Records

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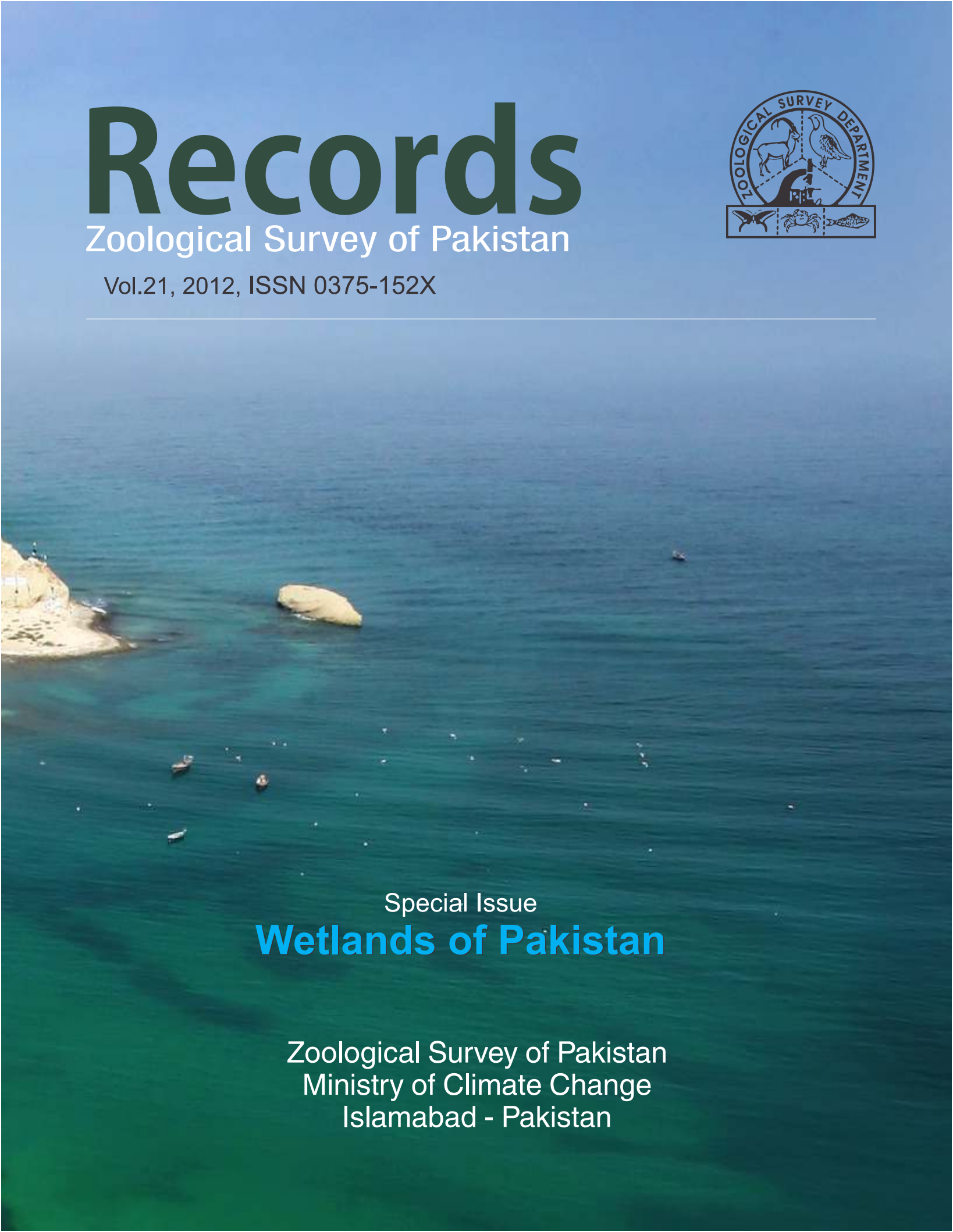

Special Issue

Wetlands of Pakistan

Zoological Survey of Pakistan
Ministry of Climate Change
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About this journal
This journal is a special edition published by Pakistan Wetlands Programme depicting an overview of various research areas related to wetlands and their associated globally significant biodiversity. This is a collection of a part of the research, which has been carried out by scientists, researchers and staff of Pakistan Wetlands Programme and other partners over the period of seven years. The concept is intended on emphasising the ecological significance of wetlands through scientific publications. These basic research ideas are opening new vistas to in-depth scientific explorations and investigations for future, in addition to creating awareness among a wide range of institutions and stakeholders. This is also to fill the gap in communal understanding regarding the critical roles that wetlands and their associated biodiversity play in providing the basics for our endurance and welfare.

About Pakistan Wetlands Programme
The Pakistan Wetlands Programme aims to promote the sustainable conservation of freshwater and marine wetlands and their dependent globally important biodiversity in Pakistan. The Programme strategy is based on two sub-sets of objectives. The first objective provides the required policy, institutional, technical and financial framework to generate positive public support, highly essential for mainstreaming of wetlands conservation. The second objective involves the design and implementation of progressive, participatory management plans for four independent Demonstration Complexes; each chosen to be representative of a broad eco-region in Pakistan. The project includes specific mechanisms which is securing financial sustainability and enhancing replication and proliferation of viable wetlands management interventions in a nation-wide, wetlands conservation initiative.

Shimshal Pamir Lakes: a prospective high altitude wetlands site for transboundary collaboration between China and Pakistan

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K E Y W O R D S

Transboundary
Shimshal Pamir Lakes
Conservation
Biodiversity
High altitude wetlands
Gilgit-Baltistan
China
Pakistan

A B S T R A C T

Gilgit-Baltistan mountainous area of Pakistan is home to a number of alpine wetlands including Shimshal Pamir Lakes. Two weeks long expedition focused on studying vegetation, birds, small and large mammals, herps and water quality parameters. Results revealed that Shimshal Pamir Lakes area fall into extreme alpine zone with no woody vegetation. A total of 58 plant species (mostly grasses); 48 birds; five large mammals; eight small mammals and four reptilian species were recorded during the study. Values for water quality parameters i.e., pH, temperature, Electrical Conductivity and Total Dissolved Solids were within permissible limits of National Environmental Quality Standards. However, Dissolved Oxygen values were slightly lower than normal and microbial growth was much higher in the lakes and their outlets. Shimshal Pamir Wetlands, their adjacent peatlands, streams, rivers and lakes contain rare and unique biodiversity common to China and Pakistan. A comprehensive transboundary conservation strategy is needed to conserve fast vanishing resources side by side offering economic opportunities to the pastoral communities of Pamir border region.

Introduction

Wetlands are the "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters" as defined by Ramsar Convention (1971). World's lakes and rivers constituting about 2.5% of the earth's water are perhaps the planet's most important freshwater resources that form the habitat of the large number of species, representing a substantial sector of the Earth's biological diversity (UNEP, 1994). Approximately 50% of the world's wetlands have been lost in the past one century due to rapid urbanisation, drainage for agriculture, and inefficient water system regulation (Shine & de Klemm, 1999).

Despite the generally arid nature of Pakistan's climate, the region supports an estimated 78,000km^2 of wetlands representing 225 significant wetlands inclusive of the nineteen sites being recognised internationally (Ali, 2005). These areas are crucial for maintaining healthy bird populations. A number of migratory birds use these sites for staging and breeding (summer breeders) during their migration, particularly waterfowl densities and their propagation is related with the number of wetlands (Bellrose, 1977). Almost 20 threatened species of mammals, 25 birds, six reptiles, one amphibian and 198 freshwater fishes of substantial economic importance are either wetlands dependent or associated with wetlands in Pakistan (Khurshid, 2000; BirdLife, 2004). Of the 75 endangered or threatened animals, 43 are totally wetland dependent including nine bird species (Ali, 2005). About one-third of bird species use wetlands for food, shelter, and (or) breeding (Ali 2005), however, the birds that visit or breed in poorer quality habitats will not contribute to a sustainable population through the years (Pulliam & Danielson, 1991).

There is an influx of winter visitor birds from northern breeding grounds, or summer breeding visitors both from the northern mountain regions and from the Indus Plains, to more warmer southern latitudes (Ali, 2005). Of the total Pakistan's bird species, 30% visit the country for a significant period of the year as long distance migrants, 43% are either Palearctic species visiting Pakistan only for breeding and 28% are regular winter visitors, which breed extra-limitally and mainly in trans-Himalayan northern regions (Ali, 2005; Roberts, 1992). Siberian Crane *Grus leucogeranus,* Sarus Crane *Grus antigone,* Dalmatian Pelican *Pelicanus crispus*, Ferruginous Duck *Aythya nyroca,* White-headed Duck *Oxyura leucocephala,* Marbled Teal *Marmaronetta angustirostris,* Sociable Plover *Vanellus gregarius,* Jerdon's Moupinia or Sindh Babbler *Chrysomma altirostre,* Lesser White-fronted Goose *Anser erythropus,* Long-tailed Grass Warbler *Prinia burnesii, and* Pallas's Fish Eagle *Haliaeetus leucoryphus* need immediate actions for conservation (Khurshid, 2000).

However, it is clear that birds do not follow rigidly defined paths and may travel over very broadly extended areas, in some cases, even to hundreds of miles. Individuals from the breeding population of a species, from the same locality may follow widely different migration routes and winter in quite separate regions, and vice versa (Moreau, 1972; Baker, 1980). Quite a large number of migratory water birds fly over the Indus Flyway and use adjacent high altitude lakes, streams, marshlands, peatlands and bogs as temporary and permanent staging, feeding and breeding grounds. The insect life and vegetation cover becomes abundant after the monsoon in these areas and so offer rich feeding conditions to the wintering birds. The common wetland birds that visit Pakistan include grebes (Podicipedidae), ducks and geese (Anseriformes), storks (Ciconiiformes), pelicans and cormorants (Pelecaniformes), herons (Ardeidae), spoonbills (Threskiornithidae), rails and crakes (Rallidae), cranes and bustards (Gruiformes), gulls (Laridae), waders (Calidridinae) and plovers (Charadridae). Utter, Hundrab, and Shandoor lakes harbour around 230 species of birds - one of the most diverse populations in mountain regions of the world. Rare species like Lammergeyer (*Gypaetus barbatus*) and Golden Eagle (*Aquila chrysaetos*) live and breed here while Demoiselle Crane (*Grus virgo*) use these wetlands for wintering, staging and feeding grounds (WWF, 2011).

Shimshal Pamir Lakes are naturally formed by the accumulation of glacial melt water, flowing into the lakes through seasonal and perennial streams and springs harbour a variety of endangered

wildlife species including Snow Leopard (*Uncia uncia*), Blue sheep (*Pseudois nayaur*), Brown Bear (*Ursus arctos*), Tibetan Wild Ass (*Equus kiang*) and Marco Polo Sheep (*Ovis ammon polii*), some of which are endemic to Karakoram mountain region. It, being a part of the famous Indus Flyway, provides nesting and staging grounds to a number of migratory birds and waterfowls. Grey Heron (*Ardea cinerea*), Northern Shoveler (*Anas clypeata*), Common Teal (*Anas crecca*), Northern Pintail (*Anas acuta*), Mallard (*Anas platyrhynchos*), Marbled Teal (*Marmaronetta angustirostris*) and Coot (*Fulica atra*) are amongst the key avifauna species of the area. Unfortunately, people living in the Pamir and adjacent areas are poor, and so depend mostly on available natural resources for food, fodder, fuel, water, shelter and thus degrade the peculiar mountain ecosystems and their associated biodiversity. Shimshal Pamir Lakes, despite having immense potential for trans-border cooperation between China and Pakistan, which have never been studied before to explore their biotic resources.

This study was, therefore, conducted as part of the Sino-Pak transboundary cooperation for conservation and sustainable development in Pamir border region to document wetland related biota of the Shimshal Pamir Lakes and explore their potential and opportunities for future collaborative conservation of key species, habitats and high altitude ecosystems in the border region between China and Pakistan.

Methods

Study area

The Gilgit-Baltistan region of Pakistan comprises an intricate system of mountain ranges, i.e. Himalayas, Hindukush and Karakoram, conjoining heads at Pamir Knot and giving birth to several valleys on their way both up and downstream the Indus River (Baig, 2001). Shimshal-Pamir is a part of Khunjerab National Park spreading over an area of 4,455.06 km^2 in the extreme north of Pakistan, along Pakistan-China border. It was designated as National Park by the Government of Gilgit-Baltistan in 1975 to protect Marco Polo Sheep (*Ovis ammon polii*) in its natural habitat (Khan, 1996). Starting right from Shimshal village, the study area extends approximately 50 km into the mountainous valley, covering different habitat types ranging from 3,078 m to 4,731 m asl at Shimshal-Pamir Lake, and then borders with China (Fig. 1).

The Shimshal-Pamir Lake, locally called *Shuvorth*, covers an area of 32 km^2 at an elevation of 4,755 m asl in the extreme north of Pakistan, along the southern border of Xinjiang, China and situated about 40 km to the northwest of Shimshal village. Sherlik is the last valley from Pakistan side, whereas Tagdumbash, Bazaar and Raskam are the three villages bordering Chinese side (Ali & Khan, 2007). Three major streams originate from Sherlik valley watersheds, flowing down the Furzeen, Mustag and Obrang Nullahs on Pakistani territory, and merge into one stream near Sherblock post before entering China. Furzin Nullah originates from Varow Shimshal pass glacier, which feeds the Shimshal Pamir Lakes and also provides water to a number of seasonal and perennial streams, peatlands, lakes and agricultural fields on the other side of the border. Lakes, peatlands and streams on both sides of the Pakistan-China border provide important habitats, staging and breeding places to a number of migratory birds and waterfowls (Ali & Khan, 2007).

Figure 1: Map of the study area (Shimshal Pamir Lakes and adjacent wetlands in Karakoram Pamir border region)

Shimshal comprises of four main villages, i.e. Farmanabad, Aminabad, Khizerabad and proper Shimshal village, having a total population of 2,500 living in 300 households. People have an agro-pastoral life pattern, subsistence farming and livestock herding being their primary sources of livelihood. A small proportion of youth are engaged in seasonal tourism activities (Ali & Khan, 2007).

On average, the area receives 11 mm of rainfall monthly and western monsoon seldom crosses the high mountains of Karakoram Range, usually staying afar. Harsh climate prevails with severe cold winters below freezing temperature from October onward, but pleasant sunny days appear with temperature ascending up to 25°C after April till the peak summer season (IUCN, 2003).

Data Collection

i). Vegetation

Stratified random quadrate method was used for vegetation assessment (Kent & Coker, 1992). Five quadrates (1 m^2) were laid at 10m interval in each stratum wherein number of individuals of each species was counted and their basal area measured. Habit, habitat, life form, distribution patterns and altitudinal range were determined for each species and different attributes like Relative Frequency (RF), Relative Density (RD), Relative Cover (RC) and Importance Value (IV) were calculated thereof. Plant samples for each species were photographed, collected, labelled and stored in Karachi University herbarium. Collected specimen were more precisely identified with the help of keys from the Flora of Pakistan (Nasir & Ali, 1970-1989; Ali & Nasir, 1989-1991; Ali & Qaiser, 1993-2007). Fresh and air dried weights of the clipped material from each quadrate was used to calculate biomass productivity and grazing pressure on the peripheral grasslands.

ii). Birds

Birds were carefully observed in all the potential habitats at dawn and dusk. Majority of the birds were identified without using binoculars but a few were identified after keenly observing with binoculars (10 x 40) and consulting reference materials (Roberts, 1992). However, basic information concerning colour, size, habits and habitat were recorded for those which could not be identified in the field, and their photographs were taken from different angles to facilitate their identification later. Conservation status of the recorded birds was determined using IUCN Red List 2001 and the relative abundance was calculated using number of individuals in each species and the total number encountered during the study (R.A = n / N).

iii). Large Mammals

Large mammals were surveyed using direct and indirect counting methods i.e., fixed point surveys, track counts, pellet counts and interviews with local residents. Surveys were held mostly early in the morning and late in the afternoon, when wild herbivores were active for grazing or drinking whereas the signs of presence i.e., animal pellets were also gathered during the day time. When observed, location, number, sex and age classes were determined

and recorded. An index of density (ID) of the number of pellet groups per unit area was then determined following ID = n / A, where n is the sum of pellet groups counted over all plots and A is the total area sampled during the study, not to estimate populations rather to locate different ungulates (Brower *et al.,* 1990).

iv). Small mammals

Small mammals like marmots and pikas were directly observed during the day time whereas nocturnal small mammals were observed either using Spot Lighting Method or Folding Sherman Traps. Traps were often set in the evening and observed early in the morning. Different trapped animals were released after their identification and recording necessary morphological data (Wilson and Reeder, 1992, 2005).

v). Reptiles

Reptiles were observed during the day time (10:00–15:00 hrs) when it was hot enough and lizards were active, basking or feeding (Heyer *et al*., 1994). Lizards were located mostly by turning stones, looking at and through bushes, and walking along dry stream beds. Fast moving agamas were manually captured by striking stones and beating sage bushes with a stick. Some were also pulled out of crevices, holes and from beneath the rocks and bushes using long metal forceps. Collected specimens were killed and preserved by injecting 10% formalin solution into belly, neck, legs and tail and tagged with field information. After necessary morphological recording, collected specimens were preserved in the Zoological Survey Department, Karachi for future study, reference and record (Khan, 2006; Baig, 2008).

vi). Water Quality

Water quality was investigated using on-spot as well as lab analysis. Samples were collected using manual sampling procedures following standard methods for examination of water by American Public Health Association (APHA). Extreme care was taken during the sampling and collected samples were on-site tested for some of the parameters i.e., surface water temperature, pH, DO and electrical conductivity while for other parameters, water samples were collected in sterilised water bottles and preserved by adding nitric acid for lab analysis.

Data Analysis

The state of the art equipment Hydrolab MS-5 was also used for on-site water quality assessment for a number of parameters including surface temperature, pH, conductivity, salinity, Total Dissolved Solids (TDS) and Dissolved Oxygen (DO). Results of the surface water quality were compared with the National Environmental Quality Standards (NEQS), US Environmental Protection Agency (US EPA) and WHO standards where applicable and/or available. Moreover, results concerning animals, plants and birds were analysed using MS Excel 2007 for simple calculations, graphs and tabulation (McCullough & Heiser, 2008).

Results

i). Vegetation

Shimshal Pamir Lakes ecologically represent a typical extreme Alpine Zone with no woody vegetation except sparsely scattered growth of few prostrate shrubs i.e., *Potentilla dryadenthoides* and *Sibbaldia tetrandra*. The week long field study ended with a record of 58 plant species belonging to 36 genera and 21 families. Asteraceae with nine species was the largest family (15.79%) followed by Brassicaceae having seven species (12.28%) of the total. Rest of the families seldom exceeded five species each. Haemicrytophytes representing 54 species (93.1%) was dominant among the floral life-forms followed by Chaemiphytes with 3 species (5.26 %) and Geophytes (1.76%). Almost 92% of the plants were perennial herbs (54 species) while only one prostrate shrub was recorded from the study area (Fig. 2).

Three plant communities were recognised in the project area, including Feldmark, small herb field and the fen community. The Feldmark community was found just below the permanent snowline, where snow melts for a short period and on the dry stony slopes. Vegetation of this community is sparse and most

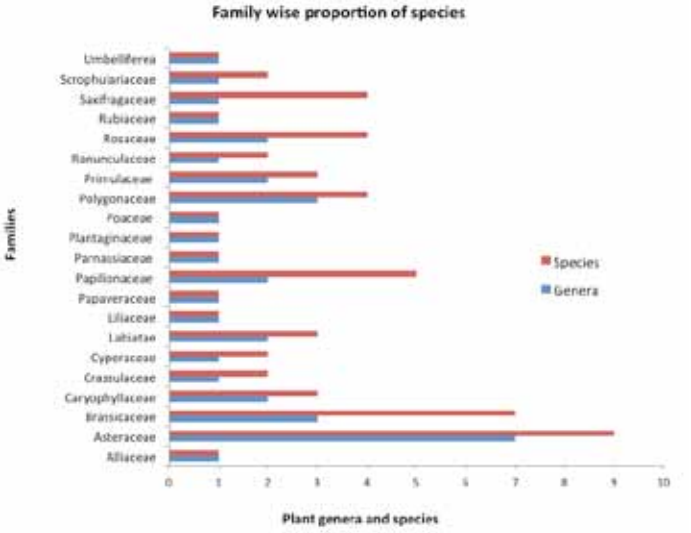

Figure 2: Family-wise proportion of plant species in the study area

of the species adapt to ecological changes withstanding intensive solar radiation and prevailing chilling temperatures. Characteristic species of the community are *Saussurea simpsoniana*, *Allardia glabra*, *Christolea crassifolia*, *Primula macrophylla moorcroftiana*, *Oxytropis macrophylla*, *Oxytropis chiliophylla*, *Potentilla pamirica pamiroalorica*. The small herb field community occurred below the late-lying snow patches perhaps due to higher availability of moisture in the form of ice melting. Vegetation in this region is dense compared to the late-lying snow patches. Characteristic species were *Aster flaccidus*, *Saxifraga hirculis alpine*, *Saxifraga oppositifolia asiatica*, *Allium carolinianum, Silene kunawarensis* and *Lioydia serotina*. Fen community was observed in the lower reaches where depressions were common with water standing for almost half of the year. *Carex stenocarpa* and *Carex psychrophilla* were the dominant whereas *Pedicularis alba* and *Pedicularis oedorei* were infrequent species of this community.

Phyto-sociologically, *Carex stenophylla* was the most dominant species with the highest IVI value (101.007) followed by *Carex psychrophilla* and *Astragalus saratagius* having 39.6254 and 8.7635 values, respectively. Value of IVI ranged between 23.6982 and 8.2423 in the remaining taxa (Table 1).

Average forage productivity of the pastures was calculated to be 66.75 kg ha^{-1} and the total forage productivity was estimated around 694,200 kg, which could hardly support a total of 715 yaks for a maximum of six months. Contrary to available total forage productivity, there were more than 5,000 yaks being grazed in addition to 2000 goats, 2000 sheep and about 500 cows at the time of survey, which all together exert tremendous grazing pressure on the peripheral grazing lands, and consequently, the catchment area of the lakes has been alarmingly degraded.

ii). Avifauna

Eight prominent locations viz., Shimshal village, Garee Sar, Pust Furzeen, Ooch Furzeen, Arbab Pureen, Shujerab Pass, Gulchin Wash Top and Shimshal Lake, representing characteristic bird

Table 1: Phyto-sociological values (IVI) for species abundance

Name of Species	D3	F3	C3	IVI
Carex stenophylla	29.46	17.02	54.528401	101.007
Carex psychrophilla	19.38	12.77	7.4795986	39.6254
Potentilla pamirica	7.752	10.64	0.7975875	19.1878
Astragalus saratagius	15.5	14.89	8.3659637	38.7635
Ranunculus pulchellus	3.101	4.255	0.8862084	8.2423
Oxytropis chiliophylla	9.302	10.64	3.7575783	23.6982
Sibbaldia tetrandra	3.101	6.383	11.077605	20.5614
Pedicularis oederi	4.651	8.511	4.3070044	17.4688
Pleurospermum stellatum	3.876	6.383	1.1077654	11.3667
Leontopodium leontopodinum	2.326	4.255	2.1534863	8.73439
Primula schlagintweitiana	1.55	4.255	5.5388023	11.3445

habitats were surveyed during the study. A total of 1,069 birds belonging to 48 species, nine orders and 24 families were recorded from the project sites. Out of the total, 20 were resident, 2 were winter visitors, 21 were summer breeders and 2 were passage migrants or year-round visitors to the study area. Description of three birds is unknown as these were recorded for the first time from the study area whereas according to the IUCN Red Data List 2010, most of the species fall in the Least Concern category. The relative abundance results showed House sparrow (*Passer domesticus*) as the most common bird and Lammergeyer (*Gypaetus barbatus*) as the least common bird species in the area. RA values for the rest of bird species remained between 0.0018 and 0.1281 (Table 2).

Almost nine bird species were recorded for the first time from the study area that include Desert Wheatear, Plain Mountain Finch, Masked Wagtail, Brown Dipper, Eurasian Chiffchaff, Tibetan Lark, White-cheeked Bulbul, Common Moorhen and Indian Tree Pipit (Table 3).

Occurrence of the above mentioned birds particularly that of Tibetan Lark (*Melanocorypha maxima*) in Shimshal valley constitute a fresh avian record, extending its distribution range further into the northern Karakoram mountain range.

iii). Large mammals

Spending about two weeks in the field (July 12 to 27, 2010) and applying all the possible direct and indirect observation methods, five mammalian species (Snow Leopard, Indian Wolf, Common Red Fox, Himalayan Ibex and Blue Sheep), belonging to two orders, three families and five genera were recorded from the study area (Table 4).

According to the IUCN Red List of Threatened Species, Snow Leopard is Endangered (E) whereas rests of the four species are categorised as Least Concern (IUCN, 2012). However, in Pakistan, Snow Leopard is Critically Endangered, Wolf and Blue Sheep are Endangered, Red Fox is Near Threatened and Himalayan Ibex is Least Concern (Sheikh and Molur, 2005). According to local respondents, population of Snow Leopard and Wolf had increased during the past two decades apparently due to increasing number of its wild prey in the area but livestock predation, particularly yaks killing, by Snow Leopard and Wolf is an emerging livelihood concern of the local people.

iv). Small mammals

Survey results revealed eight small mammal species including Cape Hare, Royle's or Indian Pika, Long-tailed Marmot, Chinese Birch Mouse, House Mouse, High Mountain Vole, Pamir Vole and Migratory or Gray Hamster belonging to two orders, five families and eight genera in the study area. All the recorded small mammals were observed directly either in the field during day time or after being trapped. However, tracks and droppings of Cape Hare, burrows of Chinese Birch Mouse and House Mouse and droppings of Royle's Pika were also observed in the study area (Table 5).

The Royle's Mountain Vole is categorised as Near Threatened (NT) species in the IUCN Red List of Threatened Species (IUCN, 2012) with a decreasing population trend while rests of the seven

Table 2: Migratory and resident birds of Shimshal Pamir and their relative abundance

#	Common Name	Zoological Name	Family	Order	Description (Grimmett, 2008)	Status (IUCN Red List 2008)	Number Observed	Relative Abundance
1	Black Redstart	*Phoenicurus ochruros*	Muscicapidae	Passeriformes	Summer breeder	Least Concern	6	0.0056
2	White Capped Redstart	*Chaimorrornis leucocephalus*	Muscicapidae	Passeriformes	Summer Breeder	Least Concern	8	0.0074
3	Blue Whistling Thrush	*Myophonus caeruleus*	Muscicapidae	Passeriformes	Summer Breeder	Least Concern	7	0.0065
4	Blue Rock Thrush	*Monticola solitarius*	Muscicapidae	Passeriformes	Summer Breeder	Least Concern	5	0.0046
5	Desert Wheatear	*Oenanthe deserti*	Muscicapidae	Passeriformes	Wintering	Least Concern	22	0.0205
6	White Winged Redstart	*Phoenicurus erythrogaster*	Muscicapidae	Passeriformes	Summer Breeder	Least Concern	7	0.0065
7	Common Rose Finch	*Carpodacus erythrinus*	Fringillidae	Passeriformes	Summer Breeder	Least Concern	63	0.0589
8	Fire Fronted Serin	*Serinus pusillus*	Fringillidae	Passeriformes	Resident	Least Concern	112	0.1047

#	Common Name	Zoological Name	Family	Order	Description (Grimmett, 2008)	Status (IUCN Red List 2008)	Number Observed	Relative Abundance
9	Great Rose Finch	*Carpodacus rubicilla*	Fringillidae	Passeriformes	Resident	Least Concern	17	0.0159
10	Plain Mountain Finch	*Leucosticte nemoricola*	Fringillidae	Passeriformes	Resident	Least Concern	14	0.013
11	Grey Wagtail	*Motacilla cinerea*	Motacillidae	Passeriformes	Summer Breeder	Least Concern	37	0.0346
12	Masked Wagtail	*Motacilla alba personata*	Motacillidae	Passeriformes	Summer Breeder	Least Concern	15	0.014
13	Citrine Wagtail	*Motacilla citreola*	Motacillidae	Passeriformes	Summer Breeder	Least Concern	32	0.0299
14	White Wagtail	*Motcilla alba*	Motacillidae	Passeriformes	Summer Breeder	Least Concern	52	0.0486
15	Red Billed Chough	*Pyrrhocorax pyrrhocorax*	Corvidae	Passeriformes	Resident	Least Concern	17	0.0159
16	Yellow Billed Chough	*Pyrrhocorax graculus*	Corvidae	Passeriformes	Resident	Least Concern	34	0.0318
17	Raven	*Corvus corax*	Corvidae	Passeriformes	Resident	Least Concern	6	0.0056
18	Golden Oriole	*Oriolus oriolus*	Oriolidae	Passeriformes	Summer Breeder	Least Concern	7	0.0065
19	Lesser Whitethroat	*Sylvia curruca*	Sylviidae	Passeriformes	Summer Breeder	Least Concern	46	0.043
20	Brown Dipper	*Cinclus pallasii*	Cinclidae	Passeriformes	Resident	Least Concern	5	0.0046
21	Eurasian Chiffchaff	*Phylloscopus collybita*	Phylloscopidae	Passeriformes	Wintering	Least Concern	17	0.0159
22	Greenish Warbler	*Phylloscopus trochiloides*	Phylloscopidae	Passeriformes	Summer Breeder	Least Concern	11	0.0102
23	Horned Lark	*Eremophila alpestris*	Alaudidae	Passeriformes	Resident	Least Concern	24	0.0224
24	Tibetan Lark	*Melanocorypha maxima*	Alaudidae	Passeriformes	Summer Breeder	Least Concern	5	0.0046
25	House Sparrow	*Passer domesticus*	Passeridae	Passeriformes	Summer Breeder	Least Concern	137	0.1281
26	Rock Bunting	*Emberiza cia*	Emberizidae	Passeriformes	Summer Breeder	Least Concern	37	0.0346
27	Wall Creeper	*Tichodroma muraria*	Sittidae	Passeriformes	Resident	Least Concern	2	0.0018
28	Brown Accentor	*Prunella fulvescens*	Prunellidae	Passeriformes	Resident	Least Concern	16	0.0149
29	Long-tailed Shrike	*Lanius schach*	Laniidae	Passeriformes	Summer Breeder	Least Concern	8	0.0074
30	Himalayan Bulbul	*Pycnonotus leucogenys*	Pycnonotidae	Passeriformes	Resident	Least Concern	16	0.0149
31	Lammergeier	*Gypaetus barbatus*	Accipitridae	Falconiformes	Resident	Least Concern	2	0.0018
32	Himalayan Griffon Vulture	*Gyps himalayensis*	Accipitridae	Falconiformes	Resident	Least Concern	3	0.0028
33	Eurasian Sparrow Hawk	*Accipter nisus*	Accipitridae	Falconiformes	Summer Breeder	Least Concern	5	0.0046
34	Common Kestrel	*Falco tinnunculus*	Falconidae	Falconiformes	Resident	Least Concern	7	0.0065
35	Chukar Partridge	*Alectoris chukar*	Phasianidae	Galliformes	Resident	Least Concern	16	0.0149
36	Himalayan Snow cock	*Tetraogallus himalayensis*	Phasianidae	Galliformes	Resident	Least Concern	21	0.0196
37	Snow Pigeon	*Columba leuconota*	Columbidae	Columbiformes	Resident	Least Concern	41	0.0383
38	European Turtle Dove	*Streptopelia turtur*	Columbidae	Columbiformes	Passage migrant	Least Concern	7	0.0065
39	Golden Eagle	*Aquila chrysaetos*	Accipitridae	Accipitriformes	Resident	Least Concern	3	0.0028
40	Common Sandpiper	*Actitis hypoleucos*	Scolopacidae	Charadriiformes	Summer Breeder	Least Concern	15	0.014
41	Little Stint	*Calidris minuta*	Scolopacidae	Charadriiformes	Passage migrant	Least Concern	47	0.0439
42	Eurasian Cuckoo	*Cuculus canorus*	Cuculidae	Cucliformes	Summer Breeder	Least Concern	33	0.0308
43	Hoopoe	*Upupa epops*	Upupidae	Coraciiformes	Summer Breeder	Least Concern	14	0.013
44	Common Moorhen	*Gallinula chloropus*	Rallidae	Gruiformes	Resident	Least Concern	5	0.0046
45	Black Billed Magpie	*Pica pica*	Corvidae	Passeriformes	Resident	Least Concern	8	0.0074
46	Bluethroat	*Luscinia svecica*	Muscicapidae	Passeriformes	Summer Breeder	Least Concern	6	0.0056
47	Brandt's Mountain Finch	*Leucosticte brendti*	Fringillidae	Passeriformes	Resident	Least Concern	44	0.0411
48	Indian Tree Pipit or Olive-backed Pipit	*Anthus hodgsoni*	Motacillidae	Passeriformes	Unknown	Least Concern	12	0.0112

Table 3: Birds recorded for the first time from Shimshal Pamir area

#	Common Name	Zoological Name	Location
1	Desert Wheatear	*Oenanthe deserti*	Garee Sar
2	Plain Mountain Finch	*Leucosticte nemoricola*	Ooch Furzeen
3	Masked Wagtail	*Motacilla alba personata*	Near Shujerab Pass
4	Brown Dipper	*Cinclus pallasii*	Near Shimshal village
5	Eurasian Chiffchaff	*Phylloscopus collybita*	Near Shimshal village
6	Tibetan Lark	*Melanocorypha maxima*	Gulchin Wash Top, Shujerab Pass
7	Himalayan Bulbul	*Pycnonotus leucogenys*	Near Shimshal village
8	Common Moorhen	*Gallinula chloropus*	Near Shimshal village
9	Indian Tree Pipit or Olive backed Pipit	*Anthus hodgsoni*	Near Shimshal village

Table 4: Large mammals of Shimshal Pamir area

Species observed	Direct	Indirect				
		Pug marks	Body parts	Scent	Scats	Respondents
Uncia uncia	-	+	-	+	+	+
Canis lupus chanco	-	-	-	-	+	+
Vulpes vulpes montana	+	-	-	-	+	+
Capra ibex	+	-	+	-	-	+
Pseudois nayaur	+	-	+	-	-	+

species have been categorised as Least Concern (LC). Among these, Royle's or Indian Pika and House Mouse have a stable population; Cape Hare is decreasing whereas the population trend of Long-tailed or Kashmir Marmot, Chinese Birch Mouse, Pamir Vole and Gray or Migratory Hamster is unknown. According to the IUCN Red List of Pakistan Mammals (Sheikh and Molur, 2005), High Mountain Vole is Near Threatened (NT) whereas, rest of the seven species have been categorised as Least Concern (LC). None of the recorded species are protected in Gilgit-Baltistan under Northern Areas Wildlife Preservation Act 1975 except Cape Hare, which is included in First Schedule. Long-tailed or Kashmir Marmot has been listed in the Appendix III of CITES.

Table 5: Small mammals of Shimshal Pamir area

English Name	Zoological Name	Order	Family	Status
Cape Hare	*Lepus capensis*	Lagomorpha	Leporidae	Less Common
Royle's or Indian Pika	*Ochotona roylei*	Lagomorpha	Ochotonidae	Less Common
Long Tailed Marmot	*Marmota caudata*	Rodentia	Pteromydidae	Common
Chinese Birch Mouse	*Sicista concolor*	Rodentia	Zapodidae	Less Common
House Mouse	*Mus musculus*	Rodentia	Muridae	Common
High Mountain Vole	*Alticola roylei*	Rodentia	Muridae	Near Threatened
Pamir Vole	*Microtus juldaschi*	Rodentia	Muridae	Less Common
Migratory/Grey Hamster	*Cricetulus migratorius*	Rodentia	Muridae	Less Common

v). Reptiles & amphibians

Fifteen specimens belonging to four species of Agamidae family viz., *Laudakia himalayana*, *Laudakia pakistanica*, *Laudakia tuberculata* and *Laudakia badakhshana*, were recorded from the study area (Table 6).

A careful review of literature with the collected specimen features showed the occurrence of *Laudakia himalayana*, *L. pakistanica*, *L. tuberculata* and *L. badakhshana* at 4,082 m, 4,172 m, 4,005 m and 4,240 m asl, respectively, never reported from such an altitude before. The terrain offers a variety of ecological barriers, in the form of fast and freezing running waters and massive glaciers with peculiar harsh climatic conditions prevailing for nine months of the year, which restricts species migration and thus increases endemism. Although one of the four species recorded from the study area, i.e. *L. pakistanica* is endemic to Pakistan, *L. tuberculata* and *L. badakhshana* are new records from Shimshal, Pakistan (Khan *et al.*, 2012).

vi). Water Quality

Water samples taken from several different locations of the lakes and their adjacent streams were tested for pH, surface temperature, electrical conductivity, salinity, total dissolved salts, dissolved oxygen and micro-organism. Results revealed that average pH

Table 6: Specimens of reptiles and amphibians collected from Shimshal Pamir area

#	Species Name	Sex	Location	Elevation (m)
1	*Laudakia himalayana*	M	N 36º 26' 27.6 E 75º 20' 01.2	3090
2	*Laudakia himalayana*	M	N 36º 26' 27.6 E 75º 20' 01.2	3090
3	*Laudakia himalayana*	M	N 36º 27' 40.2 E 75º 26' 47.0	3486
4	*Laudakia himalayana*	F	N 36º 27' 51.9 E 75º 28' 06.1	3703
5	*Laudakia himalayana*	F	N 36º 28' 10.4 E 75º 29' 28.2	4082
6	*Laudakia pakistanica*	M	N 36º 26' 27.6 E 75º 20' 01.2	3090
7	*Laudakia pakistanica*	M	N 36º 26' 27.6 E 75º 20' 01.2	3090
8	*Laudakia pakistanica*	M	N 36º 27' 40.2 E 75º 26' 47.0	3486
9	*Laudakia pakistanica*	F	N 36º 27' 51.9 E 75º 28' 06.1	3703
10	*Laudakia pakistanica*	F	N 36º 28' 10.4 E 75º 29' 28.2	4082
11	*Laudakia pakistanica*	M	N 36º 28' 19.7 E 75º 34' 53.2	4172
12	*Laudakia pakistanica*	F	N 36º 28' 19.7 E 75º 34' 53.2	4172
13	*Laudakia tuberculata*	M	N 36º 28' 25.5 E 75º 33' 21.0	4005
14	*Laudakia tuberculata*	M	N 36º 28' 23.2 E 75º 33' 07.1	3942
15	*Laudakia badakhshana*	M	N 36º 28' 04.1 E 75º 35' 44.4	4240

of the samples collected from the lake, its inlet and outlet streams ranged between 6.8 – 6.9, which means water is neither acidic (<7) nor alkaline (> 7), which is almost neutral. Similarly, surface water temperature at the time of survey ranged between 10.2°C to 10.3°C at various sampling locations. Electrical Conductivity values observed were slightly higher ranging between 216 µS cm^{-1} to 217 µS cm^{-1} in lake waters. Salinity recorded was around 0.1 ppt at all three sampling locations. A relatively lower concentration of TDS viz., 55 mgL^{-1}, 50 mgL^{-1} and 47 mgL^{-1} was recorded at south-eastern, centre and western proximities of the lakes. Almost all of the values were within permissible limits of the Pakistan NEQS (3500 mgL^{-1}) and US EPA (500 mgL^{-1}). However, the values of DO ranged between 4.4 mgL^{-1} and 4.6 mgL^{-1} for all the sampling sites, which being slightly lower than normal (4.0 – 4.6 mgL^{-1}) could have been stressful for fish species but there was no fish in Shimshal Pamir Lakes (Table 7).

Lab analysis of collected water samples for microbiological parameters including total colony count, total coliforms, faecal *E. coli* and faecal enterococci/streptococci were negative for the inlet points but it was positive in the lakes and their outlets, meaning lake water and its outflow had faecal contamination. As per WHO guidelines *(A = 0 E.coli; B=1-10 E.coli; C=11-100 E.coli and D=101-1000 E.coli per 100 ml)*, water at the inlet is somehow safe for drinking but water in the lake and its outlet streams has microbial contamination, so is not safe for drinking purposes.

Discussion

The Karakoram Pamir region has two adjoining Protected Areas located on either sides of the Pakistan - China border; Khunjerab National Park on the Pakistani side and the Taxkorgan Nature Reserve on the Chinese side of the border. The entire area maintains a similarity in its natural physiology, eco-characters and ethnic background of the people dwelling in the areas and their subsequent culture and socio-economic conditions. The endemic

Table 7: Surface water quality and Microbiological profile of Shimshal Pamir Lakes

#	Parameter	Units	Sampling Locations			Quality Standards	
			Inlet	Lake	Outlet	NEQS	USEPAQS
1	pH	mgL^{-1}	6.8	7	6.9	6.0 - 9.0	6.5 - 9.0
2	Temperature	°C	10.2	10.3	10.3	-	-
3	Electrical conductivity	µS cm^{-1}	216.2	214.8	217	-	-
4	Salinity	ppt	0.1	0.1	0.1	-	-
5	TDS	mgL^{-1}	50	52	47	3500	-
6	DO	mgL^{-1}	6.4	6.4	6.5	-	-
Source	**Sample code**	**Units**	**Vol filt 100 ml**	**No of colonies**	**F.C/100 ml**	**E. coli/ 100 ml**	**WHO Category**
Sample1	SP-	Cfu $100ml^{-1}$	100 ml	0.00	0.00	0.00	A
Sample2	SP-	Cfu $100ml^{-1}$	100 ml	1.00	1.00	1.00	B
Sample3	SP-	Cfu $100ml^{-1}$	100 ml	1.00	1.00	1.00	B

animals found in this stretch of land also roam around and across the border frequently. Even the effects of climate change are equal in its intensity on both mountain ecosystems and livelihoods of the people dependent on this area at large but until now none of the two countries have made any concerted efforts to bring the adjoining areas under collective management. The wildlife species and human communities are equally exposed to unprecedented changes crucial for long-term maintenance of globally significant biodiversity.

The Karakoram Pamir border region harbouring globally significant wildlife species i.e., Snow Leopard, Marco Polo Sheep and Blue Sheep represent one of the most important and unique wildlife areas in the mountains of Asia. Shimshal valley, the north-western part of Khunjerab National Park is known to have the western most population of Blue Sheep in its range (Wegge, 1988). Shimshal Pamir Lakes offer luxurious habitat to a number of migratory birds, especially waterfowls (Ali & Khan, 2007) and their reptilian fauna is also of high scientific interest and significance.

Although the two adjacent Protected Areas have flagship wildlife species in common and share wildlife habitats, watersheds and ecological flows across international borders but their growth has never been satisfactory for the last many years, mainly because of unregulated hunting, habitat destruction and restricted migration of wild animals across the border. Traditionally, Ibex, Blue Sheep and Marco Polo Sheep have been hunted to supplement the diet and to earn money for daily life needs. Pastures are over grazed by domestic livestock. Scattered and sparse vegetation is extracted for fuel and firewood. Predators, particularly Wolf and Snow Leopard, kill large numbers of livestock and are killed by farmers in retribution, and waterfowls are ruthlessly hunted for meat, feathers and sale.

The area is otherwise highly rich in endemic flora and fauna, freshwater ecosystems and their associated species, which if judiciously exploited and managed can bring an economic revolution for the resident pastoral communities of the border region. The future of the Shimshal Pamir wetlands in particular and the Karakoram Pamir border area in general depends largely on the current levels of anthropogenic, socio-economic and pastoral influences in the region. Poverty is common among communities on both sides of the border and subsistence agriculture and pastoralism will continue to be the major sources of livelihood for the local people. Thus future of the areas as viable reserves will depend on the willingness of people to coexist with wild animals and to prevent further deterioration of the critical habitats.

We therefore suggest to devise a multi-pronged trans-border joint conservation strategy encompassing science based species management, habitat improvement, and community based conservation programmes, with avenues for economic development and benefit sharing to restore and manage flagship species and birds, their habitats and peculiar mountain ecosystems, inclusive of High Altitude Wetlands in the Sino-Pak border region.

Conclusion

The Shimshal Pamir mountain area bordering China in the extreme north of Pakistan is known for its glaciers, snow capped peaks, high altitude lakes, alpine pastures and wildlife species of global significance. With two adjacent Protected Areas across international border, the region has defined connectivity for species, habitats, ecosystems and their associated ecological flows. However, the real benefits of trans-border conservation are yet to be harnessed. Although the need for transboundary collaboration was realised to protect the species and shared habitats but such a realisation was transformed into actions when WWF - Pakistan signed an agreement with the Xinjiang Institute of Ecology and Geography (XIEG), Chinese Academy of Sciences (CAS) for collaborative research on biodiversity of the Pamir Plateau in 1993. Shimshal Pamir wetlands, their adjacent peatlands, streams, rivers and lakes have rare and unique biodiversity and fragile mountain ecosystems, unattended so far. Further, promoting the bilateral cooperation between the two friendly countries i.e., China and Pakistan, for future conservation and joint management of common and shared resources is imperative to ensure socio-ecological resilience in the Pamir border region.

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Actinomycetes screening for bioactive potential isolated from the moist forest soils of Pakistan

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ABSTRACT

Five moist soil zones in temperate forests of Pakistan were investigated for the bioactive potential of actinomycetes. The identification of the isolates was based on their cultural and morphological characteristics among which 60 isolates were screened and recognised out of 208 isolates. The isolates identification falls under three genera including Actinomyces, Streptomyces and Nocardia spp. each with the total number of 31, 17 and 12 isolates identified respectively. The identified isolates were further screened for bioactive potential among which 15 isolates produced bioactive substances against one or more indicator strains of gram positive and gram negative bacteria and fungi. The results clearly demonstrated that temperate forest ecosystems are providing a key habitat to bioactive actinomycetes, which have an important medical, scientific and economic significance globally in general and in particular for developing countries like Pakistan.

Introduction

Actinomycetes are gram-positive bacteria that form filamentous mycelia with high G+C (guanine +cytosine) content and are widely distributed in a variety of natural and manmade environments, particularly constituting a significant component of the microbial population in temperate forest soils (Debananda *et al.*, 2009; Lam, 2006 and Ndonde & Semu, 2000 and Watve *et al.*, 2001). About 100 genera of *actinomycetes* exist in natural habitats including diverse forest zones (Yokota, 1997). Some genera such as *Streptomyces* and *Actinoadura* are widely distributed, which can be isolated from different temperate soil habitats (Williams *et al*., 1989). Among the gram-positive bacteria, *Actinomycetes* exhibit the greatest morphological differentiation with branching hyphae and specialised spore-bearing structures (Kim & Garson, 2005; Prescott *et al.,* 1993).

These bacteria are globally significant and have been extensively studied (Cragg & Newman, 2005; Bull *et al.,* 2000 and Debananda *et al.*, 2009), due to their ability to produce novel antibiotics (Goodfellow *et al.*, 1989; Williams *et al*., 1983; Crandall & Hamil, 1986; Williams *et al*., 1989 and Korn & Kutzner, 1992). Of one thousand different antibiotics known today, more than 70 % are produced by *Actinomycetes* (Bull & Stach, 2005; Edward, 1980; Imada & Okami, 1998; Kim & Garson, 2005). In addition to antibacterial activity, *actinomycetes* also produce commercially important bioactive compounds such as avermectin (Prescott *et al.,* 1993) and other secondary metabolites with biological activities (Blunt & Prinsep, 2006 and Debananda *et al.,* 2009) hence *actinomycetes* strains have many gene clusters involving the biosynthesis of melanin, carotenoid, siderophore, polyketide and peptide compounds (Omura *et al.,* 2001). To our knowledge, *actinomycetes* isolation from temperate forest soils in Pakistan have not been undertaken by researchers and this geographic region may have important bioactive *actinomycetes* traits, which could be of medical and economic benefits to Pakistan.

The current study was conducted to isolate potential soil *actinomycetes* strains from five diverse geographic regions, which fall in the temperate forests of Pakistan. The isolates were further screened for bioactive potential against selected strains of gram positive and gram negative bacteria and fungi.

Material and Methods

Study Area

Five temperate forest zones from diverse geographic locations: Miadam Forest Swat (MFS), Kalam Forest Swat (KFS) and Osherai Dara Forest Dir (OFD), Ayubia Forest Hazara (AFH), Nathiagali Forest Hazara (NFH) of Malakand and Hazara Divisions in north western Pakistan, respectively (Fig. 1) were selected for soil sampling and subsequent isolation and screening of bioactive *actinomycetes*.

These temperate forests zones having suitable rich soil conditions (~40 to 60 % volumetric water content and 5 to 8 % organic carbon on dry soil mass basis), acting as a growing media for bioactive *actinomycetes*, and these conditions provided the preliminary basis for selection of the study area for soil sampling.

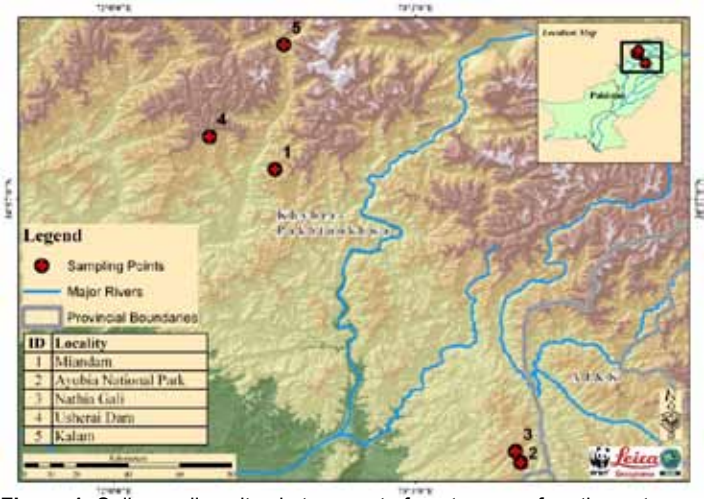

Figure 1: Soil sampling sites in temperate forest zones of north-western Pakistan

Data Collection

Soil Sample collection and pre-treatment

The soil samples were collected during May, 2009 to February,

2010. A total of 15 plots were randomly located in each forest zone (5 zones). A total of 75 soil samples were collected at a depth of 15 to 20 cm below the surface (in the mineral soil layer) to avoid sampling the organic layer acting as a nutrient source for other organisms, where most of the soil microbial activities occur. The samples were packed in sterile polyethylene bags and aseptically transported to the laboratory for further analysis. The collected samples were air dried for seven days, mixed and homogenised manually by removing roots. One gram of each soil sample was grounded, pulverised and passed through a 60 um mesh sieve for the isolation of *actinomycetes*. Each soil sample was pre-treated with 0.1 gm of calcium carbonate ($CaCO_3$) and incubated at 25^{0}C for two weeks. The soil samples were suspended in 99.0 ml sterile distilled water (Laidi *et al.*, 2006), placed in incubator shaking it at 150 rotations per minute for 30 minutes (Laidi *et al.*, 2006 and Saadoun & Gharaibeh, 2003).

Isolation of actinomycetes

Several media types were used for the selective isolation of *actinomycetes* from the soils slurries. The plate dilution method was used for the isolation of *actinomycetes* following the method of Seong *et al.,* (2001). Serially diluted suspensions were spread uniformly on a selective media of hair hydrolysate vitamin Agar (HHVA) and incubated for 2-7 days at 25^{0}C. Plates were checked for the growth of the desired *actinomycetes* colonies after incubation.

Characterisation of the isolates

Morphological characters of the isolates were investigated by gram staining method according to Hucker and Conn (1923). Common morphological characters were observed by incubating the Oatmeal Agar plates in the dark at 28^{0}C for three weeks. Cover slip culture method (Kawato and Shinobu, 1959) was carried out for the microscopic examination of the cross-hatched cultures of the isolates. Oil immersion microscope was used for determining the mycelium colour, structure and arrangements on mycelia as described by Prauser (1964). Bergey's Manual of Systematic Bacteriology (Williams *et al.,* 1983a, 1983b) was followed for the structure resemblance and comparison while the identified colour and colony-morphology were recognised according to the method of Shirling and Gottlieb (1966). The isolates were then cultured on starch-casein agar media according to the method of Pridham (1964) for the determination of colour of the arial mycelia of *actinomycetes*.

Screening of the isolates for bioactive potential

Pure isolates were screened for bioactive potential against pathogenic test organisms following the method of Kirby-Bauer as detailed in Debananda *et al.*, (2009). Isolates were inculcated and grown on GS medium (Antibiotic producing medium) through shaking the isolates in a shaker (150 rpm) at ambient temperature (~22^{o}C). Test pathogens of Gram positive bacteria *Staphylococcus aureus* (MTCC 96), *Micrococcus luteus* (MTCC 106), *Bacillus subtilis* (MTCC 121) and *Gram negative bacteria Escherichia coli* (MTCC 739) were cultured on Nutrient Agar (NA) plates while yeast/fungus *Candida albicans* (MTCC 227) and *Aspergillus Niger* (MTCC 1344) were cultured on Sabouraud Agar (SA) by following the standard procedure according to Debananda *et al.*, (2009). Antibiotic discs were saturated with the crude antibiotic extract and were applied against test-pathogens cultures on NA and SA plates. After 48 hour incubation, the zones of inhibition of the pure isolates against the test pathogens were analysed systematically.

Results and Discussion

Culture and morphology of the isolates

Numerous types of bacterial and fungal colonies of *actinomycetes* were identified among which 30 to 45 colonies were observed on each plate. Colonies selection was made, based on their colony appearance. A total of 208 isolates were subjected to microscopic analysis among which 63 isolates were obtained from the soil samples of Miadam Forest (MFS) followed by 47 from Kalam Forest (KFS), 39 from Ayubia Forest (AFH), 30 from Nathiagali Forest (NFH) and 29 from Osherai Forest (OFD), respectively. Further identification was done based on their cultural and morphological characteristics among which 60 isolates were screened. The isolates identification falls under three genera including *Actinomyces, Streptomyces, and Nocardia* as shown in Table 1.

Bioactive potential of the isolates

In a total of 60 isolates screened, 15 produced bioactive substances against one or more of the test-pathogens while 8 isolates exhibited broad spectrum bioactive potential (Fig. 2) and the results are comparable to the studies conducted by Debananda *et al.*, (2009) and Slavica *et al.,* (2005). These isolates showed bioactive potential against gram positive, gram negative bacteria and yeast/ fungi. The results of this study were similar to the studies conducted by Edwards (1980) and Egorov (1985). The isolate NFH8 (Fig. 2) showed broad spectrum bioactive potential against gram positive bacteria, S*taphylococcus aureus* (MTCC 96) and *Micrococcusluteus* (MTCC 106). Isolate KFS8 also exhibited broad spectrum bioactive potential against *Bacillus subtilis* (MTCC 121); Isolates KFS3 and AFH2 also showed broad spectrum bioactive potential against gram negative bacteria. Isolate NFH8 (Nathiagali Forest Hazara) exhibited broad spectrum antimycotic activity against *Candida albicans* (MTCC 227) while KFS8 against *Aspergillus niger* (MTCC 1344), respectively (Fig. 2). Similar and comparable results were obtained by Atta (2009) and Saadoun & Gharaibeh (2003), which show the fidelity of the experimental protocols adopted.

Table 1: Recognition and classification of actinomycetes into genera's based on cultural and morphological characteristics

No of Isolates	Actinomycetal isolate	Colony description	Microscopic assessment
31	*Actinomyces*	Branched and filamentous and micro colonies	Non acid fast and Gram positive pleomorphic cells, Y and V shaped on filament
17	*Streptomyces*	White, Gray and occasional pinkish color colony with powdery appearance as concave, convex and/or flat surface	Multiple long branching, non fragmenting, long chains , spirali and/or coils
12	*Nocardia*	Shiny colonies with aerial filaments on blurry surface	Non acid fast and Gram positive pleomorphic cells, bacillary and coccoid structure; rarely partial mycelium which fragments readily and hence produce rod shape or coccoid cell

Antibacterial potential against Gram-positive bacteria

The results revealed that six isolates exhibited antimicrobial potential against gram positive bacteria *Staphylococcus aureus,* seven against *Micrococcus luteus* and eight against *Bacillus subtilis.* The results also indicated that isolates MFS3, MFS4, KFS7, AFH2, NFH4 and NFH8 have antimicrobial potential against *Staphylococcus aureus,* while AFH2 produced minimum inhibition zone of 10 mm and NFH8 produced a maximum zone of 30 mm in diameter. The isolates MFS3, MFS4, KFS3, AFH2, AFH9, NFH4, NFH8, NFH10 and OFD3 produced antimicrobial substances

against *Micrococcus luteus;* OFD3 showed a minimum inhibition zone of 16 mm in diameter while NFH8 showed a maximum zone of inhibition of 30 mm. The antimicrobial potential of isolates were also analysed against *Bacillus subtilis*. Results indicated that MFS8, KFS8, AFS2, AFH3, AFH9, NFH4, NFH8 and OFD4 isolates produced antimicrobial metabolites. MFS8 isolate showed a minimum zone of 9 mm in diameter as compared to KFS8 which produced 30 mm zone of inhibition (Fig. 2). These results suggests that antimicrobial activity is diverse in *actinomycetes* collected from temperate forest soils and can be of significance for further insight and synthesis of these identified bioactive materials.

Antibacterial potential against Gram-negative bacteria

The isolates also showed a potential of antibacterial activity against gram negative bacteria. Six isolates: KFS3, AFH2, AFH3, AFH7,

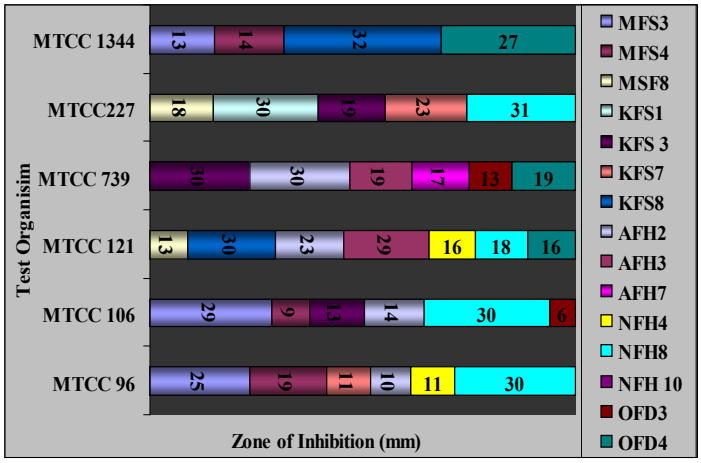

Figure 2: Antimicrobial and antimycotic activity of the isolates against *Staphylococcus aureus* (MTCC 96)*, Micrococcus luteus (MTCC* 106), *Bacillus subtilis* (MTCC 121), Escherichia *coli* (MTCC 739), *Candida albicans (*MTCC 227) and *Aspergillus Niger* (MTCC 1344)

OFD3 and OFD4 clearly inhibited the growth of *Escherichia coli*. The isolate OFD3 produced a minimum zone of 13 mm against *Escherichia coli* as compared to maximum zones of 30 mm diameter produced both by KFS3 and AFH2 (Fig. 3) demonstrating clearly that both have the capacity to completely restrict the growth of *Escherichia coli*. Similar results were obtained by Lo and Ho (2001) and Slavica *et al.,* (2005).

Antimycotic potential against fungi/yeast

For antimycotic potential against fungi, 11 isolates were used, of which 5 isolates were effective against *Candida albicans* while 6 isolates were effective against *Aspergillus niger*. MFS8, KFS1, KFS3, AFH9 and NFH8 showed inhibition zones against *Candida albicans*. MFS8 introverted to the minimum zone of 18 mm in diameter while the maximum inhibition zones of 30 and 31 mm was exhibited both by KFS1 and NFH8 respectively, showing their strong action against the *species*. The test-pathogen *Aspergillus niger* was subjected to all isolates among which MFS3, MFS4, KFS7, KFS8, AFH2 and OFD4 produced antimycotic substances against the *species*. The low inhibition zone of 13 mm in diameter was produced by MFS3 isolate while maximum antimycotic activity by producing an inhibition zone of 32 mm in diameter was shown by KFS8 (Figure 3), being the maximum inhibition zone produced in the current investigations compared to the results observed by Taechowisan *et al.,* (2003). It is probable that the isolates from these forests may have an added advantage of expressing a strong action by KFS8 and further studies are recommended to elucidate its mode of strong action.

Conclusion

The results demonstrate that the temperate soils of north-western Pakistan under temperate forests constitute a significant component of the *actinomycetes* population. Majority of the isolates showed broad spectrum bioactive potential and antimycotic and antibacterial activity against one or more test pathogens. It is also evident from the current study that these forest ecosystems in Pakistan have great potential for the discovery of bioactive actinomycetes, which could be used in future for significant bioactive strains isolation.

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Spatio-temporal microbial water quality assessment of selected natural streams of Islamabad, Pakistan

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K E Y W O R D S

Natural stream
Water quality
Faecal contamination
Spatio-temporal variation
Islamabad

A B S T R A C T

The study was conducted to examine the water quality of natural streams of Islamabad district in selected sites viz. urban, semi-urban and natural by using *Total coliforms* (TC), *Faecal coliforms* (FC) and *Escherichia coli* (*E. coli*) as indicator bacteria. During this study, a total of 44 samples were taken for three seasons (pre-monsoon, monsoon, and post-monsoon). The results revealed that almost all surveyed sites were contaminated if not all but at least in one season. Presence of FC in the stream of Margalla Hills National Park (MHNP) can be attributed to wildlife activities in the area. Urban and semi-urban areas showed higher faecal pollution in comparison to MHNP during all seasons. It was observed that 62.7 % urban, 61.1 % semi-urban and 14.2 % MHNP water samples have presence of *E. coli* for all seasons, TC and FC exceeded the 1600 MPN/100ml. The possible sources of faecal contamination include municipal waste, septic tanks in urban areas while runoff from agriculture and grazing lands, domestic animals and poultry waste in semi-urban areas are additional sources. High level of faecal pollution during monsoon season compared to pre-monsoon and post-monsoon seasons may be associated with increased run-off as a result of high density of rainfall during monsoon.

Introduction

The surface water quality is of great importance due to its effects on human health and aquatic ecosystems. Running water is highly vulnerable to pollution attributing to their role in carrying off the municipal and industrial wastewater and run-off from agriculture in its vast drainage basins. Anthropogenic influences, as well as natural processes, deteriorate surface water and impair their use for drinking, industrial, agricultural, recreation or other purposes. In Pakistan, due to lack of proper facilities of waste disposal only 1 % of wastewater is treated before being discharged directly into water bodies. It is general trend that concentration of different pollutants in urban areas is high as compared to suburb and natural environment (Lewis *et al*., 2007), which indirectly indicates anthropogenic activities. Although water bodies have their own system of keeping themselves clean but the untreated wastewater from cities is reaching above the threshold of these water sources to clean automatically (Wattoo *et al*., 2004).

There are many biological entities ranging from simple viruses, protozoan, and bacteria to complex organism deteriorating water quality (Miernik, 2004). Faecal *coliforms* and *Escherichia coli* (*E. coli*) are used as indicators of possible sewage contamination due to their presence in human and animal faeces (George *et al*., 2001; Hill *et al*., 2006; Lewis *et al*., 2007; Boyer, 2008). Other sources of faecal contamination are sewage plants, poultry farms, domestic and wild animal manure, and storm runoff (Lewis *et al*., 2007; Boyer, 2008). Although they are generally not harmful themselves, they indicate the possible presence of pathogenic bacteria, viruses, and protozoans that also live in human and animal digestive systems (Miernik, 2004). These pathogens cause serious health risk (Luther & Fujoika, 2004; Thurston-Enriquez *et al*., 2005; Hussain *et al*., 2007) and therefore contaminate water, which is no more suitable for potable supply unless suitably treated (Miernik, 2004). Since it is difficult, time consuming and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for *coliforms*.

The objective of this study is to demonstrate the impact of intense anthropogenic interference on water quality in selected sites of Islamabad Capital Territory (ICT). The importance of such survey is documented through the fact that a majority of population living in Rawalpindi uses drinking water from Rawal Lake being fed by these natural streams. This highly polluted water may cause severe illnesses especially during summer months. In order to assess the water quality, a study was conducted to monitor the water quality of these streams in selected sites of Islamabad. The main objectives of this study are to (1) monitor microbial water quality by detecting the presence of total *Coliforms*, faecal *Coliforms* and *Escherichia coli* in surface water and (2) monitor spatial and temporal variation of faecal contamination in stream's water at selected sites of Islamabad.

Material and Methods

Study area

Islamabad the Federal Capital Territory of Pakistan is situated at the foothills of Himalayas at the edge of Pothohar Plateau in north of the country at an elevation of 558 m above mean sea level (Fig.1).

Total area covered by the city is 8,010 km^2 (33^o 43$^/$ 09.6$^{//}$ N and 73 03$^/$ 23.3$^{//}$ E). Islamabad combines two ecological components: the Indo-Himalayan and Irano-Saharan ecosystem that together make it a unique location. The climate is sub-tropical semi-arid. Being present in monsoon rainfed area, it experiences two rainy seasons and receives sufficient rain. In winter, rain prevails from January to March and summer rain period extends from July to September. Fairly cold winters with sparse snowfall over the hills and sleet in the city are characteristic of area. Temperatures range from a minimum - 3.9^{o}C in January to a maximum of 46.1^{o}C in June. Average annual rainfall is 1000 mm (HWF, 2007). Rawal Lake along with two other manmade Simli and Khanpur Dams regulate the climate of Islamabad.

Data Collection

Selection of method and sampling sites

Discrete sampling technique was adopted to collect stream water samples (Thiagarajan *et al*., 2007; Kammerer *et al*., 2008). In order to examine the ecological consequences of microbial pollution, study area was divided into three parts: urban, semi-urban and MHNP. A total of 44 water samples were taken (19 in urban, 16 in semi-urban and 9 in MHNP) for pre-monsoon, monsoon and

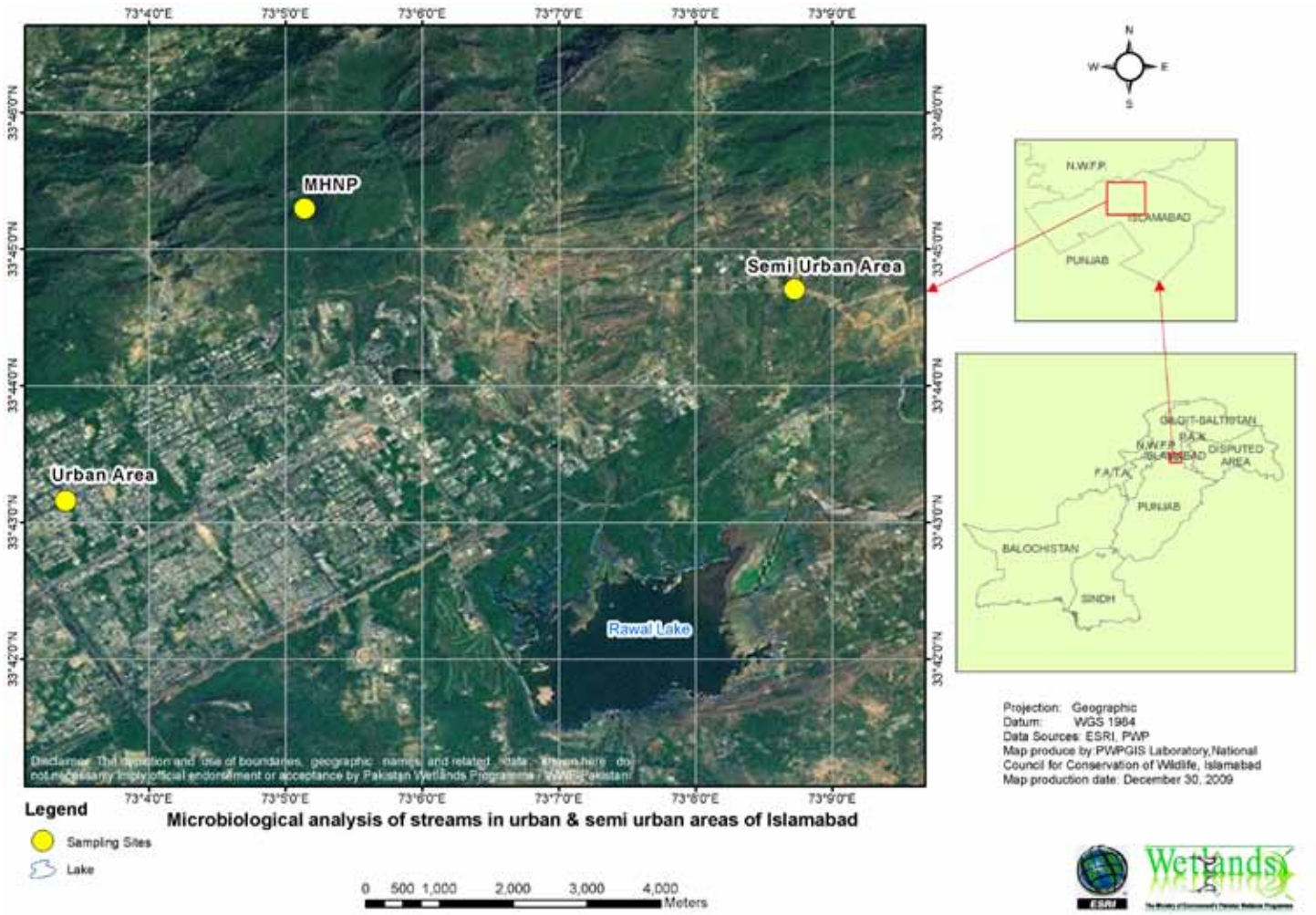

Figure 1: Study area showing the three sampling locations (Urban, Semi-urban and MHNP)

post-monsoon. Samples were collected from streams near bridge downstream in urban and semi-urban areas, while in MHNP no bridge was present hence no landmark was taken. The collected samples were analysed for *total coliforms, faecal coliforms and Escherichia coli* following Clesceri *et al*., (1998).

Water Sample Collection

Samples were collected in 2009 during base flow conditions (Lewis *et al*., 2007). All samples were collected in 100 ml sterilised plastic bottles and a space of at least 2.5 cm was left in the bottle to facilitate mixing by shaking (Hill *et al*., 2006).

Bacterial analysis

In order to ensure the quality, ten replicate tubes each containing 10 ml aliquot were used. Sample was poured in lactose broth and was incubated at 37°C for 48 hours. The production of gas in tubes showed positive results for the presence of bacteria. The Eosin Methylene Blue (EMB) endo agar plates were streak by using positive broth from presumptive test and were incubated for 24 hours at 37°C. Dark centres with green metallic shine on EMB and dark pink colour on endo agar plates are positive confirm phase. The presence was confirmed by using these positive and incubated on one lactose and one nutrient agar slant and these tubes were incubated for 24 hours at 37°C. Slides prepared from positive incubates were examined under microscope presence of gram-negative, short bacilli confirmed the presence of *E. coli*.

Data Analysis

Prior to performing the statistical analysis, the normality of the raw data was checked. Highly skewed raw data set was not normally distributed and required transformation. Due to high variation within data, it was not possible to transform the data through any test so non-parametric statistical tests were adopted for data analysis. Statistical analyses were performed using Minitab (ver. 11.12), Minitab Inc. Kruskal-Wallis test with alpha 0.05 was used to find out the difference between the groups (Rivero-Marcotegui *et al*., 1998; Rubel & Wisnivesky, 2005).

Results and discussion

Bacterial Density

The result of total *coliform*s, faecal *coliform*s and *E. coli* in surface water of study area for all three seasons are shown in (Table 1).

In urban area, the highest density of water samples with higher TC and FC count was observed during monsoon season. This high concentration may be attributed to high rainfall instances during monsoon as was proved by Hill *et al*., (2006) and WHO, (2003). As a result of these rains, the runoff from lawn, agricultural fields and over flowing of municipal waste increase phosphates and nitrates concentration in water bodies (Liu *et al*., 2000; Filoso *et al*., 2004; Williams *et al*., 2004 & 2005) which enhances bacterial growth (Mallin *et al*., 2000; Lewis *et al*., 2007). These nutrients also increased the water temperature, the critical parameter which is positively related with bacterial growth (Farooq *et al*., 2008).

Higher bacterial densities were present in semi-urban areas during all three seasons. *E. coli* were present at all, six and nine sampling sites during pre-monsoon, monsoon and post-monsoon respectively. In semi-urban areas, many gutter lines along with municipal waste directly open in streams. *Coliform*s abundances can be high possibly due to leaking or overflowing sanitary

sewers (Duda *et al*., 1982; Rose, 2006). Run-off from agriculture and grazing land is another important source of faecal pollution to surface water (Thiagarajan *et al*., 2007) in semi-urban areas. In MHNP, faecal contamination was observed during monsoon season only two sites were characterised by the presence of *E. coli*. This faecal contamination in MHNP during monsoon may be attributed to surface runoff from adjoining lands (Lewis *et al*., 2007) and source of this contamination may be the wildlife.

Temporal Variation

The results of Kruskal Wallis Test ($H_{2,57}$ = 13.62, p<0.001) illustrated that there is variation in TC concentration for all three seasons in urban area which is further explored that this variation is due to pre-monsoon p<0.0015 and monsoon, post-monsoon were similar p<1. Results showed that higher accumulation has taken place during monsoon and post-monsoon seasons. Such high concentrations can be attributed to high density of storm drains that promote the rapid flushing of bacteria (Wallberg & Johnstone, 1995) from lawns, roads and other surfaces into streams (Frenzel & Couvillion, 2002). The FC accumulation in urban areas has high variation (Kruskal-Wallis Test, $H_{2,57}$ = 25.32, p<0.000) during three consecutive seasons. All three seasons were significantly different (pre-monsoon and monsoon p<0.000, pre-monsoon and post-monsoon p<0.0003, monsoon and post-monsoon p<0.003)

Table 1: Concentration of faecal bacteria (TC=Total *coliform*s, FC=Faecal *coliform*s expressed in MPN/100ml and *E. coli* as presence/absence) for U=urban, S=semi-urban and N=Natural sites during Pre-monsoon, Monsoon and Post-monsoon seasons in natural streams of Islamabad.

Sample #	Pre-Monsoon			Monsoon			Post-Monsoon		
	TC	FC	E-Coli	TC	FC	E-Coli	TC	FC	E-Coli
U01	220	130	+ve	≥1600	≥1600	+ve	≥1600	350	+ve
U02	170	130	+ve	-	-	-	≥1600	≥1600	+ve
U03	130	27	+ve	≥1600	≥1600	-ve	≥1600	280	+ve
U04	8	8	+ve	≥1600	≥1600	-ve	≥1600	280	+ve
U05	Nil	Nil	-ve	≥1600	≥1600	+ve	≥1600	220	-ve
U06	Nil	Nil	-ve	≥1600	≥1600	-ve	≥1600	350	-ve
U07	≥1600	34	+ve	≥1600	≥1600	+ve	-	-	-
U08	≥1600	220	+ve	≥1600	≥1600	-ve	≥1600	280	+ve
U09	≥1600	33	+ve	≥1600	350	+ve	≥1600	220	+ve
U10	≥1600	17	+ve	≥1600	1600	+ve	≥1600	220	-ve
U11	≥1600	9	+ve	≥1600	34	-ve	≥1600	280	+ve
U12	50	9	+ve	≥1600	500	-ve	≥1600	280	+ve
U13	-	-	-	≥1600	34	-ve	≥1600	280	+ve
U14	34	27	+ve	≥1600	≥1600	-ve	≥1600	34	-ve
U15	280	34	+ve	≥1600	350	+ve	≥1600	33	+ve
U16	900	34	+ve	≥1600	1600	+ve	≥1600	34	-ve
U17	1600	34	+ve	≥1600	34	-ve	≥1600	350	-ve
U18	33	33	+ve	≥1600	500	-ve	≥1600	34	-ve
U19	350	350	+ve	≥1600	≥1600	-ve	1600	350	-ve
S20	≥1600	26	+tive	≥1600	220	-ve	≥1600	34	+ve
S21	≥1600	≥1600	+ve	≥1600	34	-ve	≥1600	170	+ve
S22	1600	34	+ve	-	-	-	1600	34	-ve
S23	≥1600	≥1600	+ve	≥1600	350	+ve	≥1600	33	-ve
S24	≥1600	≥1600	+ve	≥1600	280	+ve	≥1600	280	+ve
S25	110	70	+ve	≥1600	900	+ve	≥1600	220	-ve
S26	900	280	+ve	≥1600	350	+ve	≥1600	130	+ve
S27	1600	1600	+ve	≥1600	26	-ve	≥1600	350	-ve
S28	1600	1600	+ve	≥1600	22	-ve	500	33	-ve
S29	500	500	+ve	280	34	-ve	≥1600	280	+ve
S30	≥1600	≥1600	+ve	≥1600	33	-ve	≥1600	33	-ve
S31	240	240	+ve	1600	350	-ve	≥1600	350	+ve
S32	-	-	-	≥1600	34	-ve	300	130	+ve
S33	-	-	-	≥1600	33	+ve	≥1600	70	+ve
S34	-	-	-	80	27	-ve	500	34	+ve
S35	-	-	-	≥1600	≥1600	+ve	Nil	Nil	-ve
N36	26	Nil	-ve	600	35	-ve	80	22	-ve
N37	9	Nil	-ve	530	60	-ve	-	-	-
N38	14	Nil	-ve	170	13	-ve	900	Nil	-ve
N39	-	-	-	300	17	+ve	-	-	-
N40	-	-	-	100	23	-ve	-	-	-
N41	-	-	-	900	27	+ve	-	-	-
N42	-	-	-	350	30	-ve	-	-	-
N43	-	-	-	160	25	-ve	-	-	-
N44	-	-	-	500	220	-ve	-	-	-

for FC accumulation. Comparatively, low FC concentration during monsoon and post-monsoon may be the result of flooding in these streams, which has washed down the faecal contamination. In semi-urban areas, no significant difference (Kruskal-Wallis Test, $H_{2,44} = 0.23$, $p<0.892$) was observed for TC during all three seasons. On the other hand, FC accumulation varied significantly (Kruskal-Wallis Test, $H_{2,44} = 7.73$, $p<0.021$). The pair-wise comparison showed that pre-monsoon season representing the higher FC concentration is different from rest of two seasons (pre-monsoon and monsoon $p<0.0203$, pre-monsoon and post-monsoon $p<0.0114$, monsoon and post-monsoon $p<0.969$). In MHNP, maximum TC observed during monsoon and FC was present only in monsoon season.

Spatial Variation

Kruskal Wallis Test performed on TC for all sites and all seasons showed significant variation ($H_{2,115} = 16.38$ $p<0.000$) and pair-wise comparison showed variation as MHNP while the other two sites are same (urban and semi-urban $p< 0.729$, urban and MHNP $p<0.0004$, semi-urban and MHNP $p<0.0000$). High concentration of TC in urban and semi-urban areas compared to MHNP may be due to land cover. Similar results showing high concentration of faecal bacteria in urban than rural sites have been found in earlier studies (Lewis *et al*., 2007; Frenzel & Couvillion, 2002). Mallin *et al*., (2000) found that faecal *coliform*s abundance correlated positively with human population density, percentage of developed land, and percentage of impervious surface. Faecal *coliforms* density observed in three sites varied significantly (Kruskal-Wallis Test, $H_{2,111} = 8.36$ $p< 0.015$) representing that MHNP is different from rest of two sites (urban and semi-urban p< 0.834, urban and MHNP p<0.011, semi-urban and MHNP 0.0025). The highest FC accumulation taken place in semi-urban areas may not be only due to human waste; the phenomena may be attributed to domestic and wild animals (Mallin *et al*., 2000; WHO, 2003; Rose, 2006). The poultry related activities in catchment areas of Korang River, cattle rearing, and grazing sites may be important sources of faecal bacteria to streams of this area (Fernandez-Alvarez *et al.,* 1991).

Presence absence of *E. coli*

The presence absence data of *E. coli* in all three sites with seasonal variation is shown in Figure 2. It shows that highest number (62.7%) of *E. coli* presence was observed in semi-urban area followed by urban area (61.1%) and least was in MHNP (14.2%). These results are not in accordance with the standards and indicate the presence of faecal pollution in water system.

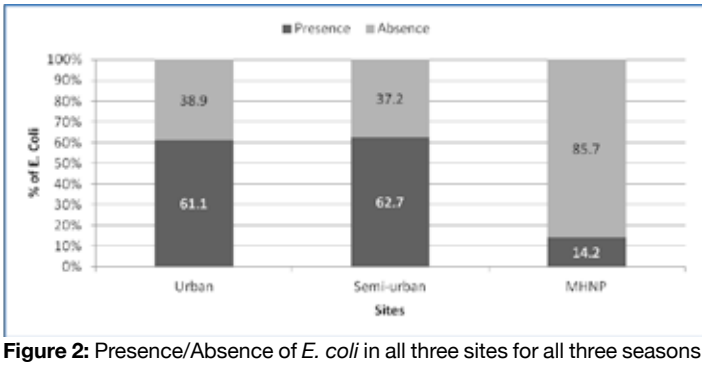

Figure 2: Presence/Absence of *E. coli* in all three sites for all three seasons

Water Quality and Health

Water quality of these natural streams is very important as these streams feed Rawal Dam, the water of which after purification is supplied to residents of Rawalpindi for drinking. However, some previous studies have detected faecal *coliforms* and other bacteria in drinking water of Rawalpindi and Islamabad (Tahir, 1989; Din *et al*., 1997; Farooq *et al*., 2008). Such situations are disappointing because the presence of faecal and other pathogenic bacteria in drinking water are causing many diseases (Agboatwallah, 2002) in the habitants of twin cities. Faecal contamination of water results in enteric infection, which may be viral, bacterial, or parasitic. The water consumed by resident of Islamabad and Rawalpindi may potentially cause such diseases. A study conducted by UNICEF (Pak-SECA, 2006) found that 20-40% of the hospital beds in Pakistan are occupied by patients suffering from water related diseases.

Conclusion

The study demonstrated that faecal pollution in natural streams of Islamabad has intensified due to lack of proper municipal waste facilities particularly in semi-urban areas. It is concluded that in semi-urban areas that faecal contamination is very high and demands dare need for remediation. The surface run-off, increased concentration of nutrients and municipal waste in urban areas are major contributing sources for higher bacterial densities. It has become clear that there are two main sources of faecal contamination i.e. natural and anthropogenic. High level of faecal pollution renders water unfit for human use prior to proper treatment. There may be the chance of presence of pathogens along with these indicator bacteria in the drinking water, which poses many diseases.

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Exploring illegal trade in freshwater turtles of Pakistan

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K E Y W O R D S

Freshwater turtles
Body parts
Illegal wildlife trade
Consumer market
Routes
Trade
Consignments
Pakistan

A B S T R A C T

The order *Chelonia* is represented by eight species of river turtles in Pakistan (excluding marine turtles and land tortoises). The survival of softshell turtle species however, is at stake due to their unsustainable catch from potential habitats for trade in their body parts. A well organised turtle trade started in Pakistan in 2002. Turtles and their body parts collected from the wild are transported to wildlife dealers in Peshawar (Khyber Pakhtunkhwa), Lahore (Punjab) and Karachi (Sindh). These cities have International exits and therefore preferred by the wildlife traffickers for export of turtle consignments. The known turtle part importing countries include China and its special administrative region Hong Kong, Vietnam and Korea. Turtle trade is not limited to desired body parts of softshell species only but hatchlings of hard shell turtles are also collected for pet trade in Sindh. The market value of turtle parts vary with respect to area. The minimum price of turtle parts is Pak Rs. 167.0 per kilogram (mean value) was observed in Khyber Pakhtunkhwa whereas the maximum price of Pak Rs. 2,663 per kilogram was recorded in Sindh. Controlling illegal trade in turtle parts is highly essential for likely survival of these species in general and softshell turtles in particular. It demands a holistic and participatory approach at community, national and international levels.

Introduction

Pakistan hosts eight species of freshwater turtles, inhabiting the Indus River, its various tributaries and smaller streams in its drainage system. These include: *Chitra indica* (EN[1]; Appendix II[2]), *Nilssonia gangetica* (VU; Appendix I), *Nilssonia hurum* (VU; Appendix I), *Lissemys punctata andersonii* (LR/LC; Appendix II), *Pangshura tecta* (LR/LC; Appendix I), *Pangshura smithii* (LR/NT; Appendix II), *Hardella thurjii* (VU) and *Geoclemys hamiltonii* (VU; Appendix I). River turtles are keystone species of aquatic habitats and are important scavengers of freshwater ecosystems, which is essential to health of freshwater bodies. They also predate on insects, snails, fish and other aquatic invertebrates. Turtles contribute to maintaining integrity of freshwater ecosystems.

Freshwater turtle populations do not cope well with targeted exploitation of their adult animals. Their life history describes that turtles species are long lived animals, also known as living fossils. A relatively smaller annual recruitment, very high percentages of hatchlings and juveniles falling prey to predators, longer incubation periods and delayed sexual maturity are the characteristics of freshwater turtles (Congdon *et al*., 1993, 1994). Depletion due to commercial harvest of adults may lead to decline of wild population of these species (Brooks *et al*., 1991).

Turtle species, both in marine and freshwaters of the world are confronting serious threats to survival in their wild habitats due to the pessimistic environmental changes. Turtles are exploited primarily for use as food and in traditional medicines in China. Trade in tortoises and freshwater turtles is a worldwide phenomenon (Georges *et al*., 2006; O'Brien *et al*., 2003; Vargas-Ramirez *et al*., 2007). Commercial trade in river turtles is intense in Asia, particularly in countries representing well established regional, national and international export markets. Among the Asian countries, Vietnam and Bangladesh were the major suppliers in the beginning but after depleting their native resources, the harvesting pressure shifted to the adjoining countries including India, Myanmar, Laos, Cambodia and Indonesia (Moll and Moll, 2004). The major problem with existing wild populations of turtles in the country is caused by illegal commercial trade in body parts of softshell species. Other threats to freshwater turtles in Pakistan encompass habitat deterioration and fragmentation due to unsustainable development; scarcity of water in rivers, canals and water diversion and extraction projects for irrigation purpose and water pollution. Turtles are perceived to be deleterious to fish economy by the fisherfolk due to lack of understanding and awareness regarding their ecological role in river ecosystems. Turtles are also accidentally caught as by catch of fish during fishing practices.

In Pakistan, freshwater turtle trade was first highlighted in 1990s. An investigative study by WWF - Pakistan and the Sindh Wildlife Department for TRAFFIC International in 1996, reported turtle trade in Sindh Province. The Indian softshell turtles were exported to China that cost Pak Rs. 50 per turtle (Shah, 1996).

Illegal turtle trade, particularly in body parts of softshell species was reported by Baig (2006), during his research studies on "Environmental Baseline Survey and Monitoring of Taunsa Barrage Emergency Rehabilitation Project". The trade network, market value of turtle body parts and the affected turtle species were stated in detail. Body parts of *Chitra indica* and *Nilssonia gangetica* were found with nomads residing nearby Taunsa Barrage. The catch was over two hundred turtles in a week and dried parts were sold to middlemen of Karachi and Lahore at the rate of Pak Rs. 100 – 200/kg (Baig, 2006). Baig (2006) also reported a truck load of turtles got emptied near *Sust*; a customs check-post between Pakistan and China for trading goods between the two countries, during a survey. The reason was improper transportation of these species in a container that resulted in their death before reaching the destination. This incident confirmed illegal export of turtles from Pakistan to China (Umeed Khalid Pers. Comm.).

[1]Conservation Status of IUCN Red List: Endangered (EN); Vulnerable (VU); Lower Risk (LR); Least Concern (LC); Not Threatened (NT)

[2]CITES Appendices:
Appendix I (lists species that are threatened with extinction and are or may be affected by trade. Commercial trade in wild-caught specimens of these species is illegal (permitted only in exceptional licensed circumstances);
Appendix II (lists species that are not necessarily threatened with extinction, but may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with the survival of the species in the wild);
Appendix III (species that are listed after one member country has asked other CITES Parties for assistance in controlling trade in a species. The species are not necessarily threatened with extinction globally).

The Pakistan Wetlands Programme (PWP) conducted baseline studies to explore illegal trade in freshwater turtles and their body parts and investigated other threats to these important wetland inhabitants. The enquiries included investigation of freshwater turtle trade routes, assessment of their market values, identification of local communities involved in trade and exploring the marketing networks. This paper is brief compilation of PWP study of the above aspects of freshwater turtles along the Indus River ecosystem.

Material and Methods

Study Area

The Indus River System is a core habitat of freshwater turtles in Pakistan. The study area comprised of Indus River and its main tributaries in three provinces; Khyber Pakhtunkhwa, Punjab and Sindh. Priority was given to the areas where fish markets existed and traces of involvement of fishermen and nomadic communities in freshwater turtles killing and trade were found. Pet markets in Sindh Province were also the focus of interest. Fig. 1 shows survey sites of the study area in the three provinces.

Khyber Pakhtunkhwa Province

The survey sites consisted of the Indus River in *Dera Ismail Khan*; a city in Khyber Pakhtunkhwa Province connecting it to Punjab Province. The town is situated on the right bank of Indus River and is one of the potential sites for freshwater turtles. The investigative study was conducted in April 2007.

Punjab Province

Rivers of Punjab feeding the Indus River including Chenab, Jehlum, Ravi and Sutlej are the likely habitats of freshwater turtles and hence visited to investigate trade in freshwater turtles. The study was focused at nine different barrages and head works constructed on these rivers to regulate water for irrigation purposes. The area along river banks, both upstream and downstream of selected barrages and head works was covered. The detailed assessment of major head works of Punjab was undertaken in October 2007.

Sindh Province

The study area in Sindh Province comprised of the stretch of the Indus River, its major canals and tributaries and natural reservoirs. Kotri, Sukkur and Guddu barrages of the Indus River were considered important study sites. The wetlands of Sindh Province were explored for trade in freshwater turtles in September 2008.

Survey methods

For the investigation of turtle trade, an open ended questionnaire was developed to collect maximum information from the targeted local communities. A species identification card was used to support the questionnaire. The geographical coordinates of the study sites were recorded by using Global Positioning System (GPS) Receiver.

Results

Freshwater turtle poachers preferentially collect *Chitra indica*, *Nilssonia gangetica* and *Nilssonia hurum* from all over the country. These softshell *Chelonians* are harvested for their body parts;

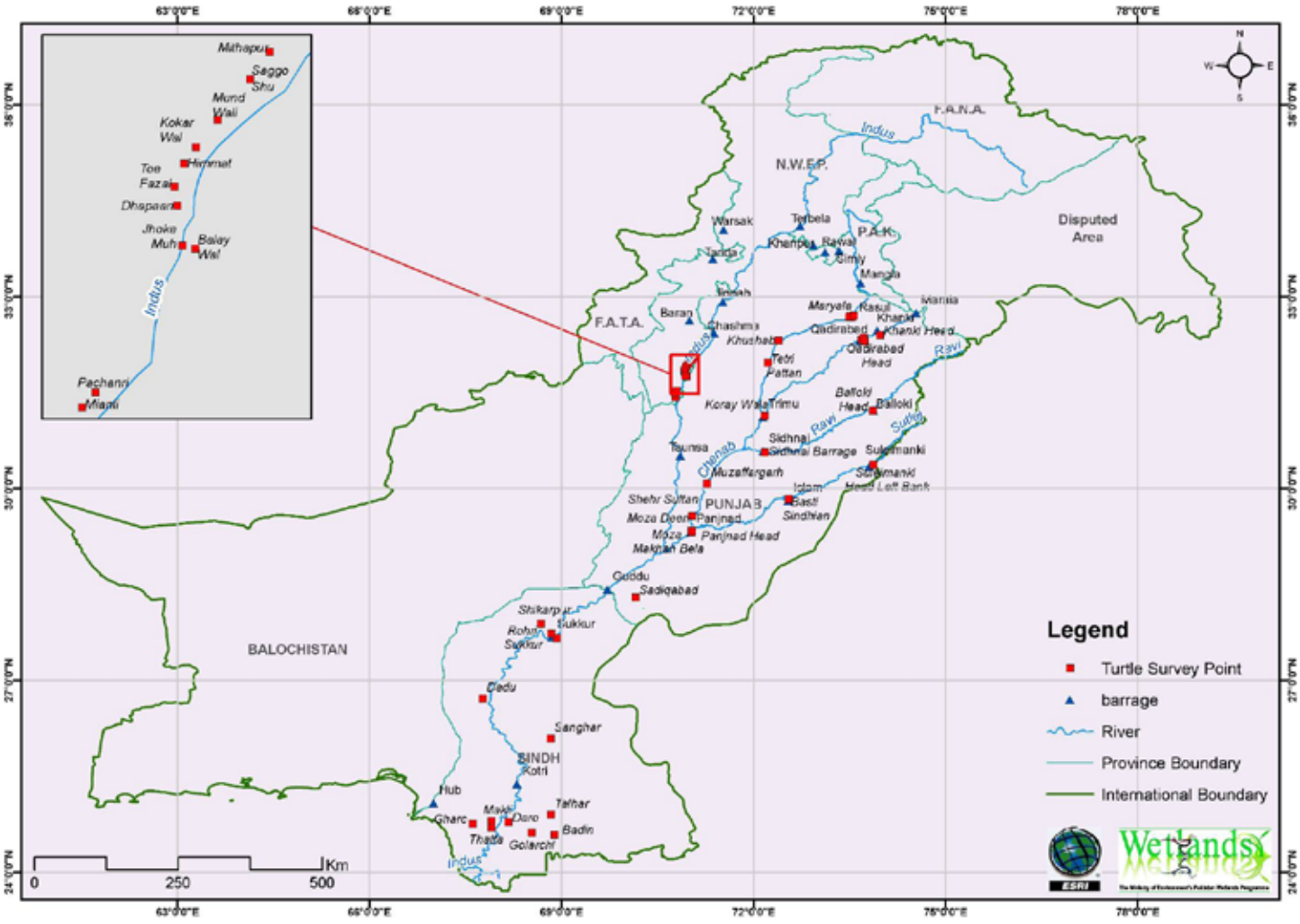

Figure 1: Study area: points showing survey sites based on the geographical coordinates

calipee and *chest pellicle*. The season for poaching is not defined but poachers prefer winters and spring when water level is low in the rivers and canals and spearing of freshwater turtles is easy. The capturing techniques vary significantly depending on the expertise of poachers and the gears available to them. Generally, spear rod, hook lines and nets are used to catch freshwater turtles. Softshell turtle species are carnivorous scavenging reptilians and therefore are easily hunted by using poisonous bait.

After capturing, turtles are processed either at the same spot or transported to a nearby processing locality; a rented house in most cases. Desired turtle parts are chopped and boiled in water with mustard powder to avoid foul smell and insect attacks, which are finally dried in open air. Turtle meat is stored in freezers to keep it fresh. Alive turtles are kept in earthen water tanks particularly constructed for turtles.

Freshwater turtles and their body parts are transported mostly by local transport during night times. Dealers have developed good terms with transporters that carry their consignment to the said destinations. Some dealers use their own vehicles for transportation of turtle consignments. Turtle hatchlings are packed in jeans bags that are kept moist so that turtles survive the long journeys. Wooden boxes and cages fitted with thermopole sheets are also used to transport alive turtles. Dried parts are carried in cartons and jute bags. Consignments are also transported by train to destined cities.

Wildlife trade dependent local communities

Nomadic communities "*Kehal* or *Mohanas*" reside along the Indus River and its tributaries as they are highly dependent on fish and natural resources of the Indus River for their subsistence livelihood. The wildlife poachers of these communities not only capture turtles but also other reptiles and mammals that they encounter during hunting. These include: snakes, monitor lizard, hedgehogs, jackals, jungle cats and otters. The tribes that were found involved in turtle trade are *Kehals* and *Mohana* (in Khyber Pakhtunkhwa Province); *Jabhel, Pakhiwal* and *Mohana* (in Punjab Province) and *Shikari, Rawara, Barha, Gurgula, Gogra, Jogi, Guruwanro*, *Bhaagri, Mallah* and *Mir Behar* (in Sindh Province). In addition, the opportunistic people from different areas of the country also collect freshwater turtles for commercial trade. A few nomadic communities consume turtle meat and eggs in Khyber Pakhtunkhwa and Sindh.

History of trade in freshwater turtles in Pakistan

According to information, the depleted fish population in the Indus River triggered trade in freshwater turtles, when it started in 2000. In Khyber Pakhtunkhwa, commercial exploitation of turtles for their body parts was introduced in the year 2006. In Punjab Province, turtle trade commenced in 2002 whereas in Sindh, it started in 2003.

Commercial value of turtles in local and national markets

Three distinct markets including local, national and international were observed for trade in freshwater turtles and their body parts. The values of freshwater turtle parts vary with markets and area. Local contractors set the rates of freshwater turtles and their body parts which are highly flexible. Comparison of rates in three provinces is given in Table 1, whereas, Figures 2, 3 and 4 show the value of turtle parts in local markets of Khyber Pakhtunkhwa, Punjab and Sindh provinces respectively.

The dried *calipee* and *chest pellicles* are sold in major cities; Lahore, Karachi and Peshawar. The value of freshwater turtles parts in national markets range between Pak Rs. 2,500 and 4,500 per kilogram. Turtle eggs are sold in Pak Rs. 5 - 10 per egg. Hard shell species of turtles are also in demand as pet, the cost of which ranges between Pak Rs. 400 and 500 per specimen, depending on the species. Wild caught hatchlings of hard shell species (*Pangshura smithii*) cost Pak Rs. 50 per turtle.

Trade routes

Wildlife dealers of large cities approach local poachers for illicit harvest of freshwater turtles. Processed body parts of wild caught river turtles are transported from local markets in small towns to national markets in large cities. Illegal trade in freshwater turtles in Khyber Pakhtunkhwa has been initiated by the wildlife traders from Lahore. The consignments collected locally are transported to provincial capital Peshawar and finally to Lahore for export. In Punjab, turtle parts gathered from potential sites are sent to Lahore whereas in Sindh, Karachi is the main hub for export of freshwater turtles and their body parts.

China, Hong Kong, Korea and Vietnam are found to be the illicit importers of turtles and their parts from Pakistan. Turtle parts from Pakistan are also exported to Iran due to a long and porous border between the two countries. China being prime consumer, majority of turtle consignments are exported to the country. Fig. 5 shows the international trade routes for turtle trade.

Discussion

The PWP's field surveys and subsequent specific investigations (2007-2008) regarding exploitation of freshwater turtles for their body parts exposed a highly organised turtle trade. The wildlife traders' network operates at all levels; local, national and international, making trade in freshwater turtles a lucrative business for impoverished nomadic riverine communities. These communities are dependent on riverine natural resources for their subsistence. Their only source of income generates by producing baskets, mats, brooms and other handicrafts from available vegetation along the river banks. These products however, have very low market value. These people cannot take part in fishing activities without being registered as commercial fishermen by fish contractors of the area. In these conditions, capturing turtles is the sole option left for them to earn money for their better living.

The local markets of freshwater turtle trade indicate high monetary values with well established networks. The newly established local markets, however, show comparatively lower prices. The principal consumer of turtles and their body parts is China where turtle meat is preferred for its delicacy and turtle parts are used in Traditional Chinese Medicines (TCM). Three fourth of Asia's 90 freshwater turtles and tortoises are seriously threatened and 18 of them are endangered (Takehisa and Shun'ichi, 2006). Freshwater turtle parts are speculated to have high medicinal importance. The countries with large Chinese populations (e.g. Taiwan, Singapore) and other oriental countries with a tradition of turtle use for food and medicines (e.g. Japan and South Korea) are also large importers (Moll and Moll, 2004).

Pakistan is signatory to the Convention on International Trade in Endangered Species of Fauna and Flora (CITES). The government of Pakistan approved the Federal CITES Law in May

Table 1: Comparison of market value of turtle parts in provinces

Provinces	Mean Value	StDev	CoefVar	Minimum Value	Median	Maximum Value
Khyber Pakhtunkhwa	167.0	79.7	47.74	50.0	165.0	300.0
Punjab	566.7	75.0	13.24	500.0	550.0	700.0
Sindh	2,663.0	1,113.0	41.82	800.0	2,750	45,000.0

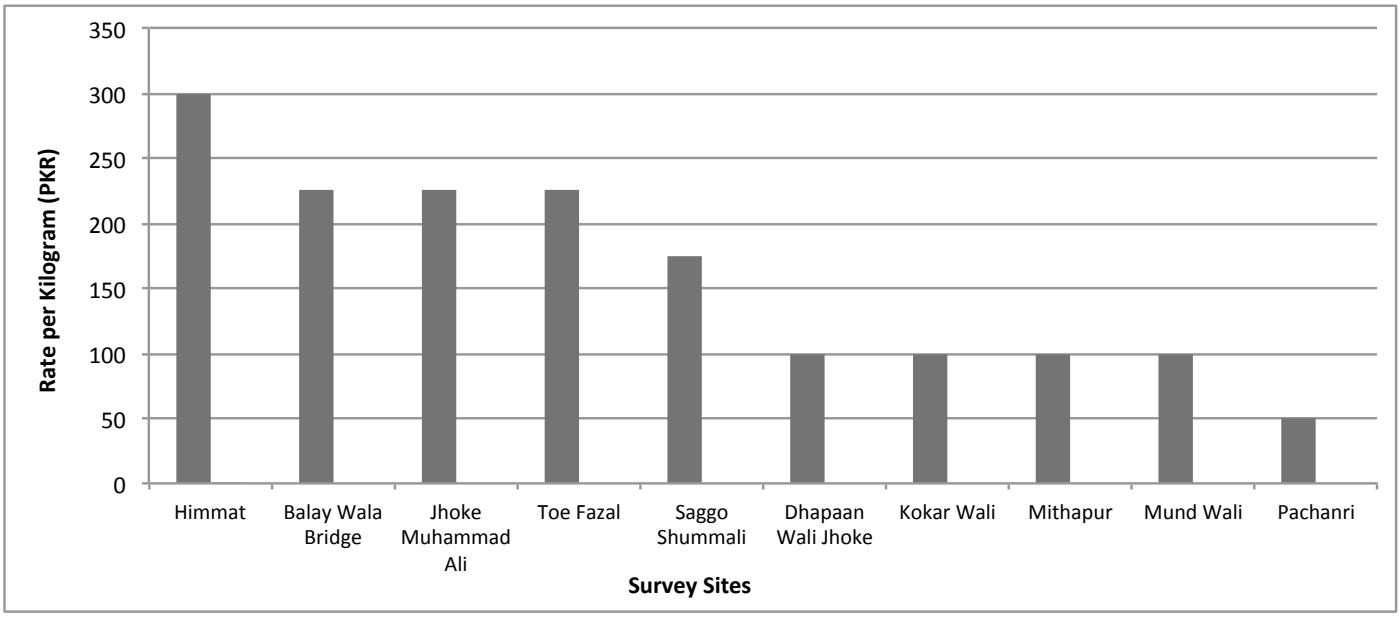

Figure 2: Rate of turtle parts (in Kilogram) in ten different survey sites located in Khyber Pakhtunkhwa

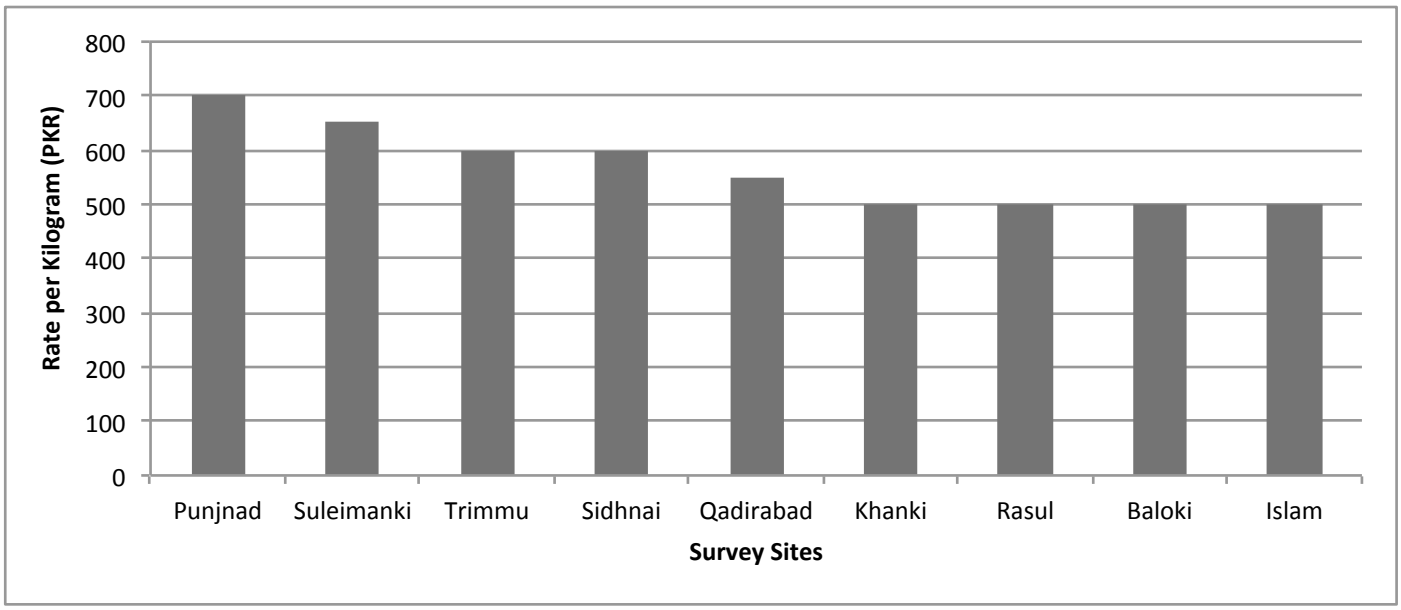

Figure 3: Rate of turtle parts (in Kilogram) in nine different barrages and head works located in Punjab

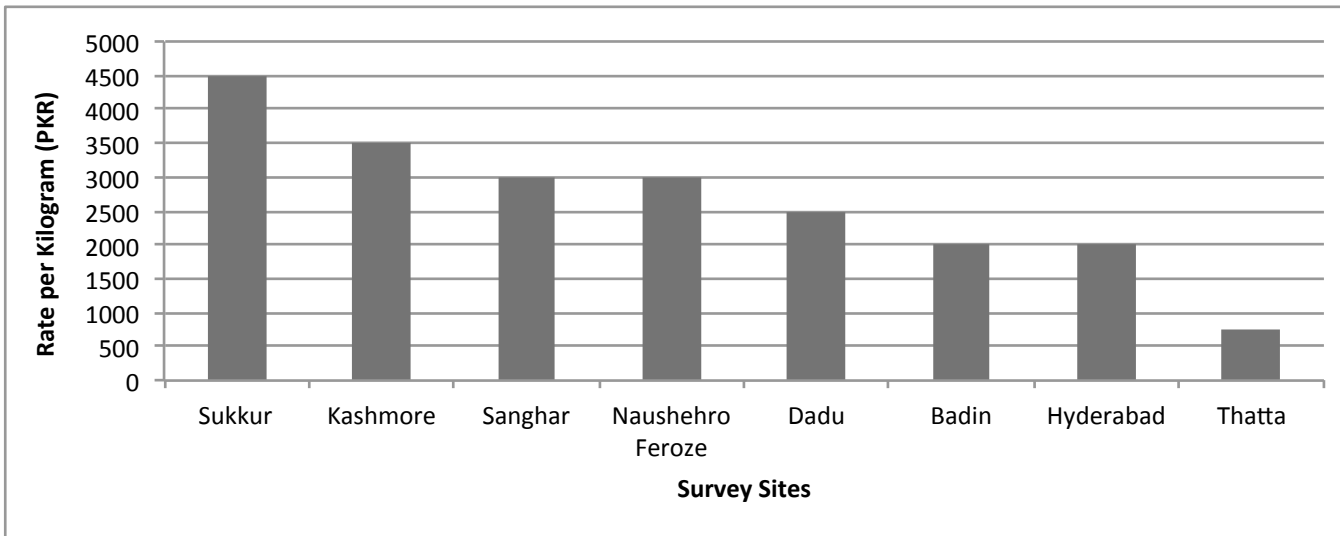

Figure 4: Rate of turtle parts (in Kilogram) in eight different survey sites located in Sindh

Figure 5: International routes of turtle trade showing importer and consumer counties of freshwater turtles.

2012, for effective enforcement of CITES legislations in Pakistan. Wildlife being a provincial subject, Khyber Pakhtunkhwa Wildlife Department and Punjab Wildlife and Parks Department revised the conservation status of freshwater turtles in 2007. In Sindh, these species are still not listed in the protected category in wildlife legislation. The confiscation of turtle parts by customs and wildlife authorities at the international airports further confirmed the study results. A huge shipment of 3,650 kg of frozen turtles, bound to Vietnam was held at sea port Karachi in 2005. The customs and wildlife authorities detained 700 kg of dried turtle parts at Jinnah International Airport, Karachi in 2007. The consignment was destined to China. According to wildlife offence records, the provincial wildlife authorities confiscated about 300 kg of dried turtle parts in Peshawar in 2007. Another seizure of 300 kg of turtle parts was made successfully by the wildlife protection authorities in Lahore in 2008.

Customs Department at the international exits, if trained and experienced can significantly contribute in controlling illegal wildlife trade. In this regard, the PWP organised a training workshop for the wildlife and customs staff to build their capacity not only in identification of wildlife and their derivatives but also shared with them national laws and international conventions for their information and awareness. The purpose of organising this event was to create awareness among the relevant government staff about recent trends in wildlife trade; identification of affected species, their body parts and other derivatives; and the potential mean and routes of transportation. The PWP drew attention of international and national media to the matter of turtle trade in Pakistan by involving electronic and print media. The international turtle conservation community invited the PWP representatives to share and discuss the plight of turtle trade at various international forums. The PWP's mass awareness campaigns through events and dissemination of awareness material positively enhanced awareness level among line departments, general public and rural stakeholder communities.

Conclusion and Recommendations

Unsustainable commercial exploitation of freshwater turtles is a serious threat to turtle survival and is completely banned for species on CITES Appendices I and II. The provincial wildlife legislations should be revised in conformity with the international commitments of the country under the CITES and the Convention on Biological Diversity (CBD). Effective implementation of wildlife legislation and inter-departmental coordination is required to curb the illegal trade in freshwater turtles and their body parts. The enforcement of the Federal CITES Law will significantly aid in preventing illegal trade in endangered wildlife species including turtles. It will considerably improve the regulation of wildlife trade to and from Pakistan. It is essential to appraise freshwater turtles trade at international level through CITES, IUCN Turtles and Tortoises Specialist Group, TRAFFIC International and other concerned organisations. Target groups need to be addressed through community based-conservation initiatives. Alternative livelihood opportunities and education and awareness programmes can help protect freshwater turtles from unsustainable harvesting. It is of vital importance to investigate turtle trade continuously as traders and poachers keep on altering their means of wildlife exploitation. There is a need for more stringent measures to curb the illegal trade and promote conservation of freshwater turtles at large.

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Estimating Hog deer *Axis porcinus* population in the riverine forest of Taunsa Barrage Wildlife Sanctuary, Punjab, Pakistan

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K E Y W O R D S

Hog deer
Population estimation
Distribution
Riverine forest *Bela*
Habitat loss
Anthropogenic pressures
Taunsa Barrage Wildlife Sanctuary

A B S T R A C T

The current study aimed at estimating the existing population status of hog deer in the Bela (riverine) forest of Taunsa Barrage Wildlife Sanctuary. The study area was divided into blocks where random line transects were laid to collect population data and to identify potential habitat of hog deer. In Bela forest, the habitat of hog deer comprises of a blend of Tamarix species with grass cover and scattered growth of Acacia, open grassy areas and water ponds. The results revealed that the estimated population of hog deer in the Taunsa Barrage Wildlife Sanctuary is 115. The core habitat, represented by Block 1 is the suitable habitat with a population of about 30 animals. The field investigation suggested that existing hog deer population is not evenly distributed throughout its historic range in Bela forest due to patchiness of its preferred habitat in the region and hence it is restricted only to Block 1. This study concludes that hog deer population is absent in areas of dense human population and agricultural areas whereas removal and cutting of grasslands inside protected area has resulted in fragmentation of population of this species. Considering the anthropogenic pressures and the natural processes, the long term viability of this small population of hog deer seems uncertain in this area. There is a need to carefully manage the hog deer population and require scientific management and immediate conservation measures.

Introduction

Hog deer (*Axis porcinus*) belongs to the family *Cervidae.* The habitat of hog deer consists of moist grasslands associated with rivers (Biswas and Mathur, 2000). It is known to have reached to highest densities in floodplain grasslands (Odden *et al*., 2005). Some reports revealed that hog deer avoids closed-canopy forest while it prefers to live in coastal grasslands (Peacock, 1933). Some conservationists regard hog deer to be an obligate grassland species in the *Terai* Arc-Landscape region of India. Studies in India and Nepal have further shown a preference for grasslands dominated by blady grass *(Imperata cylindrica)* (Biswas, 2004). In Thailand and Indo-china, alluvial floodplain grassland seems to be potential habitats to host hog deer (Maxwell *et al*., 2007). Based on the available literature, Bardia National Park population of hog deer is much higher in floodplain in comparison to the riverine regions (Odden *et al.,* 2005). The existing population of hog deer in Bangladesh is located in grassy, lightly wooded and hilly areas (Khan, 2004). Extensive tall floodplain grasslands in the Dong-Nai catchments, Vietnam are historically known for hosting high population of hog deer.

Hog deer generally grazes on young grasses, herbs, flowers and fruits and usually browse on young leaves and shoots of shrubs and particularly on *Imperata cylindrica and Saccharum spp.* (Dhungel and Ogara, 1991). It is thought to be more a grazer than a browser in Sambar (*Rusa unicolor*) region. Introduced species of hog deer in Sri Lanka, on the other hand, occurs mainly in scrub and cinnamon gardens causing significant damage to home crops (McCarthy and Dissanayake, 1992). In areas of no anthropogenic pressure and undisturbed ecosystems, hog deer apt to be crepuscular with major day-time activity and several at night, particularly in the hot and wet seasons (Dhungel and Ogara, 1991). Depending on the regions and environments, it tends to become more nocturnal and solitary due to hunting pressure. The main social group is of female and fawns; when few hog deer are together, they do not form a unit fleeing when flushed in different orders rather than as one. In Chitwan, hog deer are essentially sedentary (Dhungel and Ogara, 1991), while in cultivated landscapes like Sri Lanka, their activities are traced to be predisposed by agricultural seasons (McCarthy and Dissanayake, 1992). Based on the different seasons and environments they move into grasslands (higher-lying) in reaction to monsoon flooding in India, Myanmar and apparently all over their range (Peacock, 1933). It is evident that the rut is during September to October in Nepal and India and most probably based on captives, during September to February in China. The literature further elaborates that one to two fawns are born during April to May in Nepal and during April to October in China. The gestation period of hog deer ranges from 220 to 230 days (Dhungel and Ogara, 1991). The fawns wean at 6 months while reaching sexual maturity at 8 to12 months. The highest recorded life span of hog deer is 20 years.

Population status in Pakistan

Literature divulges that hog deer are populated in riverine grasslands beside the Indus valley and its upper tributaries. It is typically distributed in the Indus river forest reserves of Sind Province while small populations are present around the Indus mouth to the north of Sukkur (Roberts, 1977). It is also present in the Protected Areas of Chashma Barrage Wildlife Sanctuary while it has been significantly reduced in Head Islam/Chak Kotora Game Reserve. Reports further enlighten its potential presence in Lal Suhanra National Park. Taunsa Barrage Wildlife Sanctuary and possibly Rasool Wildlife Sanctuary are regarded as potential habitats for hog deer (Whale, 1996) although no documented proof is available on its recent records. In Pakistan, it is confined to the riverine forests in the plains and particularly in areas of dense grass thickets dominated by *Saccharum spontaneum*, *Saccharum munja* and *Tamarix dioica.*

The hog deer is one of the least studied species in Pakistan. Conservation efforts have therefore, been initiated by the Pakistan Wetlands Programme (WWF - Pakistan). The current study was designed to estimate its population status and distribution range, identify preferred habitat types and to evaluate threats to survival of this species in *Bela* forest of Taunsa Barrage Wildlife

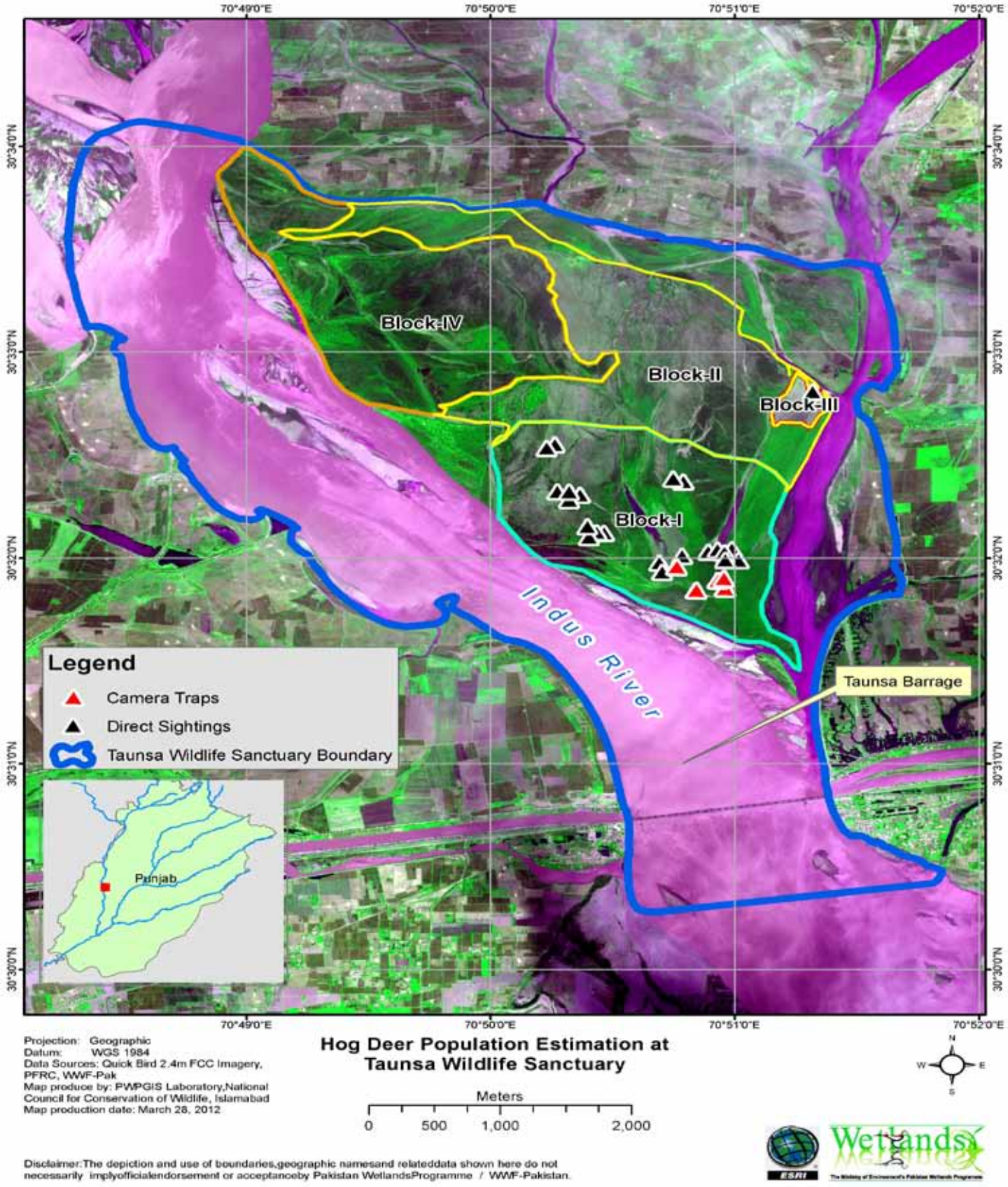

Figure 1: Riverine forest in Taunsa Barrage Wildlife Sanctuary and the Blocks surveyed during the study period

Sanctuary. Furthermore, developing a set of recommendation for sustainable management and conservation of the existing hog deer population in the Sanctuary was also an important objective of the current study. This scientifically validated approach could be further identified to conserve hog deer in Pakistan for its various ecosystem services.

Material and Methods

Study Area: Taunsa Barrage Wildlife Sanctuary

The study was focused on the *Bela* forest (N: 30°32'17.4 E: 070°50'43.8) in Taunsa Barrage Wildlife Sanctuary (TBWS), Muzaffargarh district in Punjab province of Pakistan. The area is offering potential habitats to host the population of hog deer. Taunsa Barrage was notified as Wildlife Sanctuary, a legally Protected Area, by the Punjab Wildlife and Parks Department in 1972. The Sanctuary consists of 2,800 ha area, situated about 20 km northwest of Kot Addu Town. TBWS is one of the 19 internationally important Ramsar Sites in Pakistan recognised in 1996 and also designated as an Important Bird Area (IBA) in 2005 (Li & Mundkur, 2007). It is a potential habitat to important wildlife species including hog deer and the second most endangered Indus River dolphin (*Platanista gangetica minor*). The other species of large mammals identified in this area are Wild Boar (*Sus scrofa*), Jungle Cat (*Felis chaus*) and Asiatic Jackal (*Canis aureus*). It is recognised as an important wintering site for a large number of waterbirds. Smooth-coated Otter (*Lutrogale perspicillata*) was also historically reported. The hog deer is predominantly coupled with the riverine habitat of *Tamarix* and *Saccharum,* presented in this Sanctuary that provide good hiding places to hog deer. Decline in water supply to riverine ecosystems has led to the loss of suitable habitat of this species (Robert, 1997).

Data Collection

Selection of Blocks (Compartments)

Bela forest was divided into four Blocks which are termed as Block I, II, III and IV (Fig. 1). These blocks were mapped and selected to estimate hog deer population in the study area as described in Table 1.

Reconnaissance survey

A questionnaire was developed and meetings were arranged with different community members and local inhabitants regarding the hog deer distribution in the area. Before conducting interviews, it was confirmed whether the interviewee can recognise the species by showing pictures of hog deer. The feedback from local communities was used to compile the information on the presence or absence of the species in particular areas of the Sanctuary.

Sign Survey

The indirect method of tracks and other signs; hoof impressions on the soft ground, hair and faecal samples were used for detecting the presence of the species. Binoculars were used to spot the animal and Geographical Positioning System (GPS) Receivers were used to record the coordinates of indirect signs. Measurements of foot prints were taken to identify the species with the help of an experienced hunter from the region. A data recording sheet was used to record all the field observation and possible photographs were taken.

Line transect

For the survey of hog deer, line transects were laid with a standard speed on foot and vehicle (Caughley and Sinclair, 1994). During the survey, vehicle speed of 10-15 km/hour was maintained. Transect sites were selected near feeding grounds in potential habitat areas of hog deer where their presence was confirmed during reconnaissance/track survey. The GPS location of line transects and visual sightings of hog deer during field survey was recorded.

Results and Discussion

The current study reveals that hog deer is present in the *Bela* forest of TBWS in an area of about 978.8 ha (9.8 km^2). The estimated population of hog deer comprises of 115 animals in *Bela* forest where the population density is 11.8 animals per km^2. However, the existing population is confined to Block I representing the core zone where the estimated population is about 30 animals in an area of 2.60 km^2. The total population of hog deer has been estimated by using the following formula, which is comparable to the studies of population density conducted by Burnham *et al.,* (1980) and Schemnitz (1980).

$$P = \frac{a\,z}{2\,x\,y}$$

***Where, P**= population, **a**= total area of the study, **Z**= no of animals flushed, **X**= length of strip, **y**= average flushing distance.*

It is evident that Block I presents a suitable habitat for hog deer while Blocks II, III and IV are not showing any evidence to host hog deer Population (Fig. 2). This habitat comprises of a blend of *Tamarix* with grass cover and scattered growth of *Acacia nilotica* and some open grassy areas and water ponds. The area outside this core zone is populated area with agricultural activities, burnt area and/or is dominated by *Saccharum* and *Typha* growth and hence these two species do not provide a suitable habitat to the hog deer.

Table 1: Forest blocks (compartments) selected for hog deer survey in Taunsa Barrage Wildlife Sanctuary

Block #	Area (Ha)	Area (Km^2)	Description	Dominant Vegetation
Block-I	259.2	2.592	Protected area and potential habitat to host hog deer	*Tamarix* species with grass cover and scattered growth of *Acacia*; open grassy areas, *Saccharum spontaneum*, *Saccharum munja*
Block-II	424.4	4.244	Protected area with no potential habitat to host hog deer	Dense vegetation of *Saccharum spontaneum* and *Typha* growth
Block-III	10.4	0.104	Human encroachment and agricultural lands	Populated area
Block-IV	284.8	2.848	Burnt area	Burnt area, *Saccharum* and *Typha*

Hog deer home range varies from 5 – 70 ha with a density of 0.1 animal/km^2 in grassy floodplains rising to about 19 individuals/ km^2 in riverine valleys (Fafarman and DeYoung, 1986). In Nepal, the density of the hog deer is 0.1 animal/km^2 in a riverine forest, 16.5 animals/km^2 in Savanna and 35 animals/km^2 in grassland floodplains (Wemmer and Green, 1998). Keeping in view the population size of hog deer in *Bela* forest, it is assumed that its population is stable in the *Bela* forest with population density of 11.1 animals/km^2. In the winter season, when the water level in the river drops, water channels become grassy and provide food to hog deer (Fafarman and DeYoung, 1986).

The riverine forest is gradually degrading due to unsustainable use of natural resources. The habitat of hog deer is also disturbed

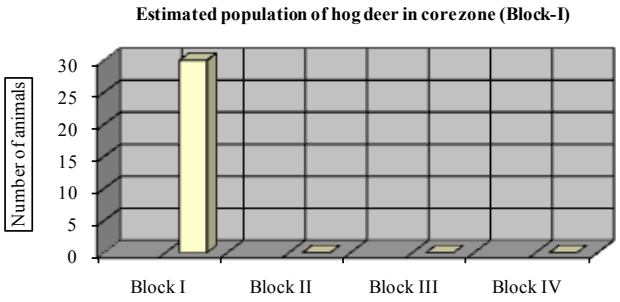

Figure 2: Estimated population of hog deer in core zone (Block I) of *Bela* forest.

due to encroachment by the local community and some cultivation of agriculture in the area. The domestic livestock may compete with hog deer for food. There are no natural predators of adult hog deer in TBWS, although fawns may be taken by Jackals and Jungle Cats (Roberts, 1997). Hunting of hog deer population is not allowed in the Sanctuary, it is however, frequent in the flood seasons when the animals disperse out of the Protected Area. In nature, it is essential to maintain a viable population of a species, having enough adaptability to cope the evolutionary forces for its survival (Soule, 1996). The small populations are subject to genetic problems, demographic fluctuations and environmental variation such as competition, disease and food supply and natural catastrophes like floods (Primack, 1993). The environmental fluctuations are high in *Bela*; high flooding would cause mortalities and would also limit the food supply thus increasing inter and intra-specific competitions. Conversion of riverine habitats into cultivated lands in periphery of the Sanctuary is negatively impacting migration routes of hog deer population.

Conclusion

This study described distribution and population estimate of hog deer in *Bela* forest of the TBWS. The hog deer is distributed and populated in core area, which provides a suitable habitat to the species; however, this patch appears to be insufficient to support growth in population. Restoring the *Bela* forest in way, which support *Tamarix* as a dominant species in the canopy is urgently needed in order to expand the habitat and to support natural increase in hog deer population. A consideration can be given to supplement the wild population in *Bela* using the captive stock; however, this has to be in line with the IUCN guidelines for the species reintroduction developed by reintroduction Specialist Group. Hog deer population is absent in areas of dense human population and agricultural areas and hence this fact showed that anthropogenic activities influence the presence of hog deer in the study area. This study revealed that there is utmost necessity of future research to ensure better management of existing population of hog deer and to find out possible ways of reducing pressures from its potential habitats.

Acknowledgements

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Impact of floods 2010 in coastal area of Pakistan – a case study of Kharo Chann, Thatta District

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K E Y W O R D S

Coastal areas
Floods and cyclones
SPOT 5
Satellite images
Object Based Image Analysis
Mangroves
Climate Change
Kharo Chann

A B S T R A C T

With the increasing impacts of climate change, coastal areas have become more vulnerable to extreme events like tsunami, floods and cyclones. The '2010 Pakistan Floods' brought disastrous impacts through destruction of property, livelihood and infrastructure. This study has been conducted by using space borne data and Satellite Remote Sensing (SRS) techniques to assess the ecological impacts of the floods at Kharo Chann, District Thatta, Sindh province. For this purpose, SPOT-5 satellite images dated 26th March and 28th September, 2010 of the study area were used for pre and post flood assessment. Detailed field survey data have been integrated with the satellite images and topographical data in a GIS environment to highlight the overall changes caused by the floods. Object Based Image analysis (OBIA) technique was used to map the eleven major land cover classes of the area. The study reveals that flood has a positive impact on density classes of '*Mesquite / Tamarix* spp. / Reeds, which has been increased from 1,225 ha to 3,341 ha within a time span of 6 months. In a few low depression areas, where the flood water remained stagnant, *Mesquite* has been damaged. The study also highlighted a decrease of 1,171 ha of 'Closed to open Mangroves Canopy'. The recent floods also resulted in land erosion in some of the areas of Kharo Chann. The land cutting due to water pressure was high near Atharki, Saleh Dandal, Jamnasar and Chor Goju villages. Approximately 38 ha land was lost around these communities. During the 2010 floods, the agriculture fields were submerged resulting in a huge loss to the local economy.

Introduction

Globally, the intensity of natural disasters has risen sharply over the past decades (Adger *et al.,* 2007). The 2010 Pakistan Floods caused by unprecedented monsoon rainfall has resulted in disastrous impacts by bringing a large part of the country underwater. Almost one-fifth of the country's land, comprising of twenty-three districts, was severely affected in Pakistan (BBC News, 2010).

WWF – Pakistan as a nature conservation organisation developed a three tier Flood Response Strategy. The provision of relief goods and rescue efforts in flood affected project sites covered the first tier of the Flood Response Strategy. The second stage covered the flood impact and damage assessments of ecologically significant areas and the third stage supported ecological and social restoration in high priority ecosystems.

The current paper deals with the GIS/RS based component of the second stage of the Flood Response Strategy. In this study, space borne data and SRS techniques have been used for the flood impact and damage assessments of Kharo Chann District Thatta, Sindh. For land cover change assessment induced by floods, pre and post flood SPOT-5 images were acquired. Detailed *in situ* field survey data has been integrated with satellite images and topographical data in a GIS environment to highlight the overall change.

The present study aims to develop the landcover map of Kharo Chann area, District Thatta, Sindh Province, and to assess the landcover change analysis of flooded area by incorporating LCCS based legend.

Material and Methods

Study area

Kharo Chann *Taluka* lies in District Thatta covering an area of about 574 km^2. It geographically extends from 67° 43' 42.35"E to 67° 29' 58.82"E longitude and 23° 52' 11.14"N to 24° 11' 03.22"N latitude (Fig. 1). The population of this *Taluka* is about 30,500 and the people of the area are below the poverty line with fishing, subsistence agriculture and livestock as the major sources of livelihood (Singapore Red Cross, 2010). The creeks comprises of dense pockets of mangrove forests of the Indus Delta (Qureshi, 1996).

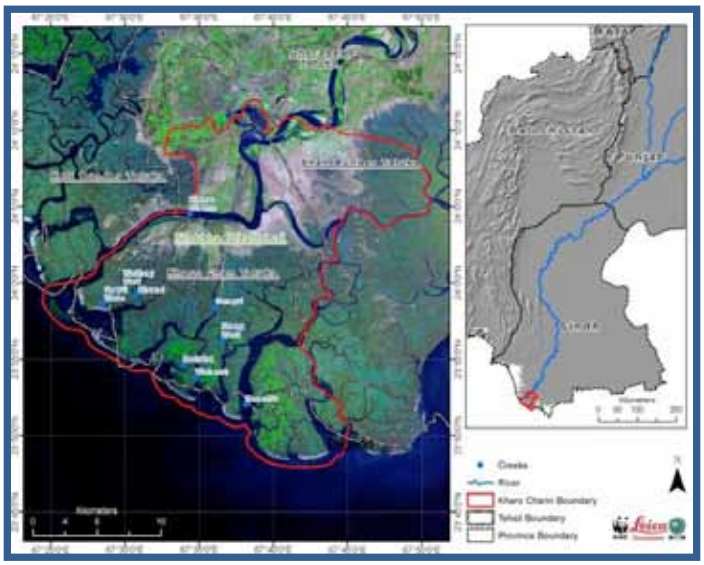

Figure 1: Location map of the study area

Data Collection

Satellite Data and Software Used

Pre and post flood satellite images of SPOT – 5 acquired on 26th March 2010 and 28th September 2010 have been used for the study. All the images were transformed to Universal Transverse Mercator (UTM) coordinate system, Zone 42 with Spheroid and Datum as WGS 84.

For the extraction of meaningful land cover classes, *Histogram Equalize* and *Standard Deviation Stretches* were applied. High Resolution Merging was done on multispectral (10 m) with panchromatic (2.5 m) images in order to sharpen and improve level of details within the satellite image. The high resolution image significantly helped in the selection of training samples and defining the rule which was set to extract the smaller objects and to map the features which are difficult to identify in the other conventional classification techniques.

For interpretation, processing and rule set developlment, Digital Image Processing Software ERDAS Imagine 8.7® and Definiens Developer 7.0® were used respectively. All the maps were developed in ArcGIS 9.0®. Microsoft Word and Microsoft Excel were used for documentation and graphical analysis. Field maps, Garmin GPS 76 CSX receiver and Canon PowerShot SX1 IS digital camera were used for field data collection, navigation and recording.

Ground Truthing

Ground truthing refers to the gathering of information about the study area by *in situ* observation from field (Sabins *et al.,* 1997).

Figure 2: (a) Field photographs of Mixed *Mesquite* spp. and *Tamarix* spp. (b) Mangroves

In order to collect Global Positioning System (GPS) coordinates of the land cover classes and its corelation with the spectral values of the satellite images, different hotspots and confusion areas were identified on satellite image and verified on the ground. Garmin 76CSX GPS receiver was used to collect 81 GPS points. Land vehicle and boat were used to navigate in the study area. During the ground truthing, it was observed that inland area, along the Indus river, consists of *Tamarix* and *Mesquite* spp. alongwith *Saccharum* and *Typha* spp., whereas, mudflat areas consist of dense patches of mangroves mostly *Avicenna marina* (Fig. 2a & 2b).

Classification – Object Based Image Analysis

In OBIA, segmentation is the first and most important step as the accuracy of the land cover is dependent on the quality and details of initial segmentation. Segmentation is a process of defining discrete objects or classes of object on the satellite image. Multiple image object levels were created and layered above the basic pixel level. Two or more image object levels build the 'Image Object Hierarchy'. It served as a storage rack for all image objects levels which represent different shelves storing the image objects. Thus, the image object hierarchy provided the working environment for the extraction of image information. All the image objects were organised into a hierarchical network of image objects. Such a network is called image object hierarchy. Muti-resolution Segmentation algorithm with parameter values i.e.

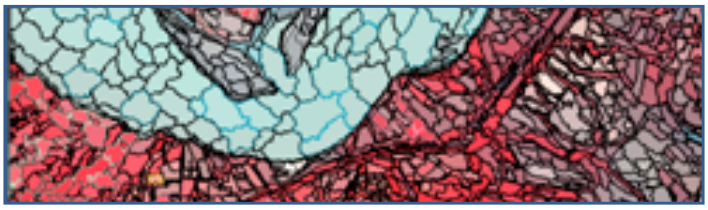

Figure 3: Image segments

scale - 40, shape - 0.1 and Compactness - 0.025 was used to get a segmented layer. The object hierarchy and segments defined for the SPOT-5 satellite images of Kharo Chann are shown in Fig. 3. Detailed fundamental steps involved in the OBIA are shown in Fig. 4.

Thematic Layers Generation: Temporal thematic maps were generated by using SPOT - 5 images (Fig. 5). The output land cover comprised of eleven classes. The area of each class was also calculated after the accuracy assessment of the output land cover maps. Definiens provides about 95 % accurate results of the output relative to the ground knowledge and samples along with the rule set.

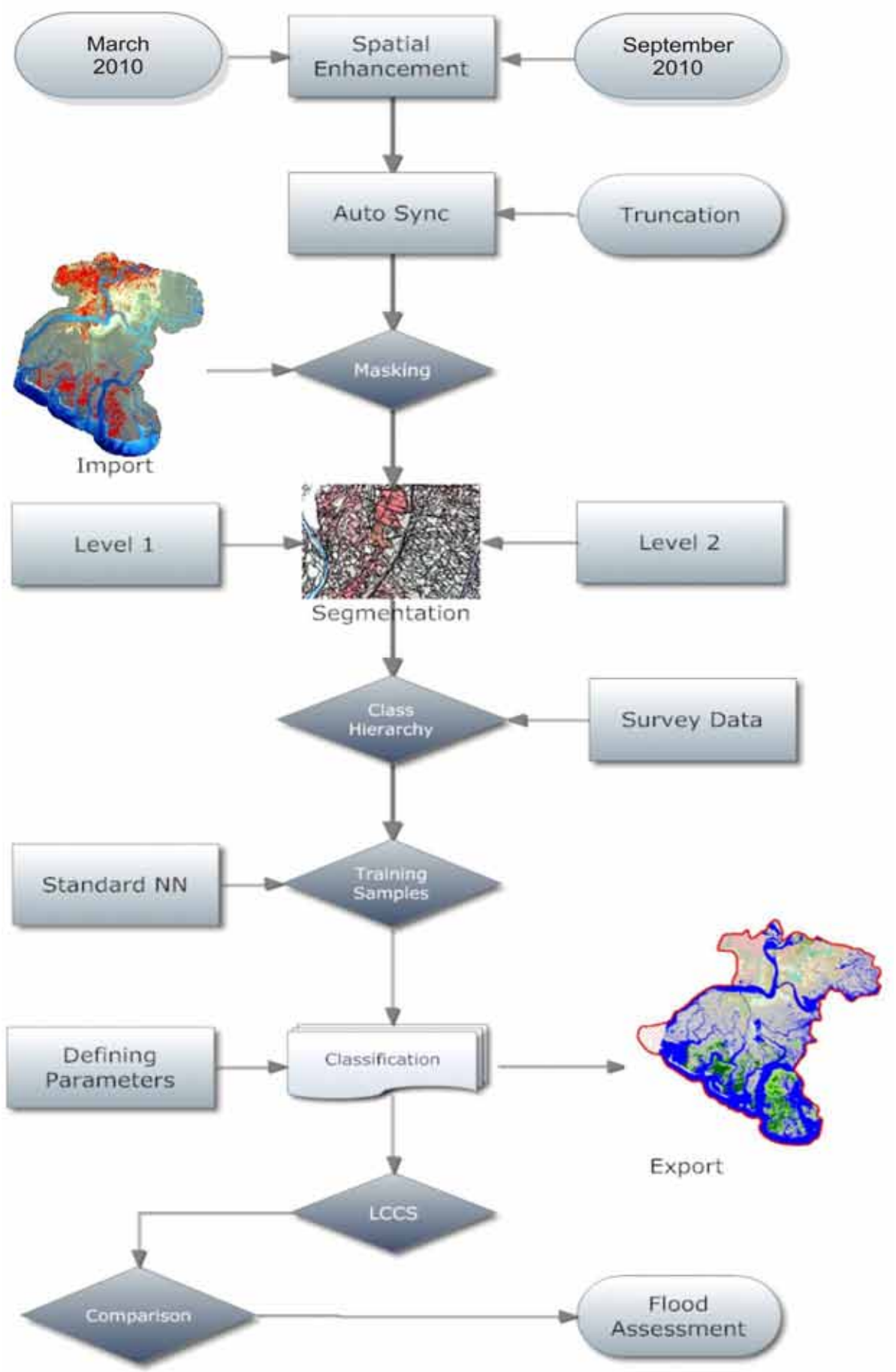

Figure 4: Flow diagram showing the detailed fundamental steps involved in Object Based Image Analysis

LCCS Legend Definition: Legend can be defined as the translator of the abstract land cover. It should be therefore scale and source independent which can lead integration of land cover of diverse areas in the same database. For land cover legend standardisation, Food and Agriculture Organisation (FAO) and United Nations Environment Programme (UNEP) introduced a Land Cover Classification System (LCCS) for legend definition (Di Gregorio and Jansen, 2000). LCCS provides harmonised and standardised legend for the land cover (Table 1). The classification legend follows the dichotomous structure which can be identified and recognised anywhere in the world. The classification system leads to mutually exclusive land cover classes, which comprise of the following:

- Unique numerical code
- Unique Boolean formula (coded string of classifiers used)
- Standard name [7]

Land cover legend of the Kharo Chann was developed using LCCS software (Table 2).

Results and Discussion

The output land cover maps contain the following three categories of the vegetation types of Kharo Chann.

1 Deltaic vegetation comprises of mangroves and salt bushes

2 Riparian vegetation is along the Indus River and its outshoots. It mainly contains *Tamarix* and *Mesquite* spp., Reeds and at a few places, some trees of *Acacia* spp.

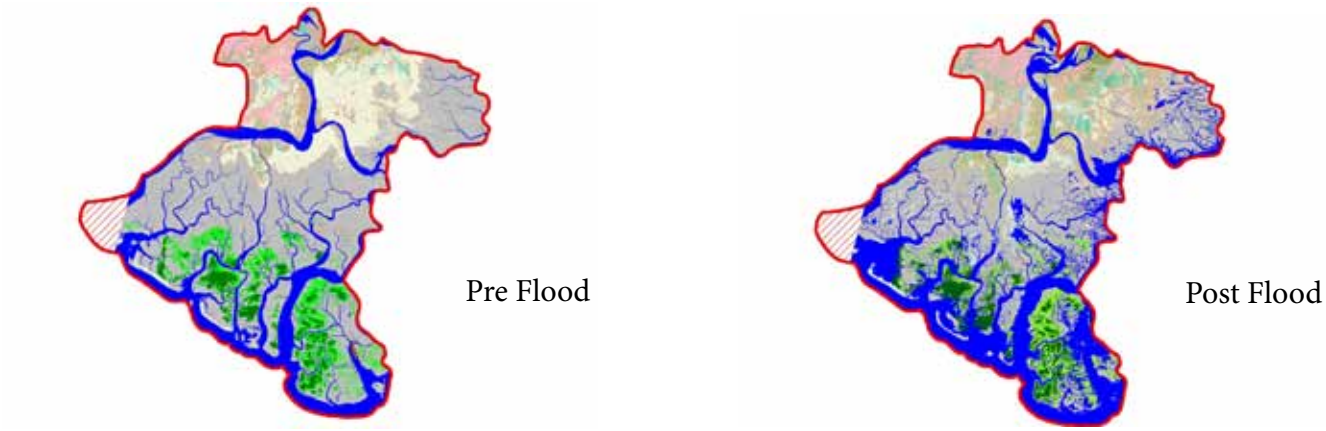

Fig. 5: Land Cover/ Land Use maps of Pre and Post Flood

Table 1: LCCS Classification

LCC Code	LCC Level	LCC Label
11239-11376	A3B1XXC2D3D9-B3C3C7C19D4	Permanently cropped area with surface irrigated herbaceous crop(s) (one additional crop) (herbaceous terrestrial crop sequentially)
40374-21348-325	A4A13B3C3XXXXF1-A6A11B4XXE5F2F6F10G3-A12B13G9	Open shrubs on waterlogged soil / open ((70-60) - 40%) short grassland with medium high shrubs
20606-13376	A3A10B2XXD1E2F2F6F7G3-B7F8G8	Broadleaved deciduous low trees with closed high shrubs
22575-13378	A3A20B2XXD1E2F2F6F7G3-B7F9	Broadleaved deciduous closed to open low trees, with open shrubs
6005 // 6009	A5 // A6B1	Bare soil and/or other unconsolidated material(s) / shifting sands / dune(s)
8003-49	A1B2-A5B5B9	Non-perennial natural water bodies (standing) (surface aspect: bare soil)
20606-15058	A3A10B2XXD1E2F2F6F7G3-F9	Broadleaved deciduous trees with open shrubs
41459	A10A12C3F1	Closed lichens on waterlogged soil.
8001-1	A1-A4	Natural water bodies (flowing)
41639-4841	A3A20B2C1D1E1-B6C4	Closed to open broadleaved evergreen medium high trees on permanently flooded land (persistent)
40113-4841	A3A12B2C1D1E1-B6C4	Broadleaved evergreen medium high trees on permanently flooded and (persistent)

Table 2: Quantitative comparison of temporal land cover mapping

Legend	Class Name	Area (ha)	
		Pre Flood	Post Flood
	Closed Mangroves Canopy	3,249	3,215
	Closed to open Mangroves Canopy	4,884	3,712
	Salt Bushes/Bushes/Grasses	6,261	9,804
	Dense *Mesquite* spp./*Tamarix* spp./Reeds	177	843
	Sparse *Mesquite* spp./*Tamarix* spp./Reeds	1,049	2,498
	Terrestrial Vegetation/Bushes	719	1,498
	Mud Flats/Wet Soil	43,184	31,649
	Saline/Sandy Area	344	3,600
	Land Soil	12,858	6,541
	Agriculture Land	2,479	2,545
	Water	17,599	30,231
	Algal Mat	78	0

3 Terrestrial vegetation comprises of the roadside plantations, natural trees along the agriculture fields/tracks and other inland scattered vegetation.

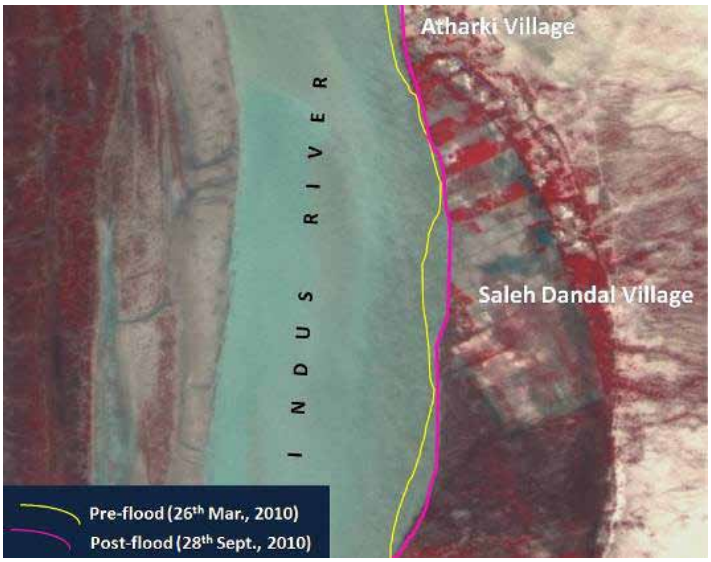

Figure 6: Land erosion status due to flood 2010

The flood intensity was reduced when it reached the study area, not much negative impact was observed (Fig. 6). However, the land cover changes observed during the temporal change analysis are mentioned in Fig. 5 and Table 2. The analysis of the thematic maps reveals an overall increase in the extent of the density classes of '*Mesquite*/*Tamarix* spp./Reeds (Table 2). The increase appears to be due to the positive impact of flood on this class especially on *Tamarix* spp. *Mesquite* spp., which is an exotic and perennial weed was present in the river bed and adjoining areas alongwith *Tamarix* spp. In low depression areas, where the flood water remained stagnant, *Mesquite* has been damaged.

These vegetative blocks have been taken away by flood waters in some of the areas. The dense patch of *Mesquite spp.* near Saleh Dandal village that appears as a maroonish red tone in the pre-flood satellite image has been dried and appears as blackish red tone in the post flood image. Although *Mesquite spp.* has been damaged in some low lying areas, but the overall contribution of the damaged class is minute compared to the healthier impact of floods on riparian vegetation.

Change analysis reveals a decrease of 1,171 ha of 'Closed to open Mangroves Canopy'. This might be due to the high tide height at the time of the post flood image acquisition or the clearing of sparse juvenile mangroves at the edges of the creeks. Climate Change By comparing the thematic maps of March 2010, and September

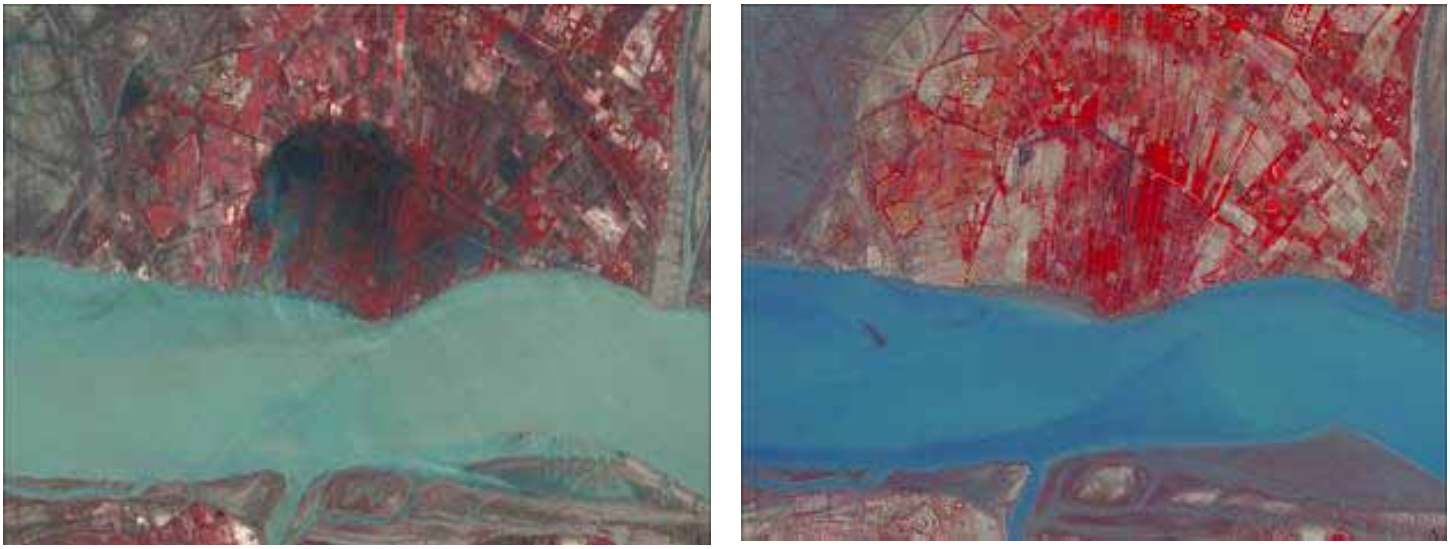

Figure 7: Pre and post flood image – *Mesquite* in low lying areas

Figure 8: Pre and post flood images - Agricultural fields submerged after the floods

2010, an increase in land cover classes of bushes and grasses has been observed. This is mainly due to the seasonal variation/post monsoon impacts. It was analysed by comparing pre (26th March, 2010) and post (28th September, 2010) flood satellite images and the land cover maps that recent floods have resulted in land erosion in some of the areas of Kharo Chann. The land cutting due to water pressure was high near Atharki, Saleh Dandal, Jamnasar and Chor Goju villages. Approximately, an area of 38 ha has been lost around these villages during the flood period. The areas near Atharki and Saleh Dandal villages have been facing land erosion since year 2000 but the floods of 2010 washed away some of the agricultural fields and houses as shown in Fig. 7.

Conclusion

The study area, once heaven for the agriculturalists has now been transformed into the saline pools due to the imbalance between the fresh and brackish water. During 2010 floods, the agricultural fields were submerged with flood water and resulted in economic loss. Despite the fact, communities have greeted the 2010 flood with the belief that agriculture land will become fertile due to the dilution of salt by freshwater flooding.

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Spatial mapping and development of a WebGIS application of wetlands of Pakistan

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K E Y W O R D S

Wetlands
GIS
Web GIS applications
Topographic mapping
Land cover/land use
Spatial data
Watershed and sub-watershed
National inventories
Wetlands of Pakistan

A B S T R A C T

Wetlands are valuable resources for wildlife and provide subsistence to communities. In Pakistan, wetlands are distributed in diverse ecosystems throughout the country. Geographic Information System (GIS) is used extensively in natural resource planning and management, all over the world. The information about the wetlands and their natural resources was patchy and was not compiled and updated systematically. Very little information was available in the form of unpublished reports. To fill the information gap, this study was conducted under the Pakistan Wetlands Programme to systematically map the wetlands resources of Pakistan. The paper discusses the procedures and techniques adopted for topographic mapping, satellite image processing and corrections, land cover or land use mapping, watershed and sub-watershed delineation and WebGIS application of the wetlands of Pakistan. This study is first ever comprehensive attempt to develop the spatial data including vector and raster datasets of wetlands at national level. The land cover, topographic maps and other spatial data is available online for the students, researchers and stakeholders. Online data availability will help to monitor and manage wetlands resources on scientific basis and will reduce data duplication. The data standards and techniques applied for the development of this inventory should be effectively used for repeated monitoring of the wetlands. It is also recommended to also develop national inventories including forest and wildlife datasets.

Introduction

Pakistan has diverse wetland ecosystems with rich biodiversity. These wetland resources are distributed almost throughout the landscape of the country. The degree of extent of these wetland ecosystems ranges from the high mountains (alpine wetlands) in Sindh and Balochistan.

The information about the wetlands and their natural resources was patchy and was not compiled and updated systematically. Very little information was either in the form of unpublished reports or available in the form of a superficial list attached to the draft Wetlands Action Plan (2003). Further, the information was available for only 48 wetlands of Pakistan in the Directory of Asian Wetlands Inventory (Lu, 1990). Globally, national wetlands inventories have been developed by various countries to map the extent and characteristics of wetlands. In order to fill the information gaps in Pakistan, a study of spatial mapping of all the significant wetlands of Pakistan was proposed under the Pakistan Wetlands Programme (PWP).

This paper discusses the first ever attempt of its kind in Pakistan to systematically map the wetlands resources with their biological and socio-ecological significance. For the systematic data handling and upgrading for future monitoring, a GIS based database was also developed which was linked with the online application of PWGIS portal for the information dissemination to government, public, and private organisations/agencies for the utilisation in their decision making for natural resources management and planning.

The specific objectives of this study were to develop spatial data layers including topographic, watershed and land cover information of the significant wetlands of Pakistan and to design and implement a mechanism to disseminate and publish data/ information to be used effectively by the national and provincial or territorial conservation agencies for strategic decision-making, regular updates and future monitoring.

Material and Methods

Spatial Data Development

Geospatial information is data referenced to a place - a set of geographic coordinates that can often be gathered, manipulated, and displayed in real time (NGAC, 2009).

For the systematic data collection, processing and dissemination, GIS team adopted a scale dependent spatial layers and metadata development approach that was managed and stored by adopting hierarchal categorisation. The hierarchical approach to wetlands inventory was adapted from 'A Manual for an Inventory of Asian Wetlands' (Finlayson *et al*., 2002) and was modified for Pakistan's situation which is shown in Fig. 1.

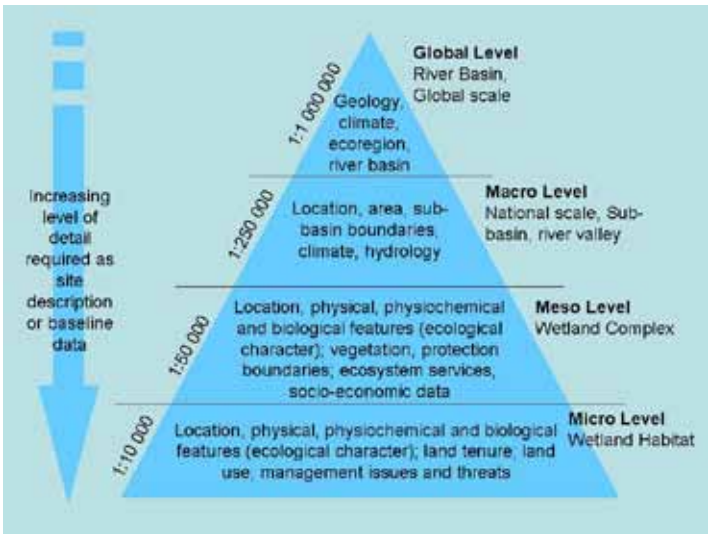

Figure 1: Hierarchical approach to wetlands inventory

Topographic Data Development

Topographic layers such as elevation, aspect, slope, accessibility (road/tracks) of the area, important watersheds/drainage pattern, settlements were established in ArcGIS using 1:250,000, 1:50,000 scale Survey of Pakistan (SoP) map sheets and 1:100,000 scale Russian topographical sheets of Pakistan for the different

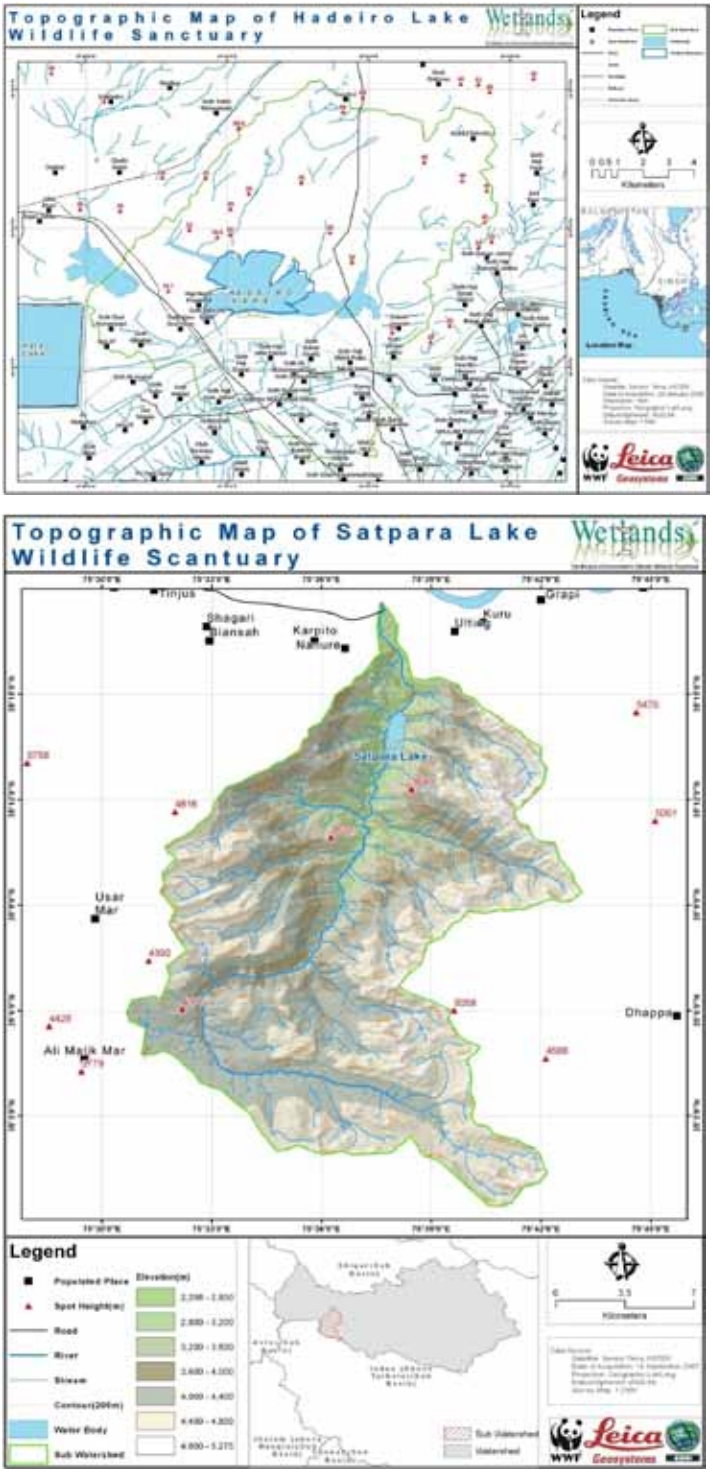

Figure 2: Vector and raster based topographic maps

wetland areas of the country (Fig. 2). This activity was undertaken through scanning and digitisation of each layer. All base layers were stored and formed the baseline GIS. In addition to the topographic sheets, Digital Elevation Model (DEM) of Shuttle Radar Topographic Mission (SRTM) of 90 meter spatial resolution and stereo-pairs of Advanced Spaceborne Thermal Emission Radiometer (ASTER) were also used to collect terrain information of the wetlands area (Lu, 1990). ArcGIS 9.3® and Silcast software were used to generate topology and to develop various types of topographic maps.

Raster Data Acquisition and Processing

Suitable and accurate spatial data saves time and cost, and gives accurate and target oriented results (Heipke, 2004). Considering this, all the available satellite images were evaluated and procured on the basis of image quality, season/date of acquisition and cost. The purchase of the images were done on the basis of scale of mapping of different wetlands e.g. medium resolution images (Landsat, ASTER, ALOS) were used for the Wetlands Complexes at 1:50,000 scale; while high-resolution images (SPOT – 5, QuickBird, GeoEye) were used for the micro-level mapping at 1:10,000 scale of the wetlands. One of the achievements was the acquisition of satellite images of the high altitude wetlands areas as most of the northern region of Pakistan were not captured by the satellites or the image quality was poor in those areas due to shadow/snow/cloud. For the new acquisition, a Scientific Team Acquisition Request (STAR) was developed and it was accepted by United States Geological Survey (USGS). As a result, more than 70% of Pakistan was captured by the TERRA satellite on the defined dates and season by WWF – Pakistan. ASTER, placed at TERRA spacecraft is a multi spectral optical sensor with 14 spectral bands that range from visible to thermal infrared band. VNIR has two (2) near infra red bands which have similar wavelengths, those are 3n (nadir looking) and 3b (backward looking). The 3b band is used to achieve the backward looking, with setting angle between the backward looking and the nadir looking is designed to be 27, 60° (Lin, 2002).

To enhance the positional accuracy of the images, all the images were orthorectified that increases positional accuracy and removes terrain distortions. The quality of the images was improved by high resolution merging with the available panchromatic layer of better resolution. Figure 3 highlights the high-resolution (0.6 m) multispectral image with improved/greater level of details which is to be integrated with GIS layers.

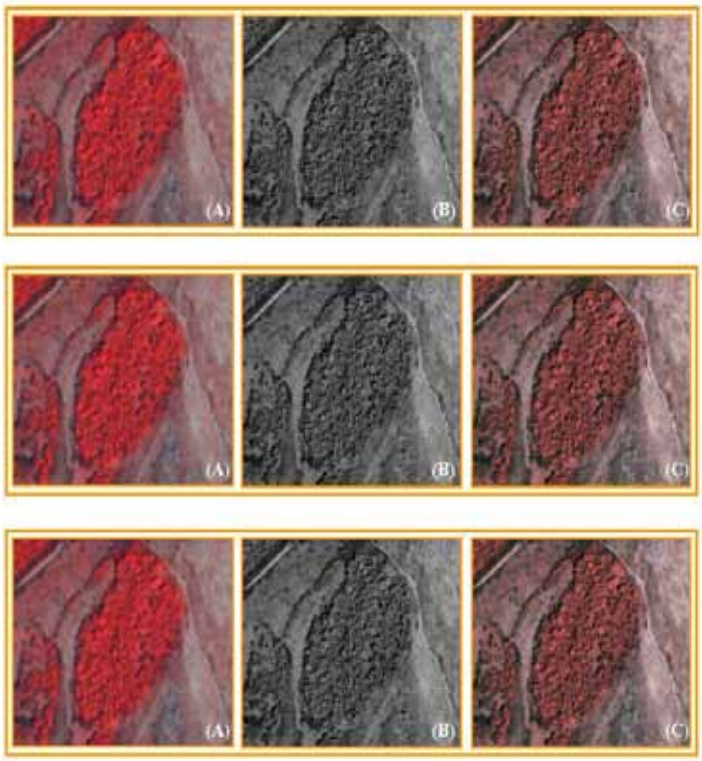

Figure 3: Zoomed parts of multispectral (A), panchromatic (B) and high resolution merged (C) imagery

Watershed and Sub-watershed Mapping

A watershed is defined as the entire area drained by a river system or by one of its main tributaries (Revenga *et al*., 1998). Watersheds play a critical role in the natural functioning of the Earth thus considered as one of the primary planning units in the field of natural resource management. The automated extraction of topographic classes from DEM is recognised as a viable alternative to traditional surveys and manual evaluation of topographic maps, particularly as the quality and coverage of DEM data increases (Garbrecht and Martz, 1996).

In this study, sub basins and watersheds (Fig. 4) have been delineated on the basis of corrected SRTM DEM acquired from CGIAR data download center. Sub watersheds were delineated based on the DEM derived from ASTER images of which the vertical accuracy approaches to 25 m, but in area with less vegetation coverage, the accuracy can rise approximately to 9-11m (Goncalves and Oliveira, 2004; Selby, 2004).

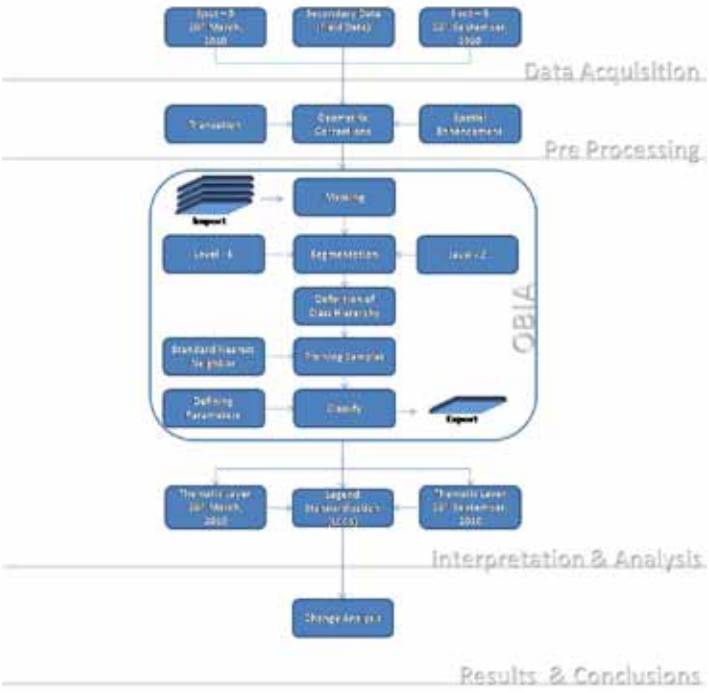

Figure 4: Watershed and Sub-watershed mapping flow diagram

Depression less DEM was prepared by calculating the sink depth and then applies the fill function. In another iteration process, the flow direction was calculated using D8 method that leads to determine all other functions like flow accumulations, stream links, and then finally watershed and stream network (Garbrecht and Martz, 1996). *Flow Length* command was used to calculate the length of the longest flow path within a given basin. Ninety meter spatial resolution DEM was used to determine the watershed boundaries with the help of flow length (Upstream). However thirty meter spatial resolution ASTER based DEM were used to determine the sub watershed boundaries.

Land Cover / Land Use Mapping

In a satellite image, it is possible to assemble groups of similar pixels into classes that are associated with the informational categories of interest to users of remotely sensed data and it is referred as image classification (Richards, 1999; Weng, 2007). The objective of image classification is to extract information from a satellite image. There are number of techniques to classify and quantify features which come under supervised and unsupervised method. In this study, supervised classification techniques were used to classify the satellite images of major wetland areas which specifically include Maximum Likelihood Classification (MLC) and Object Based Image Analysis. MLC was applied on medium resolution satellite images and the wetland areas.

The MLC tool considers both the variances and covariance of the class signatures when assigning each cell to one of the classes represented in the signature file (Kamble and Dule, 2012). With the assumption that the distribution of a class sample is normal, a class can be characterised by the mean vector and the covariance matrix. Given these two characteristics for each cell value, the statistical probability is computed for each class to determine the membership of the cells to the class. The default parameters of the software were specified according to our area of interest, each cell is classified to the class to which it has the highest probability of being a member. If the likelihood of occurrence of some classes is higher (or lower) than the average then the weights for the classes with special probabilities are specified in the a priori file. In this situation, a priori file assists in the allocation of cells that lie in the statistical overlap between two classes. These cells are more accurately assigned to the appropriate class, resulting in a better classification. This weighting approach to classification is referred to as the probability of the assigned class to the brightness values. Consequently, classes that have fewer cells than the average in the sample will receive weights below the average and those with more cells will receive weights greater than the average. As a result, the respective classes will have more or fewer cells assigned to them. When a MLC is performed, an optional output confidence raster was also produced. This raster shows the levels of classification confidence (iterations). The level of confidence, coded in the confidence raster as one, consists of cells with the shortest distance to any mean vector stored in the input signature file; therefore, the classification of these cells has highest certainty (Esri Development Network, 2008). This classification technique was applied on the medium resolution satellite images or the wetlands area that cover more than 50 km^2 land area.

In this study, some of the wetlands which requires high level of acccuracy depeneding upon the level and size of the wetlands and ultimately resolution of satellite images, Object Based Image Analysis technique was used. It is an advanced and most recent classification technique specially meant for processing and analysing high resolution satelitte images. Digital Image Processing software i.e. Definiens developer® has been purchased and used for the analysis.

The object-based classification starts with segmentation of the image into highly homogeneous image regions (or objects) (Antonio *et al.,* 1998). These image segments correspond to the approximations of real world objects which can be characterised by shape and texture. Multiresolution filter was prefeered out of Chessboard, Quadtree, Contrast Split and Spectral Difference Contrast Filter due to its capacity of including texture, sixe, scale and weightage values of the image objects.

Field Surveys

Seventy five field surveys were conducted to various important ecological wetland areas (Fig. 5) The main objective of the field surveys was to process and also verify satellite image interpretation with ground reference data. For this purpose, A3 and A2 sized field maps of satellite images in False Colour Composites (FCC) and Natural Colour Composites were developed for field data collection activities at various scales depending on the size of the wetland. Garmin Map 76 GPS Receiver, digital camera and binocular were used to record different number of ground control points and respective field observations. The land features that appeared as spectral abnormality in the satellite images were the prime focus of the field surveys. Accessible localities were surveyed while the inaccessible areas were verified through the information from government officials and local communities. In addition, the classification processes of the images were further validated by visual inspection of high resolution images available on the World

Wide Web. GoogleTM Earth combines different resolution images and updates them on a rolling basis (Conchedda *et al*., 2008).

Development of WebGIS Application

The database designed in this study was deployed in Web – based information architecture. Web based applications are the applications that require just a browser to function. The server – side application logic runs on a centralised web server in the data center.

For this purpose, PostgreSQL which is an open source, highly robust SQL 92 compliant database system was used. It contains almost all of the features that one can find in other commercial or open source databases along with some additions (Stones and Mathew, 2001). Each web page, like the screens of traditional applications, presents information to the user. The information normally comes from a Postgre SQL database server and enabling the user to view, modify or delete the authorised contents. This application was built on the same client server architecture which significantly support geographically distributed organisational structure of the Pakistan Wetlands Programme. The present PWGIS integrated database built in PostgreSQL/PostGIS will provide platform to develop a need specific online GIS by integrating it with web mapping services of UMN –Mapserver through PHP and JavaScript. This comprehensive application allows viewing, editing and analysing the spatial and non – spatial data of Pakistan Wetlands Inventory through http://pwi.pakistanwetlands.org.

Figure 5: Field photographs during wetlands surveys

Results and Discussion

This study is the first ever attempt of its kind in Pakistan to systematically map the wetlands resources with their biological and socio-ecological significance. One of the main objectives of the present study was to enhance the role of spatial data in decision making by developing and sharing it globally.

The first step of the study was spatial data development including topographic data and land cover maps. Landcover maps of the wetlands complexes at 1:50,000 scale and the significant wetlands at 1:10,000 scale were developed using medium and high resolution data respectively. The land cover maps of Central Indus Wetlands Complex (CIWC) and Taunsa Barrage (that is within the CIWC) at different level of details is shown in Fig. 6 and Table 1.

This study suggested method and techniques to delineate watershed boundaries and drainage network at multi scale. At smaller scale (1:10,000,000) three basins were delineated i.e. Dasht, Hamun-i-Mashkhel and Indus (Fig. 7 & 8). In addition, 46 sub basins and 287 watersheds were identified at national level. These watersheds and sub-watershed boundaries are useful to compile baseline information of the respective areas and their *in situ* conservation activities.

Table 1: Identified basins, sub basins and watersheds of Pakistan

Sr. No.	Basin	Sub Basin	Watershed
1	Indus	35	171
2	Dasht	8	37
3	Hamun-i-Mashkhel	3	82

Over the past decade, web-based GIS have become an integrated tool for storing, manipulating, visualising and analysing spatial data. Under the study, a web-based GIS data portal was developed which comprised of all the GIS data layers of the wetlands of Pakistan. The information system is accessible through World Wide Web to government, public, and private organisations/agencies for the utilisation in their decision making for natural resources management and planning. Pakistan Wetlands Inventory, at national level, has provided a standard platform where the relevant departments and agencies from any part of the country can share and access the relevant data and information.

Current study is first comprehensive attempt to analyse the extent and characterisation of the wetlands of Pakistan. Thoroughly documented standards and techniques applied for the development of this inventory can also be effectively used for repeated monitoring of these wetlands. This national level study also provides the basis for developing other key national inventories including forest and wildlife.

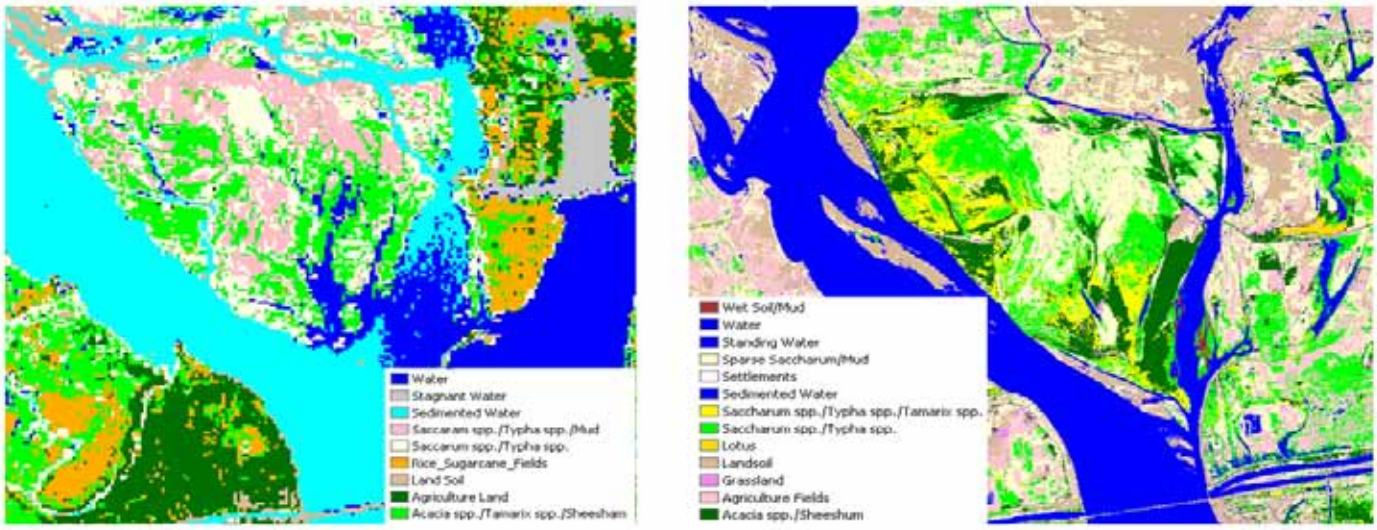

Figure 6: Land cover slice of CIWC developed using (a) ASTER and (b) QuickBird satellite images

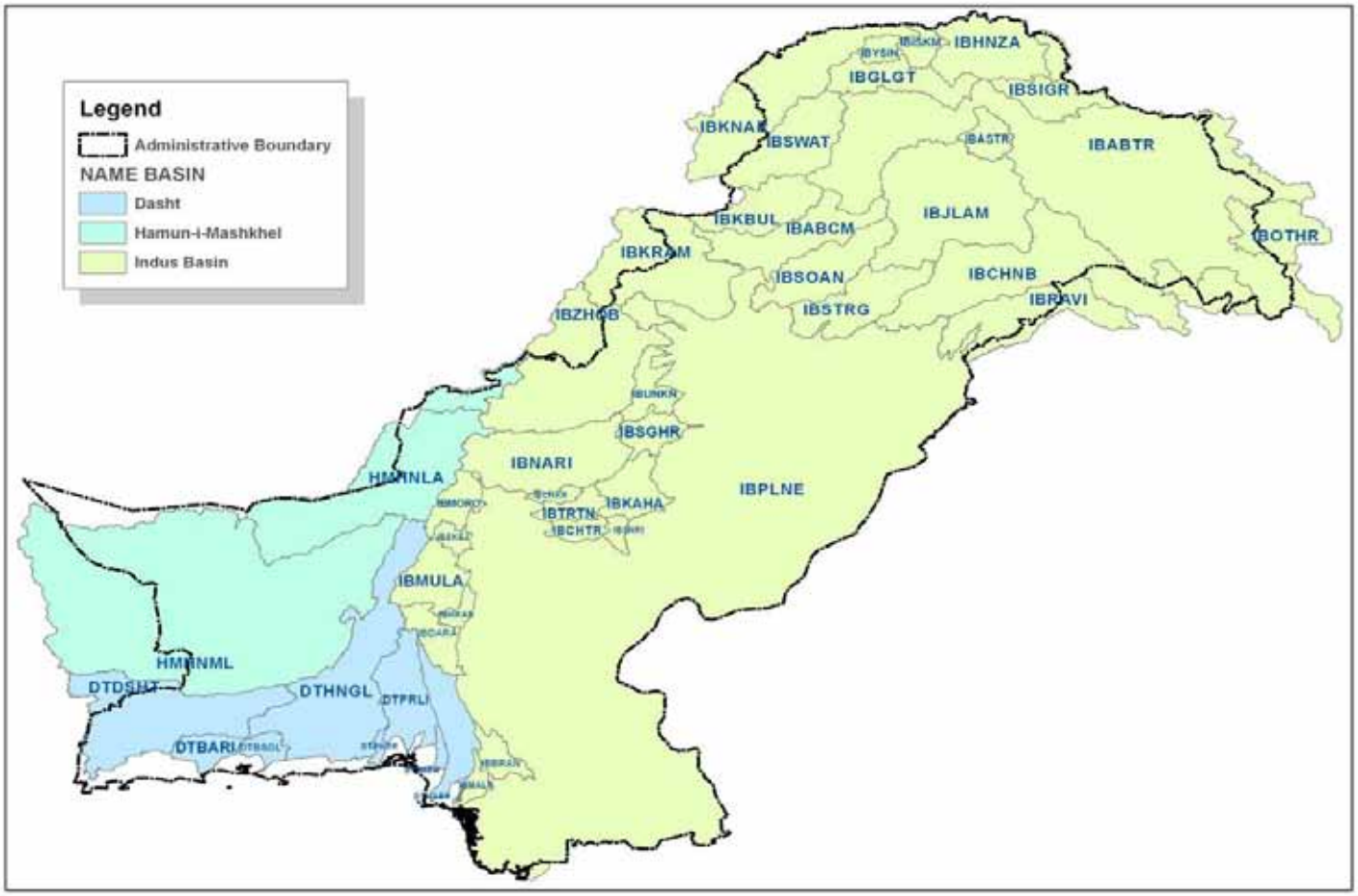

Figure 7: Extent of Indus, Dasht and Hamun-i-Mashkhel basins in Pakistan

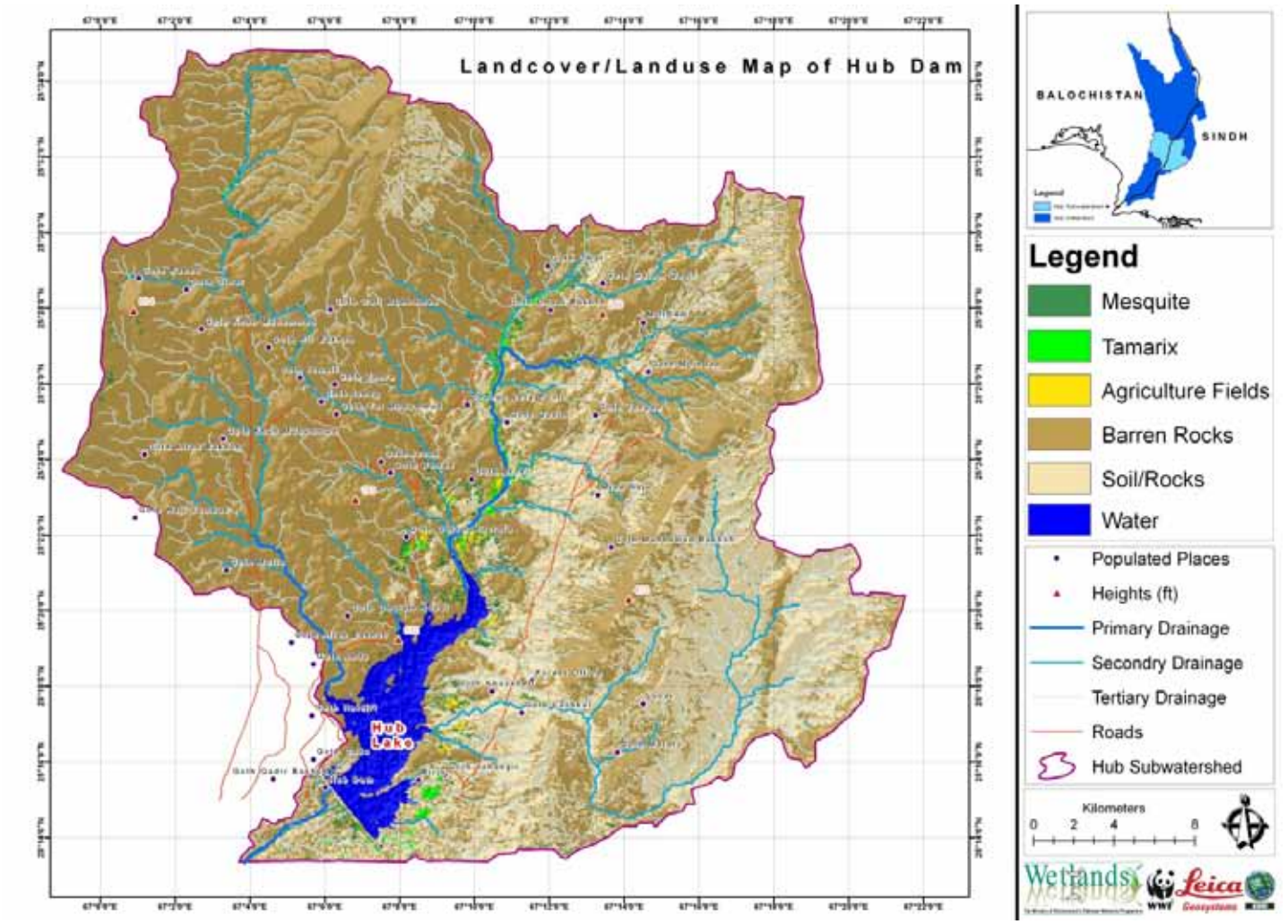

Figure 8: Sub-watershed based Land cover/Land use of Hub Dam

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Coliforms and *Halophiles* pollution in surface and sub-surface water of Salt Range Wetlands, Punjab, Pakistan

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K E Y W O R D S

Surface and sub-surface water quality
Microbial contamination
Coliforms
Halophiles
Technological development
Agriculture activites
Consumptive uses
Ground water resources
Salt Range wetlands
Wetlands in Pakistan

A B S T R A C T

Faecal Coliforms (FC) have traditionally been regarded as indicators of microbial contamination of water resource. Pathogens still pose a threat to human health, despite the fact of development in the field of microbiology and bioengineering. Although attention and management efforts have focused on treating drinking water by the Pakistan Wetlands Programme to prevent microbial contamination in Salt Range Wetlands Complex (SRWC), human activities and technological development continue to contribute directly and indirectly to contamination of surface and ground water with microbial pathogens. For example, Uchali, Namal and Jahlar Lakes in the Salt Range area of Pakistan are surrounded by agricultural lands and hence agricultural run-off from these lands end up eventually in the lakes. Agricultural practices are often contaminated with nutrients and pathogens. The major source of pathogens in agricultural run-off is farm and grazing livestock which either end up in lakes or leach down in soil profile to ground water resources. These lakes are very critical and important in terms of its consumptive and non-consumptive uses by humans and ecology in a region which already had limited freshwater resources. In order to investigate the impacts of agricultural activities on the microbial water quality of the Salt Range water resources (lakes and ground water), water samples were collected from 56 different locations each for surface and sub-surface bacteriological testing of water quality including open dug wells, hand pumps and lakes of Salt Range Wetlands Complex. Membrane filtration technique was used for the assessment of the microbiological quality of different water sources. The results were compared with WHO standards for water quality. All 56 sampling sites were found contaminated with *Coliforms*/*Halophiles* and were found unsafe for drinking and not suitable for human consumption. Processing and compilation of data reveals that 100 % samples were found contaminated with *Coliforms* and *Halophiles* even exceeding WHO Guidelines for developing countries (0-10 E-coli / 100 ml). In order to manage microbial contamination, continuous microbiological monitoring of water is essential to ensure compliance with quality standards and to protect public health. Buffer strips (grasses and wetlands) between agricultural lands and the lakes are also recommended to hold on to the run-off during rainfall and irrigation events to reduce and/or completely immobilise the FC before it reaches to the lakes. Moreover, proper livestock manure management is required to minimise the contact of rain and/or irrigation water with the manure to avoid loss of the manure slurry into surface and ground water resources. This could significantly reduce *faecal* contamination of water resources in the Salt Range, Pakistan.

Introduction

The importance of potable (drinking) surface and sub-surface water supplies cannot be overemphasised (Boyer, 2008). With increasing industrialisation, water resources available for consumptive and non-consumptive uses such as bathing, cleaning and recreation have been adulterated with industrial, agricultural, animal and human wastes as well (Miernik, 2004). Sewerage effluents contain a wide variety of pathogenic micro-organisms that may pose a possible health hazard to human population (Lewis *et al.,* 2007). The effluents which are discharged directly into recreational water without proper treatment (Hill *et al.,* 2006), it may contaminate the water by providing a growing media for microbes. The density and variety of these pathogens are related to the size of the human population, the seasonal incidence of the illness, and dissemination of pathogens within the community (Pipes, 1982). Some types of *Coliforms* bacteria also naturally live in soils and surface waters, lakes, rivers and ponds (Giannoulis *et al*., 2005). The presence of *Coliforms* bacteria in open well water indicates that urban sewerage or some other type of surface contaminated water is entering and contaminating the water supply (Van *et al*., 2007). An open well contaminated with *Coliforms* bacteria requires immediate attention. According to WHO (2003); 80 % of sickness and disease in the world are caused by inadequate sanitation and polluted water. Children below 5 years of age are more affected due to diarrhoeal diseases in Pakistan where mortality rate is 109 per 1000 live births. Many waterborne pathogens are difficult to detect and/or quantify and the specific methods to detect them in environmental water samples has still to be developed (Borrego, 1994). While *Faecal streptococci* are suggested as the recommended indicator for salt water, either *Faecal streptococci* or *Escherichia coli* can be used for monitoring freshwater (Hardina and Fujioka, 1991). Additional variables can be investigated if, they are considered relevant, such as the spores of *Clostridium perfringens* in tropical water where the traditional indicators may increase in number in water (Anon, 1996).

In order to test *coliforms* and *faecal coliforms* and more effectively recover stressed *coliforms*, a variety of simpler and more specific test have been developed among which membrane filtration method has become a common and preferred method of evaluating the microbiological characteristics of water (WHO, 2003). According to WHO for drinking water to be safe a 100 ml sample of water should not contain any *coliforms* bacteria.

Halophiles are aerobic bacteria that grow in high saline/salty environments and form a diverse group of micro-organisms (Ramos, 1993). Bacterial *Halophiles* can be found in a range of environments i.e. saline water lakes and sediments (Rodriguez, 1986). These bacteria maintain their intra-cellular ionic

concentration at low-levels while producing organic solutes to provide osmotic equilibrium of the cytoplasm with the surrounding medium (Rodriguez, 1988). The aerobic *halophilic* bacteria have not been studied extensively while in comparison to other bacteria i.e. *archaea* (Kushner, 1989).

Majority of freshwater lakes and their surrounding wetlands in Pakistan are mainly surrounded by agricultural, industrial and residential areas. Wastewater treatment is not widely practiced in rural and suburban areas of Pakistan, which lead to the discharge of wastewater into water bodies. The practices of discharging untreated wastewater into water bodies and livestock grazing around water resources may pose a serious threat to the water quality. Water in lakes is used for human and livestock drinking, bathing, cleaning and irrigation purposes. These uses with no regulatory or water treatment facilities may have deteriorated water quality and contaminated with pathogens. Keeping in view the urgency of safe drinking water, the presence of *faecal coliforms/halophiles* in surface and sub-surface water of different lakes in Punjab province, Pakistan was investigated with the following specific objectives:

1. Investigated the presence of *faecal coliforms* and *Halophiles* in water resources of the lakes and ground water arising from agricultural run-off and to educate the stakeholders involved in waterways and wetlands management for consumptive and non-consumptive uses of water resources.
2. Recommend remedial actions, if any, to address potential health risk due to *faecal coliforms* presence in the water.

Material and Methods

Site selection for sampling

Key wetlands and wells located in Punjab Province of Pakistan have significant amount of salt. Saline nature of water is suitable for growth of *Halophiles* bacteria; in addition to the unhygienic practices involved in the wetlands keep stimulating the *faecal* contamination. The vulnerable status of the region's water resources and high rate of recorded water-borne diseases in the locality has helped investigate the pertaining issue. A total 56 sites were selected for water sampling in SRWC, including five lakes (Fig. 1), four open dug wells and four hand pumps. All these water resources (surface and ground water are currently in use by the custodian community for drinking purposes and other domestic uses).

Collection of samples

Water sampling was carried out according to the recommended procedures and outlines as published in the literature. The samples for the microbiological analysis were collected in small sterilised sample bottles sized 100 ml and transported in ice bags within 6 hours of time interval from collection up to refrigerator in the laboratory (Lewis *et al*., 2007). All the samples were analysed immediately after their collection for microbiological variables. The samples were kept cold under 4°C in a refrigerator till the time of analysis.

Bacteriological analysis

Membrane Filter (MF) technique was used for bacteriological analysis. The MF technique offers advantage of isolating discrete

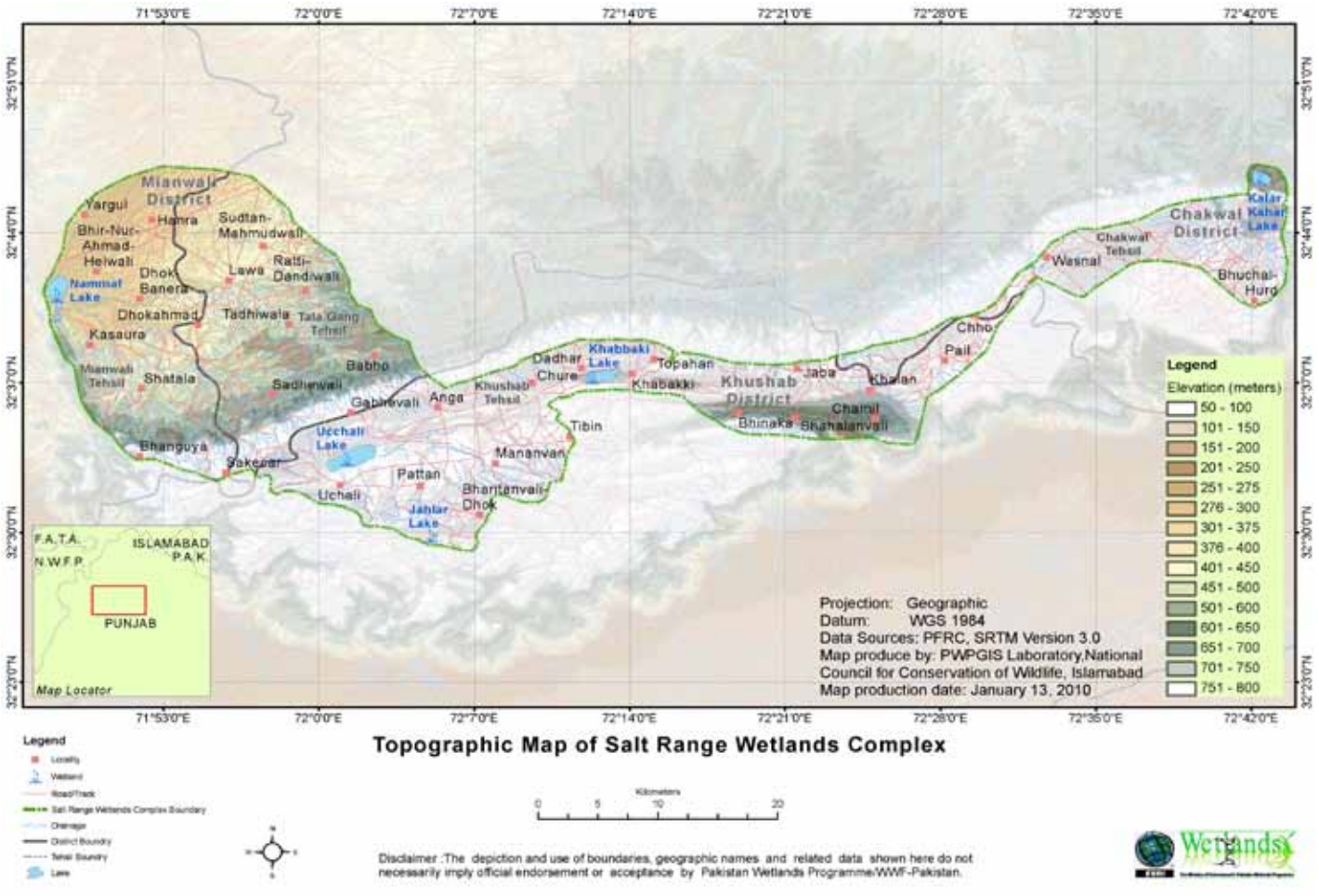

Figure 1: Five lakes of Salt Range Wetlands Complex, Pakistan

colonies of bacteria. US EPA declared that MF technique is an easy and standard technique and this was adopted for the bacteriological analysis of the water samples collected during the study.

Identification of *E-coli*

For identification of *E-coli,* brilliant green agar was used on which numbers of yellow colonies were counted using standard colony counter. The green agar is a culture medium, which contains lactose. Thus by degradation, acid raise the pH of the media which changes the colour of colonies to yellow.

Confirmation of *E-coli*

The presence of *E-coli* was confirmed on EMB (Eosin Methylene Blue) and MacConkey agar. *E-coli* exhibit green metallic sheen on EMB and pinkish white colonies on MacConkey agar (Table 1).

Identification of *Halophiles*

Halophilic bacteria were identified by providing MSA (Mannitol Salt Agar) as a growing medium. The colonies of the *Halophiles* on culture media were counted through colony counter.

Results

Analysing water samples and after deeply envisaging the drastic number of *Faecal*/*Halophiles* counts conclude a high *faecal* contamination. The results suggest a higher *Faecal*/*Halophiles* counts than WHO and US EPA standards for developing countries.

Status of *faecal coliforms*/*Halophiles* in selected water bodies

Kallar Kahar Lake

All of the samples were detected positive and show high concentration of *faecal coliforms* 324CFU/10ml in the sample labelled (KKWS2). On the other hand, the concentration of 213CFU/10ml *Halophiles* are high in number in the sample labelled (KKWS3). The lowest concentration of the *faecal coliforms* and *Halophiles* are 209CFU/10ml and 111CFU/10ml respectively (Table 2 & 2.1).

Khabeki Lake

The analysis show positive results for concentration of *faecal coliforms*, 2012CFU/10ml of sample KBWS4 to 320CFU/10ml for sample KBWS3 while concentration of *Halophiles* in a range between 156CFU/10ml in KBWS4 t 301CFU/10ml in KBWS1. The result explains that Khabeki Lake exceeds the WHO guidelines of the bacteriological standards of water quality and therefore the water is not suitable for human consumption (Table 3).

Khabeki Wells

Water extracted from wells are considered safe to drink but the detection level of aforementioned bacteria are positive and beyond WHO permissible level. High concentrations of *faecal coliforms* have been detected in the sample KBWWS3 viz 283CFU/10ml and concentration of *Halophiles* in sample KBWWS2 with 212CFU/10ml. While the lowest concentration of the *faecal coliforms* and *Halophiles* are 198CFU/10ml and 103CFU/10ml respectively (Table 4).

Uchali Lake

The analysis of samples from Uchali Lake demonstrate a range of 212CFU/10ml in sample ULWS2 to 269CFU/10ml in ULWS4 of *faecal coliforms* and the range of 101CFU/10ml in ULWS4 sample to 312CFU/10ml in ULWS2 sample of *halophiles.* The results are well above the permissible water standards of WHO (Table 5).

Uchali Well Water

High Concentration of *faecal coliforms* in the sample ULWWS4 is 267CFU/10ml of water, while concentration of *Halophiles* in sample ULWWS2 is 188/10ml, while the lowest concentration of the *faecal coliforms* and *Halophiles* are 197/10ml and 99/10ml respectively (Table 6).

Jahlar Lake

The situation of *faecal coliforms* and *Halophiles* at Jahlar Lake is not different than the other lakes of the Salt Range. The analysis of samples show the *faecal coliforms* are in the range of 233CFU/10ml in sample JLWS1 to 333CFU/10ml in sample JLWS3. The *Halophiles* concentration range determined is 142CFU/10ml in sample JLWS1 to 366CFU/10ml in sample JLWS2. This is higher according to WHO standards. Comparatively, Jahlar Lake reveals higher bacterial contamination, which could be caused due to its high salinity ratio and direct discharge of human and animal waste and defecations from the surrounding settlements (Table 7).

Table 1: showing *E-Coli* reaction with various growth media

Media	Organism identified	Selective/deferential media
Brilliant-green agar	*E-coli spp*	Brilliant green dye inhibit the growth of gram positive bacteria, *E-coli* with yellow colonies
EMB	Gram negative enteric pathogen	*E-coli* colonies purple and have metallic sheen
MacConkey	Gram negative enteric pathogen	Pinkish white colonies of *E-coli*

Table 2: *Faecal coliforms* and *Halophiles* count at Kallar Kahar Lake

Sample #	**FC**			***Halophiles***		
	EMB Media	**Qty**	**Usability**	**MSA Media**	**Qty**	**Usability**
Kkws1	Positive	314CFU	No	Positive	111 CFU	No
Kkws2	Positive	324CFU	No	Positive	203 CFU	No
Kkws3	Positive	303CFU	No	Positive	213 CFU	No
Kkws4	Positive	209CFU	No	Positive	144CFU	No

Table 3: *Faecal coliforms* and *Halophiles* count at Khabeki lake site

Sample #	**FC**			***Halophiles***		
	EMB Media	**Qty**	**Usability**	**MSA Media**	**Qty**	**Usability**
KBWS1	Positive	265CFU	No	Positive	301CFU	No
KBWS2	Positive	318CFU	No	Positive	219CFU	No
KBWS3	Positive	320CFU	No	Positive	197CFU	No
KBWS4	Positive	212CFU	No	Positive	156CFU	No

Table 4: Showing *faecal coliforms and Halophiles* count at Khabeki Wells

Sample #	FC			*Halophiles*		
	EMB Media	**Qty**	**Usability**	**MSA Media**	**Qty**	**Usability**
KBWWS1	Positive	198CFU	No	Positive	103CFU	No
KBWWS2	Positive	230CFU	No	Positive	212CFU	No
KBWWS3	Positive	283CFU	No	Positive	123 CFU	No
KBWWS4	Positive	247CFU	No	Positive	189CFU	No

Table 5: Showing *faecal coliforms and Halophiles* count at Uchali Lake

Sample #	FC			*Halophiles*		
	EMB Media	**Qty**	**Usability**	**MSA Media**	**Qty**	**Usability**
ULWS1	Positive	265CFU	No	Positive	133CFU	No
ULWS2	Positive	212OCFU	No	Positive	312CFU	No
ULWS3	Positive	219OCFU	No	Positive	299CFU	No
ULWS4	Positive	269OCFU	No	Positive	101CFU	No

Table 6: Showing *faecal coliforms and Halophiles* count at Uchali wells

Sample #	FC			*Halophiles*		
	EMB Media	**Qty**	**Usability**	**MSA Media**	**Qty**	**Usability**
ULWWS1	Positive	197CFU	No	Positive	99CFU	No
ULWWS2	Positive	201CFU	No	Positive	188CFU	No
ULWWS3	Positive	236CFU	No	Positive	171CFU	No
ULWWS4	Positive	267CFU	No	Positive	111CFU	No

Table 7: Showing *faecal coliforms* and *Halophiles* count at Jahlar Lake

Sample #	FC			*Halophiles*		
	EMB Media	**Qty**	**Usability**	**MSA Media**	**Qty**	**Usability**
JLWS1	Positive	233CFU	No	Positive	142CCFU	No
JLWS2	Positive	269CFU	No	Positive	366CFU	No
JLWS3	Positive	333CFU	No	Positive	199CFU	No
JLWS4	Positive	301CFU	No	Positive	213CFU	No

Table 8: Showing *faecal coliforms and Halophiles* count at Namal Lake

Sample #	FC			*Halophiles*		
	EMB Media	**Qty**	**Usability**	**MSA Media**	**Qty**	**Usability**
NLWS1	Positive	233CFU	No	Positive	323CFU	No
NLWS2	Positive	349CFU	No	Positive	99CFU	No
NLWS3	Positive	278CFU	No	Positive	297CFU	No
NLWS4	Positive	199CFU	No	Positive	256CFU	No

*CFU- Colony Forming Unit, *EMB-Eosin Methylene Blue, *MSA-Mannitol Salt Agar

Namal lake

One of the beautiful and historical lake of Pakistan, known as Namal Lake is also not exempted from bacterial contamination. Water quality analysis f the lake shows positive results with high concentration of *faecal coliforms* and *halophiles.* The analysis of the samples from the lake suggest the *faecal coliforms* range of 199CFU/10ml in sample NLWS4 to 349CFU/10ml in sample of NLWS2 and *Halophiles* in the range of 99CFU/10ml in sample NLWS2 to 323CFU/10ml in sample NLWS1. These levels are over the permissible WHO standards for water quality and the water is therefore not suitable for human use (Table 8).

Discussion

The range of *faecal coliforms* and *Halophiles* were high in each sample from initial to final point. *Faecal coliforms* showed elevated values from source 199CFU/10ml to 349CFU/10ml, while *Halophiles* recorded shared the range 99CFU/10ml to 366CFU/10ml in all selected lakes and well water. According to WHO standards for drinking water to be safe a 100 ml sample of water should not contain any *coliforms* bacteria. Results revealed that the quantity of *faecal coliforms* is very high in selected water sources and is above the standards of WHO. The possible cause for this contamination could be unsustainable human interference like irrigation, household use, laundry, septic tanks and direct effluents from settlements. Livestock have been noticed grazing, walking and drinking around the lakes. Farmers consolidate their livestock dung in the vicinity of lakes, where when the rain water directly flows in to the lakes, which appear like a major source of providing a growing medium for *coliforms* bacteria. Another possible cause is the intensive use of pesticides, insecticides and fertilisers in the agricultural crops around the lakes. These may be washed and the nutrient contained may provide a growing medium to bacteria.

In the light of results, the presence of high numbers of *faecal coliforms* and *Halophiles* in selected water resources indicates that the water of these lakes are not suitable for drinking purposes and other non-consumptive uses as per WHO recommendations. High rate of *Halophiles* bacteria in the wetlands is not suitable for fish as it cause de-oxygenation in water. During the field investigation in June; a large number of dead fish were recorded in the Khabeki Lake. Later on our hypothetical statement was proved correct by Punjab Fisheries Department; they claim that the mass mortality of fish was caused by de-oxygenation of the lake water. The Punjab Fisheries Department further added to their report that

blooms of red algae which caused de-oxygenation in lake water and eventually oxygen deficiency occurred, which led epidemic.

Conclusion

The *faecal coliforms* bacterial contamination level of Salt Range Lakes and well water resources is above the WHO limits for drinking purposes and thus the water from these sources is not safe for human consumption.

Implications of the Study

A spectrum of hypothetical and practical aspects regarding pathogens have been discussed which eventually goes to recommendations for taking sustainable measures in order to make the water sources safe. First, there exists a gap which needs to be filled by understanding of ecological long-term integrity of pathogens, their indicators, and consequences in linear connection to lake and ground water functions. Secondly, a comprehensive strategy should be formed to monitor and record microbial pathogens, their status, mode of action and related waterborne diseases. Proper livestock manure management is required to minimise the contact of rain or irrigation water with the manure to avoid loss of the manure slurry into surface and ground water resources. This could significantly reduce *faecal* contamination of water resources in Pakistan.

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Isolation of *Streptomyces* from the sediments of selected thermal springs of Northern Pakistan and its intrinsic susceptibility and resistance

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K E Y W O R D S

Isolation
Streptomyces
Antimicrobial
Susceptibility and resistance,
Thermal springs
Resistance
Sediments
Northern Pakistan

A B S T R A C T

This investigation aimed to examine the intrinsic antimicrobial susceptibility and resistance of Streptomyces species, isolated from the sediments of selected thermal springs located in northern Pakistan. Isolated species were subjected to morphological, physiological; biochemical and microscopic analyses. The isolates were examined for the consumption of various carbon sources, deprivation of complex compounds, susceptibility and resistance to antimicrobials and inhibitory compounds. The results indicated that all isolates demonstrated complete resistances to penicillin and ampicillin and weak resistance to Cotrimoxazole, Cephazolin, Deoxycline and Lincomycine. These isolates were moderately susceptible to Erythromycin, Cefaparazone, Cefapime, Amoxicillin and Cephradine while completely susceptible to Tetracycline, Vancomycin, Amikacin Gentamicin and Imipenem. In addition, Streptomyces isolates were more susceptible to Vancomycin and Gentamicin as compared to other antimicrobials and inhibitory compounds. This potential vulnerability of Streptomyces to Vancomycin and Gentamicin in particular, as therapeutic agents against infections by Streptomyces species is discussed.

Introduction

Filamentous soil bacteria belonging to the genus *Streptomyces* are globally accepted as significant due to their potential to produce variety of novel antibiotics as well as secondary metabolites (Williams *et al*., 1983; Crandall & Hamil, 1986; Williams *et al*., 1989; Korn-Wendisch & Kutzner, 1992). Different *Streptomyces species* produce important antibiotics, infact 70 % have been isolated from *Streptomyces* are used in medicine and agriculture (Miyadoh, 1993; Tanaka & Mura, 1993). Some *Streptomyces species* may infect lesions and scratches and instigate abscesses similar to those caused by *Nocardia species* (Huang & Chen, 1989). Severe illness caused by microorganisms have modified resistant to frequently used antibiotics has turn out to be a key universal healthcare problem in the 21st century (Alanis, 2005). Diminutive numbers of *Streptomyces species* ensure infections in humans, animals and plants (Williams *et al*., 1989). It is evident that prior to the use of the drugs, pathogens were susceptible to antibiotics and antimicrobial agents and hence treatment of infections were simple; but in most cases, the antibiotic resistance genes have instigated in the natural microbiota (Davies, 1994; Merson-Davies & Cundliffe 1994). Additionally resistance genes might be responsible for antibiotic resistance in their original organisms (Martinez, 2009; Martinez and Baquero, 2000). *Streptomyces* bacteria are usually present in the soil in the form of grains. *Streptomyces* is a medically important bacterium by producing antibiotics but at the same time it also causes diseases which are a major issue in rural areas. The infecting agent is implanted into the host tissue through a breach in the skin produced by trauma caused by sharp objects such as thorn pricks, stone or splinters. The disease is usually acquired while performing agricultural work and it generally afflicts men between 20 and 40 years old. The disease is acquired by contacting grains of bacterial that have been discharged onto the soil.

Thermal springs in the high altitude region are a special ecosystem, where probability of occurrence of species not found elsewhere is higher than other such places. *Streptomyces* being a unique species in terms of their habitat requirements, thermal springs in the northern Pakistan is hypothesised to be one of their key habitats. Since, conservation of biodiversity is one of the major aims of WWF - Pakistan, an investigation of the occurrence of this unique species in a sole habitat is critical to the goal of biodiversity complication and conservation. Keeping in view its significance for bioactive potential, and pathogenic nature at the same time, the current study was conducted to investigate the occurrence of *Streptomyces* in sediments of thermal springs in northern Pakistan in order to identify intrinsic resistance of the species against key antimicrobial agents. The study further aimed at identifying effective antimicrobial agents to cure the infections which are caused by *Streptomyces* itself.

Material and Methods

Study area

The thermal springs located in the northern part of the country has the suitable water temperature ranging between 28^{0}C and 40^{0}C, which is appropriate for growth of *Streptomyces* bacteria. This provided basis for selection of the site for this study (Fig. 1). This site forms part of the Northern Alpine Wetlands Complex of the Pakistan Wetlands Programme where one of the goals of the project is to compile its biodiversity resources. This provided the basis for selection of the sites for this study (Fig. 1). A total of six sediment samples from a depth of 20 cm were collected from all six study sites: Hajira (HJ), Garam Chasma Upper (GU), Garam Chasma Lower (GL), Chinar Bagh (CB), Tatta Pani (TP) and Hunza Nagar (HN). The samples were kept in properly labelled polyethylene bags, refrigerated and aseptically transported to laboratory for further analysis.

Data Collection

Isolation of Streptomyces species

One gram of soil samples were pre-treated with 0.1 gm of Calcium Carbonate ($CaCO_3$) and incubated at 37°C for 4 days and then suspended in 99 ml sterile solution of distilled water (Laidi *et al.,* 2006). 500 ml of Arginine Glycerol Salt medium (AGS) solution was prepared and sterilised at 121°C for 15 minutes. Laminar flow hood was pre-treated with methylated spirit and Ultraviolet (UV) light and then AGS liquid media was poured in

glass plates and kept it open for 10 minutes to solidify. Serially diluted suspensions of the soil samples were uniformly spread on the surface of AGS medium with the help of a dropper next to a spirit lamp in order to avoid any potential contamination by air borne micro-organisms (International *Streptomyces* Project - ISP).

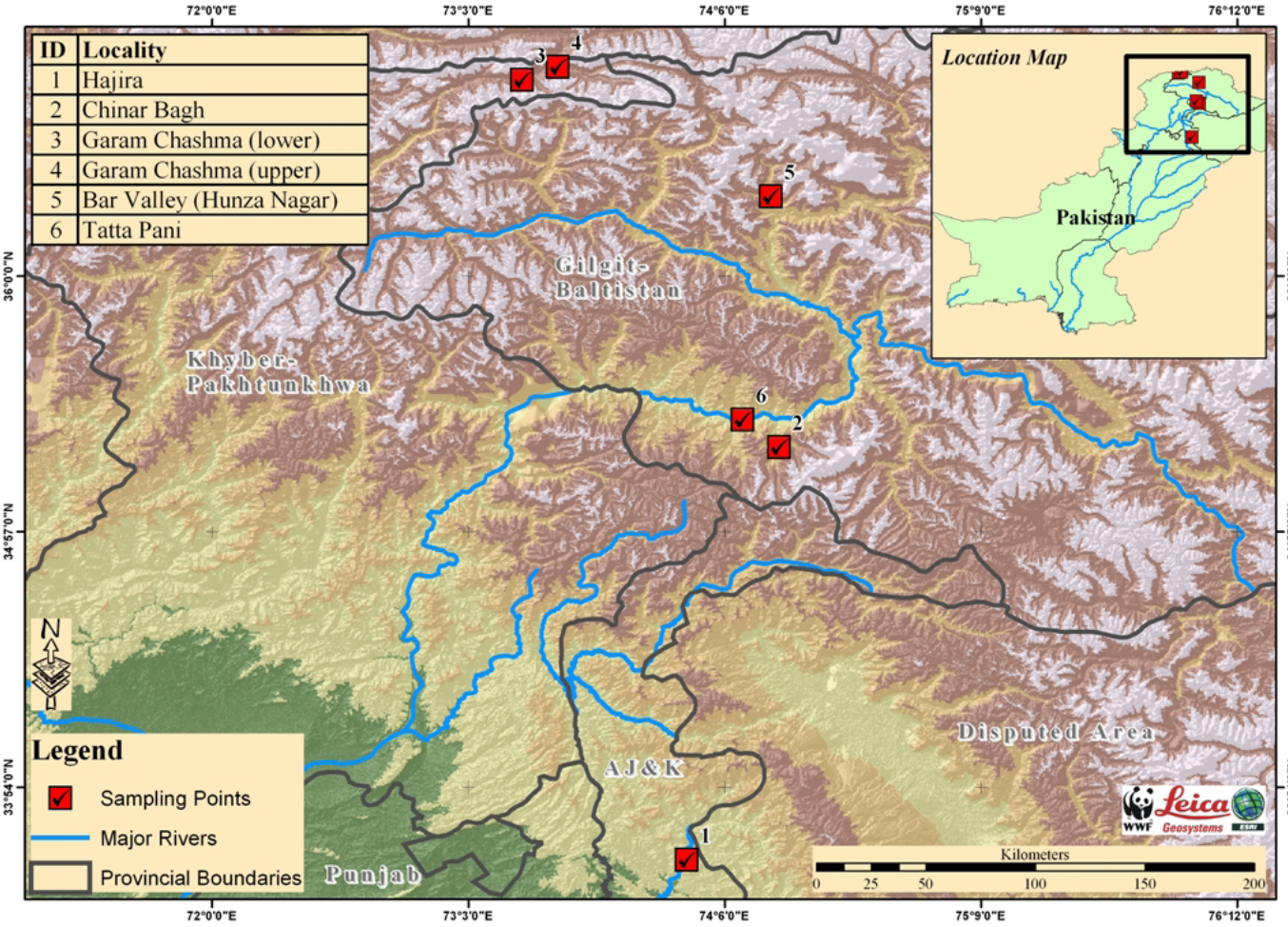

Figure 1: Soil sampling sites in thermal springs, northern areas of Pakistan

The plates were incubated at 37°C for 48 hours. After incubation period, the growth was clearly visible on plates.

Characterisation of the isolates

Gram staining, taxonomic, physiological, morphologic, and biochemical characterisation were carried out by using the methods recommended by the International *Streptomyces* Project (ISP) for characterising *Streptomyces* species (Shirling and Gottlieb, 1966). General morphology was determined using direct light microscopic examination of the surface of the cross-hatched cultures. Colours were determined according to the scale adopted by Prauser (1964). Different culture media such as Blood Agar, Chocolate Agar, Nutrient Agar, Mackcony Agar, SDA (Sabouraud Dextrose Agar) Agar and Cled (Cystine lactose electrolyte deficient) Agar were used to identify and differentiate characteristics of the species. Cells taken from the pure cultures were inoculated in flasks kept at 37°C for 48 hours in shaker incubator at a speed of 150 rotations per minute (rpm) to obtain uniform growth in AGS broth. Testing for antibiotic sensitivity was carried out following the Kirby-Bauer method. Antibiotic disks were placed onto plates and microbial interactions were analysed by determining the size of the inhibition zone.

Results and Discussion

Characteristics of *Streptomyces Species*

The results of physiological and morphological characteristics of *Streptomyces species* investigated are shown in Table 1 and Table 2. The results demonstrate that selective isolates from HJ, GU, GL, CB, TP and HN of *Streptomyces species* used all the carbon sources. Microscopic examination showed that surface of spore was smooth without adherent materials, the chain of spore was linear while slide cultures illustrated that it has aerial mycelia. These examinations are comparable with the investigations of Diab (1982) and Hongjuan *et al.* (2005). The susceptibility and resistance of all the *Streptomyces* isolated *species* was checked against the inhibitory compounds which indicated that all the *Streptomyces* isolated *species* were completely resistant to crystal violet but completely susceptible against Sodium Azide, Phenol and Potassium Tellurite (Deepika & Kannabiran, 2009). Results indicated that the range of temperature for the growth of *Streptomyces* species was 28-40°C while its NaCl tolerance was 0.025 to 0.15 g/L and pH range was 6 to 8 (Table 1), which are comparable results with the study carried out by Ibrahim (2006) and Laidi *et al.,* (2006).

Antimicrobial susceptibility and resistance of *Streptomyces species*

The mean percentage (%) of antimicrobial sensitivity and resistance of *Streptomyces* revealed that isolates from all six sites were (100 %) susceptible to Vancomycin, (99 %) to Amikacin, (98 %) to Gentamicin, (98 %) to Imipenem and (97 %) to Tetracycline. *Streptomyces species* showed modest resistance of (57 %) to Erythromycin, (56 %) to Amoxicillin, (53 %) to Cefaparazone, (51 %) to Cefapime and Cephradine respectively. The results also indicated poor growth against Lincomycine (41 %), Cephazolin

Table 1: Physiological and morphological characteristics of *Streptomyces*. *Positive (+ve)* indicates that the carbon sources have been utilised by *Streptomyces*. HJ*=Hajira, GU*=Garam Chashma Upper, GL*=Garam Chashma Lower, CB*=, Chinar Bagh, TP*=Tatta Pani, HN*=Hunza Nagar represents the sampling sites for the isolation of *Streptomyces*.

Carbon consumption	HJ*	GU*	GL*	CB*	TP*	HN*
Glucose	+ve	+ve	+ve	+ve	+ve	+ve
Xylose	+ve	+ve	+ve	+ve	+ve	+ve
Sucrose	+ve	+ve	+ve	+ve	+ve	+ve
Raffinose	+ve	+ve	+ve	+ve	+ve	+ve
Starch	+ve	+ve	+ve	+ve	+ve	+ve
Galactose	+ve	+ve	+ve	+ve	+ve	+ve
Maltose	+ve	+ve	+ve	+ve	+ve	+ve
Arabinose	+ve	+ve	+ve	+ve	+ve	+ve
Fructose	+ve	+ve	+ve	+ve	+ve	+ve
Lactose	+ve	+ve	+ve	+ve	+ve	+ve
Inositol	+ve	+ve	+ve	+ve	+ve	+ve
Glycerol	+ve	+ve	+ve	+ve	+ve	+ve
Mannitol	+ve	+ve	+ve	+ve	+ve	+ve
Rhamnose	+ve	+ve	+ve	+ve	+ve	+ve
Appearance	Mycelia	Mycelia	Mycelia	Mycelia	Mycelia	Mycelia
Range of temperature	28-40°C	28-4°C	28-40°C	28-40°C	28-40°C	28-40°C
pH Range	5.5 - 7.5	5.5 - 7.5	5.5 - 7.5	5.5 - 7.5	5.5 - 7.5	5.5 - 7.5
NaCl tolerance	0.025 - 0.15m	0.025 - 0.15m	0.025- 0.15m	0.025 - 0.15m	0.025 - 0.15m	0.025 -0.15m
Cell wall analysis	Yellow green	Yellow green	Yellow green	Yellow green	Yellow green	Yellow green

Table 2: Effect of inhibitory Compounds on *Streptomyces* Growth. **Res (Resistance)* indicates resistance of *Streptomyces* while **Val (vulnerable)* shows its vulnerability against the inhibitory compounds. HJ*=Hajira, GU*=Garam Chashma Upper, GL*=Garam Chashma Lower, CB*=, Chinar Bagh, TP*=Tatta Pani, HN*=Hunza Nagar represents the sampling sites for the isolation of *Streptomyces*.

Inhibitory Compounds	HJ*	GU*	GL*	CB*	TP*	HN*
Crystal Violet	Res	Res	Res	Res	Res	Res
Sodium Azide	Val	Val	Val	Val	Val	Val
Phenol	Val	Val	Val	Val	Val	Val
Potassium Tellurite	Val	Val	Val	Val	Val	Val

Table 3: Antimicrobial Sensitivity and Resistance of *Streptomyces* isolated species. *Negative *(-ve)* indicates vulnerability while **positive (+ve)* shows resistance of *Streptomyces* to antibiotics. *W* (Week Growth)* indicates weak growth and *M* (Moderate growth)* of *Streptomyces* in the culture media against antibiotics. HJ*=Hajira, GU*=Garam Chashma Upper, GL*=Garam Chashma Lower, CB*=, Chinar Bagh, TP*=Tatta Pani, HN*=Hunza Nagar represents the sampling sites for the isolation of *Streptomyces*.

Antibiotics	HJ*	GU*	GL*	CB*	TP*	HN*
Vancomycin	-ve	-ve	-ve	-ve	-ve	-ve
Penicillin	+ve	+ve	+ve	+ve	+ve	+ve
Ampicillin	+ve	+ve	+ve	+ve	+ve	+ve
Lincomycine	W	W	W	W	W	W
Cephazolin	W	W	W	W	W	W
Deoxycline	W	W	W	W	W	W
Cephradine	M	M	M	M	M	M
Cotrimoxazole	W	W	W	W	W	W
Amoxicillin	M	M	M	M	M	M
Cefapime	M	M	M	M	M	M
Cefaparazone	M	M	M	M	M	M
Erythromycin	M	M	M	M	M	M
Amikacin	-ve	-ve	-ve	-ve	-ve	-ve
Tetracycline	-ve	-ve	-ve	-ve	-ve	-ve
Gentamicin	-ve	-ve	-ve	-ve	-ve	-ve
Imipenem	-ve	-ve	-ve	-ve	-ve	-ve

(39 %), Cotrimoxazole (38 %) and Deoxycline (35 %), while it induced complete resistance to Penicillin and Ampicillin (Fig. 2). These results demonstrated that although *Streptomyces species* have the ability to produce antibiotics, which are noxious to their predators or their contestants but it also protect themselves against their own antibiotics by creating intrinsic antimicrobial resistance (Cundliffe, 1989). Furthermore, results clearly demonstrated that *Streptomyces species* also generated resistant to some extent to other antibacterial agents produced and protected themselves against their own antibiotics. There might be enzymatic defence pathways for their self protection e.g. Nourseothricin producer *Streptomyces noursei* creates resistant to its own antibiotics by inactivating Nourseothricin by enzymatic acetylation (Haupt *et al.,* 1986). Antimicrobial resistance and sensitivity of the *Streptomyces* isolates of different sites were checked against antibiotics, which indicated the following results as shown in (Table 3).

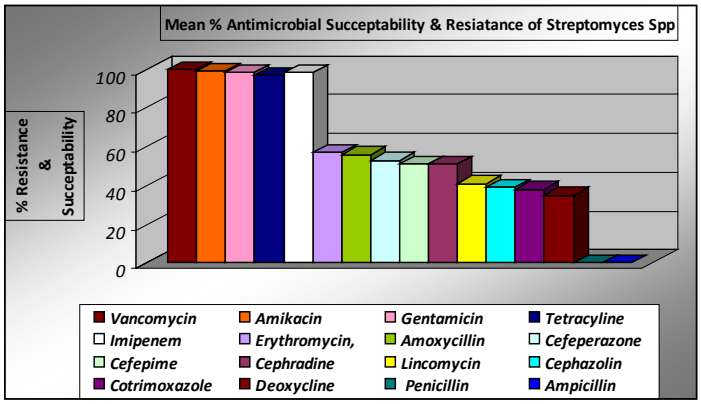

Figure 2: Mean percent, antimicrobial susceptibility and resistance of *Streptomyces* against different antibiotics in the culture media.

These results clearly demonstrate that *Streptomyces* at each location depend on its stress and competitive ecological conditions of their habitat (Walker, 1984), and showing intrinsic modifications of their target sites at each site (Hayes & Wolf, 1984). *Streptomyces erythraeus* which produce Erythromycin protect its ribosomal RNA (Potential site) by methylation to create adaptive change and intrinsic resistance (Cundliffe, 1984).

Conclusion

This study showed that thermal springs located in northern part of the country are sole habitats for *Streptomyces*, as these environments maintain an appropriate temperature regime that support the occurrence and growth of these species. This study also highlighted the range of intrinsic susceptibility and resistance of *Streptomyces* against antimicrobial agents. Thus, humans infected by this species may effectively be treated with Vancomycin, Amikacin, Gentamicin, Imipenem and Tetracycline. As this species occurs in a predominantly un-disturbed wetland region of northern Pakistan, specific protection measures need to be undertaken to protect their habitat from pollution. Their preservation is critical as a source of naturally diverse gene pool of *Streptomyces* that could have significant implications for drugs development and biodiversity conservation.

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Reducing Cotton Footprints through widespread Implementation of Better Management Practices (BMPs) in Pakistan

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K E Y W O R D S

Pakistan Sustainable Cotton Initiative
Better Management Practices
Better Cotton Initiative
Farmers
Freshwater ecosystem
Farmer Field School
Agro-ecosystem analyses
Facilitator

A B S T R A C T

WWF aims to help make agricultural commodities like cotton cultivation, part of a sustainable industry so as to make its production environment friendly and to reduce its footprint on priority ecosystems. There has been a growing concern among different stakeholders of cotton supply chain and consumers about the impacts of its cultivation. Inefficient crop management practices in cotton production contribute to water losses led to significant degradation of freshwater resources, biodiversity and the services that rivers provide. Besides this, intensive and indiscriminate use of chemical pesticides and fertilisers, contributes to serious environmental, social and economic problems in areas where it is cultivated. WWF - Pakistan and IKEA have been collaborating under "Pakistan Sustainable Cotton Initiatives (PSCI)" since 2005 for the development and promotion of site-specific Better Management Practices (BMPs) and building capacities of resource deficient smallholders to apply these BMPs as per their requirements. As a result of horizontal and vertical expansion, more than 50,000 farmers participated in the programme and were trained to grow better cotton over an area of about 200,000ha during 2011. These farmers made crop management decisions which led to 37.5 % reduction in water use, 47 % in pesticide use and around 41 % in fertiliser achieving 1:2.3 cost-benefit ratio compared with 1:1.1 by non-BMP farmers.

Introduction

In Pakistan, around 1.3 million farmers (out of total of 5 million) cultivate cotton on 3 million hectares, covering 15 % of cultivable area in the country (Pakistan Agricultural Statistics, 2009). Majority of the cotton growers in Pakistan are smallholders who face several social and economic problems resulting in insecure livelihoods which are further aggravated due to lack of access to credit facilities, information and extension services. In most cases, this situation results in indiscriminate utilisation of irrigation water and agro-chemicals. About 75 % of the total imported pesticides are used on cotton crops which is a serious threat to the ecosystem and health of the communities. The pesticide usage in Pakistan increased from 665 tons in 1980 to more than 50,000 tons during 2007 with 75 % of all the imported pesticides applied on cotton crop (PAPA, 2009). The excessive uses of agro-chemicals have led to enhancing green house gases emission resulting in increasing carbon footprints.

Increased exploitation of freshwater has led to significant degradation of freshwater resources, biodiversity and the services that rivers provide. While agriculture currently uses approximately 90-97 % of the water from the Indus River system, only an estimated 30-35 % reaches the crop and the rest is lost from irrigation channels as a result of groundwater seepage and as run-off from fields.

Traditionally, the major factors of low cotton yields include inadequacy of irrigation water and attack of different insect and disease pests. Overcoming these obstacles has been the central element of strategy of increasing yield and economic benefits to the growers with limited impacts on environment. However, this approach has resulted in increase in cost of production, lower gross margins and adverse impacts on farm workers' health and environment. There has been a substantial knowledge development in ecological crop management. However, much of this knowledge remains within research institutes or progressive growers and does not reach majority of cotton growers. Moreover, there are too many farmers and few extension people and, practically, it is impossible for these few extension workers to contact each and every farmer under the limited resources available.

Knowing the facts that cotton production is a burden on the environment, WWF - Pakistan launched Pakistan Sustainable Cotton Initiative (PSCI) in 2005 with the objective that the cotton farmers apply BMPs and an enabling environment created to facilitate and encourage the uptake and long-term use of BMPs at national and international levels (WWF, 2005-2011).

Material and Methods

Use of different participatory approaches such as Farmer Field School (FFS), Participatory Technology Development (PTD), Training of Trainer (ToT) and Training of Facilitator (ToF) have been demonstrated as effective means of BMPs dissemination. These approaches are field-based and participatory and each setting has its own problems and solutions, and farmers must be equipped and skilled to best address their problems. Under the ToT/ToF, 25-35 participants were trained over a cropping season to become Master Facilitator and they in turn facilitate widespread dissemination of knowledge to fellow farmers. The course contents were developed on the basis of problems and issues identified by experts and farmers collectively to address all aspects of farming as well as taking into consideration the socio-cultural aspects. The FFS activities were based on discovery learning process through non-formal adult education techniques involving simulation and group dynamic exercises. This model aims at helping farmers to discover and learn about field ecology and integrated crop management starting from land preparation to right seed selection, rational use of irrigation, fertilisers and pesticides, harvesting and marketing. Under these FFS, farmers learn how to best utilise indigenous resources and implement best natural resource management strategies based on the financial input.

The key to success of these approaches is empowerment of the farmers with an understanding of the agro-ecology of their own fields.

For widespread dissemination of BMPs, an innovative approach of One Village One Facilitator (OVOF) was widely used which is based on:

1. Continuous enhancement of skills and capacity-building of the farming communities
2. Discovery learning process
3. Outreach and technical backstopping
4. Continuous monitoring and quality assurance activities.

The facilitator was based in a village and facilitated implementation of different BMP activities in collaboration with local activists. Normally, one facilitator facilitated, on an average, around 150-200 smallholders covering an area of about 2,000-2,500 cotton acres. These smallholders were further sub-divided into Learning Groups (LGs) with 25 - 40 farmers in each LG. In case of large holders, a facilitator addressed 1-7 farmers only. The activities normally involve establishment of learning plots, weekly ecosystem analyses by farmer groups, discussion and decision making supported by outreach technical support.

Makhdum *et. al.*, (2002 & 2003) highlighted the importance of in-built mechanism for quality assurance and monitoring and listed criteria for evaluation of FFS. In case of persistent weaknesses, specialised capacity-building workshops were organised by inviting experts from premier research institutions and universities in Pakistan.

Results and Discussion

Over the period of time, several participatory BMPs were formulated and validated in close collaboration with research institutions like Central Cotton Research Institute (CCRI) Multan, Ayub Agriculture Research Institute (ARI) Faisalabad, Nuclear Institute of Biology and Genetics Faislabad, Water Management Institute, Faisalabad, Arid Agriculture Research Centre, Bahawalpur and later on these were disseminated through participatory approaches among farming communities in Bahawalpur, Lodhran, Rahim Yar Khan and Toba Tek Singh in the Punjab and Sukkur and Ghotki in Sindh. (Map). List of BMPs developed and disseminated are attached as Annex 1

Irrigation Management

The major BMPs were focused on modified Flatbed-Furrow Technique (FFT) based on ridge formation after first irrigation. In this technique, sowing is done on flat bed and after first irrigation, 30-40 days after sowing, ridges are made with bull plough or with the help of tractor. This technique helps in saving of around 27 - 33 % of the water.

Another technique which gains popularity among farmers, particularly, smallholders is irrigation on indicators. Five visible indicators based on plant and soil conditions were developed and tested. These include compactness of sub-soil, red streak on plant stem, stiffness of topmost portion of the plant, yellowing of top leaves and appearance of white flower. Comparison of control and experimental plots show that around 30% water can

be saved if the indicators mentioned above for experimental plots are carefully followed. As far as different water saving BMPs are concerned, higher seed cotton yield was obtained under alternate row irrigation (2,473 Kg/ha) followed by irrigation based on water scouting (2,468 Kg/ha) (Fig. 1).

Fertility Management

Several BMPs such as soil testing, side dressing, using fertiliser after irrigation, placing fertiliser, split dosing, nutrient scouting, basal dose, green manuring and composting were tested and widely disseminated. Farmers, usually apply fertiliser before irrigation which result in losses due to oxidation, seepage, drifting of fertiliser particles to corners. The results and experiences show that there could be as much as 21-27 % of the fertiliser saving as a result of application of first three BMPs only. Similarly, in case of placing fertilisers, farmer can save up to 18-26 % fertiliser and nutrient scouting helps saving of around 12-18 % of the fertilisers (Fig. 2).

Compost acts as a soil conditioner and increases its water holding capacity. Several participatory trials indicated that in the control plot, farmer applied 1,445.86 m^3 of water compared with 1,172.84 m^3 of water where compost was applied at the rate of 800 Kg/ha. Moreover, BMP farmers used 90 Kg/ha of Nitrogenous fertiliser compared with 240 Kg/ha by the control farmers, thus showing reduction of 62.5 %. BMP farmers got seed cotton yield of 2,170 Kg/ha by applying 750 ml of pesticides compared with 1,996 Kg/ha by applying 1,650 ml of pesticide by the control farmer (Table 1).

Plant Protection

Several BMPs such as conservation of beneficial, understanding ecosystem, using alternate materials (botanical pesticides), sanitation, pheromone and light traps and redistribution of beneficial, using pesticides based on pest-beneficial interaction were tested and widely applied. Roshanzada *et. al.,* (2001), reported the success of farmer led IPM programme and our experiences show that if these practices are applied as a package can help in reduction of pesticide use up to 60 %. Community cotton insect pest tracking system which was introduced couple of years back has now become a permanent practice and being implemented successfully for pre-sowing ecosystem management

Table 1: Use of fertilisers, water and pesticides in the plots where compost was applied

	Water (m^3)	Pesticide (ml/ha)	Synthetic Nitrogenous Fertilisers (kg/ha)	Yield(Kg/ha)
BMP Farmer	1,172.84	750	90	2,170
Control Farmer	1,445.86	1,650	240	1,996

of important insect pests, by removing alternate host plants. This is a community mobilisation activity, which are provided with basic training on insect identification and community members are encouraged to report about the incidence of pests. This has helped to report and eradicate major populations of mealy bug this year (Fig. 3).

The pesticide consumption in BMP plot ranged from 955 - 1,375 ml per acre compared with 2,400 - 3,000 ml in the control plot (Fig. 4).

Widespread dissemination of BMPs

During 2011, widespread BMP dissemination activities were carried out with more than 47,479 farmers over an area of around 204,400 ha as per following detail (Table 2).

Regarding adaptability of different BMPs for fertility management, maximum adaptability was observed in split dosing followed by use of nutrient indicators. In case of irrigation management, maximum adaptability was observed in case of water scouting followed by flat bed and ridge formation after first irrigation. Similarly, in case of pest management, conservation of beneficial followed by sanitary and phyto-sanitary activities and using alternate material were the most popular among the farming communities.

The BMP cotton farmers made crop management decisions which resulted in 41 % reduction in synthetic fertilisers, 37.5 % in irrigation water and 47 % in pesticides (Fig. 5 & 6) with a cost-benefit ratio of 1:2.34 for BMPs as compared with 1:1.12 of non-BMPs. The average gross margin for BMP farmers was 70 % compared with 52.86 % for non-BMP farmers, making a difference of 17.14 %.

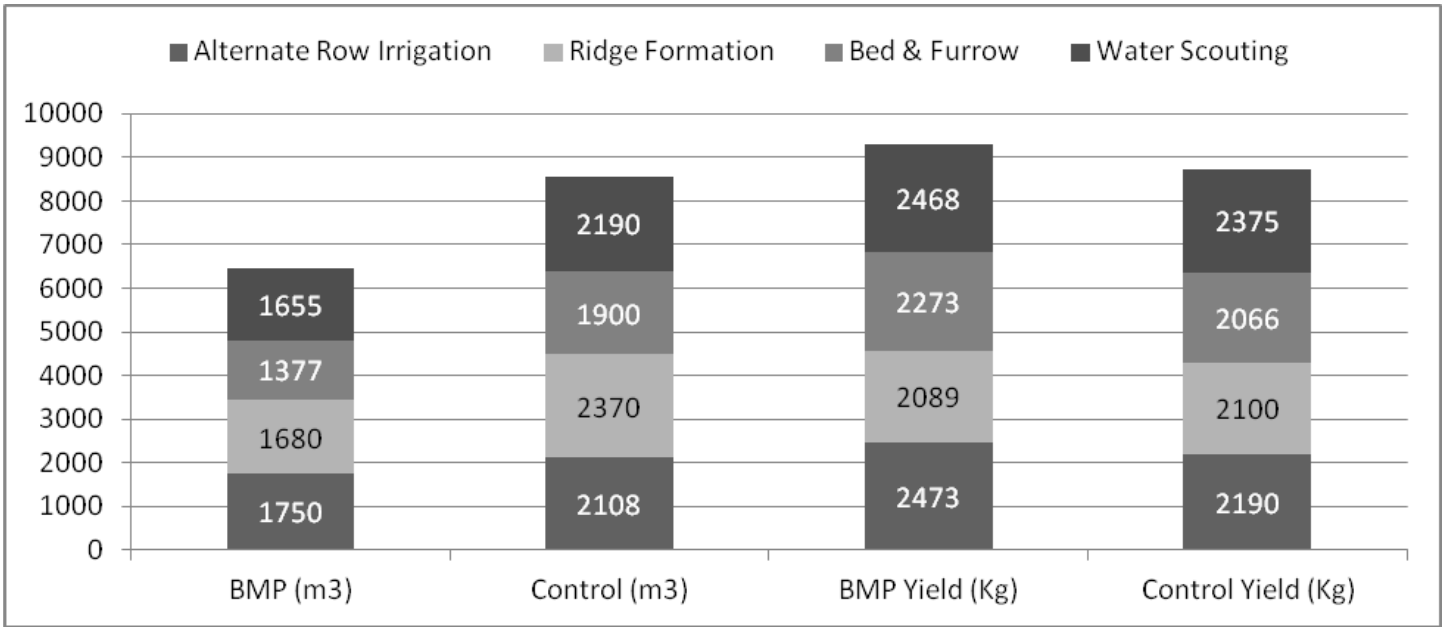

Figure 1: Quantity of irrigation water in cubic meter and yields in kg/ha in BMP and control plots under different irrigation BMPs

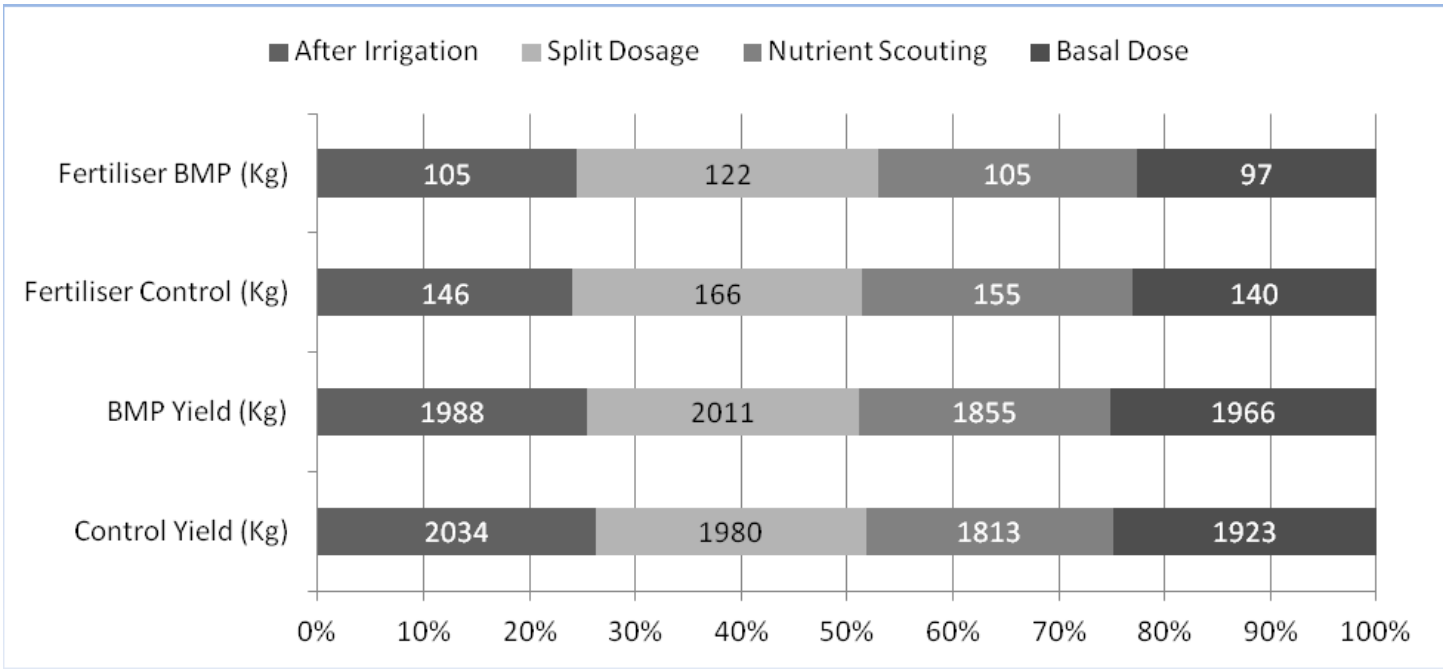

Figure 2: Use of synthetic fertilisers and yield in kg/ha in BMP and control plots

Conclusion

The programme taught smallholders to better understand biodiversity, interaction between beneficial and harmful organisms, minimising pesticide use and promoting botanical pesticides to improve environmental health and learn how to reduce water and fertiliser use by wisely using irrigation and fertility indicators, altering application techniques and enhancing use of organic manure and compost. Comprehensive analyses of the results show that cumulative irrigation water application by BMP farmers was 0.8 billion m^3 compared with 1.3 billion m^3 by the same number of control farmers over the same acreage of cotton cultivation. There is a difference of 0.5 billion m^3 of water which will help in improving the ecosystem services. Similarly, in case of synthetic fertilisers, cumulative application was 49,497 Metric Tons (MT) compared with 83,336 MT by the same number of control farmers over the same acreage. Thus, there is a saving of around 33,839 MT of synthetic fertilisers. In case of synthetic pesticides, total solution used by BMP farmers was 0.79 million litres compared with 1.48 million litres by control farmers over the same number of acreage.

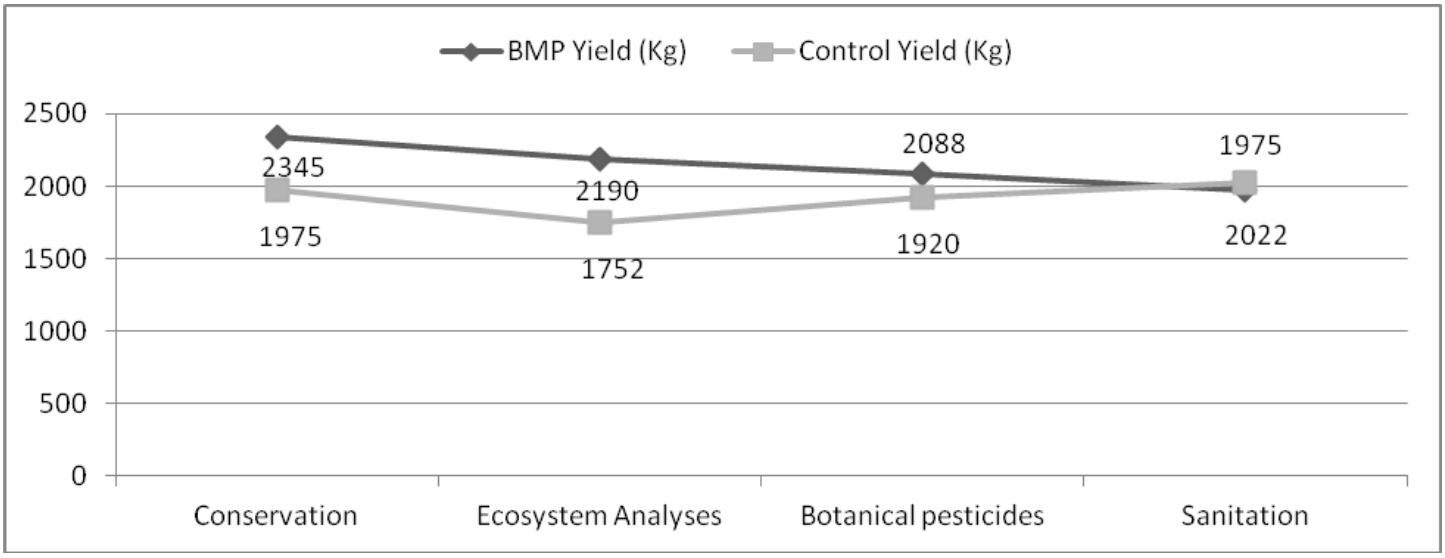

Figure 3: Yield in Kg/ha in BMP plot where IPM techniques applied and in control where pesticides were used

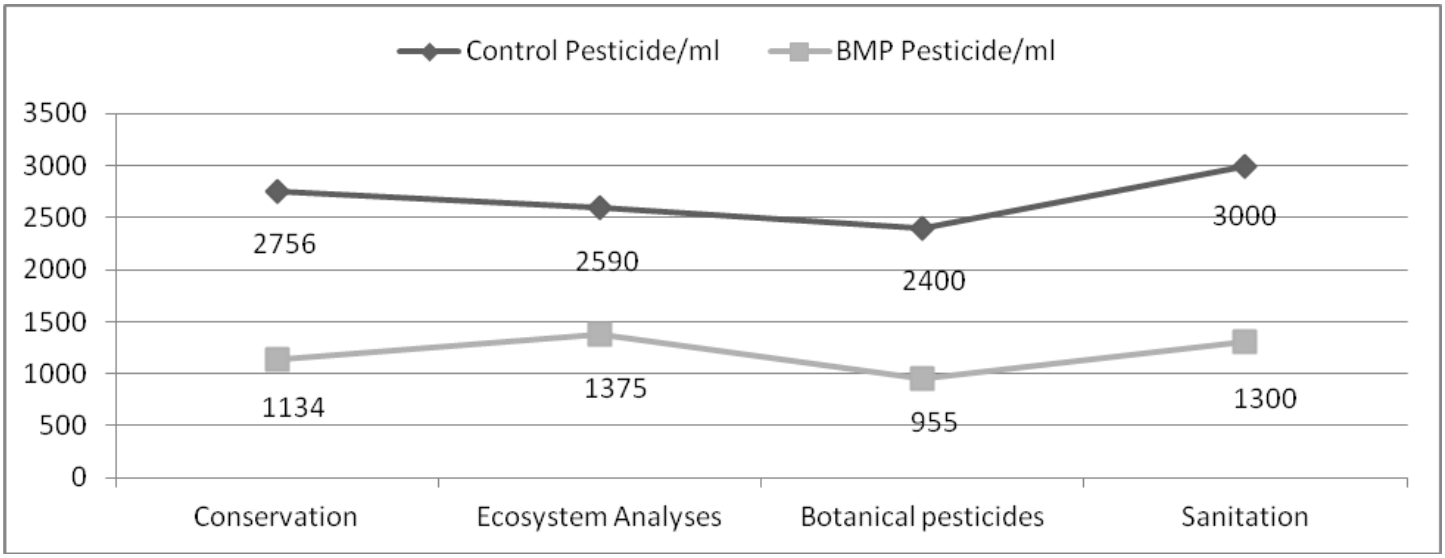

Figure 4: Pesticide application in ml in BMP and control plots

The results clearly indicate that BMP applications help reduce the cotton footprints. However, the estimation of the exact footprint values is very important to prepare response strategy, which will provide a strong foundation for increasing farm resilience in the face of climate change. Increased concentration of green house gases are causing earth's temperature to raise, while agriculture consumption, prices and farm income are affected by these temperature increases. The agriculture industry cannot be held unaccountable for the role it plays in global climate change. The cotton production lets off two sources of green house gases; methane and nitrous oxide and concentration of these gases can be reduced by implementation of BMPs.

A full environmental footprint assessment goes beyond calculating GHG emissions and water consumption, in that, it also addresses the sustainability of resource use, as well as allows a business to identify its emission- and water-related impacts and vulnerabilities, and identify potential response actions. The potential for GHG mitigation in the cotton sector is high. A range of mitigation measures will be deployed through the adoption of improved cropland management practices (reduced tillage, integrated

Table 2: Number of farmers and area of cotton cultivation under BMP during 2011.

District	Total Farmers	Total (ha)
Bahawalpur	16,700	90,000
Toba Tek Singh	14,600	26,150
Rahim Yar Khan	5,679	27,850
Sukkur & Ghotki	10,500	60,400
Total	47,479	204,400

nutrient and water management, and conservation agriculture); reduction in the emission of methane and nitrous oxide, through improved animal production, improved management of livestock waste (manure and biogas), more efficient management of irrigation water, and improved nutrient management; and sequestration of carbon, through crop cover and proper composting process.

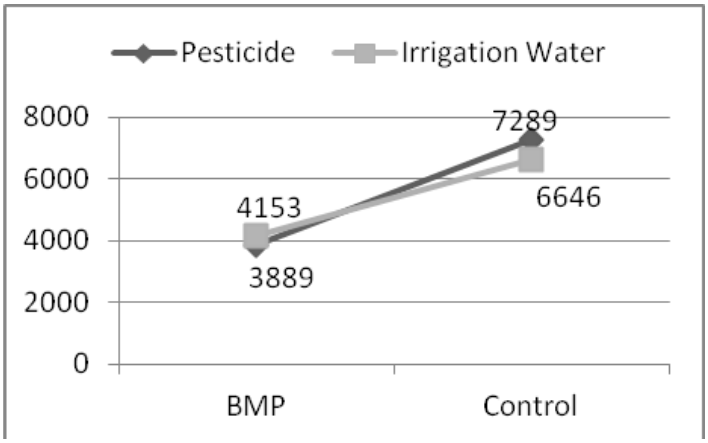

Figure 5: Average irrigation water use in m3/ha and pesticide applications in ml/ha by BMP and control of farmers

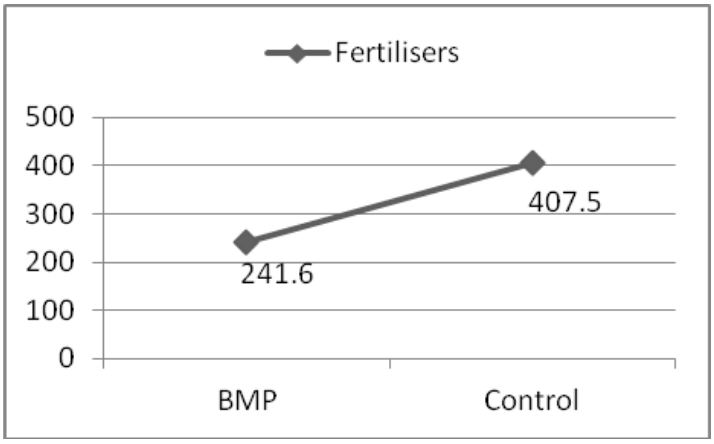

Figure 6: Average use of synthetic fertiliser in Kg/ha by BMP and control farmers

WWF -Pakistan is planning to implement a project to develop tools to quantify cotton footprints to develop their mitigation strategy with the following objectives:

1. Assessed the GHG emission and Water footprint (Environment footprint) associated with cotton cultivation in the cotton growing regions of India and Pakistan;
2. Plan of action with mitigation measures is in place to address the issue of environment footprint.

Convincing farmers to change their practices has been challenging since smallholders do not want to take risks. But on-farm research, and working continuously with these farmers while building their capacities and enhancing their farming skills, strengthening local organisations, convinced farmers that the BMPs make business. BCI and WWF – Pakistan's intention is to make BC a main stream commodity which should be available on existing market prices as conventional cotton.

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Economic valuation of wetlands: acknowledging values and services

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K E Y W O R D S

Economic valuation
Indus For All Programme
Use Value
Ecosystems
Wetlands management
Total Economic Value

A B S T R A C T

The studies on ecosystem valuation carried out under Indus for All Programme during 2007 and 2008 are reported in this paper. Five ecosystems were valuated for direct-use value (DUV), non-use value (NUV) and indirect-use value (IUV), thereby providing a total economic value (TEV). The habitats were deltaic ecosystem, rangelands**,** freshwater, forests and agriculture. In this paper, valuation of wetlands was focused and was briefly compared with the values of other ecosystems. The role of wetland valuation as a conservation tool was analysed to shape national policies of freshwater and/or wetlands management. It is concluded that such tools are very useful in the conservation of critical ecosystems as long as the information is disseminated to a wide audience.

Introduction

The term "valuation" refers to the assignment of monetary values to flows of services provided by ecosystems such as lakes and forests. In Pakistan, publishable quality valuation studies focusing on the monetization of environmental services were first produced by individual academics. A study carried out less than a decade ago, placed a Rupee value on the flow of recreational services associated with stands of forests at the Margalla Hills National Park (Khan, 2004). While the study provided results in a policy relevant format, the audience for the study was probably restricted to the Capital Development Authority, Islamabad. By contrast, a study carried out by the World Bank a few years later inspired much interest among federal-level planners and policy makers, primarily in the Planning Commission, the then Ministry of Environment, and the Finance Ministry (World Bank, 2006). This study estimated that the cost of environmental degradation in Pakistan is Pak Rs. 1.7 billion per day or USD 18.8 million (inflation adjusted May 2012 values), a figure based on service flows from rangeland and forest ecosystems together with soil salinity, soil erosion, water, urban air, and airborne lead and indoor air pollution. Most recently, only in the last four years, WWF – Pakistan, applied valuation methods to rangelands, and forest ecosystems again, but added values for three other ecosystems, namely coastal, agricultural and freshwater ecosystems (WWF, 2008). One of its goals was to set a standard for future studies applying methods to primary data, since the World Bank study neither collected field data nor applied standard valuation methods to such data, basing itself instead on secondary data. However, WWF - Pakistan's primary goal is to truly engage planners, development practitioners, and policy makers in the commissioning, oversight and application of valuation studies and their results. Accordingly, WWF - Pakistan prepared national guidelines on valuation focusing on the forest sector (WWF, 2010) and produced a number of additional policy, academic (Dehlavi and Adil, 2010), and best practices studies on ecosystem valuation and green accounting. The term "green accounting" refers to aggregate indicators that would assist environment, economic and natural resource ministries to determine how much depreciation spending to set aside year on year to replenish forests, rangelands, freshwater, and other kinds of natural capital stock after their use to fuel economic growth. For example, this refers to the amount of money to set aside to pay for afforestation and reforestation after harvesting of timber for commercial use.

This paper largely focuses on WWF - Pakistan's findings and their potential uses, also providing an accessible introduction to ecosystem valuation. In order to distinguish itself from a standard textbook introduction to economic valuation for environmental assets, Pakistan specific examples of wetlands and conservation planning are used to explain and illustrate valuation in practice. Further, also to provide a unique and applied exposition of wetlands valuation, WWF - Pakistan's practitioners who themselves implemented the first six years of a 50-year Vision of the Indus Ecoregion and who also carried out the valuation studies share here their aspirations and on-the-ground experiences. One aspiration is that ecosystem valuation becomes a redundant scientific exercise by 2060 or thereabouts in Pakistan, inasmuch as its methodology eventually becomes subsumed in standard resource accounting software; and, that its Pak. Rs. time-series data results (collected annually or at any periodicity necessitated or permitted by cost considerations and technology) become as commonplace to government statisticians as Pak. Rs. gross domestic product data. At this future date monetary, fiscal, and other policies that today help control the extent of unspent money that may be allocated for wear and tear of man-made capital such as factories, buildings, and roads, will consider generating savings to replenish natural capital stocks that fuel Pakistan's economic growth.

The habitat studied

Five ecosystems where selected for the evaluation studies. These are as follows:

Deltaic ecosystem: This encompasses the tail end of the Indus River some 200 km south of Hyderabad down to the system of creeks that run into the Arabian Sea, covering 41,440 km^2 of estuarine, mangrove and inter-tidal habitats. The mangroves in the delta are some of the most productive but critically threatened habitats in the Indus Delta.

Freshwater: Sindh has some of the most unique and ecologically important freshwater habitats in Pakistan. Ranging from the largest freshwater lakes e.g. Manchar Lake and Keenjhar Lake to the wetlands complex on the edge of Achro desert, freshwater wetlands are important to the environmental services and economics of the country and especially Sindh.

*Rangelands***:** Rangelands make up approximately 78,000 km^2 of land in Sindh. Rangelands support some of the most productive habitats occurring in arid zones, grazing lands (in irrigated areas) and mountainous regions. Rangelands are the source of livelihood for thousands of herdsmen and pastoral communities across the country. They are also a very good source of medicinal plants. For

this study, Chotiari Reservoir and wetlands complex was selected.

Forests: Forests comprise of several habitats such as riverine, irrigated plantation and mangroves. Rangelands are also considered as part of the forest management system. In Sindh, riverine forests were once widespread and played important ecological services as part of the Indus River Basin. Currently riverine forests in Sindh are confined only to patches, primarily due to the reduction in inundation as a result of construction of barrages and reservoirs upstream in the River Indus.

Agriculture: Thousands of hectares of land have been converted to agricultural land in the region. Currently, approximately 40% of land use in Sindh is agriculture. Agricultural practices in the region go back to thousands of years. Once fertile land, poor land and water management resulting into salinity and water logging, coupled with scarcity of water has rendered much of the land uncultivable.

The following discusses wetlands ecosystems and the results of valuation work undertaken by WWF - Pakistan between 2007 and 2010.

Priority wetlands

In many instances, valuable flows of services emerge from environmental assets – e.g., forests, freshwater lakes and air quality – but are not counted in billions of rupees, either on a case by case basis or for Pakistan as a whole. Let us take Pakistan's largest freshwater lake, Keenjhar Lake, as an example to illustrate types of valuable flows of services that this 14,000 ha lake provides. Among benefits that can be reaped at the lake site itself are fisheries catch and eco-tourism; referred to as "*direct use values (DUVs)*" for purposes of valuation studies. Similarly, an example of what valuation studies refer to as an indirect benefit or "*indirect use values (IUVs)*" is the supply of water, both commercial and domestic, that Karachi obtains from the lake. In the case of Karachi, one million of its nearly 20 million residents are connected to the reticulation system, and as much as 80 % of their annual domestic water needs are met by Keenjhar Lake. Finally, valuation studies refer to «*non-use values (NUVs)*" and these are the warm glows, so to speak, that people who may or may not ever have visited the lake get from knowing that it exists (*existence values*), knowing that they may one day visit it (*option use values*), and being safe in the knowledge that conservation actions may result in maintaining the lake for future generations (*bequest values*).

Ecosystem Valuation

Table 1 below lists the DUVs, IUVs, NUVs and TEVs (Total Economic Values) associated with wetlands in the Indus Ecoregion, Sindh Province, namely forest, rangeland, freshwater, coastal, and agricultural ecosystems. It is worth making several points about the values that are listed here.

Table 1: Ecosystem Values (Present Value, Rs. Billion)

May 2012	DUV	IUV	NUV	TEV
Deltaic (Keti Bunder)	9.0	0.7	0.4	10
Rangeland (Chottiari)	2.4	-	2.4	5
Freshwater (Keenjhar)	7.5	6.9	0.4	15
Forest (Pai)	0.8	0.1	1.9	26
Agriculture (Pai)	23.0	-		
Total	42.8	7.7	5.1	56

Source: *inflation adjusted figures based on WWF 2008 and Dehlavi and Adil, 2010 (All values calculated using a 10 % discount rate; assumes a limitless time horizon).*

Table 2: Ecosystem Values (Present Value, USD million)

2012 May	DUV	IUV	NUV	TEV
Deltaic (Keti Bunder)	99.5	7.8	4.2	111
Rangeland (Chotiari)	27.1	-	27.1	54
Freshwater (