Ecological Impacts of Altered Environmental Flow on Indus Deltaic Ecosystem, Pakistan: A Review

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ABSTRACT

The Indus River Delta plays a central role in the lives of the people, economy, environment, and ecological wellbeing of the region. Indus River originates from Mansarovar Lake in Tibet, India at an elevation of about 5182 m. The River Indus flows for about 2880 km down into the Arabian Sea through the Indus Delta. Indus Delta is situated in Keti Bunder, a coastal town in district Thatta, Sindh, Pakistan 180 km away from Karachi City. There are 17 major creeks making up the Delta. Waters of the River Indus have been dammed or diverted upstream. Only a fraction of water and most of the times no water is released to the Delta region and this resulted in drastic ecological disaster at Indus Delta. The Delta land is reduced and its biodiversity, ecosystem, and its resources are under threat. The objective of this paper is to make an analysis of various documents and works carried out by the environmental organizations on Indus Delta in relation to declined water flows. Reports show that the frequency and intensity of cyclones has increased in the last 30 years. Other environmental changes have only served to increase the vulnerability of the region. Beginning in the mid-19th century a huge irrigation infrastructure was developed upstream drawing water from the Indus River and its tributaries, and since then a series of barrages and dams have been built leading to over-extraction of water for agriculture. Reports show that river flows into the delta have decreased as much as 90% from the 1990s. The result is a reduced flow of nutrient rich silt, and growing sea intrusion destroying mangrove ecosystems and causing land erosion. Community livelihoods have been negatively affected by a decline in agriculture, shortage of drinking water and population displacement. This review attempted to present an overview of the impacts on the Indus Delta resulting from various driving forcing that has brought the Delta to the brink of death and destruction.

KEYWORDS: *Environmental change, Future scenario, Indus Delta, Pakistan*

Introduction

Communities have responded to changes in their environment throughout history, but the scale of negative human impacts to the earth's ecology and climate now presents formidable challenges. As people around the world begin to feel the very real effects of climate change (e.g. Krupnik and Jolly, 2002; WWF, 2008) and campaigners are counting down the time in months before a tipping point is reached**,** the need for local adaptation becomes more apparent. The Intergovernmental Panel on Climate Change (IPCC) itself states that additional adaptation measures are necessary regardless of the scale of mitigation efforts**.** But although climate changes are and will be manifested at local and regional scales, there appears to be a gap between the knowledge needed by communities and institutions to take actions locally and research outcomes on global climate change.

Questions of how to adapt to climate change are usefully framed in terms of resilience, defined as the capacity of linked social-ecological systems to absorb recurrent disturbances to retain essential structures, processes and feedbacks (Walker *et al.*, 2004). Managing for resilience will allow flexibility to adapt to change and an uncertain future of shocks and surprises which climate change inevitably brings, in order to support long term sustainability (Nelson *et al.*, 2007).

Coastal communities are particularly vulnerable to climate change with rising sea surface temperatures and atmospheric water vapour likely to cause an increase in tropical hurricane intensity and rainfall (Trenberth, 2005). The coastline of Pakistan is no exception; reports show the frequency and intensity of cyclones has increased in the last 30 years (UN/ISDR, 2005). Despite this high level of exposure, there has been little research or scholarly debate on vulnerability and adaptation potential for communities in Pakistan. During a review of the literature on adaptation to environment change in coastal areas of Asia, research examples were mapped on the Indian subcontinent (Huq *et al.*, 2003; Sarwar, 2005; Bosher *et al.*, 2007); Southeast Asia (Adger, 1997); and China. Pakistan, however, is conspicuous in its absence from this geographical spread of research.

Indus River Delta and Its Environmental Debacle

The community of Indus Delta consists of approximately 2000 households (Map 1); spread over 42 settlements, of which 28 have been submerged by the intruding sea over the last 40 years (SPDC, 2000). As with many coastal and delta areas, Indus Delta has experienced natural resource degradation due to human activity, most notably a dramatic decline in freshwater flows, so that the community is almost totally reliant on fishing in the surrounding sea and creeks and poverty remains high despite some infrastructure development. Cyclones are also hitting the area with increasing intensity and regularity.

