traditional fishing practices may have placed a sustainability burden on fishers. Traditions need not necessarily have positive sustainability implications, but even have some negative impacts.

How is one to identify a traditional fisher, or for that matter, a non-traditional fisher? Such identification is not possible from the fishing nets and gears, for most fishers, irrespective of tradition or caste, use a great diversity of contraptions to fish, despite some subtle group preferences. Given the diversity of practices in capture fisheries, the simplest way to identify a traditional fisher is now with an identity card. In 2008, I met a fisherman called Guddu Sahni from Navgachiya in the Bhagalpur district, who proudly showed me his red-cloth covered, tattered, grimy and partly torn "ID"-card resembling a ration-card like document with paper sheaves. He proclaimed, somewhat sheepishly, "the government agrees that I am a traditional fisherman." The card declared that Guddu's forefathers had always been involved in fishing in the Ganga River, or something like that. There was a newfound legitimacy to his life now, through this state-granted identification. He had had to pay a bribe of three thousand rupees, but now it seemed totally worth the effort. Guddu had, in this bargain, momentarily forgotten his poor and insecure life as a fisher, the pathetic state of his income, his children's dismal state of health, and the low water level and fish in the Ganga River in the summer of 2008. Flashing his ID-card, he said, "*ab hamein nadi se firee mein machhli marne se koi nahi rok sakta* (now nobody can stop me from fishing freely in the river)".

Outcomes of tradition for fisheries and biodiversity conservation

Like Guddu, the traditional fisher now is the man with an identity card. Fresh conflicts and disputes are now brewing over these state-sanctioned and even appropriated identities (Choudhary *et al.* 2014). This has moved the notion of tradition into an abstract and symbolic realm of cultural politics, from its material realm. In the saga of river fishery, the traditional fisher emerges as the faultless hero, while the non-traditional fisher as the villain (Kelkar and Krishnaswamy 2014). Through the production of a "traditional fisher" label, the

fisheries department has opened an identity market, rich in exploitable symbolic resources (based on Harrison 1999). Intense competition to become state-certified "traditional fishing communities" is also seen in other floodplain-dwelling castes who have been part-time or occasional fishers, but who are regarded as 'non-traditional' by Mallahs. For example, in 2014, access to power positions of elected *Gangota* leaders helped their community get legal recognition as "traditional fishers" in a matter of a few months. The Gangota people were a floodplain-dwelling caste, historically dependent on livestock-rearing, farming and labour jobs, and part-time fishing for their livelihoods (Rajesh Raj 1995). The history of the Gangota community is important because of their modern depiction as violent criminals and emerging "role" in transforming fishery relations and conflicts. Rajesh Raj (1995), in what is probably the only detailed ethnographic study of this community, describes the historical processes that marginalized these peasant caste-groups and triggered acts of collective resistance, which later took up violent forms in gang-organized crimes, even colluding with landed elites and powerful politicians (also see Chaubey 2006). Gangota regimes of terror transformed the *diara* landscapes (floodplains) of Bhagalpur district into an insecure and dangerous space. In 2014, the Member of Parliament from Bhagalpur came from the Gangota community. Current political turns show how, the Gangota, having risen to power while retaining violent practices and political nexuses, are now attempting to establish control over river fisheries. Control of fisheries has consolidated their political power, which has by now helped them transcend their public image as a crime-affiliated community. Crime, here, has provided opportunities for sustaining and intensifying their control over fishers, with their state-granted traditional identity working as reinforcement (Dal Bo *et al.* 2004). Cultural ideas of honour, natural justice, and dignity also sustain violence among fishers (Wieviorka 2003, Figueredo *et al.* 2004), alongside formal political divides.

The strategic articulation of tradition extends further in relation to different interests and bargaining power in the context of river biodiversity conservation. This becomes important for conservation outcomes – especially when traditional fishers comply with conservation efforts. In return, they demand legal exemption from being penalized or reprimanded for their negative impacts on river animals (especially for accidental bycatch of species in their fishing nets). For instance, in the case of the Ganges River dolphin, the initial antagonism to conservation has waned. Though targeted hunting has come down, accidental bycatch mortality and opportunistic exploitation of dolphins thus caught continues (Branch et al. 2013). Many fishers also poach dolphins caught in their nets (accidentally or otherwise) to extract blubber oil to use as bait to catch *Clupisoma garua* or Bachwa, a species of catfish

(Choudhary *et al.* 2006). Fishers consciously portray themselves as cohabitants of dolphins, giving rise to impressive slogans: "if the river dolphin survives in the Ganga, only then can the traditional fisherman survive". The recent '*dolphin mitra*' (friends of dolphins) program launched by the Bihar state forest department and compensatory afforestation (CAMPA: Compensatory Afforestation Fund of the Bihar state government in 2012-13) funds provided selected fisher informants with short-term cash incentives (2000 Rupees per month) in lieu of reporting destructive fishing and dolphin mortality events (Kelkar and Krishnaswamy 2014; Choudhary *et al.* 2014). In the *dolphin mitra* program's first phase, eight selected fishers from Bhagalpur received these monthly 'incentives' in lieu of their help in reporting dolphin mortality, hunting and destructive fishing events in the river. After the initial few months, most of these funds never reached the local forest department from the state headquarters. However, this program seems to be falling into corruption: as per recent accounts of some fishers, the forest department ground staff (guards and foresters) ask them to 'keep their mouth shut' even if dolphins were observed dead in gillnets. Department reputations and job security are obviously at stake here. But this revelation suggests that even two thousand rupees appear enough to dismantle the fickle 'traditional' friendships of fishermen, with Ganges river dolphins and with conservationists.

In 2019, the *dolphin mitra* program was expanded to a different level to prevent bird and animal hunting and poaching by the Forest Department. Under this plan, fishers have been provided with military-style clothes and tenting equipment on the floodplain, where they monitor and can thwart poaching and illegal fishing nets. Such moves are likely to create rebound effects and risk the lives of these fishers as well as of other part-time fishers. Such surveillance programs may not amount to actual conservation impacts or stewardship among communities. Here too, the precondition of the forest department ground staff (shared with us by these fishers) was that instances of dolphin or turtle hunting should be hushed up. "When 10,000 Rupees can be taken home to just keep quiet, which poor man won't sell his integrity?" says Bage Mahaldar, a local fisherman at Barari.

Despite this worrying issue, other background reasons may have contributed toward an overall positive perception about dolphins. There seem to be no major opportunity costs of using or not using dolphin oil with alternatives such as fish oil or palm oil, or new gears, becoming available. In the meanwhile, bycatch mortality, which remains the main direct threat to dolphins (from all net-using fishers) may be excused or hidden. Being accidental, it may not invite serious penalties, as for

targeted hunting. Supporting dolphin conservation programs has thus not required changing the status quo. However, many surprises are witnessed in case of other biodiversity. Bird hunting serves an opportunity for fishers to highlight their conflict with farming castes living in the floodplain, and how they are the neglected 'stepchildren' of the government, as opposed to farmers. Justification for this claim is provided through a moral distinction drawn between how farmers and fishers look at animals sharing their resources and space. Dinesh Babu of Bahattra claims that farmers hunt out of spite and revenge against birds, but not fishers: "farmers indiscriminately hunt birds with large traps, nets, and poisoned seeds. Birds eat their grain, so they have reason to do so. Why would we hunt birds unnecessarily?" Gore Lal adds to this point, "traditional fishers are always on the river, and they become easy targets for the forest department. We hunt birds, but only for food, not through any feeling of revenge, because we are traditional fishers." Dinesh Babu and Gore Lal are both experienced fishers, and even though they are *Gangotas*, they believe in using 'traditional fishing gears'.

The argument of traditional fishers being compatible with conservation reverses in the case of turtles. Traditional fishers make an exception here by stating that it is as much their tradition and cultural right to hunt and eat turtles as it is to fish in the river. Doron (2013) writes about fisher communities in Varanasi challenging the ban on turtle hunting prescribed by the Ganga Action Plan (Phase I) in the mid-1980s. The Ganga Action Plan identified that a decline in the number of turtles was a reason for degrading water quality, as human and cattle corpses rotted without scavenging by turtles. Fishers had agitated about the government's conspiracy against their traditional way of life (Doron 2013). Currently, in and around the Vikramshila sanctuary, many fishers who claim their commitment to the dolphin conservation program, especially those from Kahalgaon, make no such promise for turtles, which they hunt whenever the opportunity arises. Fishers have been blatant in employing tradition to justify their rampant hunting of freshwater turtles, even supplying them to high-demand markets in northern West Bengal and Bangladesh. Conservationists may think it is contradictory that tradition at once translates into sustainable fishing and rampant turtle hunting, but fishers do not see this as a contradiction. Many fishers are connected to these markets through middlemen, who also facilitate turtle trade, especially to West Bengal and Bangladesh. Interestingly, fishers themselves admit that their own hunting of reproductive adults has driven populations, and even some

species of soft-shelled turtles, to local extinction. "Mallah identity is inseparable from turtle eating. Mallahs will always catch and eat turtles – do what you can!" says Radhe Krishna Sahni of Kahalgaon, who defies conservationists openly. The fishers of Kahalgaon are widely known for their turtle-hunting skills across northern India, and have been hired in locations as far as Goa for sea turtle hunting. These fishers have also hunted and eaten the occasional gharial and mugger crocodiles coming from upstream tributaries into the Ganga. There is defiance in the way turtle hunting is viewed as fully acceptable. Fishers also use deflecting tactics and logics like "egg-laying animals should be exempt from 'conservation'", and that "because turtles lay hundreds of eggs, they can be harvested just like fish". But the same logic does not apply to capture of small-sized fish by the mosquito nets that traditional fishers hate. Fish lay millions of eggs, so by the turtle logic, such an abundance should not be affected even by illegal and non-traditional fine-sized mesh nets. However, this premise is the very basis for severe conflicts between fishing groups. The issue of turtle hunting has also created new subdivisions *within* specific fisher castes based on ideas of new hierarchies employed by fishers from their differential access to conservation programs. 'Higher' sub-castes (Gonrhis, Mahaldars) blame 'lower' sub-castes (Banpars) for the 'impure' habit of eating soft-shelled turtles that feed on human corpses. Although many fishers eat turtles, the relatively better-placed groups within them that interact more with conservationists gain from baulking at the practice. This illustrates how the 'higher' sub-castes of fishers have manipulated the bias of dolphin-focussed conservation programs in their favour, with the impacts borne by turtles.

If we track the highly variable nature of articulations about traditional identity through these variable interactions with riverine animal species, a pattern emerges. For fish species, traditional wisdom alone is showcased as capable of saving the fisheries from collapse at the hands of destructive non-traditional fishers. However this claim is not supported by the ground realities of fish stock depletion and river pollution, which have been driven more by large-scale environmental impacts than by local fishing intensity (see chapters 4 and 5). But the larger undesirable effects of fishing practices on species conservation and river ecology are negotiated, species-by-species, in creative ways. There is an uneasy equation in the case of river dolphins. Despite their support for conservation, dolphins still frequently die in gillnets of traditional fishers – by accident. The same traditional fishers are indifferent to hunting

down turtles to near local extinction – as it is their traditional and cultural right to hunt. Apart from the mixed implications for conservation of endangered river animals, are there positive spinoffs of traditional identity for conservation? With otters as metaphor, the sense of community is articulated through a pleasantly surprising harmonious discourse. Smooth-coated otters cause considerable damage to fishing nets when they attempt to take the fish caught in them. Yet, surprisingly enough, despite high losses, fishers do not mind otters. There is no persecution of or retaliation against otters to be seen in the sanctuary region. Killing an otter is seen as a sinful act that will lead to harm and ruin for the wrongdoing fisherman and this reinforces a positive and appreciative, even caring attitude towards them. The elderly and kind Ramesji Nishad, a knowledgeable and highly respected veteran fisherman of 78 years, sums it up: "otters have their own small societies, just like us, and are another *community* of fishers, just as we are." Perhaps as a result, otter densities are remarkably high, and they seem to enjoy *de facto* protection in the area. This positive outcome contrasts with some other rivers in the Gangetic plains, where local people have hunted otters to near-extinction. These contradictions between discourses about the traditional and the modern, and their outcomes for what traditions mean in turn, raise many difficult and uneasy questions for conservation in practice.

Outcomes and alliances with development interests and welfare schemes

The emerging caste and identity politics of Mallah and Nishad fishing caste-groups in northern and eastern India is built on changing demands for access to fishing rights, social justice, and development opportunities, all seen as interconnected rights and entitlements (Bagchi 2018). Fishing rights are emphasized as inalienable (Clayton and Opotow 2003, Ratner *et al.* 2014), however, in spite of recent mobilization, the vulnerability of fishers to poverty, marginality, and labour migration has never been as high as now. Sharma *et al.* (2013) summarize the socio-economic conditions and limited livelihood options of river fishing people, due to illiteracy, lack of assets or savings, and limited exposure and access to rural development schemes. As a result of these factors, fishers have been rapidly exiting fisheries, and getting involved in different occupations in nearby towns and faraway regions. With this state of affairs, they have focused on securing basic amenities and welfare schemes for their households, mainly housing schemes like the Indira Awas

Yojana, educational scholarships for children, insurance funds, subsidies for nets, gears, or boats from the state fisheries department, and access to public distribution systems, drinking water facilities, medical aid, etc. The process to secure these entitlements and opportunities is by proving with documents that they are traditional fishers, through identity cards, and cooperative memberships. Once these benefits are secured, alternatives open up and facilitate exit from river fishing. So, a fisher needs to be recognized as traditional in government registers, in order to easily quit fishing.

Daw *et al.* (2012) have shown that decisions to exit from declining fisheries in East Africa were governed both by immediate economic returns from fisheries, as well as site-specific historical factors and rapid external changes in market access, livelihood diversification, government subsidies, etc. From a livelihoods perspective, ease of exit and permeable options for occasional entry might provide a safety net to communities dependent on declining fisheries (Allison and Ellis 2001, Coulthard 2009). Total exit is typically the last choice for fishers, who instead focus on increasing diversification of livelihood opportunities (Kadfak 2020). Addiitonally, pride and identity play a major role in influencing the decisions to quit fishing (Pascoe et al. 2015). It seems that fishers, among the larger peasant classes from Bihar, have historically migrated to work as farm labour in fields of Punjab. This has been going on over many centuries. Further, many fishers who have migrated to Punjab have become involved in fish trade and aquaculture in that state (Moudgil 2016). Punjab is not a major fish-eating state by and large, and Bihari migrants have tapped into this market niche over there. Those who have stayed back have demanded farm ponds to be allotted for fish culture in areas near their settlements, to be owned and managed by groups of households. But this has not happened. Exit from fisheries directly trades off with vulnerabilities and risks of migration. Thus, seasonal fishing in the river, mainly in the dry-season or post-monsoon, remains a backup for many, which can be used with the benefits obtained by becoming ‘traditional’. However, with the current situation of reverse migration and unemployment due to the COVID-19 pandemic, even these exit routes and options may be blocked significantly in the coming years. Levels of desperation are high, and many fishers have tried their best to secure benefits by being enlisted as traditional fishers, before exiting completely.

Demanding justice: politics and the call for rights

Undoubtedly, fishers who have felt the need for political organization have not remained totally aloof or opportunistic. Instead, they have actively engaged with the changing nature of politics in India at the national and state levels. Parties such as the *Vikassheel Insaan Party* (VIP) and NISHAD party (*Nirbal Indian Shoshit Hamara Aam Dal*) in Bihar and UP are examples of parties constituted of fishing caste-groups. Political organization has focused on reservation and representation, but not as much on the call for recognition of fishing rights, human rights, inclusion, and development, based on caste and traditional identity. Many active group protests, rallies, and drives towards "*Nishad Ekta* (Unity of the Nishad caste)" have been springing up across Bihar recently, although this mobilization has been in force in UP from before (Narayan 2009; Jeffrey *et al.* 2014). Movements to mobilize fishers have also erected new heroes. A recent example is in the recent celebration of the '*Amar Shaheed Jubba Sahni Shahadat Diwas*' (Day to commemorate the martyrdom of the immortal martyr Jubba Sahni, a freedom fighter after whom the Bhagalpur Central Jail is named) on 11th March 2018 in many areas of Bihar.

In this context, it is noteworthy that the stated objective of this mobilization is the unity of the fragmented, heterogeneous, and stratified fishing populations in Bihar. However, even with the umbrella identity of the Nishad caste group, it is difficult to say whether all sub-castes of fishers (especially the most backward Bind) are included. Gartzke and Gleditsch (2006) show that states with similar cultural identities may be more prone to conflicts than those with dissimilar cultural actors. Conflicts within communities might also follow similar trends with micro-level differences being accentuated and emphasized for the creation of difference by traditional "virtues", and on subjective moral, ethical, and symbolic grounds (Alexander 1985, Opotow and Weiss 2000, Sankaran *et al.* 2017). The second feature of the movement is that the call for unity does not show any hint towards seeking intervention for current problems of river-floodplain fisheries. Departure from material needs towards symbolic and political opportunities is very evident in such electorally driven mobilization. This movement "from interests to identities" (Rothman and Olson 2001) is in the hope that new identities will help to serve old interests. However, it is striking to note that none of the new political leaders of these forums are active fishers themselves. As fisher identity is now seen more as a

symbolic resource for status and political power, the material state of fishing-dependent ceases to be of concern for fishers.

