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ORIGINAL PAPER

Fisheries enhancement and biodiversity assessment of fish, prawn and mud crab in Chilika lagoon through hydrological intervention

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Abstract The degraded state of the fragile ecosystem of Chilika lagoon on the east coast of India caused by natural changes and anthropogenic pressure was in the process of restoration through an effective hydrological intervention during 2000 after thorough scientific investigation including EIA study. The rich fisheries of Chilika lagoon that support livelihood of 0.2 million local fisherfolk was in dwindling state during the eco-degradation phase. Studies on fisheries and fish biodiversity of the lagoon for 4 years before and 4 years after the intervention showed the stark and rapid recovery of fishery immediately after opening of the new mouth with sixfold increase in average annual landing. The average productivity (11.3 t km^{-2}) and CPUE (6.2 kg boat-day^{-1}) during post intervention phase registered 528 and 464% increase, as compared to Pre-intervention years. In total, 277 species of fish and shell fish were documented as occurring in Chilika lagoon before the hydrological intervention. Inventory survey for fish and shell fish species diversity during and after hydrological intervention documented 68 and 97 species, respectively. New records of 56 species of fish and shell fish (7 freshwater, 20 brackishwater and 29 marine) were documented from Chilika lagoon after the hydrological intervention. Analysis of commercial catches showed that the migratory species contributed to the bulk of catches (75% by species and 68% by catch weight). Fish yield and biodiversity seemed to be very sensitive to salinity and hydrologic dynamics of the lagoon. Correlation analysis indicated inverse relationship between water transparency and fish catch (R^2 = 0.715; d.f. = 25; $P < 0.01$). Positive correlation between salinity and prawn landing (R^2 = 0.542; d.f. = 25; $P < 0.01$) and salinity and mud crab landing (R^2 = 0.628; d.f. = 25; $P < 0.001$). Average salinity for the whole lagoon was significantly increased by 42.7% ($P < 0.007$) as compared to pre-intervention situation. Maintenance of estuarine character of Chilika's ecosystem particularly the salinity gradient, un-hindered auto-recruitment of fish and shell fish and prevention of destructive fishing are the key factors for fisheries enhancement. Unless carefully planned conservation and regulation measures are ensured with the active participation of local communities during the early phase of restoration, the present scenario of fisheries enhancement may not sustain for longer time.

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Introduction

Chilika lagoon, a much focused designated Ramsar Site of international importance and the largest coastal wetland ecosystem in Indian sub-continent (Fig. 1) is one of the finest repositories of aquatic biodiversity and a steady source of fishery, sustaining the livelihood and nutritional need of about 0.20 million local fisherfolk. The lagoon was critically threatened during last few decades due to natural changes coupled with anthropogenic pressure. In the process of degradation of the ecosystem, the lagoon fishery became the major victim leading to the miseries of fishing communities. Hence it was imperative to restore the fragile ecosystem of Chilika lagoon to recover *interalia* the fisheries and biodiversity for the larger benefit of the wetland communities.

Hydrologically, Chilika lagoon is influenced by three sub-systems, the Mahanadi distributaries (Delta Rivers), 52 rivulets and streams draining into the lagoon from the western catchment and the sea (Bay of Bengal) as depicted in Fig. 2. The lagoon is situated at the southern margin of the Mahanadi delta; it receives less than 6% of total Mahanadi flow, but this volume represents close to half the total fresh water inflow in to the lagoon. The lagoon receives inflows from its western catchments (1,560 km^2) and runoff and irrigation drainage from delta region (2,250 km^2). The total Chilika drainage basin, including the lagoon itself and the contributing islands and coastal strip is 4,300 km^2 (World Bank 2005). The Chilika drainage basin is estimated to contribute about 1,760 million cubic metres (mcm) water into the lagoon, direct precipitation has been estimated at about 870 mcm and total evaporation losses are estimated at about 1,286 mcm (ORSAC 1988). The freshwater inflows influence the biogeochemistry of Chilika lagoon in several ways, although few of these are well quantified. First, and most importantly it is the freshwater

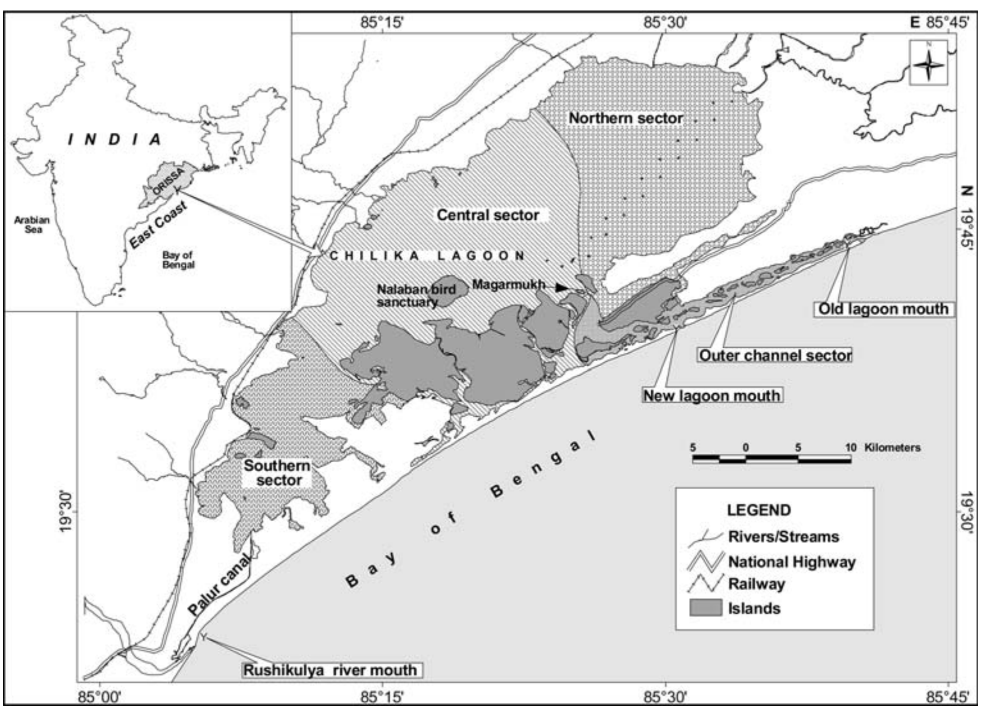

Fig. 1 Location map of Chilika lagoon showing four ecological sectors, and location of new and old lagoon mouths

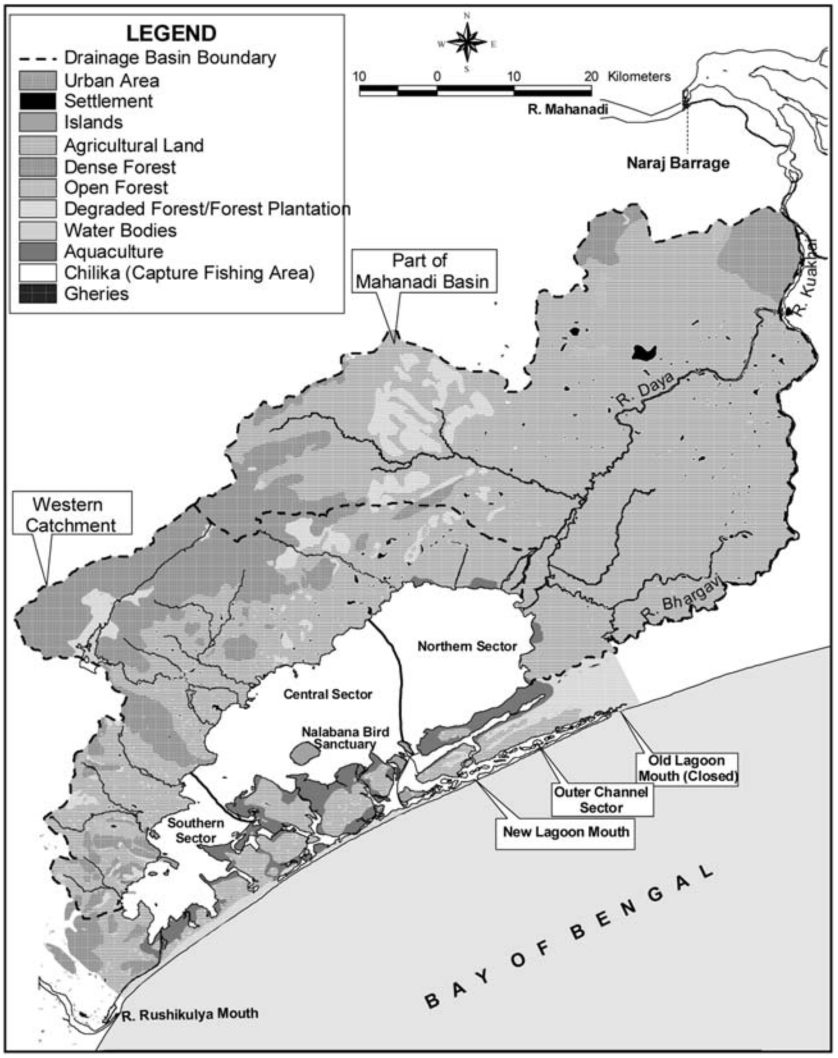

Fig. 2 Map of Chilika lagoon showing three hydrologic sub-systems, drainage basin, land use pattern and four ecological sectors

inflows that drive the spatial and temporal salinity dynamics, that contribute to the temporal and spatial mosaic of different aquatic habitats for plants and animal species, and their varying lifecycle requirements (World Bank 2005). It is primarily this dynamic salinity regime that enables the lagoon to support high biodiversity and productive fishery.

Ecologically, Chilika lagoon is an assemblage of shallow to very shallow marine, brackish and freshwater ecosystems. Salinity is the most dominant factor determining the lagoon's ecology, and the salinity dynamics are controlled jointly by the nature of the connection to the sea, associated tidal fluctuations, and the volume and timing of freshwater inflows to the lagoon from the Delta Rivers and western catchments. Both of these controlling factors are subject to natural variability, and have been affected by human activities. The lagoon is broadly divided in to four natural sectors based on the ecological characters (ecological sectors) namely, northern, central, southern and outer channel sectors (Fig. 2). The northern, central and outer channel sectors are most influenced by freshwater inflows during monsoon and tidal ingress pushing the seawater into the lagoon during November–June. These two antagonistic hydrological processes help maintain the estuarine character of the lagoon and result in high species richness, with penetration of fish faunas respectively from marine and inland origin. All the four ecological sectors of Chilika lagoon characteristically differ from each other, with different salinity pattern, bathymetry profile, species diversity spectrum, food niches, recruitment rates and productivity levels.