Managing for coastal area resilience can mean preventing extreme natural hazards from becoming a long term social disaster, especially in marginalized and impoverished communities. This invites to examine components that constitute social and ecological resilience. In the former, social memory and local knowledge systems, diversity of livelihoods, institutions are considered for collective action and robust governance systems. In the latter, ecological resilience may be enhanced through biological legacies, refugia, biodiversity conservation, spatial heterogeneity and functional redundancy of species (Adger, 2005).

The types of approaches were first examined that have been taken to describe Indus Delta, in order to assess where we could usefully contribute. First, it was noted the view taken by national government highlighting the iconic value of the Indus Delta to the Pakistan nation, which although drawing attention to the importance of this system, remains remote from the needs and specifities of local people. The Indus Delta holds the 7th largest block of mangroves, and is the largest arid climate mangrove ecosystem in the world (Shah *et al.*, 2007). In emphasizing the conservation for this critical ecosystem, environmental Non-Governmental Organizations have tended to obscure the human element integral to the system. Conversely, development agencies recognize the marginalized community and aim to meet human rights through basic infrastructure, but fail to address the natural resource base upon which the community depends.

Instead, it was seen that the indigenous peoples of the Delta region may be able to offer an alternative perspective based on their own locally specific experience and practices. The people of Indus Delta have an enduring relationship with the its landscape, are reliant on its natural resources and have thus generated knowledge in the immediate context of their livelihoods. When exploring traditional knowledge, the cosmology and value system must be recognized, underpinning the principles regulating human-nature relations**.** Resilience research shows us that decentralized co-management with community participation is most appropriate for sustainable management of socio-ecological systems through locally supported responses better attuned to the culture and specific context. The collaborative approaches include the recognition of diverse knowledge system, through which we may usefully co implement traditional and scientific western knowledge. In fact, this dichotomy is disputed to exist at all (Agrawal, 2008) and we take the view that there is a confluence between, and heterogeneity in local and non-local knowledge systems.

Incorporating community values and viewpoints in the research and decision-making process is also an issue of procedural and distributive equity and justice (Thomas and Twyman, 2007), especially pertinent for adaptation since the poorest and most marginalized are those hit hardest by climate change. By beginning a research project on Keti Bunder, we hope to represent one such community, and rather than view them as passive victims of environmental change, engage the people in debate and action for their future survival.