Politically inclined observers might herald this as caste resurgence towards social and economic mobility. However, they would have overlooked the ironic fact that a constituency (lobby) of fishers is being built despite they having to do nothing with fishing in the present, or in the future. Ahuja (2019) succinctly summarizes this as 'electoral mobilization' trumping 'social mobilization' in caste-based political parties. It is thus difficult to say whether, even if elected representatives come from families who are still actively fishing, things may improve for the material prospects of river fishing livelihoods. Even for movements such as the *Ganga Mukti Andolan*, which began with social mobilization of fishers, a shift towards political interests is apparent. Some fishers known to me, once involved in GMA activities, shared their perception that their leaders' interests now leaned towards electoral representation.

The dominant objective thus appears to be to use the new opportunity to foster personal political ambitions and secure a seat at the table of power. After Dinesh Babu's son got elected as a block-level leader from Bahattra village, it took him only about one year to buy a brand new Tata Scorpio. Fishers were amazed, and also amused, by this feat. For them, Dinesh Babu's son did well in his new role. But what else was achieved for the fishers of his village has remained a big question for some observers. Corruption of this calibre, too, is not a moral problem for many in the fishing community. Having been victims of corruption for long, participation in corruption is a need and desire today, and not the anathema that it is to liberal ideals. Participation in corruption is viewed as a leveller against the weight of past and even current injustices stacked against them (see Jeffrey (2002) and Witsoe (2011) for analyses of these processes). Banerjee and Pande (2009) show an inverse relationship between the 'quality' of politicians (in terms of honesty, integrity, etc.) and their chance of being elected, the latter determined strongly by caste identity, over any other identity or perceived virtue (Sankaran *et al.* 2017). Witsoe (2012) has argued that this transition towards caste sovereignty stems from the inability of state institutions to ensure constitutional rights for their people. Thus, the persistence of caste politics, while often unsavoury to ideas of liberal democracy, can still bring chances for meaningful democratization closer to marginalized communities (see Beteille 2012). These possibilities need to be kept alive by combining electoral and

social mobilization, which as Ahuja (2019) suggests, may have a low likelihood of conventional political success.

In the 2019 Lok Sabha elections, the Mallah community, including the Vikassheel Insan Party (VIP) initially decided to side with the National Democratic Alliance (NDA) in Bihar. The VIP claims to stand for the whole fishing and boat-ferrying communities across the Gangetic plains. But the risks faced by fishers have not been brought up on this platform. The emergence of the VIP definitely opens a new chapter in Bihar's political history that deserves to be closely monitored. The VIP has a fishing boat with sails and an oar in its logo. Its flag contains saffron to denote Hindu identity and sacrifice, indigo blue for Dalit identity, and green to display secular credentials (but not as a "green" or pro-environment symbol). It is an interesting and combined statement of plural affiliations, but is also linked to uncertainties in agendas. With the functioning of the RJD (*Rashtriya Janata Dal*) being in disarray, the pull towards a right-leaning politics driven by aspirational motivations was a factor. However, in the end the VIP ended up on the losing side with the RJD's grand alliance, in the 2019 *Lok Sabha* elections. The card of tradition and caste helped the party's rise across Bihar in a big way. The connection of the Nishad or Kewat fisherman with Lord Ram was invoked initially, probably to keep open the option of allying with the right wing Hindutva politics of the *Bharatiya Janata Party* (BJP). Narayan (2009) shows that in Uttar Pradesh, the BJP in fact employed these identity symbols to align with the political mobilization of Nishads, as of many Dalit castes, on the lines of Hindutva. In the 2020 Bihar elections, the VIP in Bihar split from the alliance with RJD and joined the NDA with the BJP, emerging on the victorious side. The rise of the VIP has thus smartly played on the strategic articulation of religious, traditional, and political identity.

Elsewhere in India too, trends of party politics are seen reflected in political mobilization of tribal and other backward caste groups, with land rights and forest rights. Bo Nielsen *et al.* (2020) show how caste remains a fundamental element of strategic articulation in political struggles for land rights in India, in the political mainstream. The case of forest rights is even more interesting to compare with our fishing rights story. Kumar and Kerr (2012) describe shifts of tribal votes towards the BJP in the 1990s, from "opportunity structures" that emerged in the political instability of that decade. When caste politics gathered steam and diversified in Bihar (in terms of representation of multiple caste groups), a similar trend was also seen

with the representation of tribal groups. Kumar and Kerr note that the role of the Campaign for Survival and Dignity (CSD) helped find support for tribals' and forest-dwellers' demands for forest rights, across party lines, leading to the more or less unanimous passage of the Forest Rights Act by the Indian government in 2006, which was a successful outcome. However, Sudheesh (2015) has argued that the actual implementation and recognition of rights suffered from state discourses reducing the "rights discourse" of the campaign to a "recognition discourse" for tribals. Similarly, in Bihar's political arena, fishers' representation has subdued the call for rights. The articulation by forest-dwellers and fishers as a "marginal society" (Choubey 2016), orphaned by the state, is reflected in both mobilizations. Initially, an important element of VIP's narrative was not just for a marginal society but also a marginalized riverine ecology. Fishers emphasized that they had faced historic injustice and neglect due to not owning land rights, which forced them to make a living on rivers. But this narrative faded away in front of the more direct appeal asking fishers to vote *en bloc* for their caste representatives. With their new alliance with the NDA in Bihar, new challenges will be imminent. The central government has a dedicated manifesto for fisheries, unlike most other parties, and is thinking of an ambitious national policy for inland fisheries. At the same time, massive transformations of rivers are imminent, with waterways, river inter-linking plans, new hydropower projects, being discussed. In this situation, fishers voting for and subscribing to the VIP could find themselves trapped between the contradicting motivations of these plans.

The space for adaptation and sustainability

I find that the dominant narrative of conflict has shifted between material and symbolic purposes and concerns. The former revolved around access or rights to fish, but the latter around state recognition as 'traditional fishers'. This is in part a response in the form of political adaptation to the aggravating regional ecological decline and local criminal appropriation and control of fisheries in Bihar. The political struggle to gain official status of being traditional has important implications for adaptation in the face of uncertainty. It remains to be seen if political mobilization can translate into social outcomes. However, there seems to be no interest among fishers in working towards reviving or creating local, rights-based, and community-centric institutions.

This lack of interest may diminish prospects for collective action in increasingly fragmented fishing community, in spite of new political opportunity.

Fishers thus have very limited options left to choose from, on a spectrum from continued persistence to full exit from the fisheries scene. But extreme choices are not helpful. A complete exit from the fishery would mean becoming an outsider to one's own community, and the resulting social costs might be difficult to buffer. Also, continuing to persist in the fishery with both economic loss and life risk would not make sense in the present day. Thus, even with the general tendency to exit, many fishers have chosen to remain linked to the fishery either through trade, or, by even forming collaborations with the anti-social, crime-driven elements that they had been opposing so far (see chapter 3). Acquiring state approval for traditional identity helps in cornering material gains through the use of symbolism. This path of political adaptation (Eriksen *et al.* 2015) implies that even if the actual fishery resource or riverine ecology degrades further, it may not matter to fishers who have decided to exit the fishery after having secured their "traditional identity" cards. From their origins in subaltern movements and the caste-based electoral politics of the 1990s, today's identity politics has moved both rightward and leftward in recent years. These shifts have resulted from a combination of following the flock, as well as disillusionments within smaller caste-based parties in Bihar. The fight for being recognized as 'traditional fishers' has brought important material benefits and access to government schemes (mainly housing and water supply). But no space has yet formed to demand livelihood security, fishing rights, or human rights. Demands for human rights and fishing rights involve important complementarities and contradictions (Song and Solimann 2019). Human rights are universal but fishing rights are exclusive, so demanding one 'bundle' of rights can compromise the other at times. Song and Solimann suggest that demands for community rights to fishing may be the bridge with human rights. The rapid erosion of the fishing community stands in sharp contrast with the portrayal of a communal and united traditional identity in the new politics. How fishing rights can be realized at the community level is difficult to guess in this situation, especially when fishers are too keen to exit the fishery whenever individual opportunity permits.

The roles and contexts in which fishers have attempted to find a place may have changed, but tangible benefits from these shifts have yet remained elusive - for both fishers and biodiversity. For the poorest and weakest of fishers, the hope that

identity cards will give them a better future appears a mirage. Guddu Sahni's 'role' as a fisher in the Ganga River has changed several times in the last twelve years I have known him. In these years, he has been on all sides of the fishery conflict: his fish catch has been extorted by criminals, poverty has forced him to work as a labourer in mafia fishing rings, he has been a *dolphin mitra* providing conservationists with vital information on poaching, and has dived in the river to find corpses of fellow fishers murdered by criminals, for the police. He has also been a rickshaw puller, farm hand, and construction labourer, in places far away from home. Until he was reincarnated as a traditional fisher in the records of the government, this was his life. Yet it is difficult to say what materially changed even after years of having received his identity card.

The resource of traditional identity: diverse uses and strategic articulation

Traditional identity could be an enabling force or a divisive force, based on how it is employed. When fishing communities still toil hard to survive by using all ways possible, how can we reconcile the varied meanings and contexts of what their traditional identities are all about? Despite all their stated differences, it is difficult to see consistent disparities in fishing practices across traditional and non-traditional fisher castes. The emergence of sub-caste level micro-politics within Bihar's fishing 'communities' has increased divisions (as predicted by Mosse, 2018) and helped fishers to corner individual benefits. The strategic use of traditional identity is also an adaptive strategy, irrespective of the consequences, costs, or benefits. The symbolic importance of the 'resource of traditional identity' today has more value for access to development benefits and state subsidies, than for access to the resource of river fish. It seems most profitable to exit the fishery, but while still ensuring recognition as traditional fishers by the state. How can conservation and development interventions ensure that the material and symbolic realms complement each other, and the former does not render the latter irrelevant?

A few key points bear mentioning through the exploration so far. First, the assertion of traditional identity may have had origins in deep-rooted social injustice. But, with historically produced social situations, it also changed to an invented label, tool, strategy, and narrative, for political assertion. Second, as the story of how fishers 'became' or were made traditional fishing communities indicates, conflicts shifted

from their material origins to purely symbolic representations. Although fish resources may have declined in the river, the discursive resources of image and identity appear to have substituted them – and are available to be fished, freely. Third, the conservation or development outcomes of allying with the interests of 'traditional people' may be mixed and inconsistent. The illustration of the making and remaking of traditional fisher communities in the Gangetic plains underlines the need for even well-intentioned conservation and human development approaches, to look beyond outcomes and at the larger political environment which produces and changes social identities (Parker 1994; Agrawal and Gibson 1999; Stets and Biga 2003; Vaccaro *et al.* 2013). In these discourses, the idea of privileging the traditional as the virtuous, needs to be unpacked and categorically revisited (Brosius *et al.* 1999; Kellert *et al.* 2000; Dove 2006). At the same time, finding how traditional knowledge and cultural practices could contribute to contemporary and local decision-making is critical to unravel (Leach *et al.* 1999; Clifford 2000; Hitlin 2003; Nazarea 2006; Doron 2013), especially in relation to future resource sustainability and social justice.

The story of traditional fishing identity in Bhagalpur resonates with numerous tales of political negotiation and struggle from across the world. Conflicts and inequalities due to ethnicity, racial identity, class, or caste (Pellow 2007) have underlay reorganization of not only economic and political institutions, but of self-identification as well (Turner 2010, Demo 2015). From India, the idea of changing identities in relation to environmental discourse has inspired a wealth of critical scholarship in diverse contexts (e.g., Rangan 2003). These histories draw upon the expressions of identity through linkages among cultural experiences, influences of power, and the motivations of local people to adapt to change. Muehlmann (2013), writing on the indigenous Cucapá fishers of the Colorado delta in Mexico traces a remarkably similar trajectory. The Cucapá, through the policy maker's gaze, are denied fishing rights because on occasion they do not 'act indigenous enough', or "*after centuries of discrimination on the grounds of ethnic difference, government policies now encourage* ***indigenous self-identification****...*" (my emphasis; Muehlmann 2013: 13-14). The irony in the ethnography comes from the way the Cucapá, now integrated with the wider society of Mexico, must become traditional once again, for the need to be categorised so by the state. In the Zambezi and Zambia river floodplains, fisher narratives and policy discourses on overfishing coalesce and diverge according to emerging notions and boundaries around traditional and

therefore righteous identities (Haller and Merten 2003; Abbott and Campbell 2009). Images of traditional people in the Amazon have been used by outsider anthropologists and activists to certify their 'authenticity' and 'exoticness' to aid donors and state agencies (Conklin 1997: 713). Li (2000) describes communities in Indonesia and the competitive politics around who captured the "tribal slot" with specific attributes and ideals held by NGOs. The articulation of tradition has strongly emerged at the edges of enclosures for appropriation and conservation of resources, in political conflict. Globally and locally, communities have drawn both from traditional old practices and social mainstreaming to form hybrid identities of 'ecologically noble citizens' (Doane 2007; Yeh 2007). Through this they are renewing their positions and stakes in environmental negotiation, building resilience in periods of civil conflict, economic reorganization, state-making and political shifts (Field 1999; Lee and Hitchcock 2001; Rangan 2003; Carrus *et al.* 2005; Furlong 2006; Dove 2006).

Does the plasticity of traditional identity imply that the Mallah fishers are merely an opportunistic community of fence sitters? Does this plasticity indicate corruption from the external influences of globalization and neoliberalism, and development and conservation discourses? Or is it just another adaptation to overcome the difficult, poor and hungry lives they lead? I argue that traditional identity has been each of these things at various historical moments and periods, which have transformed the self-images of fishing people in the Gangetic floodplains. With increased outmigration for labour jobs, new vulnerabilities, and life-changing transitions, the question is whether these fishers will remain only in the government record but not on the river? What then will be the future of biodiversity and ecology, which have shared histories with fishing people in the Ganga? Who will be the stakeholders that can demand a free-flowing river, teeming with fish and biodiversity, who could oppose the grabbing of rivers for industrial and infrastructure projects?

Conclusion: The post-river fisheries

From this exploration, conflicts over issues of fishing rights, access, institutional arrangements, or ecological sustainability, appear to culminate in issues of identity, in Bihar. The future of Gangetic fisheries is linked to how these identities are postulated, contested, and recalibrated in response to social and economic change. I call this the "post-river stage" of fishery conflicts, where the real issue is whether

rights will be secured by traditional fishermen, irrespective of whether those rights matter at all, or whether they will affect the future environment and sustainability of riverine fisheries. The post-river stage may see a river without actual fishermen, but many paper fishermen. Such a transformation threatens the riverscape that still supports thousands of the weakest river fishers, their livelihoods, and their families. The pressures of industrial development (from river-linking plans, waterways projects, hydropower, etc.) on the Ganga and its tributaries are increasing multi-fold. In these times, river-dependent fishers and associated stakeholders stand on the proverbial cusp of critical choices and decisions about their collective action and assertion. Both political and ecological choices will shape their universe of future possibilities for adaptation.

Chapter 7. Summary and Conclusion

Whither resource conflicts in Gangetic fisheries?

My Ph.D. thesis identifies and discusses processes of change leading to shifts in fishery conflicts and associated narratives, in the Gangetic river floodplains of India, with a focus on Bihar. Declines in riverine fish resources over time, and the failure of state and community institutions to adapt to uncertainties imposed by complex riverscape histories, have been variables strongly tied with these conflicts. While my investigation is on capture fisheries in particular, it has reflections even for other resource conflicts across the Gangetic plains and elsewhere. Conflict narratives, much like the river courses in which they emerged, have meandered and shifted between their material and symbolic frames over the last 300 years. These shifts do not seem to, unfortunately, promise a recovery of local institutional management regimes, or ecological conservation, or even fishers' socio-economic development. On the contrary, they suggest that a new identity politics is now dominating contests over fishery resources, and becoming an end unto itself.

The first chapter introduces the theoretical basis and explains how my study of conflicts is organized in this thesis, in which I show how and why conflict narratives have shifted between their material motivations and symbolic interests in different spatial and temporal contexts. Chapter 2 of my thesis undertakes a detailed historical overview to show how conflicts have changed and are shaped by different narratives, in relation to institutional shifts (from private to state-controlled to open-access regimes). Conflict narratives have also responded to ecological and socio-political factors, engulfing changing experiences of ecological declines and institutional control and management of fishing rights and access. There have been watershed shifts or breaks in fisheries governance regimes in colonial and post-colonial regimes, but these breaks have also carried on significant continuities. Such interplay between riverine ecology, fisher community transitions, and institutional change (Basurto and Coleman 2010, Young 2002) has transformed conflicts and posed major challenges for sustainability, social justice, and in turn, even the identities of fishing communities. Further chapters investigate why and how these shifts have taken place, and what their outcomes for and feedbacks to fishery conflicts have been.

Land-water boundaries constantly change in riverscapes with large flooding, meandering and braiding of rivers, and unpredictable channel changes. Chapter 3 investigates the implications of institutional interplay and confusions over administrative boundaries for conflicts over fishing rights and access, in dynamic floodplain riverscapes. Confusions over the hydrological uncertainty set the boundary conditions and provide a basis for power relations, local relations of production, and intervention by different institutions (state departments, informal fisher groups, NGOs, conservation groups, and mafia gangs). The dynamic riverscape responds to environmental and ecological changes, as expressed at various scales: from individual fish species and life-history stages to the entire fish community with impacts on fishers and fisheries. This chapter examines the capacity of different institutions to manage fisheries in the Gangetic plains, through 5 case studies demonstrating how such conflicts over space take place. It does so through a combination of interviews, focus group discussions, and participant observations on the one hand, and fieldwork and GIS studies on the other. I find that 1) state institutions are the most rigid and lack capacity to deal with uncertainty and shifting boundaries, 2) mafia gangs are highly adaptive and are able to control fisheries in the dynamic floodplains with the use of violence, and 3) local institutions of fisher communities stand weakened and marginalized owing to these factors, and social divides of class and caste. These institutional and community failures have caused a rapid and permanent exit of active fishing people out of the Gangetic plains, after younger fishers have mostly moved on. For those that remain, the high uncertainty of open access and risks of violence may generate a great degree of pessimism, as witnessed in the dominance of declensionist and "overfishing" narratives among fisher folk.