Chilika lagoon is a hot spot of bio-diversity inhabiting a number of endangered species listed in the IUCN Red List of threatened species (World Bank 2005; CIFRI 2005). It is an avian grandeur and the wintering refuge for more than one million migratory birds and has global importance as a waterfowl habitat (Balachandran et al. 2003; World Bank 2005). Chilika is one of the two lagoons in the world that support Irrawadi dolphin populations (World Bank 2005), which is regionally, if not internationally, important (Isabel Beasley 2003).

The first comprehensive study on faunal diversity of fish and shell fish in Chilika lagoon was carried out by Zoological Survey of India (ZSI) during 1914–1924 (RamaRao 1995) and there was no further follow up except some fragmentary reports published during later periods (Trisal 2000). The first organised fisheries investigation with holistic approach in the lagoon was carried out by the Central Inland Fisheries Research Institute (CIFRI) during 1957–1965 (Jhingran and Natrajan 1966, 1969), which was not further followed up. In total, 225 fish species, 24 prawn and 28 crab species were recorded from Chilika lagoon till 1999–2000 (Mohanty 2002). Thus, during this 40 years gap and in the face of continual ecodegradation, no attempt was made to study the lagoon fisheries including inventory of fish and shell fish biodiversity until the recent hydrological intervention in the lagoon during 2000. The conservation and management of biodiversity in general and fish biodiversity in particular were almost impossible without restoration of the lagoon ecosystem.

The Chilika lagoon supports a diverse and dynamic assemblage of fish, invertebrate and crustacean species belonging to marine, brackish and freshwater habitats, providing the basis of a productive fishery. The economic valuation of Chilika ecosystem has distinctly established the importance of fisheries resources, which account for more than 71% of the total value in monetary term (Ritesh Kumar 2003). The decadal fisheries output during 1950–1951 to 1999–2000 fluctuated between 2586 t and 7206 t (CDA 2005).

Eco-degradation in the Chilika lagoon was visibly started from the later part of seventies with increasing natural changes, such as increasing sediment load, weed proliferation, decrease in salinity regime, choking of outer channel, particularly its opening to the main lagoon (Magarmukh) and Palur canal. Excessive sediment loading to the lagoon (around 0.3 million tonnes per year) caused by river basin modification and degradation of the catchment ecology (Pattanaik 2001), caused shoal formation in the outer channel and shifting of lagoon mouth far away (30 km from the main lagoon) resulting in poor exchange of water. These natural changes distinctively contributed to the eco-degradation in the lagoon which was further aggravated by incessant anthropogenic activities such as agricultural activities by curving out extensive fringe areas with earthen dikes, prawn culture pond development along fringe areas, un-abated expansion of eco-inimical and illegal shrimp pen culture (prawn gheries) inside the lagoon covering more than 10,000 ha (11% of lagoon area) (Mohanty et al. 2004a, b), excessive fishing activity including destructive fishing.

The natural changes coupled with anthropogenic activities progressively increased resulting in the degradation of the lagoon’s ecosystem with drastic changes in the ecological characters and overall loss of biodiversity. The lagoon fisheries were major victim in the process of ecodegradation. The lagoon with estuarine character gradually moved towards freshwater ecosystem due to continual decrease in salinity level. Owing to such threatened condition of the ecosystem, the Chilika lagoon was included in the Montreux Record (Threatened list of Ramsar Sites) in 1993. The fish yield touched the nadir with all time low of 1,269 t during 1995–1996. It was therefore imperative to restore the degraded ecosystem of Chilika lagoon through hydrological intervention with ecosystem approach so as to recover the threatened biodiversity and fishery for benefit of the people of this important coastal wetland. The objectives of the present study were to assess impact of the hydrological intervention on fisheries including fish and shellfish biodiversity of Chilika lagoon.

Materials and methods

Study site

Chilika lagoon lying on the east coast of India, situated between 19°28′–19°54′ N latitude and 85°05′–85°38′ E longitude fluctuates in area from a monsoon maximum of 1,165 km^2 to a dry season minimum of 906 km^2 (annual average of 923 km^2); the linear axis is 64.3 km and average mean width 20.1 km (Pattanaik 1998; Ghosh and Pattnaik 2005). The lagoon is separated from the Bay of Bengal by a sand bar between 100 m and 1.5 km wide; a 30 km outer (inlet) channel connects the main lagoon with the Bay of Bengal (Fig. 2). The 14 km long Palur canal connects the southern end of the lagoon to the sea through Rushikulya river mouth.

Hydrological intervention

Based on the intensive studies on coastal process and two- dimensional mathematical model studies (Nayak et al. 1998) and recommendation of the Central Water and Power Research Station (CWPRS), Pune, India, a lead channel (3.2 km long, 100 m width and 3 m depth) was dredged at Magarmukh, the gateway between the lagoon and the outer channel (Fig. 3) which was heavily silt-choked. It was followed by environmental impact assessment (EIA) study carried out by National Institute of Oceanography (NIO), Goa which indicated negative environmental risk on the ecosystem. (Pattanaik 2001). An artificial mouth (New Lagoon Mouth) was opened on 23rd September 2000 by Chilika Development Authority (CDA), which reduced the length of the outer (inlet) channel by 18 km from Magarmukh (Fig. 3). The location of the new mouth with effective width of 240 m and depth of 5.5 m was just 12 km from the lagoon (Fig. 3).

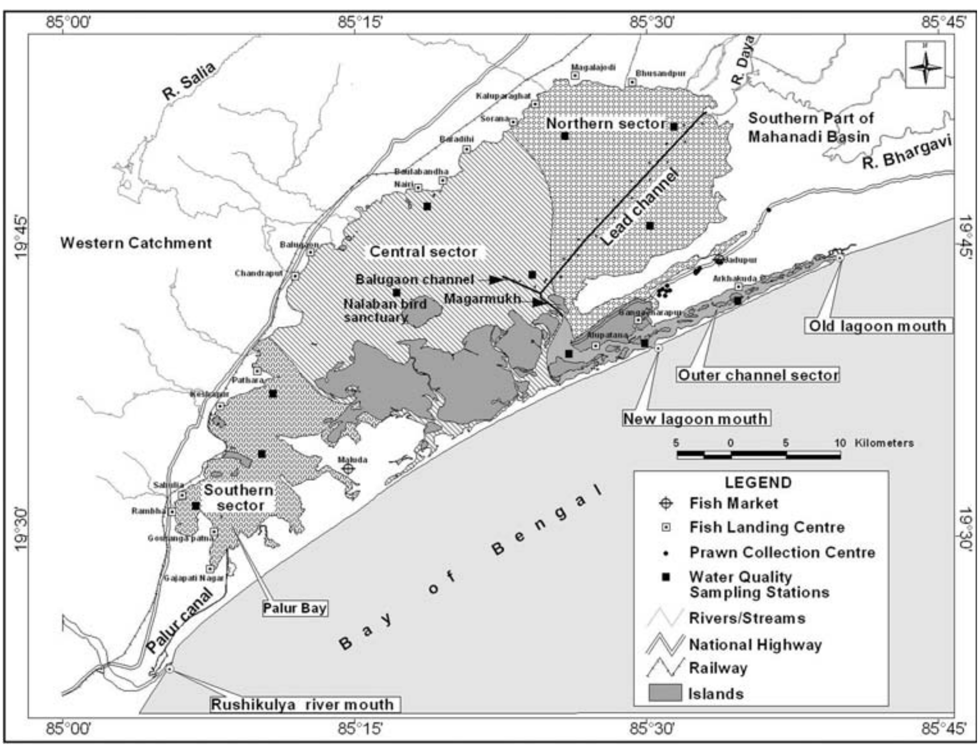

Fig. 3 Map of Chilika lagoon showing hydrological intervention, water quality sampling stations, fish landing centres, prawn collection centres, fish markets and islands

The lead channel at Magarmukh was further extended (Fig. 3) towards the river outfall point over a length of 22.5 km (25.7 km including the lead channel) for better propagation of salinity and flushing out of sediment from the northern sector. The other objectives of the dredged channel were to facilitate the dispersal of fish and shell fish juveniles to northern sector and anadromous breeding migration for Indian shad (*Tenualosa ilisha*). Another 2.8 km dredged channel (Balugaon channel) from Magarmukh in the western direction was also extended to facilitate salinity propagation and fish recruitment to central sector. The silt-choked and defunct 14 km long man-made Palur canal connecting the Palur Bay of the southern sector with the Bay of Bengal through Rushikulya river mouth (Fig. 3) was also renovated during 2004, which provided effective recruitment and migration route for fish and shell fish to southern sector. The hydrological intervention was carried out to restore the Chilika ecosystem.

Pre and post-intervention monitoring

Fish catch statistics and associated information from the analysis of commercial catches for 4 years (1996–1997 to 1999–2000) before and 4 years (2000–2001 to 2003–2004) after opening of the new lagoon mouth were collected by the Department of Fisheries (DoF), Orissa state and Chilika Development Authority (CDA) respectively following the statistical sampling method with landing centre approach developed by Central Inland Fisheries Research Institute (CIFRI) for estuarine fisheries (Gupta et al. 1991).

Sampling methods

One of the random sampling methods (systematic sampling) with landing centre approach (Biradar 1988; Gupta et al. 1991) modified for site specific conditions in Chilika lagoon was followed on monthly basis to estimate landings of fish, prawn and mud crab and to gather associated information such as, species composition, number of boats carrying catches to the landing centres, number of fishing days during the month and prevailing selling prices at the landing centres for different groups/species of fish and shell fish. Sampling was carried out at all the 18 number of established landing centres spread over four ecological sectors, two number of daily fish markets within the lagoon area and all the fourteen number of prawn collection centres on the eastern part of the lagoon (Fig. 3). Sampling for two consecutive days in 10 days intervals (6 days in a month) at each fish landing centres with 33% of boat sample size (1 boat from 3 consecutive boats), daily fish markets and prawn collection centres were carried out. Specified formats were used during sampling for collection of various informations relating to fish catch. As recommended by Jhingran and Natrajan (1969), prawn, fish and mud crab catches were monitored separately for yield study. Regular sampling of catches from different fishing gears (gill nets, drag nets, boat seines, cast nets and 'Khanda' nets traps) at the fishing grounds in four ecological sectors of the lagoon was undertaken at fortnightly intervals to collect fish, prawn and crab specimens. Analysis of commercial catches and inventorisation of fish and shell fish faunal diversity were done at the landing centres and fishing grounds as well. Identification of specimen was carried out upto species level. The collected materials were preserved in 5% formalin after taking photographs of specimen with natural colouration and undamaged external body shapes. Information on addition of new fishing boats, new fishing nets, fish merchants and utilization of ice for fish preservation were collected from the local boat building yards, sales centres for nets and netting materials, fish merchants association and ice plants in Chilika area.