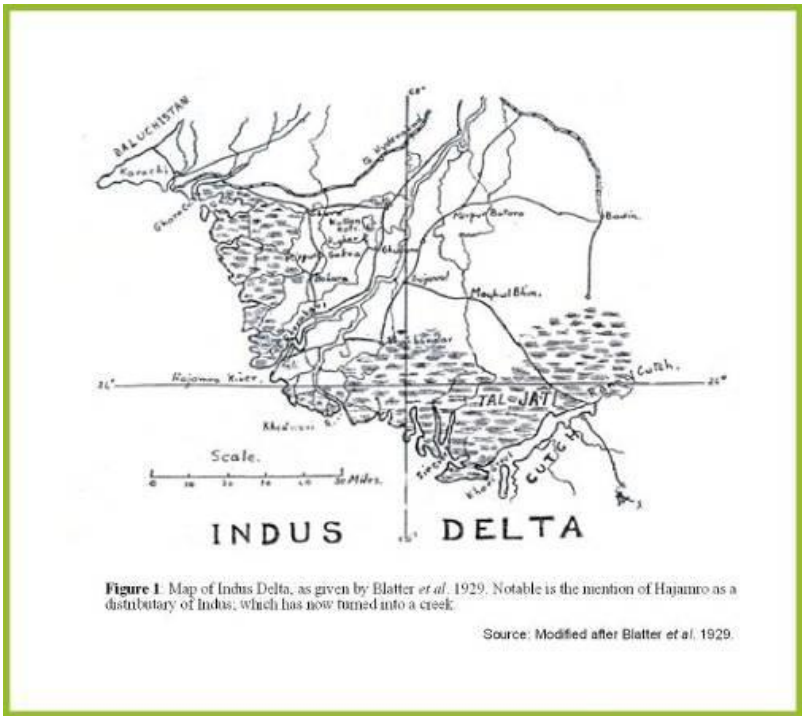

Figure 1: Map of Indus Delta, as given by Blatter *et al*. 1929. Notable is the mention of Hajamro as a distributary of Indus; which has now turned into a creek.

Source: Modified after Blatter *et al*. 1929.

Map 1: Indus Delta, Sindh, Pakistan

Understanding Environmental Change the Indigenous Way

In the midst of a tragic drama of ecological peril, how do the people of Indus Delta understand the vortex of change in which they are centred?

Previous social research in Indus Delta suggests local residents do observe local ecosystem degradation, "but they have not thought about reasons and are not particularly bothered about possible solutions" (Hasan, 2002). We challenge this observation by presenting qualitative data which illuminates the large canvas of world views and the knowledge system of a people, or more certainly a socio-ecological relationship, likely to have existed since the Indus-Ghaggar-Hakra Delta dating back 5 millennia**.** Key points have systematized loosely from Indus Delta interviews of its communities into a hierarchy of indigenous understanding about environmental change. A mind-map inspired by Centred on ideas of God, time, the universe, and values about nature, indigenous commentary extends to ecological knowledge, social consequences and the future of the community (Berkes, 2003).

The premises of this worldview include the belief in Man's reciprocal relationship with God, which is mediated by nature. Time is understood to be a circular cosmic construct, implicit within which are cycles, which extend to the time-cycle in which the Earth itself is positioned. This view is consistent with an

eschatology commonly shared by indigenous communities (Berkes, 2003). Climate change represents a disorder created by God as Man recedes from his proper role and fulfillment of sacred duties. Built on a place- based social identity, the perceived beauty of the delta landscape and its integration with history is apparent in the data. This embedded-ness or "sixth sense" of the forefathers of Keti Bunder enabled an accurate and detailed reading of nature that is now fading. As one man described, "Before, our forefathers predicted the storms all of the time. Now we cannot – it is beyond our knowledge and understanding."

Memory - the reservoirs of practices, and knowledge embedded in values and worldviews of the community, are a source of creativity and adaptation (Davidson-Hunt and Berkes, 2003) thus a key element of social resilience. World views clearly signal disorder and crisis in the locality, so that memory is becoming less attuned to ecosystem dynamics; and the ability to "read the signs of nature" through ecological knowledge is weakening.

Sea storms, their frequency and intensity are at the heart of the peril that people perceive as climate change in Indus Delta. Local views emphasize that decline in freshwater due to the installation of the large scale Indus irrigation system in the 1960"s caused lower fish catch and prevented agricultural production, reducing local income as a unremitting "press" driver. Ecological "pulse" events are manifest when cyclones are known to destroy mangrove trees, change ocean chemistry, alter soil structure and transform the face of the landscape.

The immediate consequences to the community are identified as loss of boats, houses, life and poor health. But in the medium term indebtedness increases when locals borrow ever more heavily from middlemen in order to reconstruct damage to livelihoods, and the wealthiest members of the community out-migrate leaving behind the poorest members of society.

Locals note that tribal specialization and use of ecological niches have all but disappeared. Indian scholarship tells us that socio-ecological niches are a sign of resilient systems in the region. In Keti Bunder, the Jat tribe was once a specialized camel keeping people frequenting the Delta scrublands, the Dabls's the agriculturalists in the freshwater hinterlands, and the Mohannas the coastal fishermen. Now all three tribes have been forced to move to the coast and creeks to live on fishing.

