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A REVIEW ON THE STATUS, ECOLOGICAL IMPORTANCE, VULNERABILITIES, AND CONSERVATION STRATEGIES FOR THE MANGROVE ECOSYSTEMS OF PAKISTAN

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Abstract

All over the world**,** mangroves are considered one of the highly vulnerable forest ecosystems. These are mainly found along the coastlines of tropical and subtropical regions where rivers bring freshwater and silt from the mainland to sea. They provide livelihood and numerous ecosystem services to millions of people living in the deltaic and coastal areas. These forests safeguard the properties, lands and lives of the people from storms, hurricanes and cyclones. They provide important habitats for plants and animal biodiversity. Hundreds of species of mammals, birds, reptiles, fishes, crabs, shrimps, mollusks, barnacles, jellyfishes and other invertebrates depend on mangroves for feeding, breeding, development and shelter. In Pakistan, mangrove forests are dominantly restricted to the Indus Delta which represents 97% of these forests whereas the Balochistan coast only harbors rest of the 3%. Despite their vital importance, the area under mangrove forests is continuously decreasing for the last 50 years, both in the world as well as in Pakistan. The rate of decrease is the highest in Asia and also in Pakistan. Main causes of the decline of the mangrove forests in Pakistan are the reduced freshwater and silt flow into the sea, pollution, fast pace of urbanization and development, global warming, climate change, complex tenure system, and overgrazing and extraction of timber and fuel wood. Time to time, various policies and plans have been initiated by the concerned forest departments, federal agencies, NGOs, and funding organizations leading to protection, management and enhancement of mangrove forests. Local communities have also been involved in almost every programme for implementation and achieving the targets and objectives of various projects. The actual main cause of issue is, however, never been addressed which is the release of environmental flows downstream of dams and barrages constructed on the river Indus and its tributaries. Many new approaches involving widely tested international lines of action, sound research and data collection and data analysis techniques, and use of modern technologies and gadgets like remote sensing and GIS, need to be applied for restoration and regular estimation and monitoring of the mangrove forests.

Key words: Mangroves**,** Ecosystems**,** Importance**,** Vulnerabilities, Conservation, Coastal areas**.**

Introduction

Mangroves are either trees or large shrubs and are distributed in 123 countries and regions of the world spreading over an area of 150,000 square km. All the mangrove species are adapted to high salinity, high temperature, frequent water fluctuations, windy conditions and mud and silt flats between low and high tides (Macnae, 1966). Mangrove forests cannot survive in cold conditions of high latitudes of southern and northern hemispheres and, therefore, are restricted to the tropical and subtropical coastlines approximately between 32ºN and 38ºS (Satyanarayana, *et al.*, 2011; Walter, 1977). The countries, regions and territories having major mangrove forests can be grouped into two main clusters, one represented by eastern countries like Australia, Philippines, Papua New Guinea, Malaysia, Indonesia, Thailand, Myanmar, India, Bangladesh, Sri Lanka, Pakistan, Saudi Arabia, Madagascar, Tanzania and the other consisting of western countries like Mexico, Mozambique, Nigeria, Cameroon, United States of America, and Ecuador.

In Pakistan, mangrove forests are mainly found in the swamps of Indus Delta in the coastal areas of Sindh and at scattered places along the Balochistan Coast. The coastline of Pakistan is spread over 1,050 km, out of which, a stretch of 800 km is found in Balochistan while the rest 250 km is part of the Sindh province. Mangroves are present in the whole stretch of coastal areas of Sindh, except some areas of Badin District. The coastline of Balochistan is mainly dry and without any major deltaic component and hence has few mangrove patches restricted in lagoons of Miani Hor and Kalmat Hor and in the estuary of Gwater Bay (Qureshi, 2005). Stewart (1972) based on the historical collections reported 8 species viz., *Avicennia marina, Rhizophora mucronata, Aegiceras corniculata, Ceriops tagal, Sonneratia caseotaris, Rhizophora apiculata, Bruguiera conjugate* and *Ceriops dodecandra* from the coastal areas of Sindh and Baluchistan, but presently only 1st four species are found in these areas (Saifullah, 1997). The last four species namely *Sonneratia caseotaris, Rhizophora apiculata, Bruguiera conjugata* and *Ceriops dodecandra* are extirpated (locally extinct), (Ghafoor, 1984).

Mangroves provide important resources and ecosystem services for human being in general and for marine fauna and coastal communities, in particular. These forests dissipate wind, waves and tidal energy and act as a barrier against cyclones, typhoons and tsunamis (Guebas *et al*., 2005; Wells *et al*., 2006). They also increase soil deposits along the coastal areas resulting in stabilization of the shorelines. The mangroves improve water quality by increasing dissolved oxygen content in the water and trapping nutrients and heavy metals by their dense root network (Alongi, 1996; Clark, 1998; Tam and Wong, 1999). Local communities use mangroves for fodder for their livestock and for fuel wood, charcoal and extraction of tannins. Mangrove wood is also used for making furniture and construction of huts, boats, and fishing gears (Aksornkoae *et al*., 1993; Guebas *et al*., 2000). Some of the mangrove species have medicinal values and are used for folklore medicines and insect repellants (Bandaranayake, 1998; Cornejo *et al*., 2005;

Pattanaik *et al.*, 2008). Mangroves are biodiversity hotspot areas and play a vital role in sustainability of marine biodiversity. They provide breeding ground for different species of fishes, turtles, birds, prawns, crustaceans and mollusks (Nayak and Bahuguna, 2001). They also serve as a promising habitat and shelter for sea mammals, coastal birds, marine turtles and snakes and marshy crocodiles (Ramasubramanian, *et al*., 2006).

Despite the remarkable social, ecological, and economic importance of mangroves, these ecosystems have become the most endangered habitats due to ever increasing human activities and climatic susceptibilities. Major factors contributing to mangrove loss include clearings for agricultural use, human settlements, harbors construction, establishment of industrial areas, development of tourism facilities, construction of shrimp and fish aquacultural facilities, overharvesting for firewood and fodder, production of pulp and charcoal. These forests are also being impacted badly due to water diversion for irrigation resulting in high salinity levels; increased erosion of the coastal belts; enhanced use of insecticides and pesticides in agricultural areas; oil spills; pollution, and above all global warming and climate change (Latif, 2012). All these factors along with their synergic effects, are leading towards degradation, fragmentation and loss of mangrove forest areas. Consequently, about half of the mangrove forest areas have been devastated worldwide resulting into loss of species, change in species composition and associations (Cornejo, *et al*., 2005). If this trend remains as such, it is estimated that by 2030, about 60% of the mangrove forests in the world will be lost (Alongi, 2002; Valiela, *et al*., 2001; Simard, *et al*., 2008). World over, the loss of area under mangrove forests is approaching to about 1 to 2% per year but this loss is much more pronounced in the developing countries where these forests are found in abundance (Duke *et al.*, 2007). It is, therefore, obligatory for the concerned departments to raise awareness among the coastal communities about the importance of mangrove forests and their habitats and initiate conservation and management strategies to protect them from further deterioration.

Various countries have adopted diverse strategies and plans to save and restore this unique and fragile ecosystem. It includes, proper management plans, a greater emphasis on ecological research on mangrove ecosystems, involvement of local communities, awareness raising about economic and ecological values and functions of mangrove forests, development of various management models, framing and implementation of conservation laws, imposing ban on harvesting of mangroves, adaptation of in-situ and ex-situ conservation strategies, adoption of international good practices and approaches, use of remote sensing and GIS techniques for ensuring accuracy in data, restoration of environmental flows, initiation of exclusive mangrove rehabilitation and regeneration programs, continuous afforestation practices etc.

Main objective of the present review is to overview the current distribution pattern of mangrove forests, their ecological, social and economic role and the threats and vulnerabilities being faced world over with a special emphasis to Pakistan and propose specific management considerations for protection, conservation and rehabilitation of the most fragile mangrove ecosystems.

Distribution pattern of mangrove forests in the world: Distribution of mangrove forests in the world is highly skewed and confined to tropical and subtropical regions only (Fig. 1). Although these forests are found in 123 countries and territories of the world but approximately 75% are concentrated in just 15 countries (Giri, *et al*., 2011). Mangrove forests are mainly found between 0-10^{o} North and 0-10^{o} South latitudes but their range of distribution extends to 32° North and to 38° South (Spalding *et al*., 1997). Areas under mangrove forests generally decreases with increasing latitudes, except for the region between 20° and 25° N latitudes (Fig. 2). This area has the mangrove forests of Sundarbans, the largest continuous stretch of mangrove forests in the world. Similarly, species diversity, height of mangrove trees and their biomass, decreases with increasing latitudes both in the southern and northern hemispheres.

About 80 species of mangroves have been recognized in the world out of which, only 50-60 species form the major component of the mangrove forests. The continent of Asia and especially the Southeast Asian Region not only has the largest areas of mangrove forests but it also has the highest species diversity in the world (Giesen and Wulffraat, 1998). More than 50 species of mangroves are found along the coasts of different countries of Asian Region but this number decreases in the African and American Region representing only 15 and 10 species respectively.