Landing estimation

(a) Fish landing estimation in tonnes (t) for each sampling day at each landing centre

$$E = \frac{\text{Qt}}{\text{Obt}} \times N$$

where, Qt is the total catch for all observed boats in kg; Obt is the total numbers of observed boats; N is the total boats with catches at the landing centre on the sampling day and E is the estimated landing in tonnes.

(b) Mean landing for each sampling day at the landing centre.

$$\bar{Y} = \frac{E_1 + E_2 + \cdots\cdots\cdots + E_6}{6}$$

where, E_1 to E_6 are the estimated landing for 1st to 6th sampling day during the month; and $\bar{Y}$ = Mean landing for each sampling day in tonnes.

(c) Total landing for each landing centre for each month

$$\mathrm{Ml} = \bar{Y} \times \mathrm{Dt}$$

where, $\bar{Y}$ is the mean landing for each sampling day at each landing center; Dt is the total number of fishing days availed at the landing center and; Ml is the estimated landing (t) at each landing centre during the month.

(d) Total monthly landing of all the 18 number of landing centres in the lagoon

$$\mathrm{TLC} = \mathrm{Ml}_1 + \mathrm{Ml}_2 + \cdots\cdots\cdots\cdots + \mathrm{Ml}_{18}$$

where, TLC is the total estimated landing (t) for all 18 landing centres and Ml_1 to Ml_{18} are the monthly landings at 1st to 18th landing centre.

(e) Estimated landing for two daily fish markets for the month in the similar manner as followed for the fish landing centres is denoted by ML.

(f) Estimation of prawn landings for 14 number prawn collection centres for the month following the same sampling method is denoted by Pc.

(g) Estimation of total monthly landing (Fish and prawn) for the lagoon.

$$\mathrm{TML} = \mathrm{TCL} + \mathrm{ML} + \mathrm{Pc}$$

where, TML is the total monthly landings.

(h) Species/group-wise quantity estimation was done by multiplying the average catch composition (%) with the total estimated landing for the sampling day at the landing centres and daily fish markets.

(i) Estimation of mud crab landing was done by total (100%) enumeration of packed bamboo baskets containing about 10 kg mud crabs in each basket with fresh weeds (*Potamogeton sp*. and *Najas* sp.) at each landing centre.

For computation of CPUE, number of fishing boats, number of fishing days during the year and the estimated annual landings were taken in to account. *Per-capita* income from fishing was determined from total catch value and population of active fishers. Productivity was worked out by dividing the total annual catch with the mean water spread area (WSA) of the lagoon (923 km^2).

In-situ measurement of water depth, temperature, transparency, pH, salinity and dissolved oxygen were conducted at the 12 sampling stations fixed in four ecological sectors (Fig. 3), using graduated gauge, thermometer (centigrade), secchidisc, HANA pH meter (checker-1, USA), ATAGO-10 refractometer (Japan) and D.O. meter (YSI-55,USA) respectively. Dissolved oxygen and total alkalinity of water samples were analyzed in the laboratory for cross checking following the standard methods (APHA 1995).

Data analysis

Statistical analysis of fish landing data (Estimated landings for 2,448 samples from 18 landing centres, 14 prawn collection centres and two daily fish markets during the year) for variance (Vr), standard error (SE) standard deviation (SD), kurtosis and skewness was done by using computer software ''SPSS(11.0 version)''. Correlation analysis between some water quality parameters and fish, prawn and mud crab yield were undertaken.

Results and discussion

Fish and shell fish landings

Shell fish and fish landing data for the period 1996–1997 to 1999–2000 (before the new lagoon mouth) and 2000–2001 to 2003–2004 (after the new lagoon mouth) were analyzed to evaluate post-intervention status of fisheries of Chilika lagoon in comparison to pre-intervention (Table 1).

Pre-intervention scenario

Fish, prawn and mud crab landings in Chilika lagoon during 1986–1987 were recorded at 7,283, 1,589 and 54 t respectively, which dropped to 1556.3, 180.4, and 9.0 t, respectively in 1999–2000 (Table 1). The total catch (fisheries output) declined sharply from 1985 to 1986, registering the all time low catch of 1,274 t in 1995–1996 and maintained almost the same low level of yield with slight increase until opening of the new lagoon mouth. Fish and shell fish landings during 4 years (1996–1997 to 1999–2000) ranged from 1352.21 to 1556.32 t and 146.61 to 293.21 t (Table 1), respectively. Declining trend in fisheries output could be attributed to continual decline in salinity, poor water exchange, siltation of outer channel and palur canal (recruitment routes), long distance (30 km) of old lagoon mouth, breeding and spawning failures of resident species due to degraded habitat conditions, poor recruitment of fish and shell fish seeds from both marine and riverine sources, rapid expansion of 'prawn gheries' (prawn culture pens) and unregulated destructive fishing practices (Ghosh 1998; Pattanaik 1998, 2000; Mohanty et al. 2003; Mohanty et al. 2004a, b). The fishery was also under considerable pressure due to pollution from agricultural pesticides as has been shown in land use map (Fig. 2). The central sector registered the highest catch (45%) followed by northern sector (32%), southern sector (14%) and outer channel sector (9%), respectively to the total catch from the lagoon before opening of the new lagoon mouth (Mohanty et al. 2004a, b). Analysis of commercial catch statistics indicated that the average fisheries output (1686.2 t), productivity (1.845 t km^{-2}), CPUE (1.1 kg boat-day^{-1}) and the economic value of average annual landing of fish and shell fish (1.06 million USD) before opening of the new lagoon mouth indicated the declining state of fisheries before the hydrological intervention.

Table 1 Fish, prawn and crab landings (in t) from Chilika lagoon during 1985–1986 to 2003–2004

Year	Fish	Prawn (A)	Crab (B)	Shell fish component (A + B)	AGR (Fish) %	AGR (Shell fish) %
1985–1986	7446.00	1144.00	79.00	1223.00	–	–
1986–1987	7283.00	1589.00	54.00	1643.00	–2.19	34.34
1987–1988	6863.00	1241.00	39.00	1280.00	–5.77	–22.09
1988–1989	5211.00	917.00	44.00	961.00	–24.07	–24.92
1989–1990	5493.00	1177.00	36.00	1213.00	5.41	26.22
1990–1991	3792.00	481.00	24.00	505.00	–30.97	–58.37
1991–1992	3680.00	876.00	30.00	906.00	–2.95	79.40
1992–1993	3207.00	951.00	15.00	966.00	–12.85	6.62
1993–1994	2799.00	686.00	11.00	697.00	–12.72	–27.85
1994–1995	1239.00	176.00	03.00	179.00	–55.73	–74.32
1995–1996	1056.00	213.00	05.00	218.00	–14.77	21.79
1996–1997	1352.00	281.21	12.00	293.21	28.03	34.50
1997–1998	1491.99	149.51	10.40	159.91	10.35	–45.46
1998–1999	1555.75	136.93	9.68	146.61	4.27	–87.83
1999–2000	1556.32	180.40	9.03	189.43	0.03	29.21
2000–2001[a]	3592.95	1296.26	93.54	1389.80	130.86	633.67
2001–2002	9530.03	2347.78	111.07	2458.85	165.24	76.92
2002–2003	8265.16	2478.82	149.81	2628.63	–13.27	6.90
2003–2004	10286.34	3611.37	155.51	3766.88	24.45	43.30

[a] Year of hydrological intervention

Source: (i) 1985–1986 to 1999–2000; Directorate of Fisheries, Government of Orissa State (1985–1986 to 1999–2000); (ii) 2000–2001 to 2003–2004; primary data generated by authors for Chilika Development Authority

Post-intervention scenario

During the first 4 years (2000–2001 to 2003–2004) after opening of the new lagoon mouth, fish and shell fish landings ranged from 3,593 t to 10286.3 t (average 7918.6 t) and 1389.8 t to 3766.9 t (average 2,561 t), respectively (Table 1). The post-new mouth average landings of fish and shell fish registered 431.8 and 1198.1% increase respectively, as compared to the pre- new mouth data. Prawn catch after opening of the new lagoon mouth indicated maximum increase of 1,201% in comparison to pre- new mouth prawn landings.

Although fish catch showed slight drop during 2002–2003, prawn and mud crab (shell fish) catches continued to rise during 2000–2001 to 2003–2004, which indicated that the spawning and recruitment were more successful and the environmental conditions (Table 2) particularly the salinity and water transparency were more conducive. The correlation analysis showed that the water transparency was inversely correlated with fish catch ($R^2 = 0.715$; d.f. = 25; $P < 0.001$). Similarly, salinity was found to be positively correlated with prawn catch ($R^2 = 0.542$; d.f. = 25; $P < 0.01$), crab catch ($R^2 = 0.628$; d.f. = 25; $P < 0.001$) and fish catch ($R^2 = 0.476$; d.f. = 25, $P < 0.05$). Thus, the average increase in salinity regime (42.7%) for the lagoon (Table 2) during post-hydrological intervention seems to have positively impacted the fish, prawn and mud crab catches. Continual increase in shell fish landing after hydrological intervention can be corroborated with salinity factor as has been indicated by higher significance value of correlation coefficients for prawn ($P < 0.01$) and mud crab ($P < 0.001$). However, the prawn and mud crab fisheries are influenced by their breeding and spawning success or failure in the adjacent coastal waters (Jhingran and Natarajan 1969) and their populations are more cyclical in nature, which is atleast partly due to changes in local coastal waters affecting spawning and recruitment to estuary/lagoon as observed in Peel-Harvey Estuarine System (PHES) in Australia (Lord and Associates 1998). Other parameters of water quality (Table 2) did not show any relationship with the fish catch because of complex nature of functioning of the Chilika ecosystem. The changes that followed the opening of new lagoon mouth clearly indicate that the lagoon fishery is sensitive to its salinity and hydrologic dynamics, which in turn, are strongly influenced by freshwater inflows (World Bank 2005).

