

## The Deepest Cut: Political Ecology in the Dredging of a New Sea Mouth in Chilika Lake, Orissa, India

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### Abstract

This paper explores the political and historical ecology surrounding the 2002 dredging of a new sea mouth in Chilika Lake, India. It contends that the use of Geographic Information Systems (GIS) and mathematical flow models advanced an 'environmental orthodoxy' that coalesced around the narrative of a rapidly 'shifting sea mouth'. This orthodoxy ignored historical evidence of the importance of seasonal flooding to the ecosystem's health and discounted the fishing communities' concerns regarding the introduction of prawn aquaculture. The product of over two centuries of flood control policies, this hydrological intervention has freed up waterlogged soils for cultivation and produced favourable conditions for the further spread of prawn aquaculture in the lake. While ostensibly engineered to improve the lake's ecology and benefit the fishing communities, this paper argues that the much-touted intervention has unsettled a slew of ecological relationships and primarily benefited the lake's agricultural communities. Most recently, unanticipated declines in the fishery have led to calls for further studies and government interventions. This research contends that successive attempts to engineer solutions for Chilika and its watershed are precisely what necessitate additional interventions. At the same time, it questions the Indian government's claim that the dredging of a new sea mouth was both necessary and scientifically sound.

**Keywords:** aquaculture, environmental orthodoxy, flood control, Geographic Information Systems (GIS), historical ecology, hydrological interventions, political ecology, politics of scale.

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### SEEING THE BIG PICTURE

*When you look at a mountain from far away, you think to yourself, 'How beautiful is that mountain! How green it is!' When you get closer, you find that it is rocky and steep with many thorny bushes and snakes. – Interview with a resident of the fishing community of Bhalabhadrapur, September 2005.*

With the ready availability of satellite imagery, it is now possible to zoom in and out at the click of a mouse while scrutinizing every corner of the earth. Thanks to this newfound ability to explore landscapes at varying scales, one might conclude that the proverbial 'big picture' is finally in our grasp. Unfortunately, this ability to see the big picture is not necessarily the same as the ability to grasp it. While scientists and policymakers have wholeheartedly embraced Geographic Information Systems (GIS) as a sophisticated and objective tool essential to the understanding and modelling of ecosystems, its use remains problematic.

This paper explores the recent decision by the Indian government to dredge a new sea mouth for Chilika Lake, based solely on GIS studies. Rather than a neutral depiction of reality, I contend that GIS, and the ecosystem models it is instrumental in producing, are the products of historically and politically grounded discourses. Specifically, the 'environmental orthodoxy' (Fairhead and Leach 1996; Forsyth 2003) that coalesced around the narrative of a rapidly 'shifting sea mouth' as the underlying cause for the lake's declining health is explored. This research calls into question the claim that the much-touted decision to dredge a new sea mouth was both necessary and scientifically sound.

Ostensibly undertaken to assist the fishing communities suffering from major declines in the fishery, this hydrological intervention is equivocal and best understood as the product of two centuries of flood control policies. As D'Souza (2006) recently demonstrated, during the colonial era deltaic Orissa was discursively reconfigured from a 'flood-dependent'

into a ‘flood-vulnerable’ environment in need of large-scale government dispensations. This shift stemmed from policies designed to safeguard and ensure the productivity of agricultural lands since the land was the primary source of revenue for the colonial enterprise. The ‘high-modernist’ (Scott 1998) institutional culture that this engendered – a culture that favours top-down approaches, engineering solutions and a reliance on sophisticated models to address environmental problems – remains prevalent in Orissa government circles to this day. Unfortunately, this focus on flood control and techno-fixes has ignored a large body of historical evidence on the importance of seasonal flooding to the health of the lake. This legacy of flood control also resulted in a politics of scale that focused all the attention and resources on resolving ecosystem declines at the catchment level while precluding a discussion of the larger watershed.

The privileging of the agricultural communities and confidence in the ‘expert’ advice of a small, scientifically trained, planning elite has also systematically discounted the practical knowledge of ‘non-experts’ such as fishers who have long claimed that prawn aquaculture undermines the ecosystem. The decision to site the new sea mouth without community representation resulted in the bypassing of eighteen fisher communities and provides literal and figurative evidence of how the concerns of the fishing communities have been effaced and marginalised. The government’s reliance on GIS and ecosystem models trumped the concerns raised by the affected communities and clearly highlights the political nature of these technologies.

I begin by outlining the ecological characteristics of this unique ecosystem followed by a review of the government interventions implemented to address declines in the fishery and the trending of the lake towards a freshwater ecosystem. Next, I will look at these interventions from the perspective of the traditional fishing communities, their concerns surrounding the ecological impacts of aquaculture and their opposition to the dredging of a new sea mouth. By exploring the political and historical ecology surrounding the narrative of the ‘shifting sea mouth’, I survey the history of flood control policies and call into question the necessity of this hydrological intervention. I contend that the reliance on GIS and ecosystem models privileged the lake’s agricultural communities, discounted the legitimate concerns of the fishing communities regarding aquaculture and transformed the lake into an ‘Organic Machine’ (White 1995) in perpetual need of government interventions.

### WATERSHED ECOLOGY OF CHILIKA LAKE

Chilika Lake, a pear-shaped body of water located in India on the Orissa littoral, is actually a classic tidal lagoon connected to the Bay of Bengal by a sea mouth (Biswas 1995). Often touted as Asia’s largest brackish water lagoon, the lake is approximately 65 km long and 20 km at its widest and has historically fluctuated in size from a maximum average of 1165 sq. km during the monsoon (July–October) to an average minimum of 906 sq. km in the summer months (April – July) (Ghosh *et al.* 2006). The

lake’s catchment basin of 4300 sq. km includes the lake itself and some 52 rivers and streams that flow into the lake (Ghosh and Pattnaik 2005). Among these are the Daya and Luna Rivers, which form a delta in the northern part of the lake and are tributaries of the Mahanadi, a river with a colossal watershed covering over 4% of India’s territory, an area roughly the size of Bangladesh (World Resources Institute 2003) (Figure 1).

These rivers and streams supply the lake with freshwater during the rainy season, resulting in seasonal fluctuations in salinity. The importance of this influx for the lake’s ecosystem is manifold – it maintains the lake’s brackish nature (5 – 20 ppt salinity), accounts for the variety of salinities throughout the lake, and provides the lake with nutrients. Limnologists have traditionally divided the lake into four sectors – Northern, Central, Southern and Outer Channel – based on varying salinity gradients (Figure 2).

From a limnological perspective, the lake is highly productive and boasts a diverse fishery which includes several important food-fish species as well as somewhere between 50 to 85 Irrawaddy dolphins (*Orcaella brevirostris*) (Sinha 2004). The lagoon serves as a major flyway for over 20 million migratory birds, many of which arrive from as far away as the Caspian Sea, Siberia, and Central Asia to feed while they overwinter (Biswas 1995). In recognition of this rich biodiversity, the Indian government designated the lake a Ramsar Site (Wetland of International Importance) in 1981.