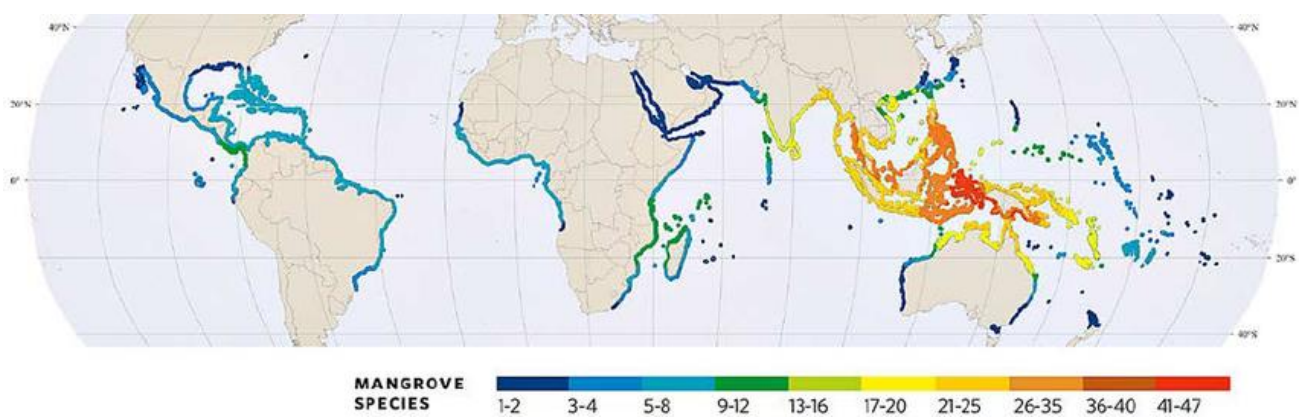

Fig. 1.World over distribution of mangrove forests.

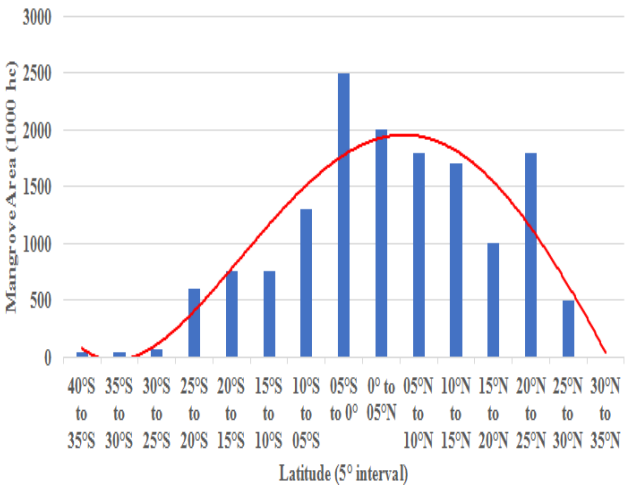

Fig. 2.Distribution of mangrove forests in world along the latitudinal gradient.

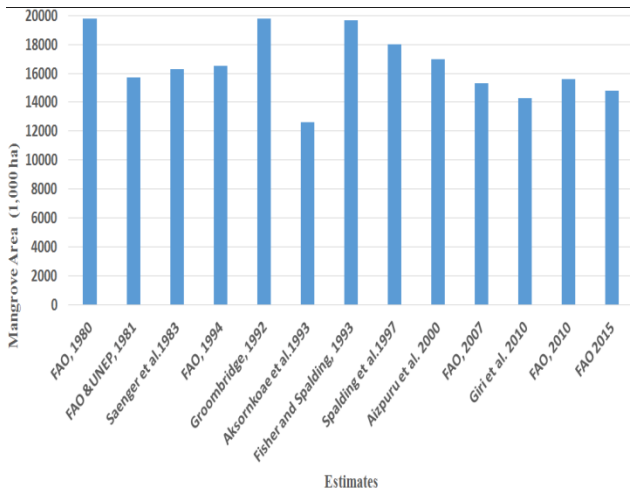

Fig. 3.Comparison of estimates of global mangroves area over the years.

Table 1. Distribution of Mangrove Forest Cover in different Regions of the World (Source: FAO, 2010).

Region	Area (Sq. km)					% Change
	1980	1990	2000	2005	2010	
Asia	77,690	61,960	66,270	64,660	62,880	-19.0
Africa	36,700	34,140	31,780	31,020	30,270	-17.5
North and CentralAmerica	29,510	24,160	23,100	23,420	23,870	-19.1
Oceania	21,810	18,600	18,410	15,370	17,590	-19.4
South America	22,220	22,250	21,870	21,750	21,610	-2.7
Total	187,930	161,110	161,430	156,220	156,220	-17.0

According to FAO (2010), the total cover of mangrove forests in the world is 150,079 sq. km, of which, 62,232 sq. km (41.46%) falls in Asia, 30,270 sq. km (20.16%) in Africa, 23,870 sq. km (15.90%) in North and Central America, 21,610 sq. km (14.40%) in South America, and 17,590 sq. km (11.72%) in Oceania. Southeastern region is the mangrove hotspot area wherein Indonesia alone has 23% of the total world mangrove forests. The other countries having biggest mangrove forests are Australia and Brazil each having about 7% of the world mangrove cover. Reduction in mangrove cover in the world has been estimated up to 17% from 1980 to 2010 (FAO, 2015). Highest loss in the area of mangrove forests in this period is assessed in Oceania (19.4%), North and Central America (19.1%), Asia (19%) and Africa (17.5%), which is almost equal in these four regions (Table 1). The lowest loss in the area under mangrove forests is estimated in South America which could be attributed to the reason that most of the mangrove areas in this part of the world are located in less urbanized regions (FAO, 2010).

There have been variations in estimates of world mangrove forest areas over the years (Fig. 3). For the present studies, the FAO data is considered as standard for comparisons with the similar data published by various organizations and individual scientists for the last many years. These variations may be due to natural phenomena and anthropogenic factors but it may also be due to use of different methodologies in different parts of the world, level of technical advancement, mapping techniques, spatial resolutions, accuracy in data analysis techniques etc. (FAO, 2003). In the last three decades, however, the losses of the area under mangrove cover has significantly increased due to anthropogenic factors. The remaining mangrove forests in all parts of the world are under enormous pressure from overexploitation, construction of dams and water diversion, pollution and oil spills, ever expanding aqualcultural practices, and climate change and global warming (Blasco *et al.*, 2001).

Mangroves are now considered as an important ecosystem worldwide for provision of livelihoods and materials and for safeguarding marine and brackish water biodiversity. Increased population pressures and lack of awareness among the coastal communities have resulted into conversion of mangrove areas into other multiple uses. The statistical data indicates that mangrove forest area has decreased from 19.8 million hectares to 15 million hectares from 1980 to 2015 indicating a loss of 5 million hectares in a period of 35 years (FAO, 2015, Fig. 3).

Status of mangrove forest cover in Pakistan: About 1,050 km coastline of Pakistan stretches in the Provinces of Sindh and Balochistan. Coastal areas of both the provinces, however, fall under varying climatic and physical conditions. The Sindh coastal area is influenced by the Monsoon Weather and is divided into Indus Delta and Karachi City Coast. The Indus Delta is the main characteristic of the coastal area of Sindh and is included in the largest five delta systems of the world. The delta area has 17 large and numerous small creeks, several mudflats scattered along the coastal area, plenty of wetlands, network of estuarine systems and a wide and gentle continental shelf. The Indus delta region is thinly populated having small settlements mainly occupied by fishermen communities. The major infrastructure like roads, industries, fish and shrimp farms, and cities are lacking. The most prominent feature of the area is the mangroves forests scattered along the coastline.