As could be seen from Table 1, the downward fish catch was most probably dominated by the progressive closure and northward migration of the lagoon mouth. From 1995 to 1996 until 1999 to 2000 a slow upward trend in catch (Table 1) is probably best attributed to increasing fishing effort in response to low fish stocks (Young et al. 2003). They also remarked that the lagoon mouth conditions that indicate recruitment potential as well as lagoon salinity should be stronger predictor of fishery catch. The lagoon habitats, especially the sea grass beds, provided the ideal condition for supporting mud crab fishery during post-intervention period. Regular flushing due to dredged lead channel and new lagoon mouth leading to removal of unwanted decomposed organic matters from the shallow sea grass beds paved ways for the greater colonization of preferred crab food items, which in turn has resulted in manifold increase in mud crab production (CIFRI 2005). During 2000–2001 to 2003–2004 the average fisheries output (10,480 t), catch per unit effort (6.2 kg boat-day^{-1}), *per capita* income of active fishers (396 USD), economic valuation of 12.2 million USD for the average annual catch and productivity (11.3 t km^{-2}) registered spectacular increase of 522, 464, 942, 1,051, and 528% respectively, as compared to the pre-intervention data (Table 3).

Changing pattern in the sectoral landings indicated increased contribution by central sector (47.13%) followed by northern sector (37.36%) and decreased landings in southern sector (5.97%). The outer channel sector registered 9.54% landing, which is almost same as pre-mouth landing. Increase in sectoral landings are attributed to improved habitat conditions after decrease in weed areas, increase in salinity regime, and effective dispersal of fish and shell fish seed after recruitment in northern, central and outer channel sectors. These three sectors were observed to have been impacted by hydrological intervention. Decreased landing in the

Table 2 Seasonal and sectoral variation of water quality parameters (mean ± SD) in Chilika lagoon during pre and post-intervention periods

Environmental parameters	Summer		Monsoon		Winter		Annual average	
	PRI	POI	PRI	POI	PRI	POI	PRI	POI
Northern sector								
Water temp. (°C)	30.4 ± 1.1	30.4 ± 1.7	29.5 ± 1.3	30.0 ± 2.8	25.1 ± 0.9	25.6 ± 0.9	28.3 ± 0.8	28.6 ± 0.6
Water depth (m)	0.9 ± 0.1	1.2 ± 0.2	2.4 ± 0.06	2.1 ± 0.1	0.6 ± 0.09	0.8 ± 0.2	1.2 ± 0.1	1.4 ± 0.16
Transparency (cm)	52.1 ± 16	39.8 ± 20	69.1 ± 18	38.0 ± 9	43.2 ± 14	46.4 ± 9	54.8 ± 9	41.6 ± 7
Salinity (ppt)	6.0 ± 2.0	14.4 ± 7.5	2.4 ± 0.9	3.1 ± 2.6	1.7 ± 0.6	2.8 ± 1.9	3.7 ± 0.6	6.6 ± 1.9
Dissolved oxygen (mg/l)	6.6 ± 0.1	6.7 ± 0.8	6.8 ± 0.6	6.2 ± 0.9	6.2 ± 1.1	7.8 ± 1.0	6.5 ± 0.4	6.9 ± 0.3
Alkalinity (mg/l)	96.8 ± 24.9	100.2 ± 18.6	79.0 ± 4.0	70.0 ± 3.9	78.6 ± 14.3	80.8 ± 9.3	84.7 ± 12.5	86.0 ± 6.1
Central sector								
Water temp. (°C)	30.0 ± 0.5	29.8 ± 1.8	29.3 ± 1.4	29.7 ± 3.0	24.8 ± 0.7	25.0 ± 2.0	28.0 ± 0.4	28.2 ± 0.8
Water depth (m)	1.1 ± 0.1	1.3 ± 0.2	1.6 ± 0.06	1.6 ± 0.1	1.3 ± 0.2	1.6 ± 0.1	1.3 ± 0.06	1.6 ± 0.1
Transparency (cm)	77.7 ± 11	68.6 ± 24	96.2 ± 11	89.8 ± 20	75.4 ± 9	89.4 ± 12	82.9 ± 8	82.5 ± 13
Salinity (ppt)	13.4 ± 4.0	16.3 ± 4.7	7.7 ± 4.6	8.1 ± 7.9	5.5 ± 1.24	6.9 ± 2.1	8.8 ± 0.5	10.5 ± 1.9
Dissolved oxygen (mg/l)	6.1 ± 0.5	6.4 ± 0.5	6.5 ± 0.4	6.5 ± 0.4	6.8 ± 0.9	7.4 ± 0.8	6.5 ± 0.1	6.8 ± 0.3
Alkalinity (mg/l)	103.3 ± 11.5	110.2 ± 2.4	87.4 ± 7.4	86.2 ± 9.0	91.5 ± 6.1	93.6 ± 7.4	94.0 ± 7.3	99.0 ± 0.7
Southern sector								
Water temp. (°C)	30.5 ± 1.2	30.4 ± 1.5	27.7 ± 1.8	30.4 ± 1.4	25.5 ± 0.8	25.9 ± 2.2	28.4 ± 0.9	28.8 ± 0.7
Water depth (m)	1.9 ± 0.09	2.0 ± 0.2	2.3 ± 0.06	2.4 ± 0.1	2.0 ± 0.2	2.2 ± 0.1	2.1 ± 0.08	2.2 ± 0.05
Transparency (cm)	91.4 ± 9	92.6 ± 49	110.0 ± 19	135.2 ± 17	103.5 ± 11	119.4 ± 29	101.6 ± 9	115.4 ± 13
Salinity (ppt)	9.5 ± 0.6	13.1 ± 3.9	11.7 ± 2.9	12.6 ± 4.3	7.4 ± 1.2	9.4 ± 0.8	9.5 ± 0.7	12.2 ± 1.2
Dissolved oxygen (mg/l)	6.4 ± 0.6	6.6 ± 0.9	6.6 ± 0.9	6.7 ± 0.4	7.2 ± 0.7	7.5 ± 0.7	6.6 ± 0.4	6.9 ± 0.1
Alkalinity (mg/l)	106.7 ± 15.9	118.2 ± 6.4	96.1 ± 6.5	96.6 ± 4.4	88.4 ± 9.0	99.6 ± 9.0	97.0 ± 8.6	108.0 ± 1.0
Outer channel sector								
Water temp. (°C)	30.0 ± 1.1	29.9 ± 2.4	27.7 ± 1.3	30.1 ± 2.7	25.5 ± 0.8	26.3 ± 1.0	18.4 ± 0.7	28.8 ± 0.6
Water depth (m)	2.7 ± 0.2	3.1 ± 0.5	3.0 ± 0.3	3.2 ± 0.4	2.3 ± 0.3	2.7 ± 0.1	2.7 ± 0.3	3.0 ± 0.1
Transparency (cm)	79.1 ± 37	67.2 ± 27	55.7 ± 5	69.6 ± 15	72.8 ± 14	90.8 ± 12	69.2 ± 2	75.4 ± 16
Salinity (ppt)	27.7 ± 1.3	32.2 ± 1.6	8.5 ± 8.6	12.6 ± 10.4	6.2 ± 2.3	19.7 ± 7.4	13.6 ± 2.0	21.6 ± 1.6
Dissolved oxygen (mg/l)	6.0 ± 0.4	6.9 ± 0.5	6.3 ± 0.2	6.8 ± 0.6	6.2 ± 0.8	7.4 ± 0.6	6.3 ± 0.2	7.0 ± 0.4
Alkalinity (mg/l)	112.2 ± 11.7	118.2 ± 7.5	79.2 ± 20.8	80.8 ± 11.1	81.6 ± 10.7	93.4 ± 13.3	91.0 ± 12.9	99.0 ± 3.0
Whole lagoon								
Water temp. (°C)	30.2 ± 1.0	30.1 ± 1.9	28.6 ± 1.5	30.0 ± 2.5	25.2 ± 0.8	25.7 ± 1.5	25.8 ± 0.7	28.6 ± 0.7
Water depth (m)	1.7 ± 0.1	1.9 ± 0.3	2.3 ± 0.1	2.3 ± 0.2	1.6 ± 0.2	1.8 ± 0.1	1.8 ± 0.1	2.1 ± 0.1
Transparency (cm)	75.1 ± 18	67.1 ± 30	82.8 ± 13	83.2 ± 15	73.7 ± 12	86.5 ± 16	77.1 ± 7	78.7 ± 12
Salinity (ppt)	14.2 ± 2.0	19.0 ± 4.4	7.6 ± 4.3	9.1 ± 4.4	5.2 ± 1.3	9.7 ± 3.1	8.9 ± 0.9	12.7 ± 1.7
Dissolved oxygen (mg/l)	6.3 ± 0.4	6.7 ± 0.7	6.6 ± 0.5	6.6 ± 0.6	6.5 ± 0.9	7.5 ± 0.8	6.5 ± 0.3	6.9 ± 0.3
Alkalinity (mg/l)	104.8 ± 16.0	111.7 ± 8.7	85.4 ± 9.8	83.4 ± 7.1	85.0 ± 10.1	91.9 ± 9.8	91.7 ± 10.4	98.0 ± 2.7

PRI, Pre-intervention period; POI, Post-intervention period

southern sector was attributable to non-recruitment through Palur canal upto 2004, migration of fish stock from southern sector to central and northern sectors (improved habitats) and reduction in fishing efforts (as many fishers migrated to central sector to get better catch). Capturing of brood stock mullets and other fishes (destructive fishing) in the outer channel during their seaward breeding migration was reduced due to shorter distance of new lagoon mouth and stronger water current in migration route. Effective recruitment of juveniles from the sea and improvement in salinity regime were probably the main factors for increased fish population and catch. The improved fishery yield during post-intervention period also indicated considerable impact on the fishing industry interms of increase in fishing boats, nets, utilization of ice in fish preservation and number of fish traders (Table 3).