The Northern Sector of the lake is deltaic and the surrounding agricultural lands are historically prone to waterlogging and flooding. That this is a structural feature and a perennial problem is confirmed by the Chinese traveller Hien Tsang, who commented in the seventh century that the land in this area was ‘low and moist’ (Xuanzang *et al.* 1957). The first systematic study of the lake reported that the Northern Sector was characterised by ‘a margin so ill-defined that, when the floods are high and the water in consequence fresh, there is no perceptible boundary between rice fields and lake; the former terminate only at the point where the water becomes too deep for rice to grow’ (Annandale and Kemp 1915).

At the other end of the lake, the Outer Channel sector extends

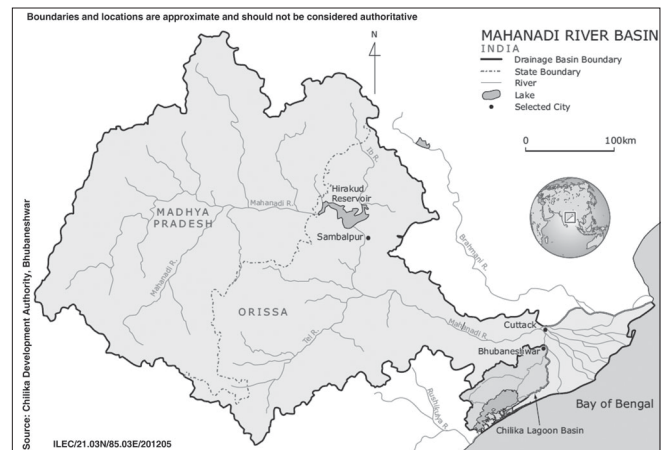
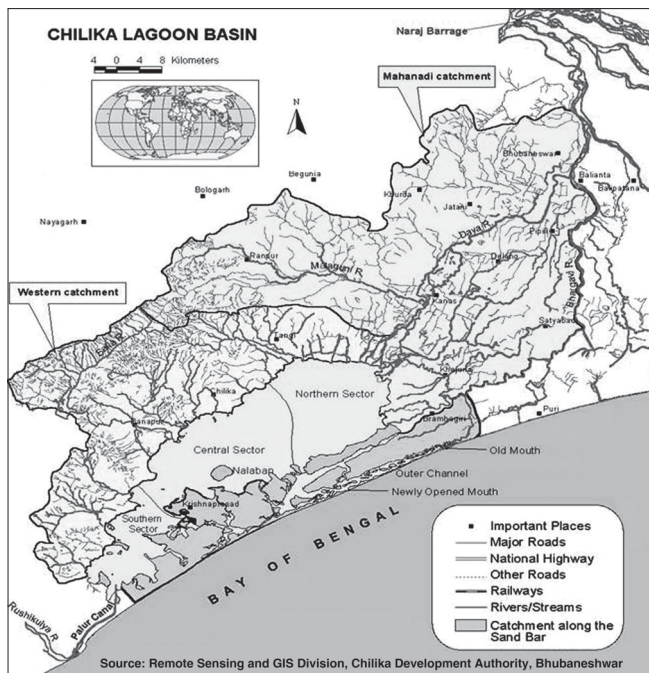


Figure 1  
Chilika lake catchment in relation to the Mahanadi river basin



**Figure 2**  
*Hydrological interventions in Chilika*

for 35 km along the Bay of Bengal and connects the lake to the Indian Ocean through a sea mouth. The *mugger mukh* (shark face) is locally known as the Inner Channel and serves to connect the Outer Channel to the main body of the lake. Prior to the opening of the new sea mouth, the Outer Channel was configured in such a way that, upon entering the lake, seawater was forced to make a ninety degree turn to the south until it reached the inner channel where it made another ninety degree turn to the north before entering the Central Sector. Because these sharp turns slowed down and reduced the force of water entering and exiting the lake, the Outer Channel fishing communities were able to fish with fixed gillnets and box traps. As this was historically the only way in and out of the lake, these communities long benefited from their strategic location.

According to official government estimates, 141 communities presently dot the lake's shore and some 200,000 people depend on the lake for their livelihood (Mohapatra *et al.* 2007). However, since these figures do not include the recent influx of individuals from agricultural communities (who fish in the lake but do not self-identify as fishers) these estimates are widely disputed.<sup>1</sup> According to the leadership of the *Chilika Matsyajibi Mahasangha* (Chilika Fisherman's Federation) at present somewhere in the vicinity of 300,000 people earn their livelihood from the lake.

### FROM SALTWATER LAGOON TO FRESHWATER LAKE AND BACK

Since its designation as a Ramsar Site, the lake has tended toward a freshwater ecosystem and suffered from changes in salinity, increases in freshwater weeds, sedimentation, siltation, and eutrophication. Reclamation of lagoon margins

for agriculture and aquaculture, the introduction of synthetic fibres for netting, and the introduction of mechanised boats have all been implicated as causal factors in the decline of the fishery (CIDA and Cenderet 1992, Ghosh *et al.* 2006, Mangla 1989, Patro *et al.* 1988, Pattanaik 2008). In recognition of the declining lake fishery and the ecological and social threats facing the lake, the state government set up the Chilika Development Authority (CDA) in 1992 under the aegis of the Orissa Ministry of the Environment.

Meant to serve as a 'coordinating body between the wide range of institutions and people with a stake in the lagoon and its basin', it was entrusted with a mandate 'to execute multidimensional and multidisciplinary developmental activities either itself or through another agency' (CDA 2008b). With the listing of Chilika Lake on the Ramsar Convention's Montreux Record of endangered wetlands in 1993, the CDA directed its energies towards restoration activities. By 1999, the CDA had funded no fewer than 25 technical studies by government research institutions to provide recommendations on how to improve the lake's ecosystem (CDA 2008e). There was unanimous agreement among all the agencies that siltation due to longshore drift in the Bay of Bengal was responsible for a 'shifting sea mouth' that resulted in the 'lengthening of the Outer Channel, reduced tidal flux, fall in salinity levels, weed infestation, decline in fishery resources, and overall loss of biodiversity and productivity' (Rajawat *et al.* 2007).

Based on three-dimensional numerical model studies and satellite imagery, these organisations concluded that it was necessary to increase the tidal flux of the lagoon by forty-five per cent so as to ensure a more 'ecologically beneficial hydrologic regime' (Ghosh *et al.* 2006). In order to accomplish this goal, it was suggested that a new sea mouth, closer to the main body of the lake, be dredged. Further recommendations called for dredging the inner channel for six km along with another 22.6 km lead channel to the mouths of the Daya and Luna Rivers in the lake's Northern Sector (Figure 2).

The modelling data suggested that the proposed interventions would effectively flush the lake, reduce sedimentation, and maintain an average 15 ppt salinity gradient in the Northern Sector during the summer months (April–July) (CDA 2008c). The increased salinity would halt the proliferation of such aquatic macrophytes as tall reeds (*Phragmites karka*), pondweed (*Potamogeton sp.*), and water hyacinth (*Eichornia crassipes*) that were choking the lake and turning it into a marsh. With great fanfare, a new sea mouth was dredged in front of Sipakuda village on 23 September 2000. The location of the new sea mouth shortened the distance between the main body of the lake and the Bay of Bengal by 18 km and was selected on the basis of satellite imagery suggesting that a sea mouth had existed at that location at some point in the past (Jellison *et al.* 2004).