Chapter 4 tries to understand what may cause and constitute overfishing in Gangetic fisheries. It examines the relative effects of environmental and hydro-climatic variability and fishing effort on long-term yields of different fish species. I assess how aggregate fishery yields and catches in the last 20 years on the Ganga River in the Bhagalpur district (Bihar) have responded to environment-fishery interactions. Ideas of resource scarcity or environmental variability have divergent outcomes for fishery conflicts. That makes it important to assess whether "Malthusian overfishing" or environmental variability have a stronger impact on fish yields or catches. I find that fishery yields are increasingly showing greater inter-seasonal

variability, thus mimicking the growing difference between dry and wet-season flows. These differences are driven by complex interactions between anthropogenic regulation of flows and climatic changes. Extreme flood pulsing appears to exert greater uncertainty for fish yields, indicating that large-scale, basin-wide environmental changes exert considerable control on fishery yields than seasonally varying local-scale fishing effort. However, the relative influences of environmental and fishery controls on yields vary with the reproductive and ecological traits of different fish species. This research also contributes to the growing body of work on impacts of climate change on riverine capture fisheries in India (e.g. see Das *et al.* 2007, 2016).

In Chapter 5, I take the investigation further on what overfishing constitutes. Here I look at the consequences of selectivity of different fishing gears on fish population dynamics, and their links with conflicts over fishing gears used by different fishing groups. Gear-use conflicts are mainly over the use of illegal fine-sized mesh nets (mosquito nets and seine nets), which larger-meshed gillnet-using fishers blame for capturing too many immature fish and causing declines in fish catches. In turn, fishers using fine-meshed nets blame gillnet fishers for harvesting reproductive adults and denting recruitment. My analysis shows that both narratives are not supported by ecological data – I find no evidence for fine-sized mesh nets or gillnets being solely responsible for fish catch declines. In fact, both types of gears are reasonably size-selective. However, gillnets that are mostly legal, and capture larger and reproductive age adult fishes, have a relatively greater impact on the yields of large-sized and high-value carp and catfish species. Fine-meshed nets, while illegal and harvesting large numbers of small-sized fish, do not seem to negatively affect many species. Thus, the relative impacts of both gear types vary with the life-history characteristics of different fish species. This brings to the fore complex contradictions: legal and 'traditional' gears may not be sustainable, while illegal gears may not be harmful. However, fine-meshed nets are operated often under the protection of mafia gangs, who harass and threaten gillnet-using fishers. Arguments of ecological sustainability of different gears are advanced by disadvantaged gillnet fishers as a reaction to the injustice and threat of the gangs. Here, identity becomes critical – because the different types of gears used are linked to differentiations between traditional and

non-traditional fishing castes. On the surface, what appear as gear-use conflicts, are actually conflicts over caste and traditional identity, which I explore in chapter 6.

Chapter 6 looks at how caste and identity politics have emerged from conflicts over fishing rights and gear-use. It analyses how the articulation of traditional identity has been shaped by conservation and development discourses with which fishers have interacted. This interface has given rise to a new wave of politics centred on caste, traditionalism, and an environmental branding of fishing communities. The question of caste in development paradigms in India has inherent contradictions, as pointed out by Mosse (2018). Political opportunity and representation appear to offer escape routes for fishers, from the dangerous everyday stressors of continuing in river fisheries. Politics might provide fishers with some means for adaptation to overcome destitution and poverty, but also implies an exit from fisheries. Exit from fisheries itself is determined by complex cultural and economic trade-offs (e.g. Daw *et al.* 2012) that political assertion based on caste identity may not recognize or address. I show that the priority of representation in identity politics has disassociated itself from demands of secure fishing rights or ecological restoration of rivers, on which livelihoods critically depend. I also describe how the politics of caste can lead to far-reaching, though often unintended and even intended ecological implications. In the Gangetic plains, the interplay of caste politics with environmental conservation interventions appears to have created many "traditional fishermen" who never actually fish. This points to future riverscapes with emptying fisheries bereft of fishing people.

Reflections on the strengths and limitations of the thesis

My thesis has evolved through my 14-year long and continuing engagement with Gangetic fisheries and Bihar. An interdisciplinary synthesis that marks the coming together of history, hydrology, ecology, institutional analysis, and sociology, is its strength and novelty. I have tried to not only view fishery conflicts from multiple lenses, but also shown that these lenses are not independent of each other in any way. The learning that came with having witnessed the change in conflict narratives over a fair bit of time, have also been helpful. Most importantly, being able to access and also shape the development of a remarkable time-series of fishery catch and effort data with my collaborators has provided for a strong quantitative basis for many

arguments I have made. I submit that these factors have contributed to new inferences, and allowed me to pose some radical questions on the existing state of fisheries in the Gangetic plains, through my work.

In spite of these strengths, I am aware that there are some missing pieces in the story. The reasons behind these limitations involve both logistical challenges and factors related to social access and structural limitations. First, the representation of women in fisher responses, for one, has been limited in my work, even if not absent. I have been reading researches in feminist political ecology pertaining to women and water (e.g. Sultana 2011). However, in the context of this work I do not extend effort in this area. Women are significantly involved in the trade and local retail marketing of river fishes (FAO 2015). They have a definitive contribution in regulating and influencing local fishing effort by fishermen based on their connections with market trade (Bibha Kumari 2016). Further, in Bihar, women have played an active role in protesting for rights to pond fisheries (Jassal 2003), and in larger movements against the *Panidari* in the Ganga Mukti Andolan (Sharma 2006). Most "successful" fishery cooperatives in the North Bihar wetlands have a majority of active women functionaries and members (Jassal 2003). And yet, in the way I have understood river fishery conflicts, responses of women are under-represented. From my limited interactions, I can say that although the perceptions of fisherwomen about the declining fisheries are similar to the men, their responses to future challenges are interesting and different in important ways. Migration out of fisheries is an important concern (Kumar and Bhagat 2012). Fisherwomen along the Ganga are seriously concerned about the education and employment of their children, and see outmigration by the men as a stressful but unavoidable reality to improve the future of their next generations. In fact, exit from fisheries and outmigration of middle-aged menfolk for labour work is facilitated strongly by women who stay behind, and provide the bedrock of support for the family. Decision-making by women at the household level is a significant background variable for men engaged in the wretched conflicts over river fisheries along the riparian. There is a need for more research on understanding of the contributions of women in fishers adapting to conflict, and the wellbeing of the entire household.

The second issue is related to some obvious logistical challenges. This pertains to the limited access I had to representatives of the fishery 'mafia' gangs. I did meet some of the "local bosses", but a significant part of the descriptions in chapter 3 has come from key respondents whose work relations have had them interacting regularly with gang members and operatives, even if they were not directly involved with these gangs. Their close understanding of gang operations was a reliable albeit indirect source of information that I could use in my study of the institutional interactions and overlaps in managing and controlling river fisheries. This was perhaps inevitable because of the nature of gang operations that involved regular crime, and their 'outlawed' status. In general, existing research on institutional management of fisheries is limited in not having acknowledged or addressed the importance of crime in fisheries control by gangs (see Katiha *et al.* 2013). With this omission, researches on livelihoods or sustainability of capture fisheries seldom engage with the conflicts and vulnerabilities that fishers face through such dangerous interactions with gangs.

The thesis also does not capture the fish traders' side of the story in great detail. Acting as vehicles for meeting fish demands in eastern India, traders are acutely aware and conscious of declining fish catches from rivers, problems like pollution and poor river flows causing stock collapses, and issues pertaining to illegal fisheries. These issues often affect the supply of fresh and dried river fishes to markets in Bengal and Assam, and neighbouring regions. In my forays into the markets of Siliguri, Farakka, Kota, and Kanpur, traders underscored strong concern about the degrading value of fish from capture fisheries amongst increasingly less discerning consumers. Many also stated that while pond culture fisheries would run their markets and give people food to eat, the cultural and culinary values that river and wetland fish carry will be lost soon. However, traders are also entrapped in the workings of economies of scale, and larger demand-supply calculations. In many instances, traders from the very fishing group that opposes mosquito nets (e.g. at Kahalgaon) seemed to have no qualms about selling fish caught in mosquito nets. How they reconcile this "business practice" with their allegations about the "destructive nature of mosquito nets" is not easy to understand. However, with recent resistance against mosquito nets, fish markets are becoming fragmented. In October 2019, I visited a new "wholesale *aarat*" located right on the riverbank at Tintanga-Bochaiya (in Gopalpur block of Bhagalpur district). This trader bought catches of

small fishes only from mosquito nets and traps around the village and sold them directly in the Siliguri market, where he had made connections. Market fragmentation creates new problems for monitoring "illegal" catches (Charles *et al.* 1999) and understanding the impacts of changing demands on small fish yields. The thesis could have benefitted from a stronger economic analysis of fish demand. Further, a closer look at labour markets related to the lengthening supply chains in inland fisheries would have also added important dimensions. However, in the interests of priority and coherence, I have left quantitative economic analyses on these factors beyond the scope of my analysis. Such analyses will be fertile substrate for future work.

Further, I wish I could include work on two additional aspects. To understand how fishers were entwined in the larger agrarian relations of production, and to study the impacts of imperial scientific bodies on the making of river-floodplain based livelihoods, future work could consider in-depth exploration of imperial archives. The second aspect is one that I consciously decided to leave out of the present scope of this thesis. My thesis keeps its focus on the biological aspects of the life histories of individual fish species (i.e. on reproduction, growth rates, dispersal/migration, etc.). But it would have been exciting to also include cultural histories of fish species in future extensions or manuscripts that will come from this work. This can expand our understanding of fish from being just the "objects" of conflict, by considering them too as "actors" in the process. Across species, cultural preferences vary, and at the most outward level, are reflected in totemic beliefs and culinary refinements. Cultural differences between fishing communities about what fishes to preferentially eat or harvest thus deserve attention in future cultural studies (see Reeves 2003).

Finally, as riverine capture fisheries show complex and unpredictable responses to hydro-climatic changes, and as fishers exit the space, their relevance to food security also diminishes in policy imagination (Narayanan 2016). Across India's inland fishers, socio-economic status, poverty levels, and livelihood insecurities and vulnerabilities remain with many gaps (Katiha *et al.* 2017). Further, concerns about the negative impacts of fishing on biodiversity (esp. endangered species like river dolphins or freshwater turtles), makes many conservationists feel that replacing river fisheries with aquaculture systems may help protect species from direct mortality in fishing nets. The ascent of aquaculture needs to be seen not just as a solution to

sustain food especially protein security, but also as a problem for wider concerns of ecological health and equity (Barange *et al.* 2018, Campling *et al.* 2012). While substituting capture fisheries, aquaculture has added to its continued neglect. Even with the exit of fishers from rivers, capture fisheries continue to sustain millions of people. The strong focus of fishery policies on aquaculture can dent the potential of riverine capture fisheries to raise the profile of free-flowing rivers as socio-ecological systems to be conserved and managed for fisheries, biodiversity, and ecosystem services together.

With new institutional and ownership arrangements emerging in aquaculture and enhanced fishery systems, it is worth observing how these could be sustained as hybrid fishery systems. This is of particular relevance for enhanced culture-capture fisheries such as in floodplain wetlands and oxbow lakes (Jha 2009). Enhanced fisheries systems blur the boundaries between the natural and the managed, the fixed and the fluid, the captured and the farm-cultured. A deeper understanding of the management and conflicts pertaining to capture and culture fisheries is crucial (Campling *et al.* 2012). My study, while addressing this peripherally, urges future research on understanding complementarities and incompatibilities between riverine-floodplain fisheries and wetland pond-based aquaculture. This analysis needs to examine the trade-offs between food security and environmental conservation more closely (Lynch *et al.* 2016b). Consumptive water use and related inefficiencies and pollution from water use in aquaculture need to be evaluated against the benefits of sustaining non-consumptive water demand and the production of vital ecosystem services through riverine capture fisheries (Cooke *et al.* 2016, Lynch *et al.* 2016a, b, Funge-Smith and Bennett 2019).

Relevance for inland fisheries policy and legislation in India and beyond

My thesis makes important contributions to global and national policy frameworks on small-scale inland fisheries. At a broader level, my work reasons for a need to provide dedicated space for inland fisheries within the Sustainable Development Goals (SDGs). At present, the SDGs include “Clean Water and Sanitation” (SDG 6) and “Life under Water” (SDG 14), which include aspects of

water pollution, river flows, equitable access to water, and marine and coastal fisheries – but NOT freshwater fisheries. This is a significant omission, which appears to be a clear reflection of the wide neglect of inland, and especially riverine capture fisheries (Lynch et al. 2020). Riverine capture fisheries remain a pivotal resource for basic subsistence, incomes and nutrition of the rural poor across Asia and Africa, and their explicit acknowledgment within the SDGs is wanting but much needed (Cooke *et al.* 2016, Lynch et al. 2020).

Two other frameworks merit discussion here. The first is the Voluntary Guidelines on Small-Scale Fisheries by FAO (VG-SSF 2014). The VG-SSF was critical to recognize the importance of securing rights and tenure in small-scale fisheries across the world. It also included concerns of liberty, peace, human rights, equal opportunity, gender representation, and rights to dignified labour and work. My thesis makes observations about the context and future of fishing rights and human rights in the context of fisheries becoming empty, and coming under the shadow of criminality. Interestingly, demands for diverse types and bundles of fishing rights continue to be strong (Huppert 2005). But, as Song and Solimann (2019) have pointed out, fishing rights are exclusive rights and mean that their demands are pivoted on the definition(s) of who is entitled to fish. So, what sorts of rights are we talking about, unless we squarely face the challenge of caste politics, as in our fishery case? Across India, most definitions of "traditional fishers" are based on caste identities even in formal legislation and policy. If, indeed, some castes are granted exclusive rights to fish (as per the standard demand), what does it imply for other fishery-dependent castes, and for new conflicts? If we move from fishing rights to human rights, then open-access fisheries could provide opportunity to everyone to access fish resources in an ideal scenario, i.e. without the influence of crime or threat, but that would not be ecologically sustainable (Charles 2011). Song and Solimann identified that the way to reconcile the contradictions between human rights and fishing rights is through community values and rights, rather than individual rights. Ruddle and Davis (2013) also advocate a similar approach, as individualism becomes rapidly connected to neo-liberal policies and market pressures on small-scale fisheries. For this, community-based and socio-environmentally responsible management of fishing rights and access need to be strengthened (FAO 2012, 2013, 2017). Community-based and co-operative management has reappeared in conservation discourses for fishing, and have been

portrayed as alternative economic systems that could help reimagine space and society's relations with riverine capture fisheries (McCarthy 2006, Kalikoski & Franz 2014). Capture fisheries break the "rules" of intensive capitalistic modes of production, such as aquaculture fisheries, and use different modes of information exchange and reciprocity in management of labour and accessing fishing areas (St Martin 2001). However, the relations of production and exchange remain strongly asymmetrical and often exploitative (Campling *et al.* 2012). The prospects for collective action and community-based or cooperative management by existing institutions such as Bihar's Co-Operative Fisheries Federation (COFFED) seem limited in a situation where conflicts intensify. Recently, the COFFED has come up with multiple cooperative management schemes for aquaculture, but its engagement with riverine fisheries has been very limited. In recent years, some reorganization of capture and culture-based fisheries through Self-Help Groups and cooperatives (Kumar et al. 2019) has been noted to increase equitable management in floodplain wetlands of North Bihar. But such examples are exceptions and not the norm. With fragmentation and conflicts within fishing communities, discourses on co-management could get rendered to mere strategic tags for neoliberal policies justifying private or state appropriation and legitimation of fishing spaces to promote market-oriented development (Jentoft 2000, Mansfield 2003). In that sense, there remains nothing "alternative" in local or community-based fisheries management models (McCarthy 2006).

The second policy framework is India's draft National Inland Fisheries and Aquaculture Policy (NIFAP 2019) by the Ministry of Agriculture and Farmers' Welfare, Govt. of India, which, by 2020, was merged into an overarching draft National Fisheries Policy (with marine and inland fisheries combined). The draft NIFAP (2019) was an important step towards guiding state legislation and policy-making in inland fisheries. Desite an ambitious and broad vision, these policies show a great deal of dependence on state and market controls on fisheries management, and the privileging of aquaculture systems over capture fisheries (Kelkar 2019a). The National Fisheries Policy recognizes the "minimal right" to accesss water for fishers, but does not engage much with the complex conflicts that exist over access and rights. According to activists, it also does not explicitly protect the inalienable rights and community entitlements of fishers, or recognize environmental responsibilities of

fishers (NPSSFI 2019). These policies use the National Water Policy (GoI-NWP 2012) as its template for ecosystem-based management of inland fisheries, but the NWP itself does not acknowledge the importance of freshwater flows for riverine capture fisheries, which it does not even recognize as important. My thesis underlines the importance of ecological flows and flood-pulse variability for riverine capture fisheries. My work contributes to discussions on how the NWP and National Fisheries Policy guidelines can be improved for the environmental management, conservation, and responsible governance of tenure in inland fisheries (see Kelkar 2019a,b).