Table 3 Status of fisheries in Chilika lagoon before and after the hydrological intervention

Variables	Pre-intervention					Post-intervention					% increase or decrease
	1996–1997	1997–1998	1998–1999	1999–2000	Avg.	2000–2001	2001–2002	2002–2003	2003–2004	Avg.	
Mean water spread area (WSA) in km^2	930	926	920	916	923	922	923	923	924	923	0.0
Total catch (fisheries output in t)	1,645	1,652	1,702	1,746	1,686	4,983	11,989	10,894	14,053	10,480	522
Economic value of catch (Million USD)	0.91	0.95	1.0	1.4	1.06	7.6	13.0	11.0	17.1	12.2	1051
Number of fishing boats	5,140	5,245	5,320	4,500	5,051	4,500	5,000	5,087	5,059	4,911	–2.8
(a) Non-motorized	3,367	3,367	3,367	2,547	3,078	2,640	3,095	3,116	3,047	2,934	–7.5
(b) Motorized	1,773	1,878	1,953	1,953	1,973	1,860	1,905	1,971	2,012	1,937	3.08
Number of fishing days during the year	303	301	306	301	305	306	345	356	336	336	10.2
Number of active fishers	27,200	27,690	28,077	28,136	27,776	30,000	30,027	30,936	31,460	30,606	10.2
Productivity (t km^{-2})	1.7	1.8	1.8	1.9	1.8	5.4	13.0	11.8	15.2	11.3	528
CPUE (kg boat-day^{-1})	1.0	1.0	1.0	1.3	1.1	3.6	6.9	6.0	8.3	6.2	464
Per capita income of active fishers (USD)	33	34	36	50	38	253	433	356	543	396	942
Addition of new fishing boats	Nil	5	75	Nil	20	21	53	70	47	48	139
(a) Non-motorized	Nil	Nil	Nil	Nil	Nil	6	8	4	6	6	–
(b) Motorized	Nil	5	75	Nil	20	15	45	66	41	42	109
Addition of new fishing nets (t)	Nil	Nil	30	42	18	28	48	65	28	42	133
Number of fish merchants	122	122	124	124	123	124	135	140	153	138	.2
Ice utilized for fish preservation (t)	433	435	450	460	444.5	1,298	3,207	2,900	3,752	2789.3	527.5

Composition of commercial catch

The commercial catch of fish and shell fish from Chilika lagoon can broadly be classified into eleven groups and seven species, respectively (Table 4). Based on number of species (faunal diversity), 10–17% fish species, 25–36% prawn species and 5–9% crab species contributed to the bulk (90–95%) of commercial catches.

Pre-intervention scenario

The average relative catch compositions (Table 4) before hydrological intervention indicates that clupeoids and catfishes dominated the catch with 23.9 and 11.8%, respectively, followed by mullets (10.2%), perches (8.9%), croakers (6.8%), cichlids (6.6%), threadfins (4.5%), beloniformes (4.5%) and tripod fishes (3.2%). Murrells (3.7%) and featherbacks (5.8%) were caught mostly from northern sector where freshwater condition and weed area dominated throughout the year. Although cichlid group was represented in the past by the single species *Etroplus suratensis* (Bloch), later during late nineties, *Oreochromis mossambicus* (Peters) occurred in Chilika lagoon as an invasive cichlid fish, probably being escaped from some island village ponds in Parikud area (central sector) and proliferated its population quickly to constitute 25–30% of cichlid population during 1999–2000 due to low salinity regime and weed areas before the hydrological intervention. The average shell fish catches (Table 4) during 4 years before new

Table 4 Total and relative catch values (% of total catch) of fish and shellfish in Chilika lake before and after opening of the new lake mouth

Fish and shellfish of commercial importance (Group/species)	Four years average catch (t) before new mouth		Four years average catch (t) after new mouth		% increase in catch	% increase/decrease in relative catch
	Catch (t)	Relative catch value (%)	Catch (t)	Relative catch value (%)		
Fish						
Mullets	151.3 ± 13.5	10.2 ± 0.5	762 ± 340	9.6 ± 2.4	403.6	–5.9
Clupeoids	355.4 ± 29.5	23.9 ± 1.3	2254 ± 798	28.5 ± 2.9	534.2	19.2
Perches	132.9 ± 29.1	8.9 ± 1.6	458 ± 293	5.8 ± 2.2	244.8	–34.8
Threadfins (*E. tetradactylum*)	67.7 ± 3.8	4.5 ± 0.3	337 ± 156	4.2 ± 1.3	397.2	–6.7
Croakers (Sciaenids)	101.6 ± 12.6	6.8 ± 0.9	741 ± 316	9.4 ± 2.3	629.5	38.2
Beloniformes (Needle fishes & Half beaks)	66.8 ± 12.6	4.5 ± 0.7	355 ± 203	4.5 ± 1.4	430.8	0.0
Catchfishes	175.7 ± 25.2	11.8 ± 1.5	1454 ± 607	18.3 ± 2.4	727.5	55.1
Tripod fish (*Triacanthus* sp.)	47.0 ± 5.2	3.2 ± 0.3	403 ± 125	5.1 ± 1.4	756.4	59.4
Cichlids	98.8 ± 12.9	6.6 ± 1.0	296 ± 183	3.7 ± 3.3	199.6	–43.9
Murrels	55.5 ± 7.9	3.7 ± 0.5	187 ± 94	2.4 ± 1.3	237.6	–35.1
Feather backs (*N. notopterus*)	86.8 ± 10.3	5.8 ± 0.5	295 ± 195	3.7 ± 2.1	240.0	–36.2
Others	149.6 ± 18.5	10.1 ± 2.0	377 ± 54	4.8 ± 2.3	152.0	–52.5
Total fish landing	*1489.1*	*100.00*	*7919.6*	*100.00*	*431.8*	
Shell fish						
Penaeus monodon	20.6 ± 5.4	10.4 ± 0.7	288 ± 66	11.2 ± 1.6	1298.0	7.7
Penaeus (Fenneropenaeus) Indicus (Indian white Shrimp)	27.4 ± 7.1	13.9 ± 0.6	421 ± 238	16.5 ± 3.7	1437.6	18.7
Metapenaeus monoceros	67.7 ± 20.1	34.3 ± 2.6	802 ± 484	31.3 ± 16.1	1085.8	–8.7
Metapenaeus dobsoni	71.4 ± 24.8	36.2 ± 2.4	736 ± 245	28.7 ± 10.9	930.7	–20.7
Non-penaeid prawns (*Macrobrachium* sp.)	NA	NA	186 ± 35	7.3 ± 4.5	–	–
Mudcrabs (*Scylla* sp.)	10.3 ± 1.1	5.2 ± 1.1	127 ± 26	5.0 ± 1.0	1137.9	–3.8
Total shellfish landing	*197.3*	*100.00*	*2561*	*100.00*	*1198.1*	

NA—not available

lagoon mouth were dominated by soft brown shrimp (*Metapenaeus dobsoni*), which formed 36.2%, followed by *Metapenaeus monoceros* (34.3%). Average catch of *Fenneropenaeus indicus* and *Penaeus monodon* were 13.9% and 10.4%, respectively. Mud crabs (*Scylla* sp.) constituted 5.2% in the shellfish catches.

Post-intervention scenario

Clupeoides and catfishes not only maintained their dominant positions with average composition of 28.5 and 18.3% respectively, but also their landings were increased during post-intervention phase (Table 4). Relative catch of clupeoides increased after hydrological intervention when the conducive estuarine character of the lagoon was reversed back. Similar observations were also made by Baran (2000) in West African estuaries. Croaker catch significantly increased with 9.4%, which was 6.8% during pre-intervention phase. Relative catch of tripod fish (*Tricanthus biaculeatus*) significantly increased from pre-intervention data of 3.2 to 5.1% during post-intervention period. Threadfins and beloniformes more or less maintained their position with regard to relative catches. In general, composition of cichlids, murrells, featherback and miscellaneous groups decreased most likely due to increased salinity regime (Table 2) and decreased weed area. Relative catch of mullets did not improve, as compared to pre-intervention position, which was attributable to conversion of traditional fisheries like ‘‘Janos’’, ‘‘Dians’’, ‘‘Uthapani’’, ‘‘Prawn trap fisheries'' etc. into the illegal and eco-inimical ''*prawn gheries*'' (Mohanty et al. 2004a, b). These human-induced activities resulted in habitat loss for mullet fishery particularly the mullet nursery areas in Chilika lagoon. However, annual catch of fish component for 4 years after hydrological intervention significantly increased as compared to pre-intervention data.

Metapenaeus monoceros was found to be the most dominant shrimp with average composition of 31.32%, followed by *Metapenaeus dobsoni* (28.7%). The relative catches of *Penaeus monodon* and *Fenneropenaeus indicus* increased during post-hydrological intervention phase, as compared to the pre-intervention data (Table 4). Maximum densities of mud crabs (*Scylla* sp.) in the outer channel and lower part of central sector occurred during post-new mouth period due to shorter and desilted recruitment route outer/inlet channel and prevalence of marine salinities for longer period, which agreed with the observation made by Lord and Associates (1998) in Dawesville channel of Peel- Harvey Estuarine System in Australia. Mud crab catch in Chilika Lagoon after hydrological intervention was observed to be maximum (64.9%) in the outer channel, followed by central sector (32.5%). Average landing of mud crabs after opening of the new lagoon mouth contributed 5.0% to the total average landing of shellfish. Four years shell fish catch before hydrological intervention (1996–1997 to 1999–2000) increased significantly after intervention.

Biodiversity status

The openness of the lagoon to marine and freshwater subsystems resulted in two antagonistic hydrological processes (freshwater and saline water) particularly in northern, central and outer channel sectors, with penetration of fish and shellfish faunas, respectively from marine and inland origin and the cyclical change of salinity gradient, provide diverse habitat conditions in Chilika lagoon for both migratory and resident/endemic fish and shell fish faunas with greater diversity. Comparatively southern sector with more stable salinity profile having least seasonal variations exhibited less ichthyofaunal diversity.

Pre-intervention scenario

During 1914–1924, Zoological Survey of India (ZSI) carried out the pioneering work on faunal diversity of Chilika lagoon and documented 112 fish species, 24 prawn and shrimps and 26 crab species (Kemp 1915; Chaudhuri 1916a–1916c, 1917; Hora 1923). During the first fisheries investigation in Chilika lagoon by CIFRI (1957–1965) and by some individual workers during 1954–1986, 101 new records of fish species were documented from Chilika lagoon (Koumans 1941; Jones and Sujansinghani 1945; Devasundaram 1954; Menon 1961; Mishra 1969, 1976a, 1976b; Jhingran and Natarajan 1966, 1969; Rajan et al. 1968; Mohanty 1973; Talwar and Jhingran 1991; RamaRao 1995; Reddy 1995; Maya Deb 1995). During 1985–1987, ZSI, while carrying out survey under Chilika Expedition Project (CEP), added four new records of fishes and two new records of crab species. Later, Bhatta et al. (2001) reported eight new records of fish species before opening of the new mouth.

Prior to hydrological intervention in Chilika lagoon, the ecosystem was under severe threats, most of which were due to natural changes and human-induced activities as described earlier and showed in the land use map (Fig. 2). During this phase, the migration, recruitment routes and habitats were considerably affected along with decline in salinity regime and proliferation of freshwater weeds. River mouths and Magarmukh were heavily silted affecting the normal functioning of the ecosystem. Such conditions are likely to result in significant changes in faunal diversity and habitats. Before opening of the new mouth during 2000, 225 fish species (149 genera, 72 families and 16 orders), 24 prawn species (13 genera, 9 families and 2 sub-orders) and 28 brachyuran crabs (22 genera, 9 families and 1 sub-order), totaling to 277 species of fish and shell fish were recorded as occurring in the Chilika lagoon since the first fish faunal survey (1914–1924) till 1999–2000, without any periodical inventorial survey for faunal diversity.