### A CASE OF EXEMPLARY GOOD PRACTICES

According to the CDA narrative,<sup>2</sup> this hydrological intervention greatly ameliorated the situation in Chilika Lake on many

levels. First and foremost, the new sea mouth positively affected the salinity regime of the lake and returned it to ‘a more natural state’ (Ghosh *et al.* 2006). The increased salinity led to a major reduction in the area dominated by aquatic macrophytes from a high of 523 sq. km in 1998 to 351 sq. km by *Ibid.* May 2001 (Ghosh and Pattnaik 2005). Species diversity discernibly improved as ‘the restoration of [the] salinity regime, improved auto-recruitment from the ocean and free-breeding migration’ (Ghosh *et al.* 2006). Fish landings rose exponentially from a low of 1600 metric tons in 1997-8 to about 14,000 metric tons by 2003. In particular, prawn landings increased to a record 3611 metric tons by 2003-4, up from only 180 metric tons in 1998 (CDA 2008c) (Table 1).

Based on ‘the average weighted price’ of fish, the CDA estimated that the windfall to the local economy from the increased yields was USD 15.1 million and the, ‘average annual income per family increased by INR 50,000 (≈ USD 1000)’ (Ghosh *et al.* 2006). In addition, the opening of the new sea mouth benefited farmers in the Northern Sector of the lake who no longer suffered from waterlogged soils and ‘crop losses of > 50,000 ha of paddy field’ (Ghosh *et al.* 2006). The new sea mouth and dredging of lead canals effectively reduced the residence time of water in the lake and minimised the risk of flooding in the lake (CDA 2008c).

Only eighteen months after this intervention, the Ministry of Environment and Forests officially requested that the lake be removed from the Montreux Record. Following an advisory mission in December 2001, the former Head of the Ramsar Science and Technical Review Panel recommended that the lake be de-listed from the Montreux Record (RAMSAR 2001). This report further recommended that ‘The Convention should consider using Chilika Lake as an exemplary good-practice case study of the application of the various Ramsar guidelines, and the use of the Convention’s tools and approaches, to address complex site and catchment management issues’ (RAMSAR 2001). In 2002 the CDA was chosen to receive the Ramsar Wetland Conservation Award and the \$10,000 Evian Special Prize for ‘wetland conservation and management initiatives’ (CDA 2008d, RAMSAR 2008a, RAMSAR 2008b).

### BYPASSED AND MARGINALISED

Considering all of the benefits attributed to the new sea mouth, I was surprised to find during my initial visit to Chilika in 2002,<sup>3</sup> that this hydrological intervention was almost universally disparaged by the fishers I interviewed. I was repeatedly told that the new sea mouth was an economic and ecological disaster for their communities. Contrary to the CDA assertion that the opening of a new sea mouth ‘was a long-standing demand of the local communities, reflecting the value of local knowledge’ (Ghosh *et al.* 2006), in the over twenty villages I visited, the fishers I spoke with expressed their desire for the government to dredge the *historical* sea mouth located across from the village of Arakhakuda. They categorically denied being consulted regarding the placement of the new sea mouth and often strongly objected to its location. Though there was general agreement that the pre-mouth situation was unhealthy for the lake, they decried the fact that the new sea mouth effectively bypassed eighteen Outer Channel communities.

Since the silting up of the historical sea mouth in 2004 (Rajawat *et al.* 2007), these voices have only grown louder. At present, the Outer Channel no longer serves as the primary recruitment route for the lake’s fishery and has, in effect, become a side channel. Many fishers have resorted to taking loans from middlemen in order to buy motorised boats so that they can travel to fishing grounds in the main body of the lake – a distance of 30 km or more. Inevitably, this has led to conflicts with other fishers as they encroach on the fishing grounds of other communities (Samal 2007).

Those villages located in the direct path of the new sea mouth and inner channel have not fared any better. Due to the configuration of the new sea mouth, water now flows directly north *with* the current into the main body of Chilika. This direct line was aided by the dredging of the inner channel and means that the tidal flows are much stronger than those experienced in the past. As a result of these increased flows, fishers are no longer able to anchor their nets or safely use their non-motorised fishing craft. While there is general agreement that the increased flows and dredged channels have reduced the threat of flooding, numerous people complained that the sea mouth is currently much wider than initially promised.

Among the positive outcomes attributed to the dredging of the new sea mouth, it is conceded that the increased salinity levels have greatly reduced the spread of aquatic macrophytes. The Northern Sector communities, where the weeds trapped sediment and accelerated the process of land formation, have received these changes positively. The farming communities have also welcomed the reduction in waterlogging since it has made it possible for them to farm their marginal plots of land. Although some fishers in the Central Sector of the lake credited the sea mouth with a moderate increase in fish, I was also repeatedly told by fishers and non-fishers alike not to put much stock in the CDA statistics. In particular, they scoffed at the notion that the new sea mouth had resulted in an economic windfall and took exception to the CDA’s assertion that ‘the participation of local communities and

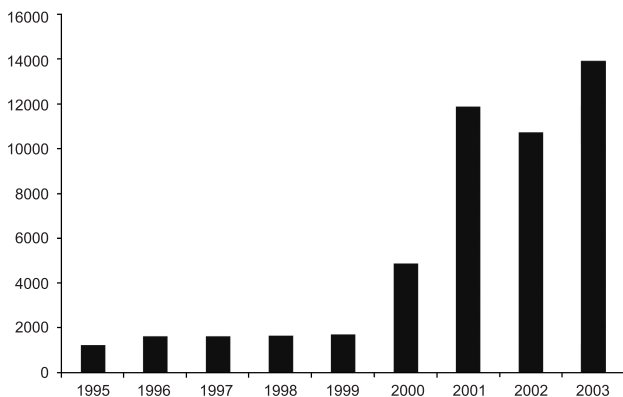


Table 1

Fish and prawn landings in Chilika from 1995 to 2003

stakeholders in planning and implementing management of natural resources, and in sharing the responsibilities of decision-making, is a key feature of the ecosystem approach adopted by the CDA for management of the drainage basin' (Ghosh *et al.* 2006).

### 'BLUE REVOLUTION' AND ITS DISCONTENTS

The overriding concern for almost all the fishers interviewed, from the top leadership to the man in the boat, centred on the introduction of prawn aquaculture and occupational displacement due to the entry of non-fishers into the fishery. The loss of fishing grounds, construction of prawn ponds in the near shore areas, choking of channels, conflict between communities, concerns about pollution and the loss of juveniles to bycatch were all recurring themes related to aquaculture (Dujovny 2007). These findings are corroborated by other researchers who surveyed the fishing community and similarly found 'near unanimity' among their respondents of the need for the government to dredge the historical sea mouth at Arakhakuda, put an end to prawn aquaculture, ban the destructive practice of collecting prawn seedlings and the use of the fine-meshed *mosari jala* (mosquito nets) (Samal and Meher 2003).