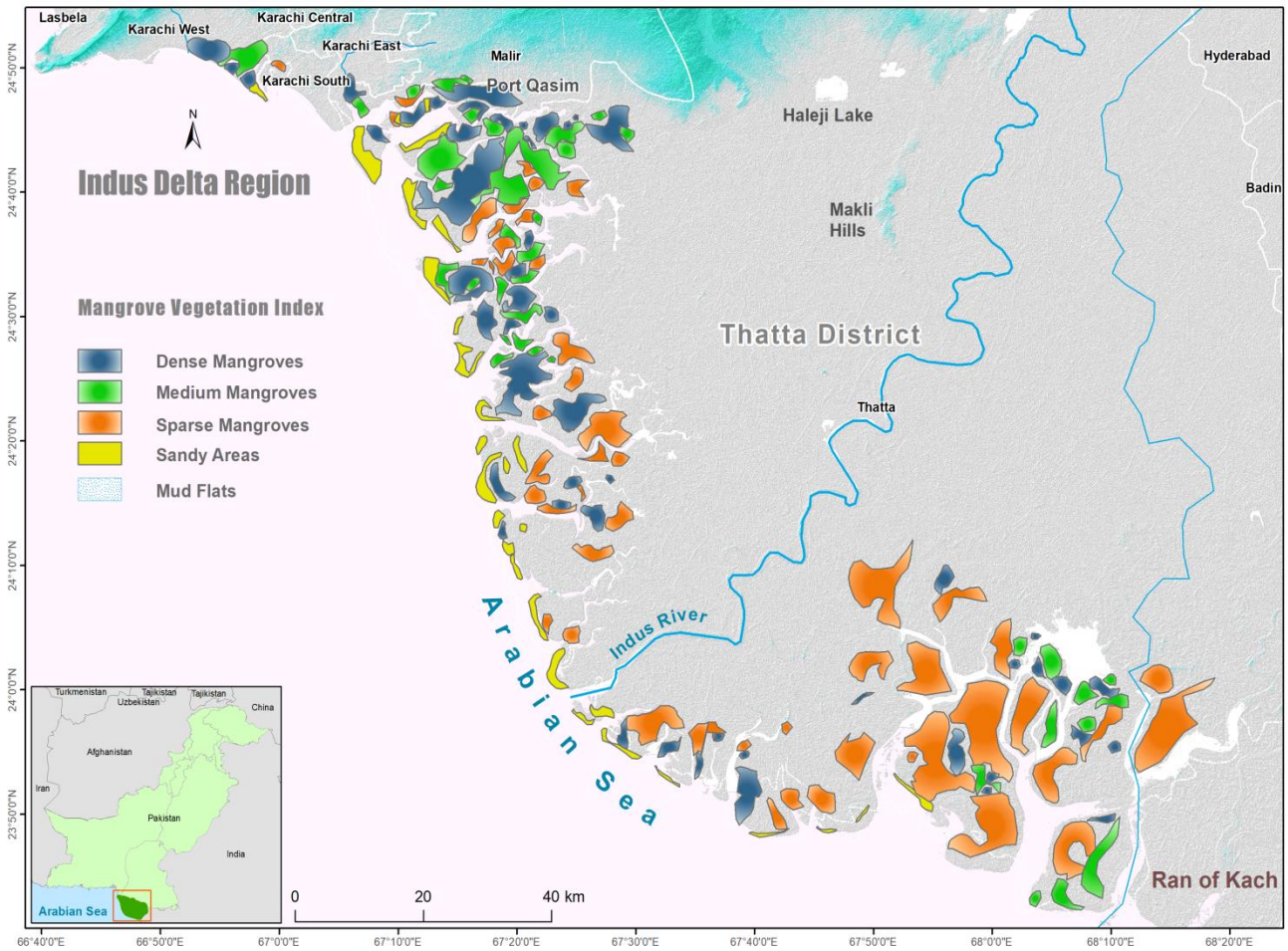

Fig. 4. Distribution of Mangrove along the Sindh and Balochistan Coasts: A- Four Mangrove hotspot areas, B- Creek Areas of Indus Delta and Sindh Coast.

The Karachi City Coast consists of scattered beaches, hilly stretches, rocky shoreline, vast mud flats, and a network of creeks, in the eastern and western sides of Karachi. Major mangrove forest areas around Karachi consist of Gharo Creek, Ibrahim Haidry, Kadiro Creek, Phitti Creek, Korangi Creek, Hawksway and Sandspit area. Karachi, which lies in the middle of eastern and western mangrove strands of this coastal region, is the biggest city of Pakistan and a major hub of industrial as well as national and international trade activities. It is one of the most populous cities of Pakistan having an estimated population of approximately 18 million.

The Balochistan coast is influenced by the Mediterranean Weather with mild winters and very warm summers. It is characterized by vast beaches, sand hillocks, and rocky shores but generally soil cover is dominantly composed of sand and silt. The coast is thinly populated having scattered settlements of local fishermen along the coastal area. Compared with Sindh coastline, the Balochistan coastal area harbors a comparatively smaller mangrove cover despite its large stretch. It is due to climatic, topographical and geographical reasons. Mangrove areas of Balochistan are restricted to limited sites covering an area of only 4,660 ha which represents about 3% of the total mangrove forest area of Pakistan (Mirza *et al*., 1988, Saifullah &Rasool, 1995, Saifullah &Rasool, 2002).

Major stretch of coastline of Sindh is covered with mangroves, the main mangrove forest areas being the creeks of Keti Bundar, Jati, Shah Bundar, Mirpur Sakro, Ghorabari, Kharo Chan, Port Qasim, Korangi, Karachi Fish harbor, Ibrahim Haidary, and Gaddani. Total forest area along the Sindh coast is estimated to be 93,177 hectares (Table 2). The area of mangrove forests along the Balochistan coast is very restricted. There are different views about the total area under the mangrove forests in Balochitan. According to Khan (1986), the total mangrove area in Balochistan is 2,000 ha but Mirza *et al.*, (1988), consider this area as about 7,340 ha. In another attempt, IUCN and SUPARCO (2003) have estimated the mangrove area of Baluchistan as 4,660 hectares using the satellite imaging technique (Table 3). Distribution of mangrove forests along the coastal areas of Sindh and Balochistan is shown in Fig. 4.

Various workers have given different estimates of areas under mangrove forests in Pakistan from 1950 to 2015 (Table 4). While considering and comparing FAO estimates of 1980 and 2015, the mangrove forest area from Pakistan has reduced from 345,000 ha to 95,000 ha for the last 35 years showing a reduction of 250,000 ha (72%). The reduction trend in the mangrove area in Pakistan is shown in Fig. 5.

Table 2. Mangrove area along the Sindh Coast (Extracted from Sawaid *et al*., 2013).

Nos.	Mangrove classes	Mangrove area (in hector, ha) in different locations of Sindh Coast							
		Keti Bundar	Shah Bundar	Jati	Mirpur Sakro	Ghorabari	Kharo Chan	Snndspit	Total
1.	Dense Mangroves	299	864	44	8,967	102	2,226	540	13,042
2.	Medium Mangroves	175	3,328	580	9,450	382	1	328	14,244
3.	Sparse Mangroves	2,490	22,560	1,997	28,709	3,519	6,428	188	65891
	Total	2964	26752	2621	47126	4003	8655	1056	93,177

Table 3. Mangrove area along the Balochistan Coast ((Extracted from Sawaid *et al*., 2013).

Nos.	Mangrove classes	Mangrove area (in hector, ha) in different locations of Balochistan Coast			
		Miani Hor	Kalmat Khor	Jiwani	Total
1.	Dense mangroves	283	-	-	283
2.	Medium mangroves	738	407	235	1,380
3.	Sparse mangroves	2997	-	-	2997
	Total	4,018	407	235	4,660

Table 4. Various estimates of mangrove areas in Pakistan.

Nos.	Source	Area	Year
1.	Biodiversity Management Information System	380,000	1950
2.	Government of Pakistan., Forestry Sector Master Plan	400,000	1965
3.	Ministry of Food, Agriculture and Cooperatives (1981), FAO, UNEP	345,000	1980
4.	Saenger *et al.,* (1983)	249,500	1983
5.	Government of Pakistan (1985)	280,000	1984
6.	Kogo *et al.,* (1985)	283,000	1985
7.	Mirza *et al.,* (1988)	250,233	1988
8.	FAO (2003)	207,000	1990
9.	Government of Pakistan (1992)	207,000	1990
10.	UNESCO (1992)	261,720	1991
11.	Spalding *et al.,* (1997)	168,300	1993
12.	Pakistan Forest Institute (2004)	159,000	1997
13.	World Conservation Institute (2000)	154,000	2000
14.	Pakistan Forest Institute (2004)	158,000	2001
15.	FAO (2005)	347,000	2005
16.	IUCN-Pak	86 727	2005
17.	Swaid *et al.,* 2013	97837	2013
18.	Mangrove For the Future Pakistan (MFF)	108 058	2014
19.	Sindh Forest Department (SDF)	283 280	2015
20.	FAO (2015)	95,000	2015

Mangrove species found in the coastal areas of Pakistan: In Pakistan, mangrove forests are distributed in the coastal areas where rivers bring freshwater and mud from mainland to sea due to which salinity of the marine water is reduced to variable extant. The mangrove forests of Sindh Coast are distributed along the 16 major creeks each of which historically has been the course of Indus River. Along the Balochistan Coast, the rivers ending up into the Arabian Sea are the Hub, Porali, Hingol, Basol and Dashat. These rivers are very small and hence bring less amounts of freshwater and mud into the sea. The mangrove forests along 990 kilometers Balochistan coastline are, therefore, restricted only to four locations.

Four different species of mangroves viz., *Avicennia marina*, *Rhizophora mucronata*, *Ceriops tagal* and *Aegicerus corniculatum* have been reported from the coastal areas of Pakistan. Two of these species, *Avicennia marina* and *Rhizophora mucronate*, however, constitute major component of the mangroves of Pakistan. Other species have been reduced considerably, and are now restricted to limited areas. The species *Rhizophora mucronata* is found in the lagoon area of Miani Hor but the species *Ceriops tagal* has a scanty distribution along Miani Hor lagoon and Khai and Daboo creeks. The species *Aegiceras corniculatum* is now almost eliminated from Sindh coast except few patches found in Pakar and Daboo creeks near Shah Bunder. The species *Avicennia marina* is presently the most dominant mangrove species in Pakistan and occupies almost 99.9% area of mangrove forests of Sindh Coast which is attributed mainly to its high salinity tolerance and resistance for other adverse climatic conditions (Qureshi, 2005).

Threats and vulnerabilities to mangrove ecosystems of Pakistan: Over the last 50 years, a significant reduction in the area under mangrove forests has been observed in Pakistan mainly in the Indus delta (Fig. 6). The delta region is increasingly going under severe threats due to variety of factors, both natural and anthropogenic. The main factors are insufficient and irregular inflows of fresh

water and silt load from Indus River, clearance of land for development projects, global warming and sea level rise, pollution, grazing and browsing of livestock, fuel wood and timber extraction and effluent from industry and Left Bank Outfall Drain (LBOD). The synergetic effect of all these factors is seriously damaging the quality and quantity of Mangrove forests in Pakistan. Due to these threats, the highly vulnerable and delicate mangrove ecosystem has been exposed to physiological and environmental stresses resulting in loss of species and their habitats, decline in fish and shellfish production. Ultimately coastal communities have to suffer due to cessation of ecosystem services, livelihoods and goods.

The mangrove forests need freshwater and silt for their long-term sustainability, growth and propagation. The freshwater reduces the salinity of the marine water which is necessary for growth of the mangrove plants and the mud provides necessary platform and nutrients for proper propagation of the seedlings and plants. Before construction of barrages and dams on the river Indus, the full fresh water discharges from the River Indus have been source for these supplies. Construction of dozens of dams and barrages and diversion of water for irrigation and production of hydroelectricity, the quantity of freshwater to Indus delta has been severely reduced. The data of discharges below Kotri barrage over the years from 1976-77 to 2003-04 shows that the total annual discharge below Kotri has been highly variable and inconsistent and clearly shows a considerable decrease in flows over the years (Fig. 7). Moreover, its duration has been reduced to two months and that too is only during the years of high floods. Total amount of water available from the whole catchments of the Indus River is about 150 maf. At the time of independence, the inflow to Indus Delta was about 80 maf but during the year 2001, it reduced to its minimum of 0.78 maf. With a total available freshwater discharge of 150 maf, the total simulated silt load becomes 400 m tones per year while the actual quantity of silt discharged in the delta region is estimated at 100 m/tons/year (IUCN, 1991) which does not suffice the actual requirement.