Post-intervention scenario

During the period January 2000 to March 2004,an organised inventory survey for fish and shell fish biodiversity was carried out which documented 144 fish species (101 genera, 61 families and 16 orders), 14 prawn species (8 genera, 5 families and 2 sub-orders) and 7 crab species (7 genera, 5 families and 1 sub-order), totaling to 165 species of fish and shell fish. After the hydrological intervention, particularly after opening of the new lagoon mouth, 56 numbers of new records of fish and shell fish species were documented comprising of 43 fish species (37 genera, 30 families and 11 orders), 4 prawn species (3 genera, 2 families and 1 sub-order), 7 crab species (6 genera, 3 families and 1 sub-order) and 2 Indian spiny lobsters (1 genera, 1 families and 1 sub-order). The spiny lobsters were recorded from the Chilika lagoon for the first time. Out of the total inventorised species of 165, 68 species of fish and shell fish were recorded during the hydrological intervention and 97 species after the intervention. The list of 221 species of fish and shell fish including 56 new records (7 freshwater, 20 brackishwater and 29 marine species) documented through inventory survey during and after the hydrological intervention is furnished in Table 5. Taking into account the habitat and occurrence factor, the post-intervention status of fish and shell fish biodiversity is presented in Table 5. Before opening of the new lagoon mouth, 38 commercially important fish and shell fish species were occurring in the commercial landings, which increased to 62 species (63% increase) during the post-intervention period. Many commercially important species having high market demand within and outside the state are still in the 'rare' status interms of occurrence. These species are likely to regain their 'abundant' status as the ecological status of the lagoon will further improve through appropriate maintenance measures for functioning of the ecosystem. Some 'rare' and 'very rare' species of marine origin shall continue to maintain their status as they temporarily use the outer channel sector for feeding purpose during high salinity phase. Fish species belonging to marine-brackish water habitat continued to dominate during both pre and post-intervention phases with 31.55 and 33.16%, respectively. Similarly fishes belonging to brackishwater-marine and freshwater-brackish water habitats were stable in their compositions during both phases. Relative abundance of freshwater species slightly decreased from 14.67% during pre-intervention phase to 13.67% during post-intervention phase, while species moving from brackishwater to freshwater habitat were decreased from 5.78 to 2.14%. The hydrological variability between the dry and the flood season is important; this results in a high mobility of the brackish zone. The major part of the zone in the rainy season exhibits hydro-chemical characteristics of a river, and is slowly occupied by strictly freshwater species (Baran 2000). Similarly, in Chilika lagoon, flood discharges into the northern sector push the saline water through northern, central and outer channel sectors into the sea, when freshwater species (post-larvae, juveniles and adults) dominate in these ecological sectors. Hence there were no marked changes in the relative abundance of pre and post-intervention phases. But during post-winter and summer seasons, distinctive changes in their relative abundance were noticed.

Out of several penaeid prawn species, five were commercial contributing more than 94% to the total prawn catches. Small sized prawns belonging to freshwater-brackishwater-freshwater habitat (do not contribute to the commercial prawn catch) constituted 55.78% of the total prawn species before intervention. Shrimp species belonging to the marine-brackishwater-marine habitat were increased during post-intervention phase forming 44.45%. *Macrobrachium rosenbergii* was found as a new record during post-intervention period. All crab species collected during pre and post new lagoon mouth periods belonged to marine-brackishwater-marine habitat. One species of mud crab (*Scylla tranquebarica*), although was occurring in Chilika lagoon since the faunal diversity study undertaken by ZSI during 1914–1924, it was hitherto not reported/documented as a separate mud crab species, other than the commonly occurring *Scylla serrata* due to continued controversy in the species identification problem in the genus *Scylla*. This controversy of species identification of the mud crabs in the genus *Scylla* was ended when

Fuseya and Watanabe (1996) and Fushimi and Watanabe (1999) confirmed by genetic variability studies in Japan that *Scylla tranquebarica* is a separate mud crab species. The recent revision of *Scylla* by Keenan et al. (1998) described four species of mud crabs including *S. tranquebarica* which occurs along with *S. serrata* in Chilika lagoon. Hence, this mud crab species has been added as a new record to the crab faunas of Chilika lagoon during post-restoration phase. Species diversity composition on the basis of occurrence status (Table 6) indicated that abundantly occurring fish, prawn and crab species increased during post-intervention phase. Abundantly occurring fish and mud crab species increased considerably from 14.22% (pre-intervention) to 34.2%

Table 5 Biodiversity inventorisation of fish and shellfish in Chilika lagoon during post-restoration period (up to December, 2004)

Family		Species	H & O Status
Fishes			
1	Carcharhinidae	1. *Scoliodon laticaudas* (Muller & Henle)	M, R
2	Sphyrnidae	2. *Sphyrna lewini* (Griffith and Smith) [N]	M, VR
		3. *Sphyrnablochii*(Cuvier)[N]	M, VR
3	Rhinobatidae	4. *Rhynchobatus djeddensis* (Forsskal)[N]	M, R
4	Dasyatididae	5. *Himantura uarnak* (Forsskal)	M, VR
		6. *Himantura walga* (Muller & Henle)	M, VR
		7. *Dasyatis marginatus* (Blyth)[N]	M, R
5	Myliobatididae	8. *Aetobatus flagellum* (Bloch & Schneider)	M, VR
		9. *Aetomylaeus nichofii* (Bloch & Schneider)	M, R
6	Notopteridae	10. *Notopterus notopterus* (Pallas)*	F, A
		11. *Notopterus chitala* (Hamilton-Buchanan)	F, VR
7	Elopidae	12. *Elops machnata* (Forsskal)*	BM, R
8	Megalopidae	13. *Megalops cyprinoides* (Broussonet)*	BM, R
9	Anguillidae	14. *Anguilla bengalensis* (Gray)	MB, A
		15. *Anguilla bicolour bicolour* (Mc Clelland)	MB, R
10	Muraenidae	16. *Thyrsoidea macrura* (Bleeker)	M, R
11	Ophichthidae	17. *Pisodonophis boro* (Hamilton-Buchanan)	MB, R
12	Muraenesoscidae	18. *Muraenesox cinereus* (Forsskal)	MB, R
		19. *Muraenesox bagio* (Hamilton)[N]	B, R
13	Clupeidae	20. *Anodontosoma chacunda* (Hamilton-Buchanan)*	MB, A
		21. *Corica soborna* (Hamilton-Buchanan)	B, R
		22. *Escualosa thoracata* (Valenciennes)	MB, R
		23. *Gonialosa manmina* (Hamilton-Buchanan)	MB, R
		24. *Gadusia chapra* (Hamilton-Buchanan)	F, A
		25. *Hilsa (Tenualosa)ilisha* (Hamilton-Buchanan)*	MB, A
		26. *Hilsa kelee*(cuvier)*	MB, A
		27. *Nematalosa nasus* (Bloch)*	BM, A
		28. *Sardinella fimbriatus* (Valenciennes)[N]	M, VR
		29. *Sardinella longiceps* (Vol)[N]	M, VR
		30. *Dussumieria elopsides* (Blecker)[N]	B, R
		31. *Ehirava fluviatilis* Deraniyagala[N]	MB, VR
14	Engraulidae	32. *Thryssa gautamiensis* (B. Rao)[N]	MB, R
		33. *Thryssa setirostris* (Broussonet)[N]	MB, A
		34. *Stolephorus bagenensis* Hardenberg*	MB, A
		35. *Stolephorus commersonii* Lacepade*	MB, A
		36. *Stolephorus dubiosus* Wongrantania*	MB, A
		37. *Stolephorus indicus* (Van Hasselt)	MB, R
		38. *Thryssa hamiltonii* (Gray)*	B, A
		39. *Thryssa mystax* (Schneider)	B, A
		40. *Thryssa polybranchialis* (Wongrantania)[N]	MB, R
		41. *Thryssa purava* (Hamilton-Buchanan)*	B, R
15	Chanidae	42. *Chanos chanos* (Forsskal)*	BM, R

Table 5 continued

Family		Species	H & O Status
16	Cyprinidae	43. *Amblypharyngodon mola* (Hamilton)	F, R
		44. *Catla catla* (Hamilton-Buchanan)*	F, R
		45. *Cirrhinus mrigala* (Hamilton-Buchanan)*	F, R
		46. *Cirrhinus reba* (Hamilton-Buchanan)	F, R
		47. *Chela bacaila* (Hamilton-Buchanan)	F, R
		48. *Chela cachius* (Hamilton-Buchanan)	MB, R
		49. *Esomus danricus* (Hamilton-Buchanan)	B, R
		50. *Labeo rohita* (Hamilton-Buchanan)*	F, R
		51. *Labeo calbasu* (Hamilton-Buchanan)	F, VR
		52. *Puntius chola* (Hamilton-Buchanan)	FB, A
		53. *Puntius sarana* (Hamilton-Buchanan)	FB, R
		54. *Puntius sophore* (Hamilton-Buchanan)	FB, A
		55. *Puntius ticto* (Hamilton-Buchanan)	FB, A
		56. *Parluciosoma daniconius* (Hamilton-Buchanan)	B, R
		57. *Salmostoma bacaila* (Hamilton-Buchanan)	FB, R
		58. *Labeo boga* (Hamilton)[N]	F, R
		59. *Labeo gonius* (Hamilton)[N]	F, R
		60. *Osteobrama cotio peninssularis* Silas.[N]	F, VR
17	Bagridae	61. *Aorichthys seenghala* (Sykes)*	F, R
		62. *Mystus gulio* (Hamilton-Buchanan)*	BF, A
		63. *Mystus cavasius* (Hamilton-Buchanan)*	FB, R
18	Ariidae	64. *Mystus vittatus* (Bloch)	FB, R
		65. *Arius arius* (Hamilton-Buchanan)	MB, R
		66. *Arius tenuispinnis* Day	MB, R
		67. *Osteogeneniosus militaris* (Linnaeus)*	MB, A
19	Siluridae	68. *Ompok bimaculatus* (Bloch)	F, R
		69. *Ompok Pabda* (Hamilton)	F, R
		70. *Wallago attu* (Schneider)*	F, A
20	Schilbeidae	71. *Ailia coila* (Hamilton-Buchanan)	F, R
21	Pangasidae	72. *Pangasius pangasius* (Hamilton-Buchanan)	FB, A
22	Sisoridae	73. *Bagarius yarellii* Sykes [N]	F, R
23	Clariidae	74. *Clarias batrachus* (Linnaeus)*	FB, R
24	Heteropneustidae	75. *Heteropneustes fossilis* (Bloch)	FB, R
25	Plotosidae	76. *Plotosus canius* (Hamilton-Buchanan)*	B, A
		77. *Plotosus lineatus* (Thunberg)*	B, A
26	Synodontidae	78. *Trachinocephalus myops* (Forster)[N]	M, VR
27	Aplocheilidae	79. *Aplocheilus panchax* (Hamilton-Buchanan)	FB, A
28	Hemiramphidae	80. *Hyporhamphus limbatus* (Valenciennes)*	B, A
29	Belonidae	81. *Strongylura strongylura* (VanHasselt)*	B, A
		82. *Strongylura liura* (Blecker)*	FB, A
		83. *Xenentodon cancila* (Hamilton-Buchanan)*	FB, A
30	Atherinidae	84. *Atherinomorous lacunosus* (Forster)	M, VR
		85. *Atherinomorus duodecimalis* (Valenciennes)[N]	M, VR
31	Syngnathidae	86. *Hyppocampus brachyrhynchus* Duncker	M, VR
		87. *Ichthyocampus carce* (Hamilton-Buchanan)	BM, VR
		88. *Syngnathus cynospilus* Blecker[N]	M, VR
32	Synbranchidae	89. *Ophisternon bengalense* Mc Clelland[N]	M, VR
33	Tetrarogidae	90. *Tetraroge niger* (Cuvier)[N]	MB, R
		91. *Sugrundus rodri census* (cuvier)[N]	MB, VR
34	Platycephalidae	92. *Platicephalus indicus* (Lineaeus)	MB, A
35	Centropomidae	93. *Lates calcarifer* (Bloch)*	MB, A
36	Ambassidae	94. *Ambassis commersoni cuvier*	MB, A
		95. *Ambassis gymnocephalus* (Lacepede)	MB, A
		96. *Chanda nama* (Hamilton-Buchanan)	MB, A
		97. *Pseudoambassi ranga* (Hamilton-Buchanan)	MB, A