For over a quarter of a century, Chilika has been at the epicentre of the 'Blue Revolution' in India. Envisaged by its backers as a way to ensure a reliable supply of protein, fish aquaculture was touted as a logical complement to the 'Green Revolution' in agriculture (Das 1991). As early as 1956, the Indian government established the Chilika Investigative Unit of the Central Ministry of Food and Agriculture with the express purpose of 'developing the fisheries of the lake to a level of optimum productivity' (Jhingran 1963). However, it was not until the proliferation of new technologies in the early 1980s and receipt of funding from the World Bank (Roy 1985) that the Orissa Fishery Department introduced prawn aquaculture on officially designated 'wastelands' as part of a supplemental income programme for low-income families titled 'Economic Rehabilitation of Rural Poor' (Mohanty 1988).

To the astonishment of all those involved, the participating families quickly discovered that they were able to earn more in four months than the government-designated official poverty line (based on *annual earnings*) (Khatua 1984). As these results became widely known, the programme served as a model for other similar efforts throughout India and beyond. This success led to a massive influx of individuals from the farming communities into the lucrative fishery and attracted the interest of investors from outside the basin (Pattanaik 2008). Due to the marginal nature of the soils in the coastal tract of Chilika, many of the individuals from these farming communities who took up aquaculture also took up fishing as their primary source of livelihood (Samal 2002). This has led to the occupational displacement and loss of fishing grounds by the fishing communities and simmering resentment between the *matsyajibi* (traditional fishers) and those they insist on calling the *ana-matsyajibi* (non-fishers).<sup>4</sup>

The promotion of the prawn industry by the government is perceived in the fishing communities as being primarily beneficial to the non-fishers' farming castes. In 1990, the non-fisher communities filed a petition in the High Court of Orissa challenging the fishers' traditional use rights to the lake<sup>5</sup> and the lease system for fishing grounds that had existed since colonial times. While the High Court insisted that it did 'not read any traditional right of the non-fishermen fishing,' it concluded that the non-fishers took up 'fishing in a big way and this reality cannot be ignored' (*Kholamuhana Primary Fishermen Co-op Society v. State of Orissa*). The High Court directed the Revenue Department to scrap the old lease system and to reallocate the lake between the two communities, with sixty per cent going to the fishers and forty per cent to the non-fisher communities (Ghosh *et al.* 2006).

Although the legislation authorizing this change in the lease policy i.e. the *Orissa Fishing in Chilika (Regulation) Bill (2002)* has yet to be passed by the State Assembly,<sup>6</sup> non-fishers and moneyed interests latched upon this ruling to forcibly take over fishing grounds in order to intensify aquaculture production in the basin. The fishing communities are deeply resentful of this ruling and reject it on the grounds that it unfairly compromises their access to their only source of livelihood. Nonetheless, when the Tata Group signed an agreement with the Orissa government to establish the Integrated Shrimp Farm Project (ISFP) on 1,400 acres of the lake, these differences were set aside and both communities united under the banner of the *Chilika Bachao Andolan* (Save Chilika Movement) (Mishra 1996). Following a 1996 public interest petition challenging aquaculture on environmental grounds, the Supreme Court of India (*S. Jagannath v. Union of India*) banned all aquaculture within 1000 meters of the lake's high water mark. While this ruling put an end to the ISFP, it has gone largely unheeded. The non-fisher communities and their backers redoubled their efforts and based on the latest CDA figures, over 130 sq. km of the lake is occupied by prawn *gherries* (enclosures) (Pattanaik 2007). The fishing communities object to the existence of these enclosures and blame the Revenue Department and CDA for not enforcing the Supreme Court ruling.

### THE NARRATIVE OF THE 'SHIFTING SEA MOUTH'

During a 2002 interview, CDA Director A. K. Pattnaik explained the pressing need for the dredging of the new sea mouth. 'The mouth keeps on shifting so the [outer] channel is created ... a new channel has stretched by another six km in the past ten years. Supposing you allow it to be like that, it would have gone, say, another six km or so within one decade or so'. This narrative of a 'Shifting Sea Mouth' that is rapidly moving up the coast is prevalent in the scientific and official literature going back to the 1970s. Since that time, the sea mouth and its shifting location has been consistently identified as the key to managing the lake's salinity levels and the continued productivity of the fishery.

The first to present this as a 'crisis narrative' was Reddy (1977), who wrote that, 'It is an established fact that the fisheries prosperity of the lake is dependent on the width of

this natural mouth of the lake. The shifting of lake mouth north-eastwards year after year causes reductions in tidal effect in the lake. This has ominous overtones from fisheries view of point [sic] and it is likely that eventually a stage may reach when self-stocking of the lake of various fish may be adversely affected'. Only four years later, the Additional Director of Fisheries in Orissa presented keeping the sea mouth open as official government policy and essential to economic development. He declared,

*The State Government feel that the mouth of the lake, which is the route for immigration of fish fry and prawn juveniles and also migration of brood stock fish and prawn to the sea should be kept open and suitable environmental conditions maintained inside the lake so that the ecological condition will lead to increased production considering the abundance of the natural food available in the lake. The main necessity for development is dredging of the lake mouth and the 30 km Outer Channel linking the lake to the sea. (Mohapatra 1981)*

In the same article, the introduction of prawn aquaculture was also discussed and Mohapatra observed that, 'Since prawn is exportable to foreign market, a brackish water fish farmer can earn about 10,000 to Rs. 15,000 per acre per annum. The low lying lands in the tidal region lying unproductive may yield quite a sum of foreign exchange by proper farming and exploitation' (Mohapatra 1981).

In 1989, the Orissa Remote Sensing Applications Centre (ORSAC) conducted studies which confirmed that the lake mouth was shrinking at a rate of 1.4 sq. km per yr (Mangla 1989). This evidence was taken as confirmation that the sea mouth was the primary cause of the lake's deteriorating health and it was decided that, '... to maintain a proper tidal and salinity balance in the lagoon, the state Government has requested the National Institute of Oceanography and the Central Water Power Research Centre (CWPRC) to provide a suitable computerised mathematical model. The idea being to open an additional inlet into the lake in the hope that this will improve conditions' (Mangla 1989). Five years later Chandramohan and Nayak (1994) of the Ocean Engineering Division of the National Institute of Technology (Goa), suggested that opening a new sea mouth located in a direct line with the dredged *mugger mukh* would help de-silt the lake, limit sediment deposition and shorten the distance between the main body of the lake and the sea.

Yet, the 'shifting sea mouth' narrative, which presents the historical sea mouth as marching rapidly and dangerously away from the lake, is not supported by the facts. It is true that there is littoral drift and the historical sea mouth is not static, but these fluctuations were neither rapid nor unidirectional. Based on data available from the CDA's own website, the historical sea mouth fluctuated only three and half km over a period of seventy-seven years (CDA 2008a) (Table 2).