There are mixed views on the future: a continued identity with place, yet an impoverishment for the next generation. The data reflect continued social cooperation yet a sense of institutional isolation mixed with large hopes placed in NGOs. For us, understanding environmental change the indigenous way was to become a starting point on which to graft our other forms of analysis of the vulnerability of Indus Delta.

Historical Perspective of Socio-Ecology (1847-2013)

Keti Bundar, a town in Indus Delta was once a thriving river port with impressive public buildings, a customs office and warehouses for exports. Today, it can barely stay above water". Through recorded history, we glean the cycles of socio-ecological change that have shaped the study site. How do past cycles of change contextualize conservation and development efforts in the proximate future? What are the opportunities and vulnerabilities that these cycles introduce?

The data challenge was to collect disparate secondary sources and coalesce it to visualize trends. We call them eras or packets of time, in which we perceive a consistent socio-ecological state. British records were available from 1855**,** as well as archeological data of the Indus Valley civilization of 3,000 BC. Given the nature of this paper, we did not incorporate archeological evidence into the results below, and adopted 1847 as our start date as this was when trade is reported to have moved from Sikkur Bandar to Keti Bunder (Smyth, 1919).

Over 160 years, we delineate four eras with key socio-ecological indicators which we call Prosperity, Disruption, Contraction and Crisis. Each is underpinned by historical events arranged under the time-line.

The Prosperity Era (1847 – 1930): A time of relative ecological stability in which natural resources were diverse and productive, supporting a vibrant local economy. In the British Gazetteer (Hughes, 1876) Keti Bunder was ranked the second most important port after Karachi. Community interviews confirm the view of Hasan (2002) of a well-defined tribal society with differentiated production modes in contiguous ecological niches of the Delta. Noteworthy is the sea submersion of an early site of Keti Bunder in 1854 (Smyth, 1919), and the beginning of colonial irrigation works on the Indus (Gilmartin, 1994). Eight species of mangrove trees were recorded by a Bombay Natural History Society survey with species richness comparable to the Sunderbans (Blatter, 1919).

The Disruption Era (1932 – 1955): A period when multi-sectoral disturbance happened to a productive socio- ecological system, marked by the Partition of India and Pakistan, the construction of the first major barrage upstream of Keti Bunder and extraction of 10% freshwater flow from the delta (Altaf A. Memon, 2005). Industrialization impacted local production modes and social order was disrupted when the ecological resources limited semi-nomadic pastoralism and shifting agriculture.

The Contraction Era (1955- 1990): A far-reaching period when 58% of the freshwater flows into the delta had been extracted as a result of the construction of 7 barrages and two of the world's largest dams (Altaf A. Memon, 2005). As a result economically important exports declined; the prized Palla fish (*Tenualosa ilisha*), once described as "plentiful" (Hughes, 1876) is now just 10%

of total annual catch; and local red rice which had been "freely cultivated" (Smyth, 1919) has disappeared by the end of the era. Almost all livelihood diversity shrank to fishing in the creek and coastal system. Large numbers migrated from Keti Bunder settlements to Karachi in the early 1960s; for example it was estimated by the community that two thirds of the 1800 population of the village of Tippun migrated away.

The Crisis Era (1990 – Present): Marked by frequent and intense sea storms, there has been loss of mangrove cover and diversity with a much diminished human population that is now among the poorest in the country (Brohi, 2004). A national water accord that promises 10 MAF (million acre feet) freshwater release into the Delta in actual fact allows only less than 1 MAF freshwater discharge into the ecosystem in 2001. The majority of mangrove cover is dominanted by one species – *Avicenia marina* (Shah, 2007).

A historical analysis of Keti Bunder shows us that over a century and a half, an age of prosperity has developed into an era of socio-ecological crisis in the system, or ecologically speaking, an alpha phase. Resilience theory suggests that an alpha phase in the adaptive cycle of a system can lead to a number of future scenarios including reproduction back into the original system if sufficient energy is regained, or unknown scenarios if energy is lost in the system (Resilience Alliance, 2007).

The Way Forward for Indus Delta

In the concluding, discussion centers on the questions that arise out of the preceding analysis. What is the context of conservation and development efforts in the near future? Where is the system opportunity and vulnerability in Keti Bunder?

Recent research shows that future scenario building is a useful tool for collaborative thinking between community and practitioners, and can trigger a break through moment given the appropriate context among stakeholders (Evans, 2008). Here we attempt to start this process of envisioning possible futures for Keti Bunder which arises from our research, but must be opened up for collective consideration by all concerned.

Local government, NGOs and community invest in a planned out-migration scheme and avert abandonment. Some elements of social unity are therefore salvaged, averting alienation and loss of memory that can result from forced migrations.

The delta as a productive creek-mangrove system is restored in patches as a result of conservation investment and some freshwater discharge. Medium chances of a planned human out-migration occur given frequency of cyclones.

Here considerable levels of social organization will enable some community units to continue to live and earn in Keti Bunder, while others are moved in a planned manner to other creek ecosystems and maintain some socio-ecological coherence elsewhere.

Local government, NGOs and community invest in development and social organization for those who plan to stay on in Keti Bunder including water and sanitation, credit and marketing infrastructure and improve livelihood diversification.

Widespread ecological integrity is restored to the delta where the system is once again fertile and productive with a regaining of freshwater balance. The system is resilient enough to withstand cyclones and protect integrity of landscape, human infrastructure and livelihoods. Chances of social rehabilitation are highest in this case, and an age of prosperity such as the earlier era may return.

Although all three scenarios are worth using for purposes of dialogue, we believe they are a continuum of possibility, contingent on resource investment and social organization, so that scenario 3 becomes the most hypothetical since it requires maximal resource investment and overcoming national needs for competing freshwater for irrigation.

Social institutional structures for collective action exist but need to be strengthened to enhance resilience. For example, there are horizontal networks in civil society through the Pakistan Fisher folk Forum, but also more informal social networks with kinship and migrant creek communities elsewhere. Local cohesion is reported to be high, especially in times of need, despite social differentiation between tribal groups. Local leadership is also needed for adaptive decision-making and is perhaps the urgent and important element that will spawn a purposeful management of future scenarios from within the community.

Future investment and research should take account of the elements of ecological resilience which may not be fully captured through this process alone. For example ecological memory in the form of propagules that represent remnants of the historical ecosystem may be exploited; refuges where exploitation and harvesting is restricted may allow species to exist in a mosaic landscape. Ecosystem patches can provide banks of resilience and the degree to which mangrove patches may form a viable functioning ecosystem is an area of investigation.

Conclusion

The community of Keti Bunder has their own world view, which based on experiential knowledge of the ecology and landscape, is increasingly subject to surprise and uncertainty. A systems view of this socio-ecological system

reveals that cross-scale environmental drivers have already served to powerfully modify the key-stone elements of the system. Local and national resilience responses are weak in comparison to the magnitude of the impacts. A synthesis of historical eras over 160 years shows a long prosperity era, followed by an onset of disruption, contraction and currently a crisis era in the socio-ecology. We discuss three possible scenarios for the site, with resource investment and social organization as key determinants of the future.

This research represents the first stage in examining Keti Bunder as a socio-ecological system in all its complexity, and number of questions for future research has arisen. Further ecological analysis is needed to assess more precisely the proximity of an ecological tipping point beyond which an undesirable system will be reached. This could inform current mangrove conservation strategies, and the potential of building ecological resilience through strategic rather than large scale restoration efforts. Secondly, an improved understanding of current community institutions for collective action, especially networks that appear to exist with migrant communities would support social resilience building. Lastly, a comparative analysis of Keti Bunder with other Delta regions such as the Sundarbans to place the site in a global context of debate and efforts to alleviate and adapt to environmental change is suggested.

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