Recently, the fisheries policy of Bihar has vested all rights and ownership of fisheries with the state fisheries department. The implications of this amendment will not be tangible until the on-ground confusions about jurisdictions of riverine capture fisheries under the fisheries department are addressed properly. Bihar is also planning to increase the duration of fishery leases in floodplain inlets and *dhab* areas. Government fishery scientists and bureaucrats have welcomed these steps as a progressive legislation. However, these will be truly progressive only upon acknowledging conflicts and working towards implementation of ecologically sustainable, socially just, and equitable policies. Further, in May 2020, Bihar announced value addition schemes through "place branding" approaches, in which 5 selected fish species will be branded by the rivers in which they are caught. The branding scheme, though not yet considered for implementation or under discussion at present[315], had hoped to yield direct benefits and higher value at the level of individual fishers. At the preliminary level, it is difficult to imagine how systems of branding or value addition can be immediately brought to open-access fisheries, when basic institutional capacity is lacking. Such a system is likely to entice greater investments by fishers and lead to higher competition over access to brand prices. The scheme may not have considered ecological outfalls. For example, it had planned to brand the "Bachwa" fish (*Clupisoma garua*) from the Ganga, which is often captured using dolphin oil as a bait. The oil is extracted from the blubber of endangered Ganges river dolphins when they get entangled and die in gillnets (see details in Sinha 2002). Such plans could become counterproductive for biodiversity, if implemented.

[315] As per a response from the Bihar state Animal resources and Fisheries Department to N. Kelkar in 2021.

From the standpoint of fisheries sustainability, the rhetoric around cleaning the Ganga and ecological restoration deserves a closer look, because of its potential for future scope for adaptation by fishing communities. Many interventions have been and are being attempted at different scales, but the degree of success appears limited to increased public awareness programs. For fishers on the Ganga, the conservation-development dyad has been unfolding along a new dimension, with the Government of India's flagship projects for a Clean (*Nirmal*) and Flowing (*Aviral*) Ganga. The National Mission for Clean Ganga (NMCG) has recently launched numerous projects (see Kumar 2020) that involve people from fishing communities to be "*Ganga Praharis*" (Ganga Sentries). Local forest departments are also taking initiatives to involve fishers in conservation messaging. Undoubtedly, these interventions make for interesting and "inspiring" posters, brochures, and photographs. Not only that, significant cash inflows have also been trickling in, along with t-shirts, caps, bags, that flag the complete branding of the Ganga Mission. The government's focus on reducing pollution in the Ganga, accompanied by a recent proposal to (grudgingly) estimate and allocate e-flows might lead to local benefits to capture fisheries. However, these benefits would be easily offset by the negative impacts of other policies involving the "capture" of the river for industrial uses (e.g. waterways). What these parallel and contradictory plans mean for the Ganga itself, and its water, fisheries, and biodiversity, has to be monitored critically in the coming years. These projects are being implemented in a "payments for compliance" mode rather than for direct conservation action or systematic monitoring. From the point of view of the fishers joining as "*Praharis*", it is affording new opportunity to earn income and status in their local political contexts. It is still early to say what comes of these performances. But, the formation of newer identities and divisions, this time by the exclusionary subtexts of environmental messaging, appears inevitable.

Capture fisheries emerging as a "criminal political economy"?

Harriss-White and Michelutti (2019) in their book "The Wild East: Criminal Political Economies in South Asia" indicate that "the world of crime does not exist in an alternative domain to that of the state but is deeply entangled with the actually existing state". Collusive relations between crime and politics, or the legal and illegal, are a defining characteristic. In simple words, if an income-generating activity is

impossible to imagine without some perception of illegal or illicit links (criminal), then that enterprise can be considered a criminal political economy. While sand mining, brick kilns, and related destructive uses of river resources are well known as 'mafia'-driven businesses, and considered sensational enough to have formed the material for Bollywood films in recent times. Fisheries across northern India gradually appear to be entering that category.

In the third chapter of my thesis, I describe the transactions between local gang bosses and Mallah fishers along the Ganga as the workings of criminal economy in operation. At river channel inlets, side-channels, bays, or confluence areas, it is considered impossible by fishers that they will fish there and not have to pay up. Moreover, the collaborations we see forming between fishers and mafia gang leaders (in getting leases through nexuses with state department officials and politicians) further legitimize the processes of corruption or interpretations of illegality within fishing communities. With the exit of bona fide fishers, barricading mosquito nets, and fixed traps installed with mafia protection are on the rise. In turn, use of active gears continues to reduce, pointing to growing "sedentariness" among riverine fishers. These trends also hint at the transformation of capture fisheries into a criminal political economy. Ironically, such economies, while violent and dangerous, may be adapted to buffer the impacts of external climatic perturbations or interventionist state regulations and policies, because of the strength and clout of institutional networks.

At present, lease periods along river-channels are for one year. In this year, the fishing leases are usually worked intensively for a period of about 3 post-monsoon months, with the erection of fine-sized mesh nets (FSMNs). These nets are illegal and regarded as destructive to fish stocks due to their excessive harvesting of juvenile and immature fish. Kolding and van Zweiten (2011) persuasively argue for a need to revisit whether harvesting juvenile or immature fish, per se, is destructive. Subsequent theoretical and empirical research in fisheries biology and policy literature deals with issues of "balanced harvesting" provides a new way to think about this. While being controversial and still debated, balanced harvesting studies provide empirical and model-based evidence that harvesting immature fishes (or other size-classes) in proportion to their natural productivity may not affect fisheries sustainability. If the degree of effort invested is proportional to seasonal productivity, such fishing might

not be particularly damaging to many species currently dominant in the fishery. However, this literature is heavily based on studies from Africa's inland fisheries, where the poorest fishers use mosquito nets. In this case, it is worth thinking through this wicked problem in case of the Gangetic plains in India. Here, mosquito nets are used in different forms by fishers for themselves, or under the control of criminals. How can "balanced harvesting" be formally implemented, given that at present they exist due to criminally controlled and illegal fishing practices, which do not seem unsustainable? This is a scenario where trade-offs and contradictions between law, tradition, social justice, and ecological sustainability become rather complicated (Klug 2002). There is a need to engage with this issue further, especially by revisiting current legal fishery regulations and policies and modifying them in order to achieve balanced harvests in a secure fishing space, without threat of violence. These findings challenge the dominant assumptions made by conservationists and development practitioners, who often equate legal and traditional practices as being ecologically benign in their impact. As I have shown with ample evidence, this may not always be the case.

The pathway to adaptation is political: the 'post-river' stage of fishery conflicts

My study examines the nature of changing conflict narratives in relation to social change and increasing environmental variability. How fishers may adapt to future ecological decline and extreme conditions is not delinked from how they negotiate social changes around them (Funge-Smith and Bennett 2019). With renewed opportunity for political representation, can fisher folk of the Gangetic plains secure individual means to overcome the impacts of environmental and climatic change, and also the means to conserve riverine ecosystems? So far, the experience shows that individual gains have been consistent for the fishers making use of the political opportunities coming their way. For fishers involving their settlements in this new wave of politics, there are some signs of improving access to benefits. But they have not been able to, or even willing to, organize community action that could leverage these opportunities towards preserving the river or the fish. The river, which is basis of the new being "traditional fishing communities", now stands on the brink of being forgotten, while the resource of identity is steadily accumulated in the form of

government I-cards, registers, and policy rhetoric. The opportunity to engage in meaningful environmental politics is thus lost, which scuttles any hopes for a truly bottom-up, community-driven engagement in restoration and innovations for sustainable fishing. I conceptualize this change as the "post-river" stage of fishery conflicts, which reimagines the river and fish only as symbols to maintain identities, not as resources to be utilized and conserved. The river becomes just a backdrop for the new caste politics of being traditional fishers, who may never actually fish.

The post-fishery river

With the post-river stage of fisheries at our doorstep, what may be said about the state of the river, when one day it is rendered completely unviable for fishing by industrial and infrastructural state-private interests? The exit of fishing peoples marks the "post-fishery" stage of the river. Permanent exit patterns indicate that options for adaptation are shrinking (Coulthard 2009, Pascoe et al. 2015). Exit of fishers due to both push and pull factors has multiple precedents from across the globe, in both developing and developed regions (e.g. Daw et al. 2012, Johnsen & Vik 2013), with lasting ecological and social impacts. For the Gangetic plains, a post-fishery stage pre-empts a dangerous period for the ecology and the biodiversity of the Gangetic plains. The thrusting of fishers into the realm of caste politics (see Bagchi 2018) takes them away from the river, making it convenient to push imminent river infrastructure projects (e.g. national waterways, river interlinking) that can have severe negative impacts on riverine fisheries, hydrological processes, and sediment-nutrient pulses (see D'Souza 2003b, Bandyopadhyay and Perveen 2007, Lakra *et al.* 2011, Grant *et al.* 2012, Kelkar 2016, Higgins *et al.* 2018). The violence, conflict, and oppression that marred river fishery livelihoods and marginalized them to dire extents have been responsible for this unfortunate reality. As fishing groups fight their petty political races, industrial grabbing of rivers is likely to continue without any local opposition. In the post-fishery river, the river might become only a conduit of water from a life-sustaining ecological entity, because there are now no fishers to stand up for it. Social movements of the past also appear to be now frozen in history. I have analysed how open-access fisheries became the Ganga Mukti Andolan's end-point, rather than starting point for investing in the ecological and social rebuilding of the river and of the fishing community (Kelkar 2018). Its aftermath is seldom discussed, but

demonstrates many failures in improving the condition of fishers. River fisheries, meanwhile, continue to diminish further from public imagination, and their critical importance to protecting our rivers and their biodiversity has become moot, because there are fewer and fewer fishing people left on the river.

The rhetoric of 'rivers flowing waste into the sea' that dominates the discourse of policy-makers and citizens in India owes its existence in part to the historical neglect and imminent extirpation of riverine fisheries and fishing communities: the biggest stake-holders in free-flowing river ecosystems dependent on river ecosystem services to human well-being. Existing dams and barrages, apart from fragmenting river flows, have also led to major problems for sediment management by trapping sediment behind them, and disturbing linkages between sediment fluxes and biological productivity. This has increased physical risks of river erosion and habitat loss for many fish and vertebrate species in river sections downstream of dams (Lakra *et al.* 2011, Sarkar *et al.* 2012). These factors are certain to severely impair future river ecosystems in terms of their productive and sustaining functions. These functions include not only fisheries or biodiversity, but also climate regulation, estuarine and coastal productivity, sediment transportation, and feedbacks between basin-scale river flow regulations, diversions, and atmospheric processes such as the Indian summer monsoon (Whitehead *et al.* 2015, Agrawal *et al.* 2019).

Indeed, the Gangetic river basin is set for a vast and unprecedented sort of environmental transformation, with projects such as river interlinking and 'national' industrial waterways on the anvil. There remain substantial doubts and concerns over their basic feasibility and unrealistic scale. Yet, processes of transformation of banksides and riverfronts have begun – with ports being sanctioned, large-scale water diversions being planned, coal and fly ash being transported by barges and so on. Such intermediate effects are likely to exert a severe toll on the livelihoods and health of riverside communities as well as riverine biodiversity. As discussed above, initiatives to reduce river pollution, though desirable, could be limited by the transformation of rivers into shipping lanes by canalization and dredging. With river interlinking, many impacts remain to yet be seen, but the transformation of hydrology and sediment flows in the Gangetic plains will likely be irreversible (Higgins et al. 2018). As numerous additional dams and canals will have to be built to "link" rivers, the future of river ecosystems and fisheries could be under severe threat. Problems of trans-boundary water sharing, pollution control, species invasions, and greenhouse

gas emissions can be further exacerbated by a greater number of dams and canals. Can reviving riverine capture fisheries avert these crises and contribute to alternative models of river restoration and water management? This question will be essential to tackle in future conservation policy.

Prospects for coexistence of fisheries and biodiversity

My thesis posits that the relationship between ecological revival and social justice, which we desire to be positive for both outcomes, may be rather complicated. Of course, the relationship will vary across ecosystems and cultures. While our normative concerns often assume synergies between ecological conservation and social justice, we need to be equally aware of the tradeoffs and risks involved. A new normative articulation that combines ecological sustainability, socio-economic equity, and environmental justice concerns is required. This requires that we recognize the biophysical and social limits for sustainable fisheries, as well as prioritize rights and entitlements, in the effort towards building coexistence. In this regard, conflicts over managing riverine capture fisheries speak to larger conservation debates on full preservation versus extractive use by local people. With future uncertainties, it is essential to consider adaptive management and policy prospects for conservation of riverine biodiversity alongside fisheries extraction. The discourse of fisheries management policies has only been exploitation-based, with conservation rarely considered as a central goal. This gap can be addressed by attentive policies for promoting sustainable and ethical approaches in fishing practices (Lam and Pitcher 2012), with adequate incentives to discourage harmful practices in fishing, avert negative impacts on biodiversity, and prevent routine and inadvertent environmentally damaging behaviours[316].

In dynamic riverine ecosystems, conventional economic calculations to predict the limits of sustainable resource extraction are difficult to apply. A river that floods every year creates new templates and resource pulses to extract from, and conventional calculations of productivity, e.g. yield per area, may be limited. Of course, this does not mean that there is scope for endless extraction. In fisheries, harvesting and conservation policies need to recognize local system characteristics and practices, rather than borrowing from dogmatic ideas of management (often

[316] For example, a study by Nelms et al. (2021) estimated significant contributions to plastic pollution in the Ganga River from fishing nets and other discards.

colonial, first-world, and mostly relevant to temperate marine environments). Fresh revision of fisheries and biodiversity conservation policies could open up a promising space for exploring prospects of cohabitation between communities that extract fish resources on the one hand, and also commit responsibility to protect endangered species and fish populations. This could help maximize the combined socio-economic and ecological values from fisheries development and ecosystem conservation. Ecologically oriented fishery policies could enhance the scope for cohabitation in a much better way than exclusive conservation zones or exploitation-centred fisheries development. For these policies to be effective, a radical shift in thinking about riverine capture fisheries by foregrounding their invaluable ecosystem services and non-consumptive water use is crucial. This can take water management paradigms beyond their standard engineering, cultural, and political rhetoric.

Epilogue

The futures of fishery conflicts and institutional responses in the Gangetic plains are very uncertain. Fishers' dilemmas of whether they exit and emigrate, or whether they jump on their new-fangled political turf are shaped by complicated trade-offs. For those who exit, the risk of moving from the identity container of being a 'fisher' to being a 'migrant labourer' or urban slum-dweller becomes high. How the vulnerabilities that migration brings to these fishers and their families compares with the risks of continuing to fish, is the question. For those who decide to continue fishing in spite of the risks, will engagement with conservation and development schemes bring economically better prospects? What narratives might help those who are now flag-bearers of fisher identity? The choices that fishers can make will decide whether they will meaningfully retain their identity, knowledge, and dignity, or whether they will trade these attributes for cash and power. Can symbolic resources substitute and transform the value of material resources, and yet lead to human wellbeing, sustainability, justice, and environmental conservation? There is no simple answer to this question, as I show in my research. Identity politics appears to reproduce even finer divisions based on identities. Alongside, the exit from fisheries continues and the ecological condition of the river and its biodiversity continues to decline. The apparent one-way shift from "interests to identities" (Rothman and Olson

2001) could be a final straw in the future sustenance of capture fisheries in the Gangetic plains.

With this story, I also hope that my research provides a more general understanding of how conflict narratives transform over time under the combined influences of history, ecology, and social identity. Given the limited engagement of historical, social, and ecological scholarship with riverine capture fisheries, my study contributes to filling a major vacuum. It could allow for fresh interpretations of links between agrarian distress and the emergence of new identity-based politics across India. It also identifies how resource conflicts respond in similar ways to the apparently opposite influences of conservation and development, by creating new groups and new forms of exclusion as it changes forms and frames. Cultural framing of conflict narratives is an important transition from material and economic framings, as shown by evolving theoretical understanding of social conflicts (Wieviorka 2013). Most importantly, social conflicts are deeply underpinned by history, identities, and ecological change, as my research demonstrates with detailed interdisciplinary analyses. In conclusion, these intermeshed factors cannot be viewed in isolation when discussing possible solutions to address resource conflicts, and understand their implications for social justice, human adaptation, economic development, resource sustainability, and biodiversity conservation in riverine ecosystems.

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Appendices

Table S1. Life-history traits of fish species/groups analysed in the study. Key to abbreviations and data sources are provided below the table.

Species	LHS	Spawner Type	Migration	Peak Catch Season	Peak Breeding Season	Use of Water Column	Use of river-floodplains by adults	Use of floodplain by larvae/YOY	Yield trend (2000-2018)
Notopterus notopterus	E	A	no	postmonsoon-spring	May-Jul	MID	EUP PLS	Y	decline
Chitala chitala	E	A	no	postmonsoon-summer	May-Jul	SURF	EUP	Y	fluctuations
Corica soborna	O	C	local	postmonsoon	Jul-Oct	MID	EUP	Y	decline
Gudusia chapra	O	C	local	postmonsoon-summer	Jan-Apr, Jul-Nov	SURF	EUP	N	decline
Gonialosa manmina	O	B	local	postmonsoon-summer	Apr-Aug	MID	EUP	N	decline
Tenualosa ilisha	P	C	anadromo	postmonsoon	Jan-Apr, Jul-Nov	SURF	EUP	N	decline
Setipinna brevifilis	O	D	potamo	postmonsoon-spring	all year	SURF	EUP	N	fluctuations
Gibelion catla	P	A	potamo	postmonsoon	May-Jul	SURF	EUP	Y	fluctuations
Labeo calbasu	P	A	no	postmonsoon-summer	Jul-Aug	MID	EUP PLS	Y	fluctuations
Labeo gonius	P	A	no	postmonsoon	Jun-Aug	MID	PAR PLS	Y	decline
Labeo rohita	P	A	potamo	postmonsoon-spring	Jul-Aug	MID	EUP	Y	decline
Cirrhinus mrigala	P	A	potamo	postmonsoon-summer	Jun-Aug	BOT	EUP	Y	fluctuations
Bangana ariza	O	C	local	postmonsoon	Jun-Sep	MID	EUP	Y	increase
Systomus sarana	P	A	local	postmonsoon-spring	Apr-Aug	MID	PLS	Y	fluctuations
Crossocheilus latius	O	A	coldwater	postmonsoon	Oct-Jan	BOT	EUP PLS	N	increase

Osteobrama cotio	O	A	local	postmonsoon-spring	Jul-Sep	SURF	EUP	Y	decline
Puntius conchonius	P	B	no	postmonsoon-summer	Apr-Aug	MID	PLS	Y	fluctuations
Puntius sophore	P	B	no	postmonsoon-summer	Apr-Aug	MID	PLS	Y	fluctuations
Amblypharyngodon mola	P	C	no	postmonsoon-summer	Apr-Nov	MID	EUP PLS	Y	fluctuations
Cabdio morar	O	D	local	postmonsoon-summer	all year	MID	EUP	Y	increase
Salmostoma sp.	P	B	local	postmonsoon	Jun-Sep	SURF	EUP	Y	decline
Securicula gora	P	A	local	postmonsoon	Jul-Sep	SURF	EUP	N	decline
Botia sp.	P	C	coldwater	monsoon	Jun-Aug	BOT	PAR PLS	N	decline
Lepidocephalichthys guntea	P	C	coldwater	monsoon	Jun-Aug	BOT	PAR PLS	N	decline
Hemibagrus menoda	P	A	local	postmonsoon-spring	Apr-Aug	BOT	PAR PLS	Y	decline
Mystus cavasius	O	B	no	postmonsoon-spring	Apr-Jul	BOT	PLS	N	fluctuations
Mystus tengra	O	B	no	postmonsoon-spring	Apr-Aug	BOT	PLS	N	fluctuations
Mystus vittatus	O	B	no	pre-monsoon	Apr-Aug	BOT	PLS	N	fluctuations
Sperata aor	P	B	no	postmonsoon-summer	Apr-Jul	BOT	EUP	Y	fluctuations
Sperata seenghala	P	B	no	postmonsoon-summer	Apr-Jul	BOT	EUP	Y	fluctuations
Rita rita	P	B	no	premonsoon	Jun-Aug	BOT	EUP PLS	N	fluctuations
Ailia coila	P	A	local	postmonsoon-spring	Jun-Sep	SURF	EUP	N	fluctuations
Clupisoma garua	P	A	no	postmonsoon-spring	Mar-Jul	MID	EUP	N	increase
Eutropichthys vacha	P	B	no	postmonsoon-spring	Jun-Aug	MID	EUP	Y	decline
Pachypterus atherinoides	O	A	no	postmonsoon-	May-Aug	BOT	PLS	Y	fluctuations

				spring					
Ompok sp.	P	A	no	postmonsoon	May-Aug	MID	EUP PLS	Y	fluctuations
Wallago attu	P	A	local	postmonsoon-spring	May-Aug	SURF	EUP	Y	fluctuations
Bagarius yarrellii	P	B	potamo	spring	Apr-Jul	BOT	EUP	N	fluctuations
Gogangra viridescens	P	B	potamo	postmonsoon-spring	Jun-Aug	MID	EUP PLS	N	fluctuations
Pangasius pangasius	P	A	potamo	postmonsoon	Mar-Aug	SURF	EUP	N	decline
Heteropneustes fossilis	P	B	no	monsoon	Jul-Oct	BOT	PLS	Y	decline
Johnius coitor	P	B	potamo	postmonsoon-summer	Mar-Jun	MID	EUP	N	decline
Johnius gangeticus	P	B	potamo	postmonsoon	Jun-Sep	MID	EUP	N	decline
Chanda nama	O	D	no	postmonsoon	Mar-Oct	MID	EUP PLS	Y	fluctuations
Parambassis ranga	O	D	no	postmonsoon	Mar-Oct	MID	EUP PLS	Y	fluctuations
Xenentodon cancila	P	A	potamo	postmonsoon-summer	Jun-Sep	MID	EUP	N	decline
Glossogobius giuris	O	C	no	spring_postmonsoon	Mar-Oct	BOT	EUP PLS	N	increase
Channa punctata	E	C	no	postmonsoon	Oct-Jan	SURF	PAR PLS	Y	decline
Channa marulius	E	C	no	postmonsoon	Apr-Oct	SURF	PAR PLS	Y	fluctuations
Channa striata	E	C	no	premonsoon	Apr-Sep	MID	PAR PLS	Y	fluctuations
Mastacembelus armatus	E	A	no	postmonsoon-summer	May-Aug	MID	EUP PLS	N	decline
Macrognathus pancalus	E	A	no	postmonsoon-summer	May-Jul	MID	EUP PLS	N	fluctuations
Macrognathus aral	E	A	no	postmonsoon	Jul-Sep	MID	EUP PLS	N	decline
Rhinomugil corsula	P	A	no	postmonsoon-spring	Jul-Sep	SURF	EUP	N	fluctuations
Sicamugil cascasia	O	C	no	postmonsoon-summer	Jul-Sep	SURF	EUP	N	fluctuations
Tetraodon cutcutia	P	NA	potamo	monsoon	Jul-Sep	BOT	PAR PLS	N	decline

Penaeus sp.	P	C	local	postmonsoon	all year	BOT	EUP PLS	N	decline
Macrobrachium sp.	P	A	potamo	postmonsoon-summer	May-Oct	BOT	EUP PLS	N	decline

Key: LHS: Life-history strategies, classified as E=Equilibrium, O=Opportunistic, P=Periodic (based on Welcomme *et al.* 2005, Winemiller *et al.* 2003); Spawner type: A=Single, well-defined spawning peak per year, B=Single, but prolonged spawning peak per year, C=two spawning peaks per year, D=year-round breeders with no clear spawning peaks (based on Prabhu 1956, and Qasim and Qayyum 1959); Migration: no=resident non-migrant, local=local movements only, potamo=potamodromous, anadromo=anadromous, coldwater=migrating from colder tributary waters into the Ganga River; Peak Catch Season: post-monsoon is defined as October to December, spring as February-March, summer as March-May, pre-monsoon as May-June, monsoon as June-September (from Dey *et al.* 2020, personal observations); Peak Breeding Season months are as per Qasim and Qayyum 1959, Dey *et al.* 2020, and others in Appendix S6); Use of Water Column: BOT=bottom, MID=mid-column, SURF=surface; Use of river-floodplain by adults: EUP=Eupotamonic, PAR=Parapotamonic, PLS=Plesiopotamonic (based on Welcomme *et al.* 2005); Use of floodplain by larvae: YOY=Young-of-Year, Y=Yes, N=No; Yield trend: decline and increase are understood as monotonic declines or increases, fluctuations refer to erratic, seasonally cyclic, or unpredictable catches with no clear trend.

Table S2. Length (L∞ (infinite length), Lmat (length at maturity), weight (W∞) data, and length-weight regression parameters **a** and **b** for fish species were compiled from diverse data sources (see Appendix S6). Optimal length (Lopt) and mega-spawner length (Lmega) were estimated as per Froese (2004), from which % mature, % optimal, and % mega-spawners were derived from all recorded catches. Lengths at first capture were obtained from catch data.

Species	L∞ (cm)	a	b	W∞ (kg)	Lmat (cm)	Lopt (cm)	Lmega (cm)	Length at first capture (cm)	% mature	% optimal	% mega-spawners
Notopterus notopterus	62.2	0.00617	3.05	1.83	24.1	41.47	45.61	7.5	0.08	0.05	0.01
Chitala chitala	125	0.035	2.61	10.4	75	83.33	91.67	9.5	0.18	0.04	0.08
Corica soborna	4.4	0.00759	3.02	0	3.2	3.2	3.52	3.5	0.53	0.28	0.24
Gudusia chapra	14	0.0118	3	0.03	9	13.5	14.84	7	0.3	0.03	0.03
Gonialosa manmina	14	0.0118	3	0.03	9	13.5	14.84	7	0.3	0.03	0.03
Tenualosa ilisha	44.7	0.00977	3.01	0.91	25.3	27.86	30.65	9	0.05	0.02	0.02
Setipinna brevifilis	27	0.004	3	0.08	16.3	18	19.2	10	0.06	0.03	0.03
Gibelion catla	115	0.009	3.06	18.2	52	76.65	84.3	7	0.13	0.01	0.13
Labeo calbasu	103	0.01175	3.03	14.76	33	51	56.2	7.5	0.38	0.08	0.28
Labeo gonius	153.3	0.00513	3.1	30.57	76	86.23	94.85	15	0.02	0.01	0
Labeo rohita	102	0.00977	3.02	11.37	55	64.91	71.4	7.5	0.15	0.02	0.13
Cirrhinus mrigala	102	0.0072	3.22	21.14	55	68	74.8	9	0.12	0.05	0.06
Bangana ariza	31.5	0.00933	3.03	0.32	18.5	21	23.1	8	0.03	0.01	0.02
Systomus sarana	26	0.01096	3.01	0.2	15.6	14.72	16.19	4.5	0.24	0.05	0.17
Crossocheilus latius	16.1	0.00741	3.1	0.04	10.1	9.09	10	8	0.17	0.13	0.04
Osteobrama cotio	15.2	0.00955	3.01	0.03	10	8.69	9.56	7	0.18	0.17	0.01
Puntius conchonius	14	0.0105	2.95	0.03	9.4	11.6	12.8	6.5	0.2	0.18	0.01
Puntius sophore	14	0.0105	2.95	0.03	9.4	11.6	12.8	6.5	0.2	0.18	0.01
Amblypharyngodon mola	21.1	0.00851	3.18	0.14	12.9	14.07	15.47	4.5	0.2	0	0

Cabdio morar	21	0.0068	3.1	0.09	12.5	16.1	17.75	4.5	0.13	0	0
Salmostoma sp.	19	0.006	3.08	0.05	10	10.67	11.74	7.5	0.04	0.04	0
Securicula gora	25.8	0.00741	3.06	0.16	15.5	14.54	16	15	0.45	0.34	0.11
Botia sp.	8.4	0.01	3.04	0.01	5.6	5.42	5.96	4.5	0.67	0.62	0.05
Lepidocephalichthys guntea	15.4	0.00661	3.11	0.03	9.7	10.27	11.29	4.5	0.67	0.62	0.05
Hemibagrus menoda	46.9	0.00794	2.95	0.68	26.5	26.66	29.32	18	0.48	0.12	0.35
Mystus cavasius	32	0.00933	2.98	0.29	23.8	21.33	23.47	8	0.06	0.02	0.02
Mystus tengra	19	0.01122	2.99	0.08	11.8	12.67	13.93	4.5	0.41	0.38	0.02
Mystus vittatus	22	0.0138	2.95	0.13	13.5	14.67	16.13	6	0.05	0.02	0.02
Sperata aor	168	0.006	2.97	24.4	73	112	123.2	12	0.21	0.18	0
Sperata seenghala	168	0.006	2.97	24.4	73	112	123.2	12	0.17	0.07	0.02
Rita rita	85	0.01023	3.02	6.87	30	56.67	62.33	20	0.48	0.15	0.07
Ailia coila	31	0.0068	3	0.2	18.5	20.65	22.7	4.5	0.01	0	0
Clupisoma garua	63.1	0.00631	3.05	1.95	34.5	42.07	46.27	10	0.15	0	0.01
Eutropichthys vacha	40	0.006	3	0.38	25	33.7	37.08	7	0.06	0.02	0.01
Pachypterus atherinoides	16	0.0063	3	0.03	8.25	13.75	15.13	6.5	0.04	0	0
Ompok sp.	31	0.006	3	0.18	17.5	25.5	28.05	7.5	0.04	0.02	0
Wallago attu	243	0.0065	2.9	53.85	85	162	178.2	7.5	0.02	0	0
Bagarius yarrelli	250	0.00417	3.11	119.6	100	166.67	183.33	115	0.83	0.19	0.26
Gogangra viridescens	9.1	0.0065	3.1	0.01	6.1	4.71	5.18	5	0.78	0.73	0.04
Pangasius pangasius	283	0.00933	2.98	188.89	120	188.67	207.53	100	0.35	0.15	0.07
Heteropneustes fossilis	28	0.00389	3.12	0.13	16.7	18.39	20.23	4.5	0.01	0.01	0
Johnius coitor	16.9	0.00955	3.06	0.06	10.6	11.27	12.39	10	0.2	0.08	0.02
Johnius gangeticus	12.8	0.01	3.02	0.02	8.2	8.53	9.39	10	0.2	0.08	0.02
Chanda nama	10	0.0186	3	0.02	3.1	6.6	7.3	3	0.7	0.28	0.42
Parambassis ranga	10	0.0186	3	0.02	3.1	6.6	7.3	3	0.7	0.28	0.42

Xenentodon cancila	41.7	0.001	3.15	0.13	23.8	25.49	28.04	7.5	0.04	0	0
Glossogobius giuris	29.5	0.00851	3.06	0.27	17.5	17.91	19.7	10	0.04	0.01	0.01
Channa punctata	28	0.01047	2.98	0.22	16.7	18.67	20.53	4.5	0.08	0.04	0
Channa marulius	185	0.0076	2.98	43.35	58	116.05	127.65	6	0.16	0.03	0.01
Channa striata	56.5	0.00955	2.97	1.53	31.3	35.6	39.15	4.5	0.43	0.05	0.03
Mastacembelus armatus	92.7	0.00407	2.86	1.72	48.8	61.8	67.98	7.5	0.05	0.02	0
Macrognathus pancalus	26	0.00417	3.01	0.08	11.5	16.18	17.79	5	0.04	0.02	0
Macrognathus aral	65.8	0.00282	2.96	0.68	35.9	39.8	43.78	5	0.02	0	0
Rhinomugil corsula	47	0.0102	3	1.06	26.5	40.5	44.5	8.5	0.05	0	0
Sicamugil cascasia	11	0.0115	3	0.02	7	10.2	11.25	6.5	0.25	0.1	0
Tetraodon cutcutia	15.9	0.02692	2.88	0.08	10	9.61	10.57	4.5	0.23	0.14	0.09
***Penaeus* sp.**	22.2	0.006	3.09	0.09	14	14.64	16.1	6.5	0.01	0	0
***Macrobrachium* sp.**	20.3	0.11	3.2	1.68	8	11.3	12.45	6	0.4	0.05	0.12

Table S3. Egg diameter, absolute and relative fecundity values, and K (proxy for growth) obtained from data sources listed in Appendix S6.

Species	Egg diameter (mm)	Absolute Fecundity (min.)	Absolute Fecundity (max.)	Maximum relative fecundity (ova/g)	K (/year)
Notopterus notopterus	1.05	200	2400	0.71	0.22
Chitala chitala	3.5	10000	20000	1.44	0.21
Corica soborna	0.26	400	3240	1820	2.77
Gudusia chapra	0.3	30000	50000	1250	1.19
Gonialosa manmina	0.48	30000	50000	1250	1.23
Tenualosa ilisha	0.65	40000	1325500	753.59	0.64
Setipinna brevifilis	1.2	4000	50000	341.77	0.41
Gibelion catla	2.3	2500000	4500000	192.35	0.32
Labeo calbasu	1.18	450000	800000	42.36	0.15
Labeo gonius	1.12	9000	230000	3.91	0.06
Labeo rohita	1.06	55000	3500000	156.29	0.28
Cirrhinus mrigala	1.1	1500000	2500000	94.625	0.09
Bangana ariza	0.7	200000	250000	696.59	0.21
Systomus sarana	0.8	10000	225000	590.45	0.4
Crossocheilus latius	0.7	1500	8500	121.95	0.48
Osteobrama cotio	0.65	3000	6000	132.35	0.49
Puntius conchonius	0.81	5000	8000	260	1
Puntius sophore	0.85	5000	8000	260	1
Amblypharyngodon mola	0.81	1200	18000	69.565	0.38
Cabdio morar	0.96	1800	20000	128.235	0.35
Salmostoma sp.	0.65	10000	30000	384.615	0.41
Securicula gora	0.58	15000	30000	145.161	0.31
Botia sp.	0.51	5200	55000	1225	0.6
Lepidocephalichthys guntea	0.81	4500	10000	219.69	0.84

Hemibagrus menoda	1.1	22000	230000	186.39	0.18
Mystus cavasius	0.6	10000	40000	87.719	0.18
Mystus tengra	0.43	10000	25000	233.33	0.63
Mystus vittatus	0.55	10000	40000	198.41	0.31
Sperata aor	1.15	130000	450000	11.89	0.055
Sperata seenghala	1.1	130000	450000	11.89	0.055
Rita rita	1.7	45000	125000	2.14	0.06
Ailia coila	0.6	600	1400	4.93	0.32
Clupisoma garua	1.87	15000	40000	14.10	0.14
Eutropichthys vacha	0.62	150000	250000	520.83	0.25
Pachypterus atherinoides	0.89	2000	3000	96.15	0.6
Ompok sp.	0.8	2000	20000	61.45	0.31
Wallago attu	1.55	65000	450000	4.78	0.05
Bagarius yarrellii	1.23	1000000	2800000	15.88	0.02
Gogangra viridescens	NA	200	1800	166.67	0.4
Pangasius pangasius	1.21	70000	155000	0.596	0.21
Heteropneustes fossilis	0.99	1300	47000	190.157	1.11
Johnius coitor	0.54	20000	240000	2363.64	0.84
Johnius gangeticus	0.58	20000	240000	5909.09	1.1
Chanda nama	0.45	2500	5000	197.37	1.1
Parambassis ranga	0.45	2500	5000	197.37	1.1
Xenentodon cancila	1.4	140	200	1.34	0.43
Glossogobius giuris	0.52	9000	18000	50.37	0.69
Channa punctata	0.7	3000	26000	67.44	0.9
Channa marulius	0.9	2000	40000	0.48	0.23
Channa striata	0.8	3000	30000	10.81	0.42
Mastacembelus armatus	1.5	900	7500	2.44	0.42

Macrognathus pancalus	0.7	800	1200	13.16	0.9
Macrognathus aral	0.7	500	1000	1.103	0.25
Rhinomugil corsula	0.9	9000	17000	12.276	0.22
Sicamugil cascasia	0.4	6000	10000	533.33	0.88
Tetraodon cutcutia	NA	450	1600	13.14	1.05
Penaeus sp.	0.2	45000	400000	2557.47	2
Macrobrachium sp.	0.45	40000	90000	38.69	0.63

Table S4. Proportional catch-at-age data from cross-section data averaged across years from 2000-01 to 2017-18. Maximum ages and age-at-maturity were estimated from age-length relationships based on von Bertalanffy models (see Figure S5.2).

Species	**Estimated age at maturity (yr)**	**age0+**	**age1+**	**age2+**	**age3+**	**age4+**	**age5+**
Notopterus notopterus	2.228	0.92	0.035	0.0135	0.02	0.0115	NA
Chitala chitala	4.363	0.81	0.03	0.08	0.07	0.01	NA
Corica soborna	0.469	0.95	0.049	0.001	NA	NA	NA
Gudusia chapra	0.865	0.205	0.76	0.03	NA	NA	NA
Gonialosa manmina	0.837	0.205	0.76	0.03	NA	NA	NA
Tenualosa ilisha	1.304	NA	NA	NA	NA	NA	NA
Setipinna brevifilis	2.258	0.71	0.23	0.055	0.005	NA	NA
Gibelion catla	1.881	0.836	0.031	0.002	0.007	0.065	0.059
Labeo calbasu	2.575	0.53	0.15	0.08	0.18	0.045	0.015
Labeo gonius	11.412	0.925	0.05	0.02	0.005	NA	NA
Labeo rohita	2.767	0.83	0.02	0.025	0.07	0.05	0.005
Cirrhinus mrigala	8.609	0.766	0.1034	0.1	0.02	NA	NA
Bangana ariza	4.214	0.965	0.016	0.0155	0.0035	NA	NA
Systomus sarana	2.291	0.76	0.05	0.1	0.086	0.004	NA
Crossocheilus latius	2.056	NA	NA	NA	NA	NA	NA
Osteobrama cotio	2.189	0.13	0.685	0.17	0.012	NA	NA
Puntius conchonius	1.113	0.5	0.48	0.02	NA	NA	NA
Puntius sophore	1.113	0.5	0.48	0.02	NA	NA	NA
Amblypharyngodon mola	2.487	0.95	0.05	NA	NA	NA	NA
Cabdio morar	2.584	0.32	0.5	0.14	0.029	NA	NA
Salmostoma sp.	1.822	0.95	0.0446	0.001	0.0024	NA	NA
Securicula gora	2.962	NA	NA	NA	NA	NA	NA

Botia sp.	1.831	0.35	0.33	0.31	0.005	NA	NA
Lepidocephalichthys guntea	1.325	0.35	0.45	0.19	0.01	NA	NA
Hemibagrus menoda	4.625	NA	NA	NA	NA	NA	NA
Mystus cavasius	7.564	0.45	0.48	0.03	0.015	0.01	0.015
Mystus tengra	1.54	0.508	0.112	0.33	0.05	NA	NA
Mystus vittatus	3.068	0.63	0.06	0.29	0.02	NA	NA
Sperata aor	10.365	0.475	0.31	0.0263	0.08	0.08	0.0003
Sperata seenghala	10.365	0.443	0.38	0.065	0.033	0.033	0.015
Rita rita	7.255	0.45	0.06	0.04	0.05	0.08	0.32
Ailia coila	2.838	0.875	0.11	0.002	0.002	0.0002	NA
Clupisoma garua	5.652	0.67	0.18	0.11	0.02	0.015	0.005
Eutropichthys vacha	3.923	0.85	0.119	0.003	0.0017	0.0017	NA
Pachypterus atherinoides	1.208	0.84	0.114	0.03	0.015	NA	NA
Ompok sp.	2.682	0.907	0.04	0.013	0.017	NA	NA
Wallago attu	8.609	0.917	0.0315	0.02	0.02	0.01	NA
Bagarius yarrellii	25.541	0.06	0.05	0.015	0.002	0.05	0.823
Gogangra viridescens	2.774	0.28	0.25	0.22	0.22	0.03	NA
Pangasius pangasius	2.627	0.21	0.16	0.14	0.12	0.24	0.13
Heteropneustes fossilis	0.817	0.49	0.5	0.008	0.0001	NA	NA
Johnius coitor	1.175	0.45	0.51	0.02	0.014	0.006	NA
Johnius gangeticus	0.93	0.45	0.51	0.02	0.014	0.006	NA
Chanda nama	0.337	0.95	0.039	0.011	NA	NA	NA
Parambassis ranga	0.337	0.95	0.039	0.011	NA	NA	NA
Xenentodon cancila	1.967	NA	NA	NA	NA	NA	NA
Glossogobius giuris	1.304	0.975	0.0095	0.0083	0.0055	0.00099	NA

Channa punctata	0.907	0.92	0.05	0.025	0.005	NA	NA
Channa marulius	1.636	0.74	0.12	0.05	0.045	0.03	0.015
Channa striata	1.922	0.56	0.36	0.05	0.02	0.01	NA
Mastacembelus armatus	1.78	0.74	0.24	0.005	0.007	0.008	NA
Macrognathus pancalus	0.649	0.96	0.025	0.01	0.005	NA	NA
Macrognathus aral	3.155	0.97	0.02	0.01	NA	NA	NA
Rhinomugil corsula	3.771	0.45	0.497	0.04	0.01	0.003	NA
Sicamugil cascasia	1.15	0.795	0.147	0.05	NA	NA	NA
Tetraodon cutcutia	0.944	0.56	0.35	0.09	NA	NA	NA
Penaeus sp.	0.498	0.99	0.0004	0.0008	NA	NA	NA
Macrobrachium sp.	0.795	0.865	0.09	0.04	NA	NA	NA

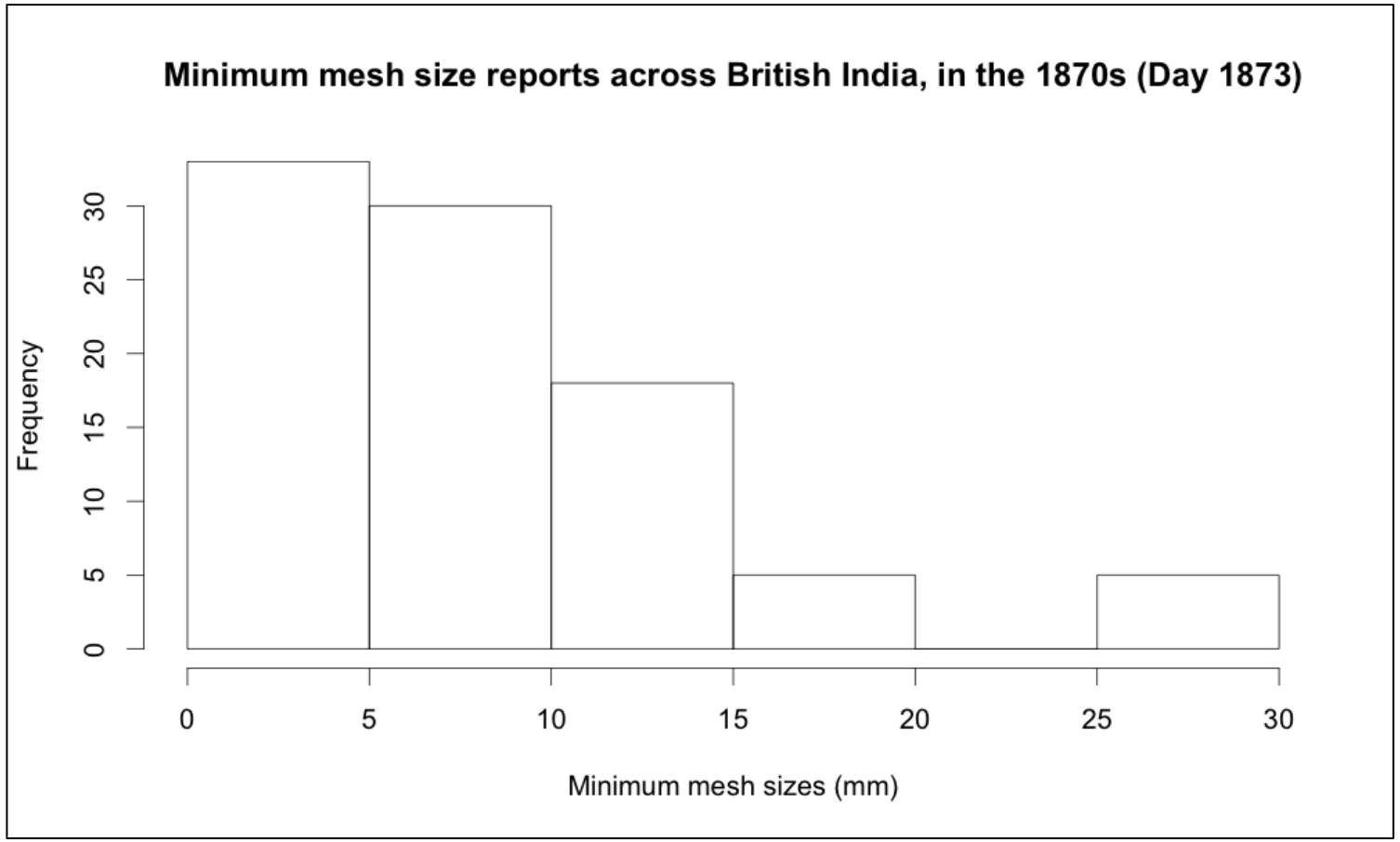
Table S5. Estimates of total mortality (Z) derived from catch-at-age data, natural mortality (M) estimated empirically using an averaged estimate from Alverson and Carney (1975), Pauly (1980), Hoenig (1983), Gunderson and Dygert (1988), and Jensen (1996), as per data availability, and fishing mortality (F) calculated as F = Z-M. Mortality estimates were used to explore the relative impacts of environmental variability and fishing impacts on different fish species. Fmsy (fishing mortality at maximum sustainable yield) and catchability (q) estimates were obtained from time-varying (dynamic) surplus production models in the library TropFishR of R software. The β (H) parameter denotes the coefficient to determine hyperstability in the catch per effort-yield relationship (estimates of β (H) significantly less than 0.5 were taken to indicate particularly strong hyperstability; see Erisman *et al.* 2011, Alós *et al.* 2019).

Species	**Z**	**M**	**F**	**Fmsy**	**q**	**β (H)**
Notopterus notopterus	0.99	0.68	0.31	NA	NA	NA
Chitala chitala	0.64	0.41	0.23	0.2	0.0003	0.44
Corica soborna	3.45	2.71	0.74	NA	NA	NA
Gudusia chapra	3.27	1.99	1.28	0.5	0.0006	0.63
Gonialosa manmina	3.27	1.99	1.28	0.5	0.0006	0.63
Tenualosa ilisha	NA	NA	NA	NA	NA	NA
Setipinna brevifilis	1.75	1.04	0.72	0.63	0.002	0.58
Gibelion catla	1.71	0.62	1.09	1.32	0.005	0.84
Labeo calbasu	0.48	0.35	0.13	0.32	0.005	0.646
Labeo gonius	1.92	1.08	0.84	NA	NA	NA
Labeo rohita	1.75	0.61	1.14	0.24	0.0176	0.97
Cirrhinus mrigala	1.23	0.66	0.57	0.5	0.01	0.704
Bangana ariza	2.07	0.84	1.23	1.13	0.016	0.796
Systomus sarana	1.01	0.92	0.09	0.24	0.015	0.55
Crossocheilus latius	NA	NA	NA	0.49	0.003	0.48
Osteobrama cotio	2.14	1.18	0.97	0.25	0.015	0.717

Puntius conchonius	3.22	1.82	1.4	0.5	0.011	0.76
Puntius sophore	3.22	1.82	1.4	0.5	0.011	0.76
Amblypharyngodon mola	NA	NA	NA	NA	NA	NA
Cabdio morar	1.2	1	0.2	0.21	0.0003	0.707
Salmostoma sp.	2.84	1.1	1.74	1.3	0.02	0.88
Securicula gora	NA	NA	NA	NA	NA	NA
Botia sp.	1.66	1.44	0.22	NA	NA	NA
Lepidocephalichthys guntea	1.5	1.23	0.27	NA	NA	NA
Hemibagrus menoda	NA	NA	NA	0.45	0.04	0.81
Mystus cavasius	0.88	0.62	0.26	0.3	0.0013	0.54
Mystus tengra	2.03	1.28	0.75	0.3	0.0013	0.54
Mystus vittatus	1.19	0.99	0.19	0.3	0.0013	0.54
Sperata aor	1.45	0.43	1.02	0.27	0.0036	0.56
Sperata seenghala	0.76	0.43	0.33	0.16	0.0036	0.56
Rita rita	1.21	0.45	0.76	0.28	0.0015	0.465
Ailia coila	2.23	1.02	1.21	0.15	0.003	0.71
Clupisoma garua	0.98	0.55	0.43	0.29	0.0008	0.57
Eutropichthys vacha	2.23	0.91	1.32	0.5	0.002	0.64
Pachypterus atherinoides	1.39	1.13	0.26	0.45	0.014	0.79
Ompok sp.	2.12	1.05	1.07	0.68	0.011	0.48
Wallago attu	1.19	0.49	0.7	1.27	0.09	0.36
Bagarius yarrellii	1.14	0.29	0.85	0.29	0.0022	0.925
Gogangra viridescens	0.81	0.8	0.01	0.43	0.0186	NA
Pangasius pangasius	0.41	0.36	0.05	NA	NA	NA
Heteropneustes fossilis	4.27	1.46	2.81	NA	NA	NA
Johnius coitor	1.35	0.9	0.45	0.16	0.0017	0.43

Johnius gangeticus	1.35	0.9	0.45	0.16	0.0017	0.43
Chanda nama	2.25	2	0.25	NA	NA	NA
Parambassis ranga	2.25	2	0.25	NA	NA	NA
Xenentodon cancila	NA	NA	NA	NA	NA	NA
Glossogobius giuris	1.52	1.1	0.42	0.42	0.052	0.88
Channa punctata	1.69	1.43	0.26	NA	NA	0.53
Channa marulius	0.76	0.55	0.19	NA	NA	0.53
Channa striata	1.19	0.83	0.37	NA	NA	0.53
Mastacembelus armatus	1.52	0.81	0.71	0.48	0.008	0.43
Macrognathus pancalus	1.69	1.39	0.3	0.26	0.034	0.607
Macrognathus aral	2.3	1.05	1.25	0.26	0.034	0.607
Rhinomugil corsula	1.54	0.7	0.84	0.67	0.0075	0.78
Sicamugil cascasia	1.62	1.6	NA	2	0.03	0.97
Tetraodon cutcutia	1.82	1.82	NA	NA	NA	NA
Penaeus sp.	7.81	2.85	4.96	NA	NA	NA
Macrobrachium sp.	2.26	1.55	0.71	NA	NA	NA

Figure S1. Minimum mesh size reports from 91 measurements compiled by Francis Day from official reports of 12 provinces in the 1870s. Nets with mesh sizes <5 mm were historically used to capture small fish in the Gangetic plains, but have become central to gear-use conflicts in recent times.



Appendix S6. Compilation of references on sources on fish biology and life-history trait data.

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Family Danionidae (subfamily Chedrinae)

Salmostoma bacaila Hamilton 1822, *Salmostoma phulo* Hamilton 1822 *(Chelwa)*

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Cabdio morar Hamilton 1822 *(Pihora, Harda, Matiya, Gaindhla Pihor)*

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Securicula gora Hamilton 1822 (*Ghorchelwa / Hasta*)

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Family Danionidae (subfamily Rasborinae)
Amblypharyngodon mola Hamilton 1822 *(Marwa)*

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Family Cyprinidae (subfamily Labeoninae)

Crossocheilus (=Tariqilabeo) latius Hamilton 1822 *(Gahuma)*

86. Singh Patiyal, R., & Iqbal Mir, J. (2017). Length–weight relationships of 21 fish species from the upland Ganga River Basin tributaries of Central Indian Himalaya. *Journal of Applied Ichthyology*, 33.4, 861-863.

Labeo calbasu Hamilton 1822 *(Kalbous)*

87. Dey, S., Srivastava, P. K., Maji, S., Das, M. K., Mukhopadhyay, M. K., & Saha, P. K. (2007). Impact of climate change on the breeding of Indian major carps in West Bengal. *Journal of Inland Fisheries Society of India*, 39, 26–34.
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Gibelion (=Labeo) catla Hamilton 1822 *(Katla)*

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Labeo rohita Hamilton 1822 *(Rehu)*

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Labeo gonius Hamilton 1822 *(Kursa)*

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Cirrhinus mrigala Hamilton 1822 *(Mirka)*

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Bangana (=Gymnostomus) ariza Hamilton 1807 *(Bata)*

136. Ahammad, AK. S., Ahmed, M. B. A., Akhter, S., & Hossain, M. K. (2018). Landmark-based morphometric and meristic analysis in response to characterize the wild bhagna, *Labeo Ariza* populations for its conservation. *Journal of the Bangladesh Agricultural University*, 16, 164-170. doi:10.3329/jbau.v16i1.36498.
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Chagunius chagunio Hamilton 1822 *(Bhegnotani, Bhori Bata)*

138. Singh Patiyal, R., & Iqbal Mir, J. (2017). Length–weight relationships of 21 fish species from the upland Ganga River Basin tributaries of Central Indian Himalaya. *Journal of Applied Ichthyology*, 33.4, 861-863.

Family Cyprinidae (subfamily Smiliogastrinae)

Systomus sarana Hamilton 1822 *(Darhi)*

139. Deori, D. J., Abujam, S., Dakua, S., & Laishram, S. (2017). Investigation on feeding, growth and condition factor of certain ornamental fish from Brahmaputra River at Dibrugarh, Assam, India. *Journal of Fisheries Sciences*, 11, 43–47.
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Puntius sophore Hamilton 1822 *(Lamba Pothia), P. ticto* Hamilton 1822 *(Pothia)*

145. Deori, D. J., Abujam, S., Dakua, S., & Laishram, S. (2017). Investigation on feeding, growth and condition factor of certain ornamental fish from

Brahmaputra River at Dibrugarh, Assam, India. *Journal of Fisheries Sciences*, 11, 43–47.

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Pethia conchonius Hamilton 1822 *(Gol Pothia)*

153. Hossain, M. Y., Sayed, S. R. M., Rahman, M. M., Ali, M. M., Hossen, M. A., Elgorban, A. M., Ahmed, Z. F. and Ohtomi, J. (2015). Length-weight

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Osteobrama cotio Hamilton 1822 *(Gurdha, Pithari)*

156. Deori, D. J., Abujam, S., Dakua, S., & Laishram, S. (2017). Investigation on feeding, growth and condition factor of certain ornamental fish from Brahmaputra River at Dibrugarh, Assam, India. *Journal of Fisheries Sciences*, 11, 43–47.
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Family Bagridae

Sperata aor Hamilton 1822 *(Natta Aria)*

160. Dubey, B. V. K., Sarkar, U. K., Kumar, R. S., Mir, J. I., Pandey, A., & Lakra, W. S. (2012). Length–weight relationships (LWRs) of 12 Indian freshwater fish species from an un-impacted tropical river of Central India (River Ken). *Journal of Applied Ichthyology*, 28, 854–856.

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Sperata seenghala Sykes 1839 *(Tagwa Aria / Tengri)*

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Family Sisoridae

Bagarius yarrelli Sykes 1839 *(Baghar)*

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Gogangra viridescens Hamilton 1822 *(Hadda, Jhanki)*

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Family Pangasiidae

Pangasius pangasius Hamilton 1822 *(Pangaas)*

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Family Siluridae

Wallago attu Bloch & Schneider 1801 *(Buari, Boali, Barari)*

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Ompok spp. (Popta): *Ompok pabda* Hamilton 1822, *O. pabo* Hamilton 1822, *O. bimaculatus* Bloch 1794)

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Family Heteropneustidae

Heteropneustes fossilis Bloch 1794 *(Singhi)*

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Family Ailiidae

Clupisoma garua Hamilton 1822 *(Bachwa, Gehrua Bachwa)*

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Silonia silondia Hamilton 1822 *(Siland)*

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Ailia coila Hamilton 1822 *(Sutri)*

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Family Horabagridae

Pachypterus atherinoides Bloch 1794 *(Patasi)*

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Family Belonidae

Xenentodon cancila Hamilton 1822 *(Kawwalol)*

253. Borthakur, M. K. (2018). Study of gonadosomatic index and fecundity of fresh water fish Xenentodon cancila. *Journal of Entomology and Zoology Studies*, **6**, 42–46.

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Family Synbranchidae

Monopterus cuchia Hamilton 1822 *(Bamach)*

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Family Mastacembelidae

Mastacembelus armatus Lacepede 1800 *(Bami)*

257. Afzal Khan, M., Khan, S., & Miyan, K. (2012). Studies on length-weight and length-length relationships of four freshwater fishes collected from River Ganga. *Journal of Fisheries and Auatic Sciences*, 7, 481–484.
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Macrognathus pancalus Hamilton 1822 *(Peela Gainchi, Hara Gainchi)*

264. Pathak, B. C., Mir, J. I., & Serajuddin, M. (2013). Morphometric variation among barred spiny eel *Macrognathus pancalus* (Hamilton, 1822) populations

from the Ganges and Brahmaputra river basins, India by using geomorphometrics. *Journal of Biology*, 3, 15–20.

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Macrognathus aral Bloch & Schneider 1801 *(Peela Gainchi, Hara Gainchi)*

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Family Mugilidae

Rhinomugil corsula Hamilton 1822 *(Arwari/ Harwari)*

269. Akter, H., Islam, M. R., & Hossain, M. B. (2012). Fecundity and Gonadosomatic Index (GSI) of Corsula, *Rhinomugil corsula* Hamilton, 1822 (Family: Mugilidae) from the Lower Meghna River Estuary, Bangladesh. *Global Veterinaria*, 9, 129–132.
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Mugilidae) fish *Rhinomugil corsula* (Hamilton, 1822) in the Ganges, northwestern Bangladesh. *Journal of Coastal Life Medicine*, 1, 253–258.

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Sicamugil (=Minimugil) cascasia Hamilton 1822 *(Khaksi)*

276. Ojha, J., & Mishra, A. K. (1993). Interspecific variations in the functional organization, dimensions and scaling of gills in relation to body weight of the Gangetic Mullets, *Rhinomugil corsula* (Ham.) and *Sicamugil cascasia* (Ham.) (Mugilidae, Mugiliformes). *Proceedings of the National Academy of Sciences India*, 59, 567–580.
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Family Ambassidae

Chanda nama Hamilton 1822 *(Gol Chanda), Parambassis ranga* Hamilton 1822 *(Lamba Chanda),* etc.

278. Baitha, R., Sinha, A., Koushlesh, S. K., Chanu, T. N., Kumari, K., Gogoi, P., Ramteke, M. H., Borah, S., & Das, B. K. (2018). Length-weight relationship of ten indigenous freshwater fish species from Gandak River, Bihar, India. *Journal of Applied Ichthyology*, 34, 233–236.
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Family Sciaenidae

Johnius coitor Hamilton 1822, *Johnius gangeticus* Talwar 1991 *(Bholwa/ Pattharchatti)*

286. Sarkar, U. K., Naskar, M., Roy, K., Sudheesan, D., Gupta, S., Bose, A. K., Srivastava, P. K., Nandy, S. K., Verma, V. K., Sarkar, S. D., Karnatak, G., Cabral, H. (2018). Baseline information of reproduction parameters of an amphidromous croaker *Johnius coitor* (Hamilton, 1822) from Ganga river basin, India with special reference to potential influence of climatic variability. *Aquatic Living Resources*, 31, 4.

Family Nandidae

Nandus nandus Hamilton 1822 *(Dhalo)*

287. Baitha, R., Sinha, A., Koushlesh, S. K., Chanu, T. N., Kumari, K., Gogoi, P., Ramteke, M. H., Borah, S., & Das, B. K. (2018). Length-weight relationship of ten indigenous freshwater fish species from Gandak River, Bihar, India. *Journal of Applied Ichthyology*, 34, 233–236.
288. Parameswaran, S., Selvaraj, C., & Radhakrishnan, S. (1971). Some observations on the biology and life history of *Nandus nandus* (Ham.). *Proceedings of the National Academy of Scienes India*, 73, 132-147.

Family Gobiidae

Glossogobius giuris Hamilton 1822 *(Gulli/ Bulli/ Bulla/ Gulla)*

289. Hossain, M. Y., Jasmine, S., Ibrahim, A. H. M., Ahmed, Z. F., Rahman, M. M., & Ohtomi, J. (2009). Length-weight and length-length relationships of 10 small fish species from the Ganges, Bangladesh. *Journal of Applied Ichthyology*, 25, 117–119. doi:10.1111/j.1439-0426.2008.01168.x.
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Family Osphronemidae

Trichogaster spp. Bloch & Schneider 1801, *Colisa* spp. Cuvier & Valenciennes 1831

294. Baitha, R., Sinha, A., Koushlesh, S. K., Chanu, T. N., Kumari, K., Gogoi, P., Ramteke, M. H., Borah, S., & Das, B. K. (2018). Length-weight relationship of ten indigenous freshwater fish species from Gandak River, Bihar, India. *Journal of Applied Ichthyology*, 34, 233–236.
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Family Channidae

Channa marulius Hamilton 1822 *(Gajaal / Saur)*

297. Dua, A., & Kumar, K. (2006). Age and growth patterns in *Channa marulius* from Harike wetland (a Ramsar site), Punjab, India. *Journal of Environmental Biology*, 27, 377–380.

298. Khan, M., Afzal Khan, S., & Miyan, K. (2012). Length–weight relationship of giant snakehead, Channa marulius and stinging catfish, *Heteropneustes fossilis* from the River Ganga, India. *Journal Of Applied Ichthyology*, 28.1, 154-155.
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Channa punctatus Bloch 1793 *(Saur, Sauri), Channa striata* Bloch 1793 *(Garai)*

302. Afzal Khan, M., Khan, S., & Miyan, K. (2012). Studies on length-weight and length-length relationships of four freshwater fishes collected from River Ganga. *Journal of Fisheries and Auatic Sciences*, 7, 481–484.
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306. Pararneswaran, S., & Murugesan, V. K. (1976). Breeding season and seed resources of murrels in swamps in Karnataka state. *Journal of the Inland Fisheries Society of India*, 8, 60-67.
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309. Singh Patiyal, R., & Iqbal Mir, J. (2017). Length–weight relationships of 21 fish species from the upland Ganga River Basin tributaries of Central Indian Himalaya. *Journal of Applied Ichthyology*, 33.4, 861-863.

CRUSTACEANS

Family Palaemonidae

Macrobrachium spp. Spence Bate 1868 *(Gorra / Gorla / Bada Jhinga)*

310. Ara, M. G., Nobi, M. N., Fatema, M. K., & Ahmed, Z. F. (2014). Evaluation of condition factor of a small indigenous freshwater prawn, *Macrobrachium lamarrei* (Milne-Edwards, 1837) in Bangladesh. *International Journal of Natural and Social Sciences*, 1, 71–76.
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315. Prasad, S., Kanaujia, D. R., & Patra, A. K. (2012). Diversity, abundance and composition of large freshwater prawn species in the Ganga river system. *The Biosean*, 7, 685–689.
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rosenbergii: analysis of marked prawns in an experimental population. *Biological Bulletin*, 181, 379–386.

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Family Penaeidae

Penaeus sp. Fabricius 1798 , *Metapenaeus* sp. Wood-Mason 1891

321. Rao, A. V. P. (1967). Some observations on the biology of *Penaeus indicus* H. Milne Edwards and *Penaeus monodon* Fabricius from the Chilka Lake. *Indian Journal of Fisheries*, 14, 251-270.
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Appendix S7. Glossary of non-English words and other non-standard usages in the thesis.

Alphabetical Index

Abwabs (Persian): Royalty or tribute.
Akbar: Emperor Akbar, the third Mughal ruler of India.
Alaungpaya (Burmese): The king of the last dynasty that ruled Myanmar, from the 1750s to 1885.
Amils (Persian): Rent collecting clerk / official.
Andolan (Hindi): Movement - refers usually to a social movement seeking radical change.
Anta Jal or *Onta Jal or Bhati Jal (Hindi, Bengali):* A commonly used fishing trap with fykes placed along river banks, known from ancient literature and ubiquitous in the present day. Another common type is the *Chudi Jal*, a type of fyke-net fish trap.
Arat or Aarat (Hindi, Bengali, Maithili): Fish mart / wholesale or retail fish shop, in a fish market or standalone.
Aratdar/ Aaratdar (Hindi, Bengali, Maithili): Fish shop/mart owner, whole-seller or retailer.
Arsi Jal (Hindi): A kind of fishing trap.
Arthashastra (Pali/Sanskrit): Treatise on economics by Kautilya (or Chanakya or Vishnugupta) from the medieval period (dating possibly to 300 BCE, but disputed).
Aryans: Term used for groups and tribes that immigrated into India from Central and Western Asia around 3500 years ago, in multiple waves.
Ashoka: Emperor of the Maurya Dynasty (born 304 BCE, reign to death: 268-232 BCE), who ruled almost the entire Indian subcontinent during his reign.
Aviral (Hindi): Incessant, ever flowing.
Bachwa (Hindi, Bengali): A species of catfish *Clupisoma garua* Hamilton 1822, which is captured with nets and baited hook-lines. This fish is caught often with the use of dolphin oil or fish waste oil, used in a bait made with goat entrails, chicken offal, or other combination of meat and vegetable waste. Bachwa is used to refers to the closely related catfish *Eutropichthys vacha* Hamilton 1822.
Badmaash (Hindi): Cheat or swindler.
Bagdi (Bengali): Name of a fishing and cultivator caste.

Bahuwa Jal (Hindi): A passive fish trapping method with square structures erected with bamboo stakes and fenced with mosquito nets. Similar to *Chappa or Chippa Jal.*

Ban-kar (Urdu, Hindi, Bengali): Taxes (kar) or rents paid on the use of forests (ban) or forest products, usually extracted by landowners or the state, which claimed ownership of forests.

Banpar (Hindi/Maithili): Name of a fishing caste, usually associated with fishing and hunting of wild river animals.

Barari: Name of a suburb of Bhagalpur, which has a Gonrhi fisher settlement by the Ganga.

Bari (Hindi): Refers to a barricading type of fishing net. A mosquito net (1 mm) is woven around a large structure of bamboo frame built across river stretches to block the flow and catch small fish. Mostly used in side-channels and inlets, during the monsoons and post-monsoon months. Illegal type of fixed engine or gear.

Barh Mukti Abhiyan (Hindi): Movement for "Freedom from Floods" in the Kosi floodplains of northern Bihar.

Bauri: Name of fishing and cultivating caste.

Bebajiya: Name of fishing and cultivating caste in eastern Bengal.

Beel (Bengali, Assamese): Floodplain wetland, swamp, oxbow lake, or temporary or permanent village pond.

Bepari or Bajari (Bengali, Hindi): Merchant or Trader.

Bharatiya Janata Party (BJP): India's largest political party, currently forming the national government of India.

Bhadralok (Bengali): Term to refer to Bengalis from the educated urban middle-class and regarded as social elites.

Bhassan (Bengali): Name of fishing groups fishing in Jalkars by paying temporary rents to access private water bodies.

Bhatiyara: Name of fishing and cultivating caste.

Bhirka Jal (Hindi): Cast net, thrown from a boat or from a bank, and drowned with sinkers in the form of a ring, to capture fish.

Bhoi (Hindi): Name of a major fishing caste and tribe, distributed across central, western, and northern India.

Bhojpuri (Hindi): Pertaining to the region of Bhojpur, i.e. western Bihar and parts of eastern Uttar Pradesh.

Bihari (Hindi): characteristic of Bihar.

Bind or Bin (Sanskrit/Hindi): Name of a fishing and hunting caste, regarded as one of the lower sub-castes.

Brahmins (Sanskrit): As per the Varna system in Hinduism, the upper castes with rights to knowledge and ritual duties.

Buddhist: Practitioner of Buddhism.

Chabis (Hindi): Name of fishing and cultivating caste.

Chains (Hindi): Name of a fishing caste.

Chaklai: Name of a fishing and trading caste.

Chamar: Name of a caste practicing cobbling, leather and hide work, and manual labour.

Chanan (Hindi): Name of a private fishery (see Jalkar) in southeastern Bihar.

Chandal or Chandala (Sanskrit/Hindi): Outcaste communities living across India. Used as a slur to refer to so-called lowly castes.

Chatti Jal (Hindi): "Carpet gear", used by fishers to sweep fish along shallow riverbanks by dragging it from the shore like a small seine. Usually made of small mesh sizes < 20 mm.

Chaukies: Outposts or toll-posts.

Chaurs, Chars (Bengali, Hindi, Assamese): Large islands or peninsulas in rivers of eastern and northeastern India and Bangladesh, often with significant human resident populations.

Chero (unknown origin): A tribe that once ruled forested regions to the south of the Ganga, residing in the Kaimur and Chota Nagpur plateau of present-day Bihar and Jharkhand.

Chitala (Hindi, Bengali): A featherback fish species *Chitala chitala* Hamilton 1822, highly prized for its taste in Bengal.

Current Jal (Hindi, Bengali): Word used to refer to light nylon monofilament gillnets with small mesh sizes, often less than 60 mm, and used to drift along the river.

Dalit: (In the Indian caste system) a member of the lowest caste, may or may not be the same as untouchable.

Damas or Dhabs (Bengali, Hindi): Floodplain wetlands (ponds, oxbow lakes, tectonic lakes) or other water bodies formed in depressions in floodplains after floodwaters recede. Often fished by auctioning out short-term leases to bidders.

Dandies (see Manjhees or Maunjhees): British term to refer to boatmen employed under contract, for river navigation.

Dasa or Jalika (Bengali): Fishing people without land ownership, whose primary livelihood is fishing, hunting, and foraging.

Das Shikari (Bengali): Name of a fishing and hunting caste and tribe.

Datiya (Bengali): Name of a fishing, cultivating, and trading caste.

Delhi Sultanate (Turkish): The empire of the Turkish rulers (Sultan or king) of Delhi in the 13th century.

Dhaars (Hindi): Flows, refers to river channels. See *Kosi Dhaars.*

Dhaivaras (Bengali, Sanskrit): Fishing people also known to own or cultivate land. May be similar to or root word of *Kaivarta* (see which).

Dhinwar, or Jhinwar (Sanskrit, Hindi, Punjabi, Bengali, Marathi): A major fishing caste-group across western, northern, and central India. The name may derive from the root word *Dhaivara* (see above).

Diara (Hindi, Maithili): Term for Chars or Chaurs used in Bihar.

Dinghis/denghis/dingy/dongha (Bengali, Hindi): Small boats, used for fishing and/or local movements by floodplain-dwelling communities. Donghas also refer to dug-out canoe boats.

Diwani (Persian, Hindi): Power and rights to extract rents and taxes.

Dolphin mitra (Hindi): Friends of the dolphin (the name of the conservation program run by the Bihar state environment and forest department).

Dom (Hindi): Name of a downtrodden and semi-nomadic caste in eastern India, practising carcass scavenging, pig-rearing, foraging and fishing, cremation services, basket-weaving, manual labour, and minor trading.

Duars (Bengali): "Gate", or "doors": refer to the parts of the Terai region in northern West Bengal, which also mark "passage" from Northeastern India to the Gangetic plains of northern India.

Dulia or Dohuriya (Hindi, Bengali): Name of fishing and cultivating caste.

Dusadh (Hindi): Name of a cultivating caste in Uttar Pradesh, Bihar, and West Bengal, often regarded as a low and untouchable caste.

Farakka: town in West Bengal where the Farakka barrage on the Ganga was built in 1971 and commissioned in 1975.

Farman (Persian, Urdu, Hindi): Stately order.

Ferae naturae (Latin): Wild=Ferae, Naturae=Natural Being. Refers to fish and other wildlife.

Ganga Mukti Andolan (Hindi): 'Campaign to free the Ganga', a fishers' movement.

Ganga prahari (Hindi): Sentries of the Ganga.

Gangaberamud lands (Persian/Hindi): Lands "recovered" from the Ganga, i.e. floodplain land emerging after flood recession or a major channel course change.

Gangapath Jalkar: Name of a Jalkar or private fishery on the Ganga, from Sultanganj to Rajmahal in present-day Bihar and Jharkhand.

Gangashikist lands (Persian/Hindi): Lands "defeated", or literally, "taken away" by the Ganga, during major floods or channel course changes.

Gangota or Ganggots: Caste group largely dependent on agricultural labour, share-cropping and livestock-rearing, living along the floodplains of the Ganga.

Gangrar or Ganrar (Bengali): Name of a fishing and hunting caste from Ronggopur, East Bengal or present-day Bangladesh.

Ghashi: Name of a caste practising fishing and manual labour professions.

Ghat (Hindi): Steps leading to a river from the bank.

Ghatwar (Hindi): A person appointed to extract rents from boatmen at river ghats in Bihar, a practice called *Ghatwari*.

Ghosh family: Family of Mahashay Taraknath Ghosh who owned the private fishery on the Ganga River from Sultanganj to Pirpainti, and later till Farakka through sublessees.

Gochhel Jal (Hindi): Large nets made from thick fibres, with large mesh sizes (> 250-300 mm) used as a large drift-and-drag net to capture large sized fish species. Many fishers usually take part in setting large Gochhel jals.

Gonrhi or Gorhi (Hindi): Name of a fishing caste regarded as one of the superior fishing sub-castes. Also see Mahaldar.

Mahaldar (Hindi): Gonrhi fishers use the surname and title Mahaldar in north and east Bihar.

Gupta: Name of one of the largest Indian empires that ruled the Indian subcontinent from c. 319 to 547 CE.

Guria: Name of a fishing caste group occurring in Bihar, Bengal, and up to Assam.

Pramanik family: Family of Haji Aziz Pramanik who owned private fishery on the Ganga River from Rajmahal to Farakka and further downstream, and sublet it to tenants/owners.

Haldar (Bengali): Surname, often generic; also a name of a fishing caste in Bengal.

Haree (Hindi, Punjabi): Name of an itinerant and nomadic caste in northern India, often practising fishing.

Hawa Jal (Hindi): Term for light monofilament nylon gillnets with small mesh sizes.
Hilsa (Hindi) or Ilish (Bengali): The Clupeid fish species *Tenualosa ilisha* Hamilton 1822, iconic and extremely popular and prized in Bengali culture and cuisine.
Hul (Bengali): Mutiny.
Ijaradars (Persian / Hindi): Tenant or Lessee of a Jalkar (see Jalkar).
Ilaakas (Hindi): Territory.
Inn (Burmese): River channel inlets along the floodplain.
Jalkar (Persian, Hindi, Bengali): Literally means "Water Tax" through which it also indicates the private right to fish.
Jiani (Bengali): Name of Namasudra sub-caste group involved in fish trade.
Jirati (Bengali): name of a group of contract-fishing peasants and fishers.
Kaagaj (Persian, Hindi): Paper, used to refer to legal documents.
Kachal jal (Bengali, Hindi): Seine net operated by 10-15 fishermen dragging the net along a river channel or wetland from two boats to capture whatever fish come in the dragging path.
Kadhera (Hindi): Name of a fishing and cultivating caste.
Kahar, or Kahal or Gharuk (Hindi): Palanquin-bearer (also a caste name).
Kaibartta or Kaivartta or Kaivarta or Keora or Kewat (Hindi, Bengali, Oriya): Name of fishermen, also a caste group name, often used as generic to all boatmen and fishermen.
Kanu, Kahnu (Hindi): Name of a caste whose members are involved in manual labour, as cooks or servants, and also as helpers on boats or in fishing operations.
Kapda Jal (Hindi): Mosquito net (1 mm mesh size) used in the river for fishing, by dragging along the channel from a boat or from the bank, often a generic term to refer to mosquito nets used in fishing.
Kandal: Name of a fishing caste.
Kantwar or Dhawa (Hindi): Name of a fishing, cultivating, and servant caste group.
Kanungo / Qanungo (Urdu/Persian): Record keeper or bookkeeping clerk, under the employ of the Mughal Administration.
Catla or Katla (Hindi, Bengali): A popular and prized carp fish species, *Gibelion catla* Hamilton 1822.
Kewat: Name of the boatman who ferried Ram, Lakshman and Sita across the river, in a famous episode from the *Ramayana* epic. In the Ramayana, Ram is the king of the Ayodhya kingdom, Sita his queen, and Lakshman his younger brother.

Kharwar or Kherwar: Name of a cultivating and fishing tribe from central and northern India.

Khas lands (Urdu, Hindi): fallow land owned by government, with no property rights allocated to anyone or for any purpose.

Khud-kasht (Hindi): Land cultivated personally by landowner.

Khulwat (Hindi, Bhojpuri): Name of a fishing caste.

Koeri (Hindi): Name of a cultivating caste of Bihar, regarded as a "middle caste".

Kol (Hindi): In Bihar, kols are water bodies, inlets, or side-channels connected with the main river channel at one or both ends. If a river channel splits around an island, leaving a smaller channel on one side of the island, it is called a kol. Smaller drainages connected perennially with the active (main) river channel are also called kols.

Kosi dhaars (Hindi): Palaeo-channels and anabranches of the Kosi River. Literally, *dhaar* means flow.

Kuchcha road (Hindi): Unpaved mud-street.

Kurmi (Hindi): Name of a cultivating caste of Bihar, often same or similar to Koeri.

Lathaits or Lathials (Hindi): Musclemen wielding large *lathis* or wooden pole-sticks or clubs, used by locally powerful landowners to guard their lands.

Maa Ganga: Mother Ganga, refers to the river.

Machhua (Hindi, Bengali): Name of a fishing caste, often used as generic term to refer to any fishermen or boatmen.

Magh (Hindi): Name of a caste group in Bengal, North-eastern India, and Myanmar, with a possible link to Austro-Asiatic groups.

Mahabharata: Hindu epic narrating the battle of the Kaurava and Pandava princes.

Mahaldar (=Gonrhi): Name of a fishing caste. See *Gonrhi.*

Mahals: A land tenure system called *Mahalwari* was introduced in 1833 British India, which comprised of defining land clusters called "Mahals", which included many adjacent villages. Peasants were allowed to own lands, but were made to pay a fixed rent (66% of produce) to the British government.

Mahi-Farosh (Arabic or Persian): Name of a fishing caste in Muslim regions of Bengal, used as generic term for fishermen (means "fish-capturer").

Mahto (Bengali, Hindi, Assamese): Surname used by many castes and communities in eastern India. Often used for village heads, similar to *Mukhia* (see which).

Majhis/ Manjhis: Name of a fishing and boat-ferrying caste or tribe – used as generic term for fishers and boatmen along the Ganga.

Maimal (Bengali): Name of a fishing and trading caste in Bengal.

Mallah (Arabic): Caste group mainly comprising fishers and boat-ferrying people.

Malo (Bengali): Name of a marginalized labourer or part-time fisher caste in riverine Bengal.

Manasollasa (Sanskrit): Sanskrit text from the 12th century on arts, knowledge, and literature, and other pursuits of kings.

Mandal (Hindi, Bengali): A common surname across north, central, and eastern India. The surname is mostly used by people from mid- and low- or "scheduled caste" groups, e.g. Gangota, Namasudras, etc., but also found in other caste names. Not to be confounded with Mandal in Mandal Commission.

Manu-Smriti (Sanskrit): Ancient legal text or treatise prescribing the social codes and laws of Hindu religion. Literally "Laws of Manu".

Matsyanyaya (Sanskrit): Law of the fishes, used to describe a state with no law or order.

Maurya: The largest Empire that ruled the Indian subcontinent from 322 to 185 BCE.

Mouns (Hindi, Maithili, Bhojpuri): Floodplain lakes and wetlands formed by the accumulation of water from rainfall and seepage in tectonic depressions.

Meherpore: A district in the Khulna province of present-day Bangladesh (erstwhile East Bengal). The Meherpore court case yielded an important judgment on customary fishing rights in the 1880s.

Mostajirs (Arabic): Term used to denote help-seeker or refugee.

Mrigal or Mirka (Hindi / Bengali): A popular carp species, *Cirrhinus mrigala* Hamilton 1822.

Mughal: Pertaining to the Mughal rule and administration of India.

Muhtarifa (Arabic): tax on trades or professions.

Mukhia (Hindi): Title referring to village leader or chief, also the name adopted by some caste groups in northern India and the Nepal plains.

Muriyari (Hindi, Bengali): Name of a fishing caste.

Musahar (Hindi): A downtrodden and marginalized Dalit caste in northern and eastern India. Also regarded as an aboriginal community in some regions, their name means "rat-eater", highlighting their marginalized conditions.

Nallah (Hindi, Bengali): Drain or seasonal stream, or small temporary rivulet.

Namasudra (Bengali): An outcaste and untouchable community in Bengal, similar to *Chandalas*, living in destitution and poverty.

Nankar (Persian, Punjabi, Bengali): Land given to peasants or 'servants', in exchange for bread (food), and worked as a labour exploitation system.

Naxalite (Hindi): Of Maoist-communist guerrilla groups and insurgents in South Asia. From Naxalbari, a village in West Bengal famous for a 1960s anti-state armed revolt.

Nishulk shikaarmaahi cards (Hindi): Cards given to fishermen in Bhagalpur district, Bihar, for free fishing in flowing rivers and water bodies.

Nikari (Bengali): Fish trader or retailer.

Nirbal Indian Shoshit Hamara Aam Dal (Hindi): Name of a political party in Uttar Pradesh, abbreviates to NISHAD. Means "Our Common Group of Powerless, Exploited, Indians".

Nirmal (Hindi): Clean or pure.

Nishad or Nisad (Sanskrit): Caste group closely related to the Mallah, known as fishing, hunting and boat-ferrying people.

Omrah or Umrao (Persian): Mughal noble or elite.

Paharia (Hindi): Name of a tribal group in the hill regions of eastern India, practising hunting, foraging, and fishing.

Pala (Bengali, Sanskrit): Ruling dynasty of the Gangetic plains from Bihar to Bengal from the 8^{th} to 12^{th} centuries CE.

Paikar (Hindi, Bengali): Fish trader or retail market vendor.

Pargannas or Pergunnahs (Bengali, Hindi): District sub-divisions in Mughal India.

Thika (Hindi): Contract.

Panidari (Hindi): Water-lording, like land-lording. (*Pani*=water, *dari*=ownership and control rights). Private control of a landlord family over a river stretch was called their "Panidari". Similar use for *Thikadari* and *Thikadar*.

Patni: Name of a fishing and cultivating caste.

Pattas (Hindi): An informal or formalized lease to enjoy use rights and access to particular resources, land, or water bodies.

Peshkashes (Persian): Gift offerings or tributes

Pirpainti: Name of town in Bihar's Bhagalpur district.

Plassey or Palashi: Town in present-day West Bengal (erstwhile Bengal Presidency).

Pod (Hindi, Bengali, Telugu, Odiya): Name of a fishing and cultivating caste.

Polo bidroha (Bengali): A peasant rebellion/resistance act which involved fishing with a trap called Polo, to protest against restriction of customary access to fish under Company rule.

Polowallahs (Bengali): Fishers using the Polo trap.

Pratihara (Sanskrit): A type of land grant in North India from the 8th to 12th century CE. Similar to another type of land grant, *Gahadavala*.

Puranas (Sanskrit): Sanskrit literature on legends, traditions, philosophy, and mythology.

Rahadari (Hindi): Tolls on goods and ferry boat traffic.

Raiyat or ryot (Hindi): Peasants or peasantry.

Raja or Rajah (Hindi, Bengali): King, chieftain, little king, or satrap.

Rajbansi or Rajbongsi: Name of a fishing caste in Bengal.

Rajput: Name of a Kshatriya clan group from Rajasthan. Literally, "King's descendant".

Ramacharitam (Sanskrit): Sanskrit poem written by Sandhyakaranandin in the 11th or 12th century during the Pala Empire.

Ramayana: Hindu epic regarded as an important mythological epic in Hindu religion.

Rashtriya Janata Dal (RJD): A major political party in Bihar and northern India, known for its caste-based politics.

Rohu, Rehu, Rui (Hindi): A highly popular and prized species of carp fish, *Labeo rohita* Hamilton 1822.

Sairat or Sayar (Persian, Hindi): incomes sought as toll taxes or rents or tickets to access particular areas.

Salami (Persian, Urdu): Tribute or token of respect to elites or those in power.

Santhals or Sontals (origin unknown): A tribal group residing in eastern India.

Sevak (Hindi): servant, used as 'devotee'

Sipahi (Hindi): guard, sentry, or soldier.

Sirki Jal or Sirka Jal (Hindi): a fishing contraption made from large plant fronds and twigs, used specifically to capture river mullet species *Rhinomugil corsula* Hamilton 1822.

Smritis (Sanskrit): A form of ancient Hindu literature. Literally, Smriti means recollection or memory. Smritis included compilations of myths and legends, epics, law books, and codes, e.g. Puranas, Ramayana, are Smritis.

Sorahiya: Name of a fishing caste in UP and Bihar.

Suba (Urdu, Hindi): State or province.
Tharu (Nepali): An ethnic group residing in the Terai, and practising small shifting cultivation, gathering of forest products, fishing, and hunting.
Tiyars (Hindi, Bengali): Name of a fishing and hunting caste.
Turaha or Toraha (Hindi): Name of a fishing caste.
Toufir diara (Hindi, Urdu): Floodplain land, often temporary and emergent, exempted from rents, and cultivated by local farmers who access it first.
Varna (Sanskrit): Literally, *Varna* means type or class or category, and forms the basis of social stratification in Hinduism, by caste. The *Shudras*, *Vaishyas*, *Kshatriyas*, and *Brahmins* are the four Varnas. Many *Dalit* and tribal groups are not included in any of the four Varnas.
Vedic (Sanskrit): The Vedic period is from 1500 to 500 BCE, and includes the time in which the ancient texts of Hinduism, the Vedas, were written and disseminated.
Vikassheel Insaan Party (Hindi): A political party in Bihar with membership of fishing caste groups only. The name means "Progressive Peoples' Party".
Vaishnava (Sanskrit): Sect or tradition worshipping Vishnu. See *Vaishnavism.*
Yadav: Name of a widespread "middle" caste-group across India, practising livestock rearing, cowherding, dairy, and minor cultivation.
Zamindar, Zamindari (Persian): Landowners with vast tracts of land under their ownership, and with autonomous or semi-autonomous rule of their regions or states, with suzerainty to the Mughal and British administrations of India. They formed the elite and autocratic ruling class in northern and eastern India, with severe exploitation of peasantry under their rule. Also called *Talukdar* in Assam.

Conversions between local units and SI metric units

Weights

1 sér = 0.93 kg
1 maund = 37.32 kg = 40 ser = 3200 tola
1 tola = 11.664 grams

Lengths

1 inch = 25.4 mm, Yinch = thumb thickness
1 cubit = 444 to 529 mm, sometimes to 1200 mm, based on a measure of forearm length (from tip of middle finger to base of palm (ancient measurement unit).

1 pound = 453.592 g

1 kg = 2.20462 pounds

Net mesh size conversions

Fishermen often reported net mesh size in “finger lengths”, which we noted as FMN, or Finger Mesh Size. FMN lengths and sizes were converted to metric measurements based on linear regression models (estimated by the Ordinary Least Squares or OLS method) on physically measured nets (n=1563). The following rules were obtained for all conversions: 1) For mesh sizes below 100 mm, gillnet mesh size in millimeters = 17.113 + 10* FMN, 2) For mesh sizes above 100 mm, gillnet mesh size in millimeters = 17.113 + 20* FMN.

Statement about anonymity of interview respondents

Names of all interview respondents, including fishers, state government officials, other stakeholders, wherever used, are pseudonyms or changed names. This has been done to maintain full anonymity of respondent identity.