### THE HISTORICAL SEA MOUTH

Historical and cartographic research reveals that the historical sea mouth has been in the same general vicinity

Table 2

Location of old sea mouth in relation to the village of Arakhakuda

1914	6 km NE
1965	8 km NE
1986	4½ km NE
1991	5½ km NE

Data retrived from <http://www.chilika.com/about.htm>

between Manikapatna and Arakhakuda since at least the early part of the seventeenth century. Indeed, the first British accounts of the region describe a shallow sea mouth just north of the Chilika port of Manikapatna that made for a perilous crossing:

*The 18 dicto [August, 1631] wee ankered in the rode of Manegapatan being near about 20 leagues to the eastward of Calepar ... Here againe upon the first opportunity we sent [our] shalop ashore, which one came well of againe; the second time [she] was cast away upon the bar and lost 4 men, but by [the help of the?] blackes shee was saved and brought ashore. Besides on [this bar?] was lost and split to pieces 3 or 4 of the contry boates about the sam time, with some other disastrous accidentes that happened unto us in this place ... - Thomas Watts, Master of the Hopewell, at Bantam to the Company, January 2 [29], 1632. (Foster 1910)*

Less than a century later in 1708, Hamilton visited Manikapatna and described it as adjacent to 'a great inlet from the sea' (Hamilton *et al.* 2001). Nineteenth-century British maps of the region further confirm the existence of a sea mouth in this part of the Outer Channel (Blanford 1859). Venkatarathnam (1970) reports that, 'the position of the inlet during 1889 (according to the hydrographic chart of the marine survey of India) corresponds to that of the present period'.

Historical sources also reveal regular anthropogenic interventions as the local communities and the Public Works Department maintained the historical sea mouth when it was blocked up by sedimentation and littoral drift. Sterling (1846) is the first to mention that the mouth was excavated by the government in the 1820s and locates it a mile north of Manikapatna at that time. In a public lecture given in 1915, Annandale stated that, 'The narrow channel through this bar would soon be closed up entirely if it were not kept open artificially. Every few years a new passage has to be cut by the Public Works Department, and even so the size and position of the opening are constantly changing' (Annandale 1915).

There is also evidence that when the mouth was not dredged, the lake waters would forcibly open a channel to the sea during the rainy season. In his inimitable style, Hunter described this as 'An eternal war between the rivers and the sea: the former struggling to find vent for their columns of water and silt; the latter repelling them with its sand-laden currents, and giving a northward bend to their estuaries as they enter the Bay. Where the river has the complete mastery, it sweeps out to the ocean, scouring for itself a channel through the sand' (Hunter 1872). Sewell (1922), who was the first scientist to study the lake's salinity, reported that such a breach had occurred shortly before his

arrival: '... we believe that [the] channel became closed, i.e. towards the end of the dry season. The mouth is known to have been open in April 1919 and in the same month of 1920, and changes in its position are known to have occurred in the former year. We have little doubt that it was closed for a considerable period in the summer of 1919'.

By 1927, the lake mouth was completely silted up. At the urging of 'zamindars cultivating the areas adjoining the lake', the Bihar and Orissa Government undertook a Rs 40,000 dredging project to 'keep the mouth open, and thus minimize the devastation caused by floods in this area' (Pitt 1932). Yet, within a short period of time, the new mouth was closed by sand storms. More recently, following the devastating cyclone of 11-12 September 1972, two new mouths were opened *in addition* to the historical sea mouth due to storm surge and flooding (Mohanty 1975). However, within a matter of several years both of these closed up and only the historical sea mouth remained.

### FROM 'FLOOD-DEPENDENT' TO 'FLOOD-VULNERABLE'

Historically, the lake and the surrounding lowlands were prone to seasonal flooding.<sup>7</sup> 'Of the thirty-two years ending in 1866, twenty-four have been years of flood, so serious as to require additional remissions of revenue. During the last fifteen of them, there has only been a single one in which such remissions have not been required' (Hunter 1872). Anandale and Kemp (1915) observed that 'The great changes in salinity of the Chilika Lake are due, as has already been explained, to the floods of fresh water which enter it each year at the northern end from several branches of the Mahanadi system... The floods that enter the lake at the close of the monsoon ... expel all the salt water from the northern portion, driving it through the Outer Channel to the sea, and are of sufficient volume to raise the level of the lake some 5 or 6 feet above the mean of the dry season'.

The Northern Sector of the lake regularly suffered the brunt of these inundations. This was partly because the northwesterly monsoon winds would pile up the lake's waters in front of the discharging rivers just as they were in spate, and partly because of upstream embankments that shifted the floodwaters to the lower reaches of the river. The results were often catastrophic, such as during the 1866 floods when 275 square miles of the Puri District were inundated to a depth of three to ten feet for a period ranging from five to forty-five days (Hunter 1872).

Considering the extent of flooding, it is hardly surprising that the tradition of hydrological interventions and sea mouth modifications dates back to British times. As early as 1858, Captain W. D. Short proposed that the Chilika sea mouth be widened in order to allow for the faster release of floodwaters (D'Souza 2006). Only a year later, Captain J.C. Harris proposed the 'Daltala Cutting', which was intended to funnel water from the upper reaches of the Mahanadi River into Chilika and from there to the sea. Because of the vast amounts of water involved and the average drop of 3½ feet per mile along its route, the entire plan hinged on the ability to ensure

that water could be quickly expelled from the lake. This meant that 'unless a vast opening to the sea was provided, the whole country for thousands of square miles would be submerged ... and half the Puri district drowned' (Hunter 1872). Ultimately, the plan was deemed impracticable and shelved.

As the above examples clearly demonstrate, flood control programmes and engineering solutions to environmental problems have a long pedigree in Orissa. In *Drowned and Dammed* (2006), D'Souza traces this approach back to the arrival of the British and the introduction of capitalist private property rights. He contends that the focus on land revenue administration manifested itself in a flood control regime designed to ensure the productivity of land while protecting it from disturbance. At the same time, these hydrological interventions served to justify British rule and were touted by the colonial government as examples of 'English humanity and English engineering skill' (Hunter 1872).

D'Souza convincingly demonstrates that prior to the arrival of the British, the Mahanadi delta was a 'flood-dependent' region employing an elaborate system of overflow irrigation that both benefited the rice crops and reduced sedimentation in the river channels. The British insistence on flood control discursively reconfigured the delta into a 'flood-vulnerable' landscape and the annual floods as a 'calamity of season' (D'Souza 2006). Ironically, the building of embankments only aggravated hydraulic volatility and therefore the Orissa delta was seen as particularly in need of British rule and hydrological interventions. As a result, these policies were continued because the colonial government 'could not backtrack on its environmentally-debilitating policies without undermining the very architecture of its rule and the social economic fabric of its existence' (D'Souza 2006).

During the waning years of colonial rule, the colonial government approved a final, grandiose flood control plan that sought to control the Mahanadi and its tributaries at the watershed level. Inspired by the Tennessee Valley Authority (TVA) and completed with United States assistance, the Multi-Purpose River Valley Development (MPRVD) project resulted in the construction of both flood control and power-generating dams. The Mahanadi was to be 'remade' to serve the state and 'deltaic inundation, in a sense, was no longer meant to be a part of nature, a geomorphological process, a temperamental flood-prone river, but instead a humming current of carefully controlled and calibrated water that was meant to lubricate a new physical context for India' (D'Souza 2006). The Hirakud Dam – the world's largest earthen dam – was completed in 1953, became operable in 1958 and its reservoir reached full capacity in 1966. Other dams and barrages were constructed downriver, including the Naraj Dam above Cuttack, which diverted the waters of the Daya and Bhargavi Rivers that flow into Chilika Lake in an attempt to minimise flooding in the deltaic Northern Sector.