Table 5 continued

Family		Species	H & O Status
37	Serranidae	98. *Epinephelus tauvina* (Forsskal)	M, R
		99. *Epinephelus coioides* (Hamilton)[N]	M, R
38	Teraponidae	100. *Terapon jarbua* (Forsskal)*	MB, A
		101. *Terapon puta* (cuvier)*	MB, A
39	Sillaginidae	102. *Sillago sihama* (Forsskal)*	MB, A
		103. *Sillago vincenti* Mc. Kay[N]	MB, VR
40	Carangidae	104. *Carangoides paraeusteus* (Bennelt)	MB, A
		105. *Caranx carangus* (Bloch)	MB, A
		106. *Caranx sexfasciatus* (Quoy and Gairnard)	MB, R
		107. *Megalaspis cordyla* (Lineaeus)	B, R
		108. *Scomberoides tala* (Cuvier)	M, R
		109. *Selaroides leptolypis* (Cuvier)	M, R
		110. *Scomberoides commersonianus* (Lacepede)[N]	M, VR
		111. *Scomberoides tol* (cuvier)[N]	M, VR
		112. *Selar crumenophthalmus* (Bloch)[N]	M, VR
		113. *Trachinotus mookalee* (Cuvier)[N]	M, VR
41	Leiognathidae	114. *Leiognathus dussumieri* (Valenciennes)	M, A
		115. *Leiognathus brevirostries* (Valenciennes)	M, A
		116. *Leiognathus equulus* (Forsskal)	M, A
		117. *Leiognathus bindus* (Valenciennes)[N]	M, VR
42	Lutjanidae	118. *Lutjanus johni* (Bloch)*	MB, R
		119. *Lutjanus russelli* (Blecker)*	MB, R
		120. *Lutjanus argentimaculatus* (Forsskal)	MB, R
43	Datnioedidae	121. *Datnioides quadrifasciatus* (Sevastianov)*	B, A
44	Gerreidae	122. *Gerreomorpha setifer* (Hamilton-Buchanan)*	BM, A
		123. *Gerres oyena* (Forsskal)*	B, A
		124. *Gerres abbreviatus* (Blecker)[N]	BM, R
		125. *Gerres filamentosus* (Cuvier)*	B, A
		126. *Gerres limbatus* Cuvier	MB, VR
45	Haemulidae	127. *Pomadasys argenteus* (Forsskal) *	MB, R
		128. *Pomadasys kaakan* (Cuvier)[N]	M, R
46	Sparidae	129. *Acanthopagrus berda* (Forsskal)	MB, R
		130. *Crenidens crenidens* (Forsskal)*	MB, A
		131. *Rhabdosargus sarba* (forsskal)*	B, A
47	Sciaenidae	132. *Daysciaena albida* (Cuvier)*	MB, A
		133. *Dendrophysa russeli* (Cuvier)*	BM, A
		134.*Paranibea semilactuosa* (Cuvier)	M, R
		135. *Protonibea diacanthus* (Lacepede)	M, R
48	Monodactylidae	136. *Monodactylus argenteus* (Linnaeus)	M, R
49	Drepanidae	137. *Drepane punctatus* (Linnaeus)	MB, R
50	Scatophagidae	138. *Scatophagus argus*(Linnaeus) *	MB, R
51	Nandidae	139. *Nandus nandus* (Hamilton-Buchanan)	B, R
52	Cichlidae	140. *Etroplus suratensis* (Bloch)*	BF, A
		141. *Oreochromis mossambicus* (Peters)[N]	F, A
53	Mugilidae	142. *Liza macrolepis* (Smith)*	BM, A
		143. *Liza melinoptera* (Valancienues)*	BM, A
		144. *Liza parsia* (Hamilton-Buchanan)*	BM, A
		145. *Liza subviridis* (Valenciennes)*	BM, A
		146. *Liza tade* (Forsskal)	MB, R
		147. *Mugil cephalus* (Linnaeus)*	BM, A
		148. *Rhinomugil corsula* (Hamilton-Buchanan)*	FB, A
		149. *Valamugil cunnesius* (Valenceinnes)*	BM, A
		150. *Valamugil speigleri* (Blecker) *	MB, A
54	Scombridae	151. *Scomberomorus linolatus* (Cuvier)	M, R
		152. *Rastrelliger kanagurta* (Cuvier)[N]	M, VR
55	Trichuridae	153. *Eupleurogrammus glossodon* Blecker[N]	M, VR
		154. *Lepturacanthus savala* (Cuvier)[N]	M, VR

Table 5 continued

Family		Species	H & O Status
56	Sphyraenidae	155. *Sphyraena jello* (Cuvier)[N]	M, VR
57	Polynemidae	156. *Eleutheronema tetradactylum* (Shaw)*	M, A
		157. *Polydactylus indicus* (Shaw)	MB, R
		158. *Polydactylus plebeius* (Broussonet)[N]	MB, VR
58	Eleotridae	159. *Eleotris melanosoma* Blecker[N]	M, VR
59	Gobiidae	160. *Acentrogobius cyanomos* (Blecker)	B, R
		161. *Acentrogobius globiceps* (Hora)	B, R
		162. *Glossogobius giuris* (Hamilton-Buchanan)	FB, R
		163. *Olegolepis cylindriceps* (Hora)	BF, R
		164. *Oxyurichthys microlepis* (Blecker)	MB, VR
		165. *Yongeichthys criniger* (Valenciennes)[N]	B, VR
60	Acanthuridae	166. *Acanthurus mata* (Cuvier)[N]	M, VR
61	Siganidae	167. *Siganus canaliculatus* (Park)[N]	M, R
		168. *Siganus javus* (Linnaeus)	MB, R
62	Trypauchenidae	169. *Tripauchen vagina* (Bloch and Schneider)	MB, VR
63	Anabantidae	170. *Anabas testudineus* (Bloch)	F, R
		171. *Anabas cobojius* (Hamilton-Buchanan)	F, VR
64	Belontidae	172. *Colisa fasciatus* (Schneider)	F, R
		173. *Colisa lalia* (Hamilton)	F, R
65	Channidae	174. *Channa striatus* (Bloch)*	FB, A
		175. *Channa punctatus* (Bloch)	FB, A
		176. *Channa marulius* (Hamilton)[N]*	F, R
66	Mastacembelidae	177. *Macrognathus pancalus* (Hamilton-Buchanan)*	BF, A
		178. *Mastacembelus armatus* (lacepede)*	BF, R
67	Bothidae	179. *Pseudorhombus arius* (Hamilton-Buchanan)	MB, R
		180. *Pseudorhombus triocellatus* (Bloch)[N]	M, R
68	Cynoglossidae	181. *Cynoglossus puncticeps* (Richardson)	MB, A
69	Soleidae	182. *Euryglossa orientalis* (Bloch)	MB, R
70	Tricanthidae	183. *Triacanthus biaculeatus* (Bloch)*	B, A
71	Tetradontidae	184. *Chelonodon fluviatilis* (Hamilton-Buchanan)	MB, R
		185. *Chelonodon patoca* (Hamilton-Buchanan)	MB, R
		186. *Tetradon cutcutia* (Hamilton-Buchanan)	MB, R
		187. *Takifugu oblongus* (Bloch)	MB, R
Shrimps and Prawns			
1	Penaeidae	1. *Metapenaeus affinis* (H.Milne-Edwards)	MB, R
		2. *Metapenaeus dobsoni* (Miers)*	BM, A
		3. *Metapenaeus monoceros* (Fabricius)*	BM, A
		4. *Metapenaeus ensis*DeHaan[N]	MB, R
		5. *Penaeus(Fenneropenaeus) indicus*(H.Milne-Edwards)*	BM, A
		6. *Penaeus monodon* (Fabricius)*	BM, A
		7. *Penaeus Semisulcatus* (de-Haan)*	BM, R
		8. *Penaeus canaliculatus*(Oliver)[N]	MB, R
2	Palaemonidae	9. *Macrobrachium lamarrei* (H.Milne-Edwards)*	B, A
		10. *Macrobrachium malcomsonii* (H.Milne-Edwards)*	F, R
		11. *Macrobrachium rosenbergii*(DeMan)*[N]	F, R
		12. *Macrobrachium equidens*(Dana)[N]	B, R
		13. *Macrobrachium rude* (Heller)*	B, A
		14. *Exopalaemon styliferus* (H.Milne-Edwards)	FB, R
		15. *Periclimenes (Harpilius) demani* Kemp.	BB, R
3	Atyidae	16. *Caridina propinqua* de Man	BF, VR
4	Callianassidae	17. *Callianassa (Callichirus)maxima* H.Milne-Edwards	B, VR
5	Upogebiidae	18. *Upogebia (Upogebia) heterocheir* Kemp.	FB, VR
Lobster			
1	Palinuridae	1. *Panulirus polyphagus* (Herbst) [N]*	M, VR
		2. *Panulirus ornatus* (Fabricius)[N]*	M, VR