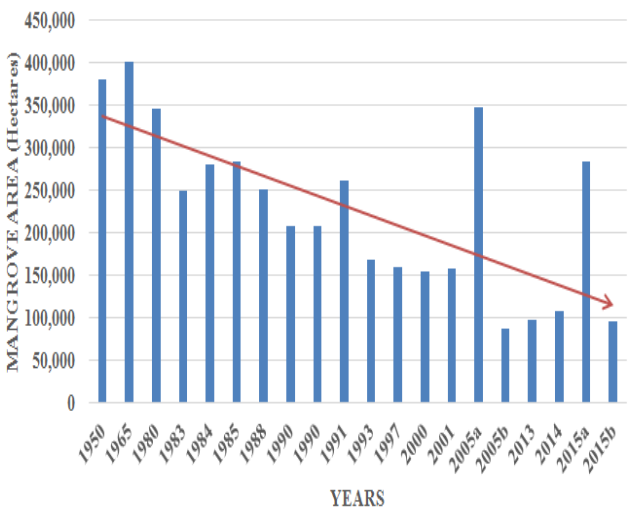

Fig. 5. Trend in the reduction of Mangrove areas in Pakistan based on the data in Table 4.

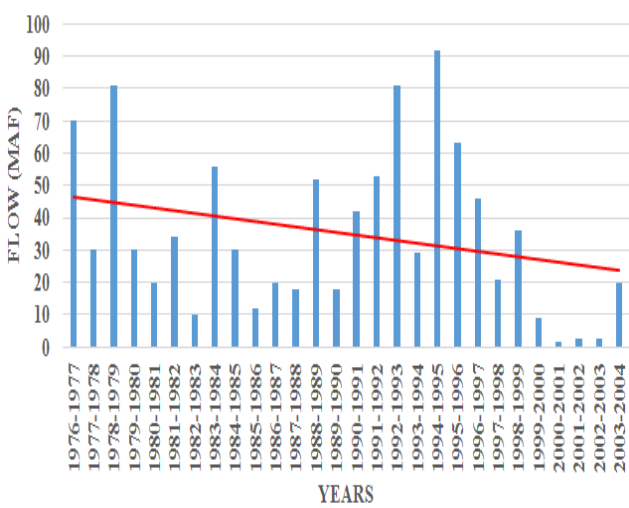

Fig. 7. Discharge of Indus below Kotri Barrage (Data Source: Technical Committee on Water Resources, Govt. of Pakistan, 2005).

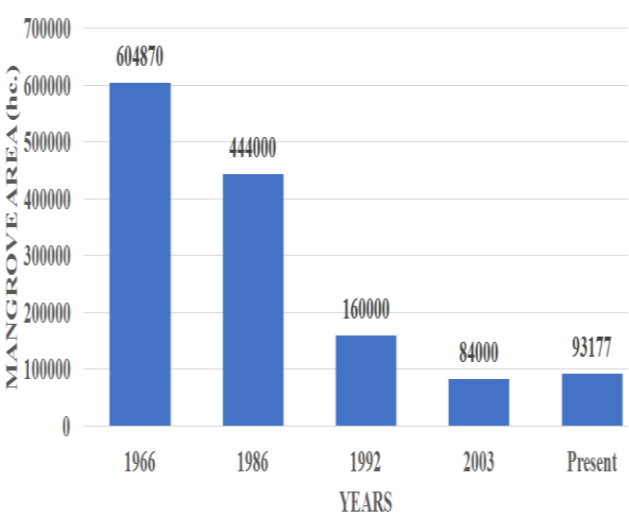

Fig. 6. Decrease in Forest area in the Indus Delta (Sources: Coastal Environmental Management Plan for Pakistan, UNESCAP, GOP and Sindh Forest Department).

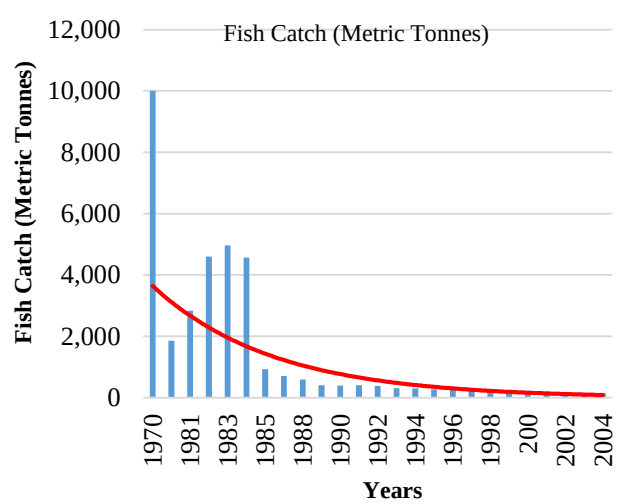

Fig. 8.Landings of Palla Fish, *Tenualosa ilisha*, in the Indus Delta Region.

As a result of reduced flow in the Indus Delta, the salinity of the sea which has been 15-20 ppt half a century ago, has now increased to 45-50 ppt which is unfavorable for the growth of most of the mangrove species. Moreover, the mangrove area of the Sindh coast has been deprived of the uniform dispersal and spreading of silt brought in by the river Indus and its tributaries from its catchment area. As a result of reduced flow and enhanced salinity, the mangrove cover has reduced, both, quantitatively as well as qualitatively. The surviving Indus Delta mangroves are now not only scanty but also stunted and suffering from diseases especially the Dieback (Top-dying) disease. The mangrove species, *Avicennia marina*, has a higher tolerance of salinity and is the only species thriving in most of the coastal areas of Pakistan while other species are gradually declining and becoming extinct.

Global climate change and consequent rise in sea level is an emerging threat to mangrove ecosystem of the Indus delta. For the last 100 years, a sea level rise of 1.1 mm has been projected at Karachi resulting in a loss of 1,700 km^2 of the land of the coastal area of Sindh due to sea intrusion (Qureshi and Khan, 1988). Rise in sea level causes a strong wave action, higher tides, aggravating currents, inundation stress, sediment erosion and high salinity at landward zones. All these factors, coupled with reduced flows and silt, are posing serious threats and seaward margin of mangrove strands are showing recession along the coastal areas of Pakistan.

Pollution threat in the Balochistan coast is lower at the moment as there is no any big city or mega project along the coast. Pollution level as such in the Delta area is also less pronounced due to lack of any direct pollution source in the area but the pollution brought by the rivers Kabul, Sindh, Jhelum, Chenab, Ravi and Sutlej from the effluents of industries, cities and agricultural fields in Khyber Pukhtunkhwa, Punjab and Sind end up in the Indus Delta. This pollution is, however, diluted to some extent by the freshwater brought in by these rivers except when the water flows in the rivers are very low. Mangrove strands along the Karachi City Coast are, however, under sever threat of pollution generated from industries, municipal wastewater, ship breaking industry, ports, and oil spills. More than half of the industrial units of the country are located in Karachi and 70% of the international trade of Pakistan is being handled from this city. Number of industrial units which was about 10,000 during 1990s, has now gone beyond 30,000. About 40,000 tons of industrial waste and 20,000-25,000 tons of oil finds its way into the sea from city of Karachi. Furthermore, 115 million gallons of municipal sewers generated each day is drained into the sea. Over the years, this pollution has affected the mangrove forests near the creeks of Karachi resulting into a stunted growth of mangroves. This deterioration of mangrove habitats is resulting into loss of biodiversity and production of fish, shrimps and crabs which are commercial commodities of Pakistan.

The pressure of overharvesting of mangrove forests in the coastal areas is another reason of degradation of this natural resource. Coastal communities use mangrove forests for fodder, fuel and timber. It is estimated that about 18,000 tons of mangrove firewood is extracted from the Indus Delta by 100,000 people living along the coast of Sindh. As a result of ever increasing population and lack of any alternate source, this demand is continuously increasing with the passage of time. Leaves of the most dominant species of mangroves, *Avicennia marina*, is considered the best fodder for animals and is being widely browsed and grazed by herds of camels, cattle, goats and sheep (Amjad *et al.* 2007). The leaves of the mangroves are regularly collected by the local people for their livestock. All this overharvesting and overexploitation of the mangrove forests is putting substantial pressure on the already dwindling mangrove strands.

The Left Bank Outfall Drain (LBOD) has been constructed for the reclamation of more than two million hectares of agricultural lands in Shaheed Benazirabad, Sanghar, Mirpurkhas and Badin districts of Sindh for lowering the water table and reducing the problem of water logging and salinity in these districts. The canal drains the surface and sub-surface saline water through a network of lateral and spinal drains. The effluent of LBOD is disseminated into Dhoro Puran Outfall Drain (DPOD) and Kadhan Pateji Outfall Drain (KPOD) which is ultimately discharged into the Indus Deltaic region. This saline water loaded with high salt content, insecticides and pesticides is added into coastal creeks. This increase of salinity in mangrove areas is detrimental to marine biodiversity, mangrove forests and local communities residing in the coastal belt.