### STAGNANT WATERS

Although the MPRVD and Hirakud Dam have not accomplished

the stated goal of preventing flooding in deltaic Orissa,<sup>8</sup> their construction has resulted in reduced flows to Chilika Lake. Yet, the CDA neither commissioned studies regarding the impact of upstream diversions nor explored any watershed alternatives that would address the reduced flows prior to the opening of the new sea mouth. This is particularly surprising if one considers that the possible impacts of these flood control policies on Chilika were well known and widely discussed in the 1950s. In a revealing passage, Jones and Sujansingani warned that ‘The cumulative effect of reduction in the volume of flood water reaching the Lake may well be a loss in respect of the fisheries’ (1954). In addition, they explained that,

*The hydrological conditions, specially the salinity, are likely to undergo a great change in the next few years as with the completion of the Hirakud and Mahanadi projects the flow of water in the Kathjuri and consequently into the Lake will be reduced and will in turn cause rise in the salinity beyond the present levels leading to changes in the animal and plant life in the Lake. It is doubtful if the prevailing wide range of salinity would continue as before accommodating such a rich variety of fish life in different seasons and different parts of the Lake. Fish life in the Lake seems to thrive on the annual flushing of the Lake by flood waters which push out the stagnant water of the previous monsoon season and replace it completely, preventing the shallow area from becoming a marshy and swampy lagoon where fish cannot live and grow. (Jones and Sujansingani 1954)*

What the authors could not predict was that the decline in freshwater flows would lead to a decrease in average salinity due to the silting up of the sea mouth. Throughout the 1960s, average salinity declined from 17.5 ppt in 1957-8 to 9.0 ppt in 1972-3 (Biswas 1995).

Contrary to the CDA assertion that the ‘shifting sea mouth’ was causing the fishery decline and the spread of aquatic macrophytes, the evidence points to watershed-level flood control practices that prevented the seasonal flushing of the lake. Large freshwater flows are critical to the health of the lake because they supply it with nutrients and chelating agents. Far from being an unnatural tendency, the first historical reports and scientific studies attest to the regularity of flooding and the fact that during the monsoon and post-monsoon season, most of the lagoon regularly became a freshwater lake in the Northern Sector for at least as far south as the inner channel (Annandale and Kemp 1915, Banerjee and Roychoudhury 1966, Hunter 1872, Mohanty 1975, Sewell 1922). Since this regular flooding maintained the sea mouth open or resulted in the opening of a new mouth, the residence time of this freshwater was limited and weed growth was contained.

Another factor that has further slowed down the flow of water and increased the residence time of water in the lake is the introduction of prawn aquaculture. This has increased the rate of sedimentation in the lake, thereby causing the sea mouth to silt up more rapidly than it would otherwise. *Gherries* (enclosures)<sup>9</sup> in the lake – whether they are constructed of bamboo or fine netting – act as obstructions which prevent water from mixing and hence results in reduced salinity levels as well as lower levels of oxygen that adversely affect the

fish population of the lake. Prawn enclosures also increase the amount of nitrogen and phosphorous in the water, thus causing eutrophication while spurring the growth and spread of algae and aquatic macrophytes (Abbasi and Mishra 1997, Pattanaik 2008).

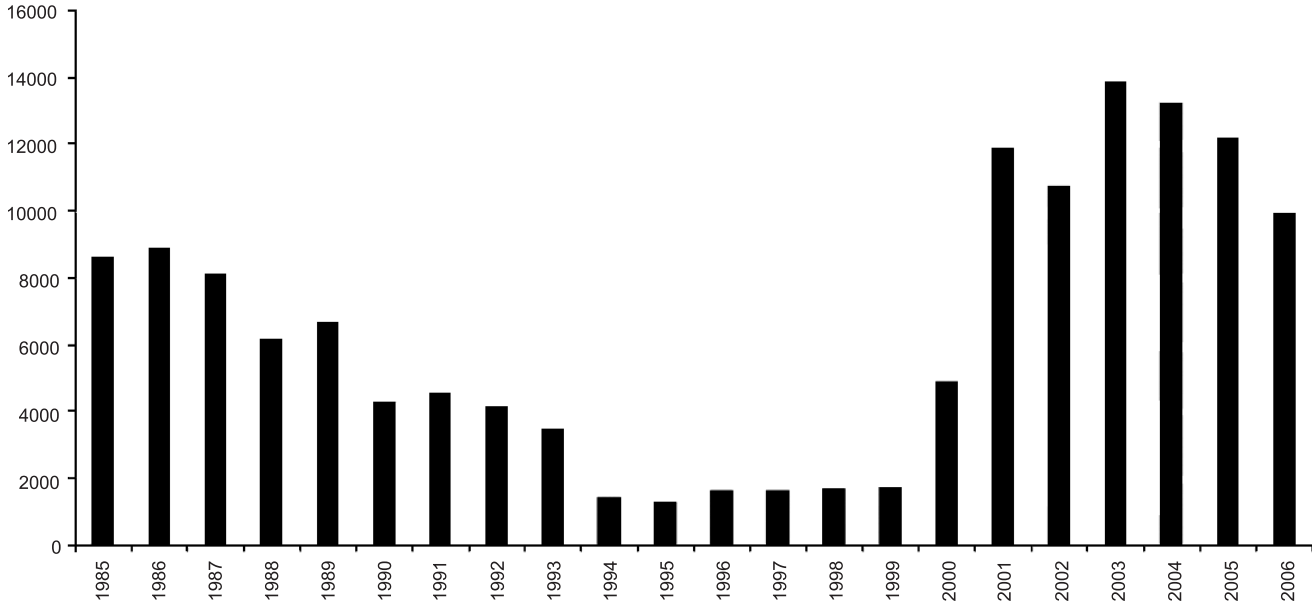
Since there is a cost saving in materials and effort when building *gherries* in the lake’s channels, these have all been expropriated by the adjacent communities for prawn aquaculture. These channels are critical to the ecosystem and their loss is highly detrimental to the fishery because they serve as migratory routes and nursery grounds for many fish species such as mullet and prawn. Finally, since it is cheaper to obtain prawn seedlings from local sources rather than government hatcheries, fine mesh nets are used to catch the small prawn (Dujovny 2007). This leads to the destruction of many other species that are caught as bycatch. Often this bycatch is dried in the sun, ground up, and sold to the local prawn farmers as fish-meal. Though all of the above factors are specific to Chilika Lake, they are consistent with a large and growing body of literature surrounding the detrimental environmental and social impacts of prawn aquaculture in South Asia and throughout the tropics (Bhatta and Bhat 2002, Patil and Krishnan 1998, Pradhan and Flaherty 2008, Primavera 1997).

A look at the fish landing statistics reveals that, since the introduction of prawn culture in 1982, the fishery has been in steady decline. With the introduction of trade liberalisation in 1991 and the 1992 Orissa High Court ruling allocating the local farming communities forty per cent of the lake, the decline in landings is even more precipitous (Table 3). Recent faunal diversity studies also demonstrate that Jones and Sujansingani’s (1954) predictions regarding the possible loss of fish species following the completion of the MPRVD project were prophetic. The studies reveal that from 1954 to 1995 the lake witnessed a decline from 138 fish species to 69 (Ghosh *et al.* 2006). In short, reduced flows due to flood control policies and the introduction of prawn aquaculture account for the declining health of the lake at least as well, if not better than, the narrative of the ‘shifting sea mouth’.

#### FROM MANAGED ECOSYSTEM TO ORGANIC MACHINE

Similar to the case of Guinea’s Kissidougou Prefecture described in *Misreading the African Landscape* by Fairhead and Leach (1996), an ‘environmental orthodoxy’ developed around Chilika’s ‘shifting sea mouth’. In the African case, the environment was depicted as suffering from rapid deforestation due to anthropogenic pressures, when in reality it was precisely the inhabited savannah landscapes that were converting into forest. In the case of Chilika, the narrative of the ‘shifting sea mouth’ was presented as the underlying cause for the lake’s declining health at the same time that the local fishing communities were consistently insisting that it was the introduction of aquaculture that is negatively impacting the ecosystem.<sup>10</sup> In both cases, ‘The origins and endurance of such landscape misreading have depended, in part, on the





**Table 3**  
*Chilika fish landings from 1985 to 2006*

relations of production of scientific knowledge within the powerful economic and institutional structures which apply it' (Fairhead and Leach 1996).

As the use of mathematical flow models and satellite imagery clearly demonstrates, scientific approaches were privileged and central to validating the official claims that the sea mouth was shifting and a new sea mouth needed to be dredged where it was eventually dredged. According to the CDA, 'The application of remote sensing and geographical information systems serves as an important management and monitoring tool, and the scientific results obtained from the targeted studies and modelling efforts provided vital clues for restoring the lake's salinity gradient' (Ghosh *et al.* 2006). To accept this assertion uncritically would, however, ignore the fact that neither science nor its instruments can be separated from human context. As Turner (2003) pointed out, Remote Sensing and GIS are not 'neutral mediators of reality' and run the risk of being 'a straightforward mediator of political economic interests or an overly blunt purveyor of bias and ignorance of local situation'.

The privileging of satellite imagery and flow models is emblematic of what Scott (1998) has termed an 'imperialism of high-modernist planned social order ... that excludes the necessary role of local knowledge and know-how'. These tools provided the 'vantage point of a helicopter hovering far above the ground: in short, a God's-eye view, or the view of an absolute ruler' (Scott 1998). More importantly, the reliance on remote sensing and ecosystem models systematically undermined the legitimate concerns of precisely those stakeholders it was ostensibly helping. Since these 'sophisticated' tools are presently only available to the policymakers, this places the local communities at a disadvantage and forces them into the unenviable position of passive receivers of government-

produced 'vital research information' (Ghosh *et al.* 2006) about their own surroundings.

Ironically, because of the longstanding discourse surrounding flood control that acted as an underlying 'social frame' (Forsyth 2003), this synoptic view also failed to see the bigger picture and misdirected all attention to the Outer Channel of the lake. As the growing literature on the politics-of-scale has clearly shown, scale is neither a given nor politically neutral but rather socially constructed (Marston 2000, Meadowcroft 2002, Swyngedouw 1997, Wilbanks 2006). Lebel (2006) noted that this can be especially problematic in the case of Environmental Impact Assessments (EIA) since scales risk being adjusted to reflect the jurisdictions of the government agencies responsible for overseeing a particular ecosystem. Satellite imagery can then be convincingly used to demonstrate 'complete' areal coverage while at the same time avoiding the difficult question of which areas should be covered or whether multi-scalar impacts need to be taken into consideration. The ready accessibility and immediacy of satellite imagery, and the fact that these images have only been available since the launching of Landsat in 1972, further skews the data by limiting temporal scales. This can lead to an 'effacement of history' (Brosius 2004) that discounts the important role of humans in landscape management, while at the same time perpetuating an equilibrium ecosystem model that favours homeostasis (Gunderson and Holling 2002).

As a social construction, there is also the risk that scales will be adjusted to support political or economic agendas. For instance, in the case of Chilika it is unclear whether the decision to dredge the new sea mouth (based on catchment rather than watershed level data) may have been influenced by trade liberalisation agendas and the government promotion of aquaculture. After

all, as the epicentre of this burgeoning industry, Chilika continues to be an important source of hard currency for the Indian government. According to the latest statistics, India is second only to China in quantity of fish produced by means of aquaculture. Almost all of the prawn produced in India is destined for foreign markets, and worth an estimated USD 715 million in 2004 (Fisheries and Aquaculture Department 2007).

Although the CDA asserts that its decisions have been made on the basis of 'valid science' and the agency has garnered acclaim both at home and abroad, its dual mission opens the door to conflicting interpretations of its interventions. On the one hand, it has been tasked with maintaining the ecological integrity of the lake, while on the other hand, its mandate as the Chilika Development Authority is to 'execute multidimensional and multidisciplinary developmental activities' (CDA 2008b). The result is that the CDA has failed to clarify the role of economic considerations in its decision-making processes, raising questions regarding the agency's priorities.

For example, the CDA has presented the opening of the new sea mouth and the stated goal of 15 ppt salinity in the Northern Sector during the dry season (April – May) as an ecological necessity (CDA 2008c). Yet, this directly contradicts the advice of a panel of water experts who recommended that the government 'maintain optimum level of salinity of 8-15 ppt, everywhere *except* in the Northern zone' (CIDA and CENDERET 1992; author emphasis). While the increased salinity was presented as necessary to halt the spread of aquatic macrophytes, these interventions have opened up the Northern Sector to prawn aquaculture and ensure that there is precisely the right salinity gradient at the height of the prawn season. Although the dredging of the sea mouth and the *mugger mukh* up to the Daya and Luna River deltas is presented by the CDA as beneficial for the fishery and the fishing communities, it is precisely the farming communities of the Northern Sector of the lake who are able to increase their agricultural production now that they no longer have to worry about waterlogged soils. These same communities can now also build prawn ponds and enter the fishery to practice prawn aquaculture.

Could these interventions, which were ostensibly meant to benefit the fishing communities, lead to further occupational displacement and marginalisation? While the CDA statistics regarding the remarkable recovery of the lake's fishery seem heartening at first glance, it is unclear if this is really the result of an improved ecosystem or simply due to an increase in prawn culture and a change in sampling that now includes prawn from aquaculture sources.<sup>11</sup> Though there are clearly issues of relative poverty between the traditional fishing communities and those who have recently entered the fishery, the fishers have legitimate reasons for concern if past trends are any indicator of what lies ahead. As Samal and Meher (2003) noted, the intensification of prawn aquaculture in the lake resulted in, 'an improvement in economic conditions of some non-fishermen [came] at the cost of the fishermen whose fishing fields have been squeezed.'<sup>12</sup> As long as the CDA and the state government fail to address the pressing issue of aquaculture such nagging doubts will remain.

At the same time, recent proposals to grant the CDA sweeping police powers to deal with the issue of aquaculture under the proposed Orissa Fishing in Chilika (Regulation) Bill (Ghosh *et al.* 2006) need to be carefully considered. In particular, CDA's role in what Sivaramakrishnan (1999) has termed 'statemaking' needs to be examined. As his study of forestry practices in the Midnapore District of West Bengal revealed, clumsy state interventions in the clearing of woodlands, eradication of vermin, sedentarizing of tribal populations, and stabilisation of cultivated lands often worked at cross-purposes, leading to contradictory impacts. For example, relocating tribal groups in the name of forest protection led to increases in vermin populations and undermined the goal of extending the area of cultivatable land. The result was that the colonial authorities were compelled to increase their involvement through additional layers of bureaucracy in order to deal with ecological problems and social unrest.

Similarly, in the case of Chilika, government interventions going back to the colonial era have had contradictory results. Flood control policies led to increased flooding in deltaic Orissa and spurred increased government interventions. The decision to harness the river systems for the good of the state under the MPRVD has not accomplished its stated goal of eliminating flooding in the delta, but has stemmed the flows to Chilika and choked the lake with sediment. The declining health of Chilika has led the government to establish new layers of bureaucracy such as the CDA in order to engineer a solution to the ecological problems previous government interventions have wrought. As the narrative of the 'shifting sea mouth' clearly shows, these government bureaucracies are often blinkered by their own institutional traditions. This often manifests itself in unexpected and self-contradictory ways. Indeed, there is a certain irony if one considers that the new sea mouth was dredged in part to prevent flooding, but is necessary precisely because there are no more floods.

Most recently, the bypassing of the Outer Channel communities has resulted in cultural adaptations such as a shift to dolphin tourism and the importation of new varieties of gill nets (*alim jal*) that can withstand the stronger currents. Both of these developments have led to increased dolphin mortality and new layers of government bureaucracy (Sinha 2004). In 2007, the CDA was granted Wildlife Warden Status (Government of Orissa 2007) by the state government and is reportedly looking into the possibility of declaring the new sea mouth area and Outer Channel a marine protected area that would be off-limits to fishing and motorised boats.

In the *Organic Machine*, White (1995) colourfully describes how the Columbia Basin Project, a TVA-inspired programme of navigation canals, flood control and power-generating dams converted the Columbia from a rushing river into a 'rationalized river' that 'would flow when and where managers desired it to flow'. Similar sentiments were expressed regarding the MPRVD, which was supposed to 'liberate the cultivator from the 'tyranny of the monsoon', by effecting the 'rationalization and control' through technical interventions of the otherwise volatile river systems' (D'Souza 2006).

As a result of recent (2004-06) unexpected declines in the fish catch (Table 3), the CDA has belatedly woken up to the importance of freshwater flows into the lake and secured funding from the World Bank to develop an Integrated Management Action Plan for Chilika Lagoon (World Bank 2005). The plan will assess the impact of the Naraj Dam water diversions on the lake and calculate how much water should be released to help maintain the lake's salinity levels (Ghosh *et al.* 2006). It appears that once again, the government authorities have chosen to calibrate and prod Chilika to flow according to schedule rather than confront the difficult decisions that need to be taken regarding flood control and aquaculture.

To accomplish this perennial goal, GIS studies, mathematical flow models, and satellite imagery have been solicited once again by the CDA to properly model the lake's ecosystem beyond the immediate catchment level. As White (1995) wryly noted with regard to the Columbia, 'In a very real sense the Columbia has taken the logical step beyond being an organic machine. It has become a virtual river'. Much like the Columbia, Chilika is now expected to mimic its virtual self in order to return to what CDA officials have characterized as a 'more natural state' (Ghosh *et al.* 2006).

Unfortunately for environmental engineers with visions of equilibrium and balance in nature, Chilika has a long history of stochasticity. This was most recently and forcefully demonstrated in August and September of 2008, with the sudden and unanticipated opening of two new mouths to the north of the new sea mouth (Mishra 2008). Once again, the lake proved that, regardless of the various efforts to manage and reshape it, it ultimately remains 'tied to larger organic cycles beyond our control' (White 1995).

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## Notes

1. Fishing in Orissa has traditionally been a caste-based occupation and those who practice fishing are members of scheduled castes (or 'other backward castes') and thus part of the so-called low-caste 'untouchables'. Among the *jatis* that have traditionally fished in the lake are *Kaibarta*, *Keuta*, *Khatia*, *Khandara*, *Tiary*, *Gokha* and *Nolia*.
2. The following discussion relies heavily on Ghosh, *et al.* (2006) which is almost identical to Ghosh and Pattnaik (2005). Both of these papers were written together with Dr. Ajit Kumar Pattnaik, the recently reinstated Chief Executive Officer of the CDA, who oversaw these interventions from 1997-2006. Jellison, *et al.* (2004) acknowledges Dr. Pattnaik as a fact checker, and Mohapatra, *et al.* (2007) was written by CDA employees and a CDA consultant. All of these articles are consistent with the information available at the official CDA website ([www.chilika.com](http://www.chilika.com)). In addition, I personally interviewed Dr. Pattnaik and Dr. K. S. Bhatta, limnologist and senior CDA scientist, regarding the new sea mouth in 2002 and 2005.
3. I spent May through July, 2002 in Chilika thanks to funding received

through an Ethnographic Research Training Grant from the National Science Foundation. Extensive fieldwork from January 2005 through May 2006 was funded through a National Science Foundation Dissertation Improvement Grant.

4. Some 'non-fishermen' bristle at this designation and point out that they have always fished in the lake for *tarkari* (meals). While there are reputedly members of every *jati* (subcaste) fishing in the lake, the vast majority of those that have entered the lake are from the *Khondait* agricultural caste.
5. These traditional use rights extend at least as far back as 1805 and were enshrined in the 1897 Settlement of the district (Taylor and Maddox 1899). Successive legal rulings, including in post-independence India have confirmed these rights.
6. In a slight adjustment to the Orissa High Court ruling, the 2002 Bill allocates seventy per cent of the lake to the fishers and thirty per cent to the non-fishers.
7. Hunter (1872) relates that, 'The various Fiscal Divisions of Puri district are classified according to the extent to which they are liable to such calamities. Among them, those on the shores of the Chilka are stated to be entirely within the reach of the inundations'.
8. Flooding in the Mahanadi river basin has occurred in 1955, 1982, 2001 and most recently in September 2008. Though there has been occasional localized flooding in the Northern Sector of the lake, major flooding throughout the lake and in the Outer Channel region has not occurred since 1972.
9. In the Chilika area three kinds of prawn culture are practiced. Prawn *gherries* are enclosures in the lake, *bundhs* are near shore impoundments and *pokhori* are onshore ponds that are often converted rice paddy.
10. For the classic South Asian case of an environmental orthodoxy that was debunked, see Thompson and Warburton (1985) and Thompson, *et al.* (1986) questioning the then prevailing view that deforestation in Nepal was causing floods in India and Bangladesh. For an exhaustive list of environmental orthodoxies, see Forsyth (2003).
11. Prior to 2000, the Orissa Fishery Department was responsible for collecting fish landings data. Following the opening of the new sea mouth, the CDA was tasked with data collection (Mohapatra, *et al.* 2007).
12. The authors found that 'the average income of the fishermen households (Rs 3,721) is significantly lower than that of non-fishermen households (Rs 4,117)' (Samal and Meher 2003). This socio-economic study was the only social study financed by the CDA prior to the opening of the new sea mouth.

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