Table 5 continued

Family		Species	H & O Status
Crabs			
1	Calappidae	1. *Matuta planipes* Fabricius	MB, R
		2. *Mutata lunaris* (Forsskal)[N]	MB
2	Leucosiidae	3. *Philyra alcocki* Kemp.	MB, VR
3	Ocypodidae	4. *Ocypoda macroara* (H.Milne-Edwards)	MB, R
4	Grapsidae	5. *Varuna litterate* (Fabricius)	MB, R
		6. *Sesarma quadrata* (Fabricius)[N]	MB
5	Portunidae	7. *Portunus pelagicus* (Linnaeus)*	MB, A
		8. *Scylla serrata* (forsskal)*	BM, A
		9. *Thalamita crenata* (Latre)	MB, R
		10. *Charybdis cruciata* (Herbst)[N]	MB, R
		11. *Charybdis callianasa* (Herbst)[N]	MB, R
		12. *Portunus sanguinolentus* (Herbst)[N]	BM, A
		13. *Scylla tranquebarica* (Fabricius) *[N]	BM, A
		14. *Podophthalmus vigil* (Herbst)[N]	MB, R

[N] New records; *commercial species; H & O, habitat and occurrence; M, marine; B, brackishwater, F, freshwater; MB, marine-brackishwater; BM, brackishwater-marine; FB, freshwater-brackishwater; BF, brackishwater-freshwater; R, rare; A, abundant; VR, very rare

Table 6 Biodiversity status (habitat and occurrence) of fish and shellfish in Chilika lake during pre- and post-restoration phases

Status parameter	Pre-restoration (1914–2000) 'Recorded species'			Post-restoration (2000/2001–2003/2004) 'Inventorised species'			
	Fish	Shrimp & Prawn	Crab	Fish	Shrimp & Prawn	Lobster	Crab
Percentage composition of species by habitat (%)							
Marine	21.33			21.93	5.55	100.00	
Brackishwater	9.78	8.33		11.76	33.33		
Freshwater	14.67	8.33		13.37	11.11		
Marine-Brackishwater	31.55	12.50	92.86	33.16	16.67		85.71
Brackishwater-Marine	5.78	20.84	7.14	5.88	27.78		14.29
Freshwater-Brackishwater	11.11	50.00		11.76	5.56		
Brackishwater-Freshwater	5.78			2.14			
Percentage composition of species by occurrence (%)							
Abundant	14.22	33.33	7.14	34.23	38.89		21.43
Rare	49.78	37.50	14.28	41.71	33.33		28.57
Very rare	36.00	29.17	78.58	24.06	27.78	100.00	50.00

Inventorisation of species during pre- and post-restoration phases are taken into consideration

(post-intervention) and from 7.1% (pre-intervention) to 21.4% (post-intervention) respectively.

Species richness

Species richness of estuaries and lagoons is defined as the number of species encountered at least once within ecosystem limits which depends on the openness of the systems and characteristics of the spatio-temporal variation in salinity gradient (Baran 2000). Chilika lagoon, which has estuarine characteristics, influenced by three hydrologic sub-systems exhibits four distinctive ecological sectors. These four sectors show variations in species richness (SR) varying with the seasons. As observed from the species inventorial survey undertaken during post-new lagoon mouth period, three sectors (northern, central and outer channel sectors) were more influenced by two antagonistic hydrological processes resulting from freshwater inflow from rivers and catchment streams and sea water ingress from the sea.

Freshwater inflow into the lagoon remains active and strong during June–November. Although feeble inflow of freshwater from rivers continues throughout the year; the seawater influx dominates during December–May. Therefore freshwater species in northern sector are gradually replaced by brackish water species from December onwards. They are again gradually replaced by freshwater species, coming in the river flows from July onwards. Similarly the outer channel sector is strongly influenced by both strong freshwater flow during rainy season and strong seawater ingress during winter and summer seasons. Therefore, the species richness of fish and shellfish faunas in those sectors showed wider variations, whereas least variation was observed in the southern sector due to weak freshwater inflow for shorter duration and restricted exchange of water through Palur canal (before renovation in 2004).

Outer channel sector (OCS) registered the highest species richness (62.4%) in summer and in winter (54.6%). Central sector (CS) came in the second order with 48.4–50.7% of species richness (SR). Northern sector (NS) registered the highest SR of 34% during winter. Southern sector (SS) showed minimum variation (14.9–16.7%) in species richness. Higher species richness in the outer channel sector is due to entry of more marine species during summer and winter for feeding purposes, except few others for breeding (threadfins, some clupeoides, etc.). In general, species richness is due mostly to a succession of species temporarily using these ecological sectors for feeding, spawning or shelter. Baran (2000) also made similar observation in West African estuaries. Dominance of marine or freshwater species in the ecosystem depends mainly on the salinity gradient pattern, which shows wide range variations in NS, CS and OCS, while SS exhibits more stable salinity with least fluctuations. After the new lagoon mouth, spectacular increase in salinity regime was observed in four ecological sectors, increasing marine species (51.8%) among new record of fish and shell fish species during the post-intervention period. Species richness in different sectors was also governed by cyclic changing pattern of salinity regime. The annual average salinity for the whole lagoon during post-intervention period registered 39.4% increase in comparison to pre-intervention base year (1999–2000). The comparison of mean salinity values using *t*-test for three seasons (summer, rainy and winter) and four ecological sectors of Chilika lagoon during pre- and post-hydrological intervention phases showed significantly higher salinity regime ($P < 0.007$) during post-intervention phase. There were no significant differences when mean values of other physico-chemical parameters for different seasons and sectors before and after intervention (Table 2) were compared. Thus effective ingress of sea water during semi-diurnal tides and considerable increase in salinity flux improved the marine and brackishwater habitats in the outer channel and in the lagoon, respectively (Trisal 2000; Mohanty 2002), which was probably the main contributing factor for more new records of fish, prawn and crab species during the post-intervention period.

Ecorestoration

Although hydrological intervention was key to restoration of Chilika lagoon, some other ameliorative measures outside the lagoon, particularly the vast catchments (2,250 km^2) under Mahanadi river basin and 1,560 km^2 western catchments (Fig. 2) are also important. With a view to arresting silt loading and maintaining proper dynamic salinity regime of the lagoon that underpins its ecological characters, preferential freshwater inflow into the lagoon through Naraj Barrage (Fig. 2) on Mahanadi river has been found to be vitally important (World Bank 2005). The Orissa Department of Water resources (ODWR) is presently all set to regulate the freshwater inflows at Naraj Barrage following the recommended operational rules. Large-scale implementation of participatory micro-watersheds and catchment treatment through plantation in the western catchment are being carried out by CDA with local community participation to restore the degraded catchment ecology. The awareness campaigns through NGO activities are regularly carried out among agricultural farmers in the fringe and island areas of the lagoon to use biofertilizers and pest-resistant paddy seeds to minimize agricultural and pesticide pollution.

Sudden increase in fishery output, significant rise in salinity regime, flushing of silt, decrease in weed areas and overall enhancement of environmental condition were observed as positive impact of the hydrological intervention where as population decrease in some fish and shell fish species (*Etroplus suratensis* and *Macrobrachium sp*.) was noticed to be negative consequence.

The hydrological intervention including maintenance of the new lagoon mouth, flushing channels and Palur canal together with the above mentioned measures in the surroundings and with conservation and wise use of its resources through active community participation the ecorestoration of the lagoon is likely to be achieved within the next few years, which can be assessed through regular spatio-temporal monitoring of changes in ecological conditions and biodiversity status.

Conclusion

The changes in fish catch and species diversity that followed the opening of the new lagoon mouth under the hydrological intervention programme in Chilika lagoon clearly indicated that they are very sensitive to the salinity and hydrologic dynamies, which in turn are strongly influenced by freshwater inflows. However, the fish diversity and abundance (and hence catch) would depend on the complex interaction between inflows, outflows, lagoon biogeochemistry, fish population, spawning and recruitment success and food web dynamics. The opening of the new lagoon mouth apparently has resulted not only in quick recovery of the lost fishery but also tremendously altered the course in annual catch, CPUE and number of fishing days in a good development indicating the availability of substantial fish catch round the year. As the current fishery of Chilika, after hydrological intervention, is in a transient mode, regular close monitoring is recommended so as to keep track on the possible changes in it besides to understand the level at which the fishery may stabilize in the long run. Stabilization of fishery would largely depend on keeping the natural changes and human-induced activities (as stated earlier) under control and operation of all the environmental variables to their optimum including unhindered recruitment of fish, prawn and crabs, both from marine and riverine sources. Under the current changing scenario of the lagoon fishery, it is imperative that the fish yield potential of the lagoon and maximum sustainable yield (MSY) and efforts (MSY) are assessed at the earliest to formulate exploitation and management strategy. The northern sector of the lagoon which acts as the nursery ground for a large number of fresh and brackishwater fish species and breeding ground for anadromous fish species, its proper maintenance is a *sine-qua-non*. Time series data on monthly CPUE, length frequency of economic species and attributes of crafts and gears used are essential to facilitate a holistic study on the dynamics of fish population in the lagoon need to be gathered from now onwards. Further research is also required to develop a carrying capacity model for harvesting the desired quantity of fish on a sustainable basis. Decrease in relative abundance of mullets during post-intervention period needs further investigation. A follow up holistic fisheries investigation needs to be initiated at least 6–7 years after opening of new lagoon mouth to assess the changes in ecosystem health and fisheries so as to review the present management protocol. Inview of the changed ecological regime including the enhanced fish yield and biodiversity, owing to hydrological intervention, there is an urgent need to manage the ecology and fisheries of the lagoon in an integrated and responsible manner which can be achieved through active participation of the resource users (fishers), in fishery conservation and management processes, protection of interests of the traditional fishers, gathering of scientific evidences, setting appropriate conservation and management objectives, regulation of fishing practices (phasing out of destructive fishing) through appropriate legislation, post-harvest practices, education and capacity building measures, maintenance of new lagoon mouth, flushing channels, palur canal, restoration of catchment ecology and ensuring preferential freshwater inflow through Naraj Barrage. There is need for an ecosystem approach to periodically evaluate the changes that can assess the restoration status.

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