The synergic impact of all these anthropogenic factors has resulted into detrimental impact on the mangrove ecosystems of Pakistan in general and on the mangroves of the Indus Delta Area in particular. This has resulted into decline in overall biodiversity of the coastal ecosystem, the worse example of which is the severe decline in population of the famous migratory fish of coastal areas of Sindh, the *Tenualosa ilisha* (Palla). This fish migrates from sea into the Indus River for breeding. It had been a major livelihood for the fishermen communities of the delta area. Deterioration of the deltaic ecosystem has resulted into a severe decline in the population of this species during the last many decades (Fig. 8).

Conservation and management policies and practices for mangrove ecosystems in Pakistan: Various natural and anthropogenic pressures to mangrove ecosystem of Pakistan are being mitigated to possible extents through various management practices, development projects, legislative policies, awareness raising campaigns and involvement of communities and NGOs (Fig. 9). To what extant all these efforts have been fruitful in reversing the situation, is a question for future research. Present situation of the mangrove forests and its associated biodiversity apparently shows that conservation of mangrove forests need a paradigm shift in planning and policy framework, management practices, result oriented research, involvement and coordination of stakeholders, capacity building and seriousness of all relevant organs of state.

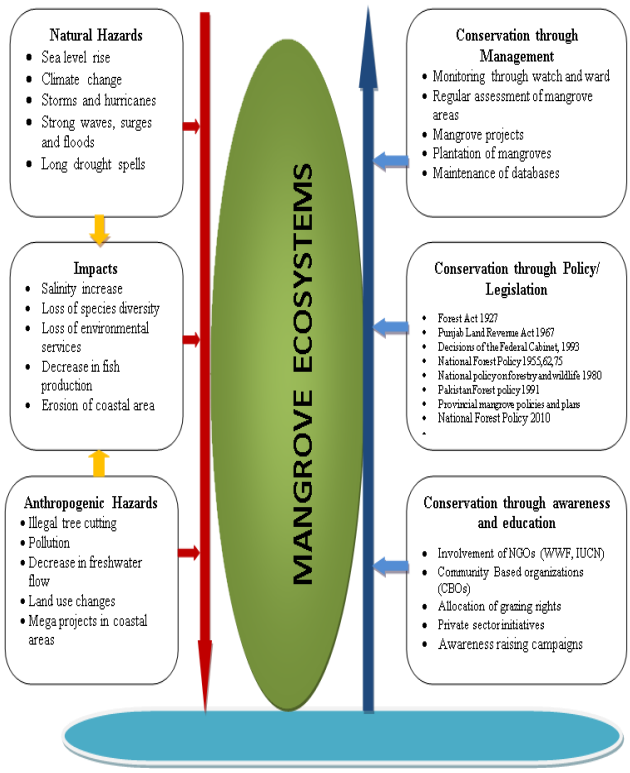

Fig. 9.Mangrove Conservation Policies and Practices in Pakistan verses Natural and Anthropogenic Threats.

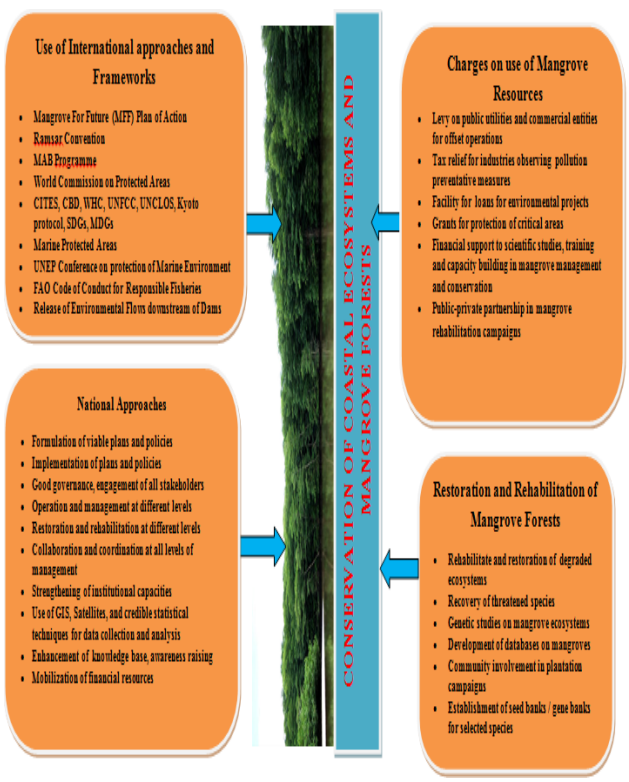

Fig. 10.New approaches and Strategies for Mangrove Conservation.

Mangrove management and policy framework as well as mangrove land tenure in Pakistan has a long history. Initially, mangrove areas were considered wastelands and had no any separate management policy. The Mangrove areas of Sindh, therefore, have remained under the administrative control of Sindh Board of Revenue (SBOR). The Board had no any institutional arrangements and expertise for the conservation of mangroves forests. In 1958, mangrove areas of Sindh gained some importance and out of a total area of 636,485 hectares under mangrove forestland, 364,000 hectares was transferred to the Sindh Forest Department (FAO, 2005). The remaining 272,485 hectares, however, remained under the jurisdiction of Board of Revenue. In 1973, Port Qasim Authority (PQA) was established for the enlargement of Port Qasim and consequently an area of 64,400 hectares of mangroves was transferred from SFD to PQA with the condition that these mangrove forests will retain the status of protected areas ((IUCN Pakistan, 2005). In addition, an area of 500 hectares under mangrove forests in the east of Karachi is managed by Karachi Port Trust (KPT). In 2010, Sindh Government issued a notification and declared all mangrove areas managed by all these departments and authorities, as protected forests. Similarly, out of 4,660 hectares of mangrove areas of Balochistan, only 294 hectares are managed by Balochistan Forest Department (BFD) while remaining areas are, either under the control of local communities or Board of Revenue (IUCN Pakistan, 2005).

The first national forest policy was issued in 1955 with the aim to increase the area under forests. Under this policy, reservation of land was stressed for raising plantations along canals, roads, railways wastelands and unused government lands. At this time, however, mangrove areas were not under the jurisdiction of the forest department. In 1962, National Forest Policy was launched mainly to conserve healthy mangrove cover for the shelter of coastline and plantation of commercially valuable mangrove species. In 1975, a new forest policy was framed with the objective to form cooperative societies, initiation of awareness raising campaigns and use of legal instruments for protection of the forests. In 1980, the National Policy on Forestry and Wildlife was framed with the aim to involve local people in tree plantation and establishment of national parks. Under this policy, SFD established a Coastal Zone Afforestation Division in 1985 which started various activities including plantation of mangroves on bare mudflats and gathering all mandatory information required for management of mangroves. Another policy, the Pakistan Forest Policy was launched in 1991 which, though, was considered participatory but could not achieve its all objectives (Ahmed and Mahmood, 1998). The National Forest Policy issued in 2010 underlines the need for the sustainable management of forests and its associated biodiversity, wetlands, watersheds, rangelands and wildlife. It also ensures provision of financial resources and technical support for using modern techniques like remote sensing and GIS, for carrying out research activities to monitor the forest covers in an effective manner.

Planting and protection of mangrove strands is an important component for long term sustainability of mangrove forests. Primarily, the provincial forest departments are responsible for plantation and protection of these forests. In pursuance of this obligation, Sindh Forest Department and Balochistan Forest Department have

planted 72,000 hectares and 800 hectares of mangroves respectively between 1947 and 2012 (ADB, 2014). Provincial forest departments also have responsibility for managing proper watch and ward of mangrove forests under their jurisdiction as well as enforcement and implementation of respective rules and regulations. In addition to the provincial departments, IUCN and WWF are also actively involved in mangrove plantation and restoration activities. Both these NGOs have signed various contracts with different Community Based Organizations (CBOs) for plantation and protection of these forests.

Freshwater supply from rivers along the Balochistan coast is limited due to their smaller size, low precipitation and upstream use of water. Mangroves of Sindh coast, on the other hand, are located at the mouth opening of the Indus River which drains an area of 1,165,000 km^2 and has an annual estimated flow of 165 MAF. Various dams, barrages, headworks, and link canals have been constructed by Pakistan and India on the river Indus and its tributaries driving almost all the water for agricultural use. Consequently, high salinity tolerance species of mangroves, *A. marina*, is still surving while other species have gradually become extinct and the suviving mangroves have become sparse and stunted. Importance of restoration and maintaining environmental flows for sustainability of ecosystem integrity of rivers, estuaries and deltas has been recognized and given proper attention in policies and legal frameworks in many countries of the world. Pakistan has also recognized this need and Water Apportionment Accord (WAA) of 1991 between the four provinces of Pakistan, has guaranteed an escapade of 10 maf flow water for the Indus Delta. Release of this flow is, however, hardly being respected (Fig. 7) and it is feared that this situation may further worsened with ever increasing water requirements in the era of global warming and climate change. It is, therefore, recommended that Environmental Flows for the Indus Delta be reviewed and simulated afresh and a mechanism for release of minimum ecological flows be devised at national level.

Main organizations supporting mangroves related projects in Pakistan are WWF, IUCN, ADB, UNEP, Engro, and LNG while support from private sector is almost nonexistent at this moment (FAO, 2015). The best project completed for mangrove conservation in Pakistan was initiated in 2009 with the loan from Asian Development Bank. The project mainly focused on planting of sustainable and income generating mangrove strands on 8,000 hectares of land owned by the government and local communities. IUCN-Pakistan was responsible for overall monitoring of the project as well as plantation of mangroves on community land (ADB 2014). Through this project mangroves were planted on an area of 10,259 hectares which was way beyond the initial target set for the project. Survival rate of this plantation was above 95% which was considered highly satisfactory (ADB 2014). Sindh Forest Department has also set the Guinness World Record in 2013 by planting 847,250 mangrove saplings with the help of 300 local coastal volunteer planters at Kharo Chan, Thatta, Sindh.

WWF-Pakistan has also started various activities for restoration of mangroves strands in the coastal areas of Pakistan. One of the major initiative in this direction was launching of mangrove plantation campaigns under the project "Indus For All Programme". These campaigns resulted into restoration of 7,500 hectares of area of the Indus Delta where the mangrove forests had already died out. Various teams of WWF regularly also visit the areas of mangrove forests to collect regular data and maintains a database of all the information, activities and initiatives in the mangrove forests found in coastal belt of Pakistan. The WWF in collaboration with SUPARCO, have constructed concrete pillars in the sites where mangrove restoration experiments are underway so that data on any possible change could be recorded and monitored using fixed point photography technique.

New approaches and strategies for mangrove conservation: Although Pakistan has initiated considerable conservation policies and framing of relevant laws, strategies and guidelines for conservation of its mangrove forests but it still needs to put in lots of efforts in this direction. Despite all the efforts, the mangrove forests of Pakistan are facing serious threats and the area under mangrove forests is squeezing with every passing decade. The country, therefore, has to change its line of action and adopt a holistic approach using modern technologies and interventions for conservation of its already dwindling mangrove resources. This approach should encompass implementation of best practices and duplication of success stories at international level (Fig. 10) in accordance with our local environmental condition and social structure

The country should adhere to the conservation guidelines and policy frameworks provided in international treaties and obligations like Mangroves For Future (MFF) plan of action, Ramsar Convention, MAB Programme, World Commission on Protected Areas, Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Convention on Biological Diversity (CBD), UNESCOs' World Heritage Centre (WHC), United Nations Framework Convention on Climate Change (UNFCCC), United Nations Convention on the Law of the Sea (UNCLOS), Millennium Development Goals (MDGs), Sustainable Development Goals (SDGs), Marine Protected Areas (MPA), UNEP Conference on protection of Marine Environment and FAO Code of Conduct for Responsible Fisheries. In partly pursuance of the guidelines in these international fora, the coastal areas of Sindh and Blochistan should be declared as National Parks, Biosphere Reserves, and Ramsar Sites for sustainable development and conservation of natural resources. Pakistan and the concerned provincial departments should conform to the international obligations regarding mangrove forests and coastal ecosystems of Pakistan.

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of Sindh Coast are located at the mouth opening of the Indus River which drains an area of 1,165,000 km^2 and has an annual estimated flow of 165 MAF. Construction of dams, barrages and canals on the Indus River and its tributaries has resulted into driving of almost all the water for agricultural use. Consequently, high salinity tolerance species of mangroves, *A. marina* , is still surving in the Indus Delta while other species have gradually become extinct and the suviving mangroves have become sparse and stunted. Importance of restoration and maintaining environmental flows for sustainability of ecosystem integrity of rivers, estuaries and deltas has been recognized and given proper attention in policies and legal frameworks in many countries of the world. Pakistan has also recognized this need and Water Apportionment Accord (WAA) of 1991 between the four provinces of Pakistan, has guaranteed an escapade of 10 maf flow for the Indus Delta. Release of this flow is, however, hardly being respected (Fig. 7) and it is feared that this situation may further worsened with ever increasing water requirements in the era of global warming and climate change. It is, therefore, recommended that Environmental Flows for the Indus Delta be reviewed and simulated afresh and a mechanism for release of minimum ecological flows be devised at national level.

Pakistan needs to include mangrove ecosystems as high priority area in its development plans and policies. Specific policies frameworks at country, province, district, and tehsil level need to be devised including well thought development strategies, better stakeholder's coordination, good governance and uninterrupted restoration and rehabilitation practices for development and protection of coastal ecosystems. Further delays in devising a comprehensive programme and poor planning and implementation of development plans, failure of governance and lack of coordination between the stakeholders in the existing framework, can lead to an irreversible loss and degradation of mangrove forests.

Financial resources are essential for conservation practices of mangrove forests. Appropriate funds can be raised by levying an environment surcharge on commercial entities, industrial units, shipbreaking industries, cargo ships, ferryboats, hotels, recreational centers etc. using the mangrove areas for their activities or polluting the marine environment. Income generated from these sources can be used for developing mitigation offsets, enhancing patrolling in the mangrove areas and rehabilitation and restoration of deteriorated mangrove ecosystems. Government should also give incentives and tax relief to industries implementing pollution preventive measures. Financial resources should also be allocated for protection of critical habitats, carrying out scientific studies, and trainings and capacity building of the staff involved in conservation and management of mangroves.

Rehabilitation of mangroves depends on soils and hydrological aspects of the area. The middle and upper intertidal zones are most favorable areas for rehabilitation programmes. An understanding of normal hydrologic patterns in the area, knowledge pertaining to ecology of individual species, patterns of reproduction, propagule distribution, and successful seedling establishment is important before initiation of any rehabilitation project. Artificial propagation of mangroves includes the use of mature propagules, saplings and small plants. The best time for mangrove planting is when the propagules are mature and in season. Mature mangrove propagules are collected from the mother tree and are generally kept in moist plastic bags for three days for seasoning. Transplant saplings (wildings) are either collected from nurseries or scooped from the natural forests.

Concerned departments should have a comprehensive survey of all the coastal areas and collect data to identify the most promising areas for rehabilitation of mangrove species especially for reintroduction of lost species. They also should seek the support of local communities, local governments, NGOs, volunteers, elders, religious leaders, and media so that every segment of society could play its role for success of the rehabilitation campaigns. Relevant departments should also ensure the surplus supply of saplings, propagules or nursery plants without compromising the health of natural mangrove strands. Mangrove nurseries can be established in specific areas for this purpose if so desired.

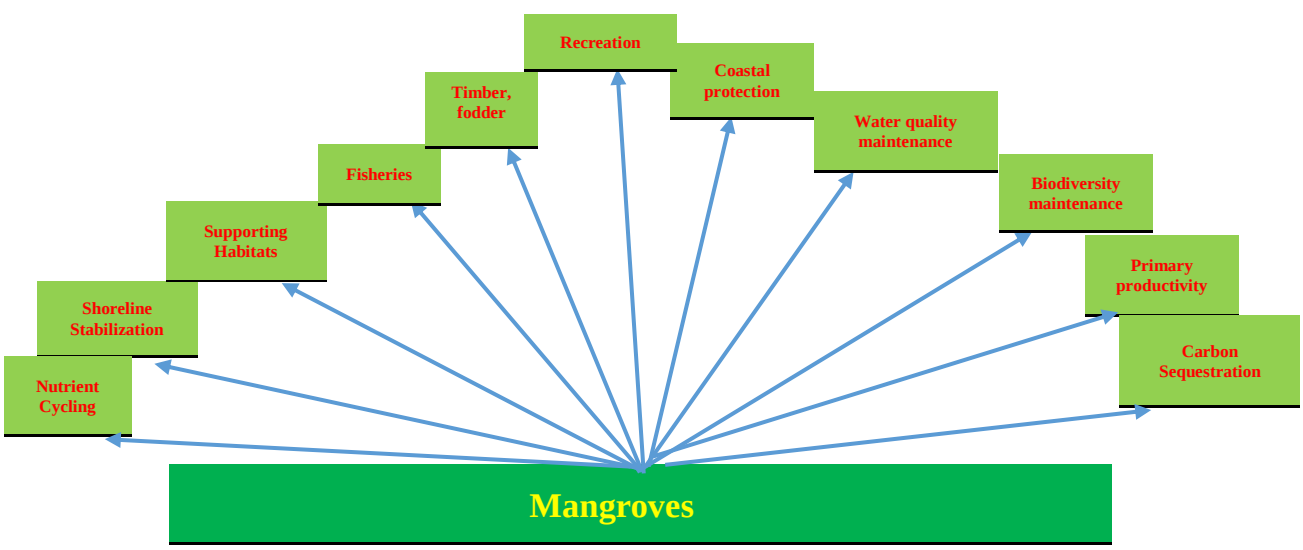

Fig. 11.Ecosystem Services provided by the Mangrove Ecosystem.

Ecosystem services provided by mangroves: Like various other ecosystems of the world, mangroves also provide four categories of functions and services viz., provision, regulation, support, and culture functions. There are more than 50 functions and services identified for mangroves but nutrient cycling, shoreline stabilization, supporting habitats, fisheries production, recreation, coastline protection, water quality maintenance, production of timber and fodder, biodiversity conservation and protection, primary productivity and carbon sequestration are considered the most important (Kumar, 2016). Other important services are purification of water, genetic resources, provision of food, inhabitable climatic conditions, clean air, fertile land, pollination, tsunami impact mitigation, buffering against extreme environmental events, climate change mitigation, productive soils, adequate livelihoods, bio-chemicals, reduction of pests and diseases, pharmaceuticals and medicines, energy resources, barrier effect, knowledge systems, tourism, and refugium for iconic species. All these functions contribute towards human wellbeing including breathing, drinking, nutrition, shelter, physical health, mental health, security of continuous supply of services, security of health, security of access to services, family cohesion, community and social cohesion, and social and economic freedom. The important ecosystem services provided and functions performed by the mangrove ecosystems are briefly given in Figure 11 below:

Biodiversity supported by mangrove ecosystem of Pakistan: Mangroves constitute an important ecosystem world over and provide diverse niches for aquatic and terrestrial fauna and flora (Saifullah, 1997). Indus Delta has the largest mangrove strands in the coastal regions of Pakistan having four species with variable areas of occupancy. The species *Avicennia marina* is very common and occupy 90% of the area while *Rhizophora mucronata* covers an area of 8%. The species *Aegiceras corniculatum* and *Ceriops tagal* are very rare and occupy only 1.5% and 0.5% of the mangrove area respectively (Sindh Forest Department, 2014). Structural complexity and heterogeneity of mangrove ecosystems has the capacity to harbor a high level of biodiversity as they provide breeding habitat, nursery grounds and refugium for many of the marine organisms.

The aquatic species associated with mangrove forests are the marine fishes, shrimps and crabs. A strong positive correlation has been observed between mangrove forests and fish production in many areas of the world and it has been established that productivity of fish and shrimps decline where mangrove forests are removed (Twilley *et al*., 2000, Primavera 1995, Baran 1999, Naylor *et al*., 2000). Marine fish fauna of Pakistan consists of 850 species out of which about 129 species (Table 5) depend on mangrove forests for breeding, feeding and shelter. It has at least 30 species of crabs and shrimps (Table 6) and more than 500 species of marine invertebrates. Role Marine fisheries play a significant role in the economy of the country. It is estimated that this sector provides direct jobs to about 300,000 fishermen while another 400,000 people get job indirectly through the industries associated with this sector. Share of fisheries sector in total GDP of the country is around 0.3% and about 1.3% in the agricultural GDP. Out of total production of 700,000 tons of fish in Pakistan, more than 430,000 tons come from marine resources. The export volume of Pakistani seafood products is estimated to be 130,000 tons representing a total value of USD 226m.

In addition to aquatic fauna, the mangrove forests and adjacent habitats have 85 species of birds, 21 species of reptiles, 16 species of small mammals, 5 species of large mammals, 15 species of dolphins and porpoises, and 70 species of plants other than mangroves. Due to its ecological and biological importance, the Indus Delta has been included in one of the 200 Global Eco-regions and in 2002, it was designated as Ramsar Site due to its importance as a significant staging site for migratory birds. The area is also very rich in having diverse ecosystems with rich wildlife and has been declared as a Wildlife Sanctuary by the Sindh Wildlife Department.

In addition to fish, crabs and shrimp species, the mudflats of the Indus Delta are packed with migratory birds during the winter season. Millions of migratory birds visit the coastal areas of Pakistan during winter. The mangrove forest also serves as the habitats for globally threatened species such as, Hump-backed dolphin, Common dolphin, Spinner dolphin, Bottlenose dolphin, Finless Porpoise, fishing cat, estuarine crocodile, and the Indus blind dolphin. Survival of rare and endangered species depends on health and diversity of habitats in the coastal and marine ecosystems. Five out of seven species of turtles found in the world over, are found in the coastal areas of Pakistan. These species include *Lepidochelys olivacea* (olive ridley turtle), Green *Chelonia mydas* (green turtle), *Eretmochelys imbricate* (Hawksbill turtle) *Caretta caretta* (Loggerhead turtle) and the critically endangered species, *Dermochelys coriacea* (Leatherback turtle). The threatened whale shark (*Rhincodon typus*), the largest fish species in the world can be found off the coast of Karachi, while the last population of one of five threatened species of Asiatic wild ass (*Equushemionus*) occurs in the salt marshes of the Rann of Kutch in Badin and Tharparkar districts. Sea snakes are also an important component of the mangrove ecosystems. Snake species, *Hydrophis cyanocinctus*, *Hydrophis caerulescens Hydrophis mamillaris*, *Microcephalophis gracilis*, *Pelamis platurns* and *Ephydrina schistosa* are commonly seen in the mangrove areas of the coastal areas of Sindh and Balochistan.

Table 5. Fish Fauna found in the Mangrove Ecosystems of Pakistan.

Sr. No.	Species	Family	English name	Local name
1.	*Albula vulpes*	Albulidae	Bonefis, ladyfish	Viaat
2.	*Arius arius*	Ariidae	Threadfin sea catfish	Singhara
3.	*Arius caelatus*	Ariidae	Engraved catfish	Khagga
4.	*Arius crossocheilus*	Ariidae	Roughback sea catfish	Khagga
5.	*Arius dussumieri*	Ariidae	Blacktip sea catfish	Khagga
6.	*Arius maculatus*	Ariidae	Spotted catfish	Khagga
7.	*Arius teniuspinis*	Ariidae	Thin spine catfish	Khagga
8.	*Arius thalassinus*	Ariidae	Giant catfish	Khagga
9.	*Osteogeneiosus militaris*	Ariidae	Soldier catfish	Khagga
10.	*Strongyluraleiura*	Belonidae	Banded needlefish	Kangi, Kango
11.	*Strongylurastrongylura*	Belonidae	Banded needlefish	Kangho
12.	*Pseudorhombus arsius*	Bothidae	Largetoothed flounder	Kuker-jeeb
13.	*Alepes djedaba*	Carangidae	Shrimp scad	Seem, Bangra
14.	*Carangoides chrysophrys*	Carangidae	Longnose trevally	Seem, Bangra
15.	*Caranx para*	Carangidae	Banded scad	Bangra, Kakkar
16.	*Decapterus macrosoma*	Carangidae	Short fin Scad	Seem
17.	*Megalaspis cordyla*	Carangidae	Tarpedo Scad	Bangra
18.	*Parastromateus niger*	Carangidae6	Black pomfret	Kala poplet
19.	*Scomberoidescommersonnianus*	Carangidae	Blacktip leatherskin	Aal, Saram
20.	*Trachinotus blochii*	Carangidae	Snubnose Pompano	Sonab
21.	*Trachinotus mookalee*	Carangidae	Indian pompano	Sonaf
22.	*Scoliodon latucaudus*	Carcharhinidae	Spadenose shark	Mangra
23.	*Chirocentrus dorab*	Chirocentridae	Dorab wolf herring	Kerli, gairi
24.	*Nematalosa nasus*	Clupeidaae	Long-ray bony bream	Daddi-palli
25.	*Sardinella albella*	Clupeidaae	White Sardinelle	Tarli, Luar
26.	*Sardinella gibbosa*	Clupeidaae	Goldstripe sardinella	Tarli, Luar
27.	*Sardinella longiceps*	Clupeidaae	Oil Sardine	Tarli/ Luar
28.	*Sardinella sindensis*	Clupeidaae	Sindh Sardinelle	Tarli, Luar
29.	*Anodontostoma chacunda*	Clupeidae	Shortnose Gizzard Shad	Daddi-palli
30.	*Dussumieria acuta*	Clupeidae	Rainbow Sardine	Tel-tempori
31.	*Escualosa thoracata*	Clupeidae	White sardine	Mithoo
32.	*Hilsa kelee*	Clupeidae	Kelee shad	Palli
33.	*Ilisha megaloptera*	Clupeidae	Bigeye ilisha	Palli
34.	*Ilisha melastoma*	Clupeidae	Indian ilisha	Palli
35.	*Opisthopterus tardoore*	Clupeidae	Tardoore	Koor, Palli
36.	*Pellona ditchela*	Clupeidae	Indian pellona	palli
37.	*Tenualosa ilisha*	Clupeidae	Hilsa shad	Palla
38.	*Tenualosatoli*	Clupeidae	Toli shad	Nur-Palla
39.	*Cynoglossus macrostomus*	Cynoglossidae	(Malabar tonguesole	Sole
40.	*Cynoglossus puncticepus*	Cynoglossidae	Speckled tonguesole	Sole
41.	*Cynoglossus bilineatus*	Cynoglossidae	Tongue soles	sole
42.	*Cynoglossus dubius*	Cynoglossidae	Tonguesoles	sole
43.	*Cynoglossusarael*	Cynoglossidae	Brown Tongue soles	Sole
44.	*Aphanius dispar dispar*	Cyprinodontidae	Killi fish	Killi fish
45.	*Himantura walga*	Dasyatidae	Dwarf whipray	Pittan
46.	*Drepane punctata*	Drepanidae	Spotted sicklefish	Rupichand
47.	*Echeneis naucrates*	Echeneididae	Live Sharksucker	Masi
48.	*Elops machnata*	Elopidae	Tenpounder	Kinarhal
49.	*Coilia dussumieri*	Engraulidae	Anchovy	Patia
50.	*Thryssa dussumieri*	Engraulidae	Thryssa	Physa
51.	*Thryssa hamiltonii*	Engraulidae	Thryssa	Physa
52.	*Thryssa mystax*	Engraulidae	Moustached thryssa	Physa
53.	*Thryssa setirostris*	Engraulidae	Thryssa	physa
54.	*Thryssa vitrirostris*	Engraulidae	Orangemouth Anchovy	Physa
55.	*Gerres filamentosus*	Gerreidae	Long-rayed silver- biddy	Jerkari
56.	*Gerres poieti*	Gerreidae	Strongspine silver biddy	Jerki
57.	*Gerres oyena*	Gerreidae2	Lined silver-biddy	Jerki
58.	*Boleophthalmus dussumieri*	Gobiidae	Mud skipper	Gullo
59.	*Scartelaostenuis*	Gobiidae	Indian Ocean slender mudskipper	Gullo
60.	*Carangoidesmalabaricus*	Gobiidae	Malabar trevally	Kakkar
61.	*Psammogobiusbiocellatus*	Gobiidae	Sleepy goby	Gullo
62.	*Glossogobius giuris*	Gobiidae	Tank gobby	Gobby
63.	*Periophthalmus barbarus*	Gobiidae	Atlantic mudskipper	Gobby
64.	*Periophthalmus weberi*	Gobiidae	Weber's mudskipper	Gobby
65.	*Pomadasys argenteus*	Haemulidae	Grunter	Dhother

Table 5. (Cont'd.).

Sr. No.	Species	Family	English name	Local name
66.	*Pomadasys kaakan*	Haemulidae	Grunter	Dhother
67.	*Pomadasys maculatum*	Haemulidae	Saddle grunt	Dhother
68.	*Pomadasys stridens*	Haemulidae	striped grunter	Bukra
69.	*Harpadon nehereus*	Harpadontidae	Bumbay duck	Bombil
70.	*Hemiramphus far*	Hemiramphidae	Blackbarred halfbeak	Thute
71.	*Hyporamphus dussumieri*	Hemiramphidae	*Dussumieri halfbeak*	Thute
72.	*Hyporamphus(Hyporamphus) limbatus*	Hemiramphidae	Congaturi halfbeak	Thute
73.	*Lactarius lactarius*	Lactariidae	False trevally	Bukko
74.	*Lates calcarifer*	Latidae	Baramundi	Dangri
75.	*Leiognathus blochi*	Leiognathidae	Twoblotch ponyfish	Kaanteri
76.	*Leiognathus brevirostris*	Leiognathidae	Short nose ponyfish	Kaanteri
77.	*Leiognathus equulus*	Leiognathidae	Common Ponyfish	Kaanteri
78.	*Leiognathus daura*	Leiognathidae	GoldstripePonyfish	Kaanteri
79.	*Leiognathus splendens*	Leiognathidae	Splendid ponyfish	Kaanteri
80.	*Secutor insidiator*	Leiognathidae	Slender barred ponyfish	Kaanteri
81.	*Lutjanus johnii*	Lutjanidae	One spot golden snapper	Hira
82.	*Lutjanus argentimaculatus*	Lutjanidae	Red snapper	Hira
83.	*Liza carinata*	Mugilidae	Keeled mullet	Boi, Mori
84.	*Liza melinoptera*	Mugilidae	Large scale gery Mullet	Boi, Mori
85.	*Liza parsia*	Mugilidae	Gold spot mullet	Boi, Parsi
86.	*Liza subviridis*	Mugilidae	Green back mullet	Chhodi
87.	*Mugil cephalus*	Mugilidae	Large scale mullet	Pharra, Boi
88.	*Valamugil cunnesius*	Mugilidae	Long arm mullet	Pharra, Boi
89.	*Upeneus vittatus*	Mullidae	Yellow-striped goatfish	Manori
90.	*Congresox talabonoides*	Muraenesocidae	Pike congers	Bam
91.	*Muraenesox cinereus*	Muraenesocidae	Silver conger eel	Bam
92.	*Pisodonophis cancrivorus*	Ophichthidae	Longfin snake-eel	Bam
93.	*Grammophites suppositus*	Platycephalidae	Softfiin flathead	Kuker
94.	*Platycephalus indicus*	Platycephalidae	Bartail flathead	Kuker
95.	*Eleutheronema tetradactylum*	Polynemidae	Four finger threadfin	Seeri, Ranwas
96.	*Filimanus heptadactylus*	Polynemidae	Sevenfinger Threadfin	Seeri
97.	*Polynemus indicus*	Polynemidae	Indian threadfin	Seeri, Ranwas
98.	*Polynemus sexfilis*	Polynemidae	Sixfinger threadfin	
99.	*Polynemus sextarius*	Polynemidae	Black spot threadfin	Seeri
100.	*Psettodes erumei*	Psettodidae	Indian flounder	Hajjam
101.	*Scatophagus argus*	Scatophagidae	Spoted scat	Korgi
102.	*Johnieops sina*	Sciaenidae	Small salmon	sua
103.	*Johnius dussumieri*	Sciaenidae	Bearded croacker	Mushka
104.	*Johnius belangerii*	Sciaenidae	Jewfish	Mushka
105.	*Johnius dussumieri*	Sciaenidae	Silver Jewfish	Mushka
106.	*Otolithes ruber*	Sciaenidae	Rosy jewfish	Mushka
107.	*Protonibea diacanthus*	Sciaenidae	Jewfish	Sua
108.	*Rastrelliger kanagurta*	Scombridae	Indian mackerel	Bangra
109.	*Scomberromorus guttatus*	Scombridae	Indo-Pacific king mackerel	Kalgund
110.	*Epinephelus diacanthus*	Serranidae	Thornycheek grouper	Gisser
111.	*Epinephelus fuscoguttatus*	Serranidae	Brown-marbled Grouper	Gisser
112.	*Promicrops lanceolatus*	Serranidae	Giant Grouper	Dhambo
113.	*Sillago sihama*	Sillaginidae	Silver whiting	Bhambore
114.	*Mystus gulio*	Siluridae	Long whiskers catfish	Tengara
115.	*Brachirus orientalis*	Soleidae	Oriental sole	Phani
116.	*Solea elongate*	Soleidae	Elongate Sole	Phani
117.	*Solea ovate*	Soleidae	Uvate Sole	Bans Patta
118.	*Acanthopagrus berda*	Sparidae	Black Bream	Dandya
119.	*Acanthopagruslatus*	Sparidae	Yellow fin sea Bream	Dandya
120.	*Sparidentex hasta*	Sparidae	Sobaity seabream	Dandya
121.	*Sphyraena putnamiae*	Sphyraenidae	Barracuda	Kund
122.	Pampusargenteus	Stromateidae	Silver pomfret	Achopito, Sufaid poplet
123.	*Pseudosynanceia melanostigma*	Synanceiidae	Blackfin stonefish	
124.	*Terapon jerbua*	Teraponidae	Jerbua terapon	Ginghra
125.	*Terapon puta*	Teraponidae	Smallscale terapon	Ginghra
126.	*Gastrophysus lunaris*	Tetradontidae	Moontail blassop	Ginghra
127.	Lagocephalus lunaris	Tetraodontidae	Lunartail puffer	Toroo
128.	*Lepturacanthus savala*	Trichiuridae	Hairtail	Talwar
129.	*Trichiurus lepturus*	Trichiuridae	Large head hairtail	Talwar

Table 6. Shellfish species associated with mangrove ecosystems of Pakistan

Sr. No	Species	Family	English name	Local name
1.	*Penaeus indicus*	Penaeidae	White shrimp	Jaira
2.	*Penaeus marguiensis*	Penaeidae	White shrimp	Jaira
3.	*Penaeus mondon*	Penaeidae	Tiger shrimp	Kalri
4.	*Penaeus penicilatus*	Penaeidae	White shrimp	Jaira
5.	*Penaeus canaliculatus*	Penaeidae	Shrimp	Kalri
6.	*Penaeus semisulcatus*	Penaeidae	Shrimp	Kalri
7.	*Penaeus japonicus*	Penaeidae	Shrimp	Kalri
8.	*Parapenaeopsis stylifera*	Penaeidae	Shrimp	Kalri
9.	*Parapenaeopsis hardwickii*	Penaeidae	Shrimp	Kiddi
10.	*Parapenaeopsis sculptilis*	Penaeidae	Shrimp	Kiddi
11.	*Metapaenaeus affinis*	Penaeidae	Shrimp	Kiddi
12.	*Metapaenaeus mutates*	Penaeidae	Shrimp	Kalri
13.	*Metapaenaeus brevicornis*	Penaeidae	Shrimp	Jaira
14.	*Metapaenaeus monoceros*	Penaeidae	Shrimp	Kalri
15.	*Metapaenaeus stebbingi*	Penaeidae	Shrimp	Kalri
16.	*Solenocera crassicornis*	Solenoceridae	Shrimp	Kalri
17.	*Scylla serrata*	Portunidae	Mud crab	Kekra
18.	*Charybdis feriata*	Portunidae	Crab	Kekra
19.	*Portunus pelagicus*	Portunidae	Blue crab	Kekra
20.	*Portunus sanguinolentus*	Portunidae	Crab	Kekra
21.	*Matuta lunaris*	Matutidae	Crab	Kekra
22.	*Matuta planipes*	Matutidae	Crab	Kekra
23.	*Panulirus polyphagus*	Palinuridae	Lobster	Lobster
24.	*Uca annulipes*	Ocypodidae	Fiddler crab	Kekra
25.	*Uca urvillei*	Ocypodidae	Fiddler crab	Kekra
26.	*Macrophthalmus depressus*	Ocypodidae	Mud crab	Kekra
27.	*Metopograpsus thukuhar*	Grapsidae	Shore crab	Kekra
28.	*Sesarma lanatum*	Sesarmidae	mudflat crab	Kekra
29.	*Sesarma plicatum*	Sesarmidae	mudflat crab	Kekra
30.	*Heteropanope glabra*	Pilumnidae	mudflat crab	Kekra

Conclusion

Mangroves are one of the most endangered and fragile ecosystems of the world and distributed in the tropical and sub-tropical regions of the world. The area under mangrove forests is declining throughout world but this decline is more pronounced in Pakistan due to many natural and anthropogenic pressures including shortage of freshwater flow in the Indus delta, blockage of silt laden water by dams and headworks in the Indus Basin, overharvesting, pollution, several natural phenomena and anthropogenic pressures. Mangroves provide numerous ecosystem services like protection of shorelines, purification of water, supply of oxygen, and stability of climate. They are considered biodiversity hotspot areas and serve as the seed supply centers and refugia for thousands of marine species including the fishes, shrimps and crabs which is one of the major export commodity of Pakistan. They provide food, wood, timber, fuel wood, fodder, medicines, and livelihoods to coastal communities. It is feared that ever decreasing mangrove cover will not only diminish water quality, biodiversity, eliminate fish breeding and nursery grounds but will also result into increased vulnerabilities of human safety at the long run. There is, therefore, a need to adopt internationally recognized best practices and modern approaches and techniques at all levels of management for conservation, management and rehabilitation of mangrove resources of Pakistan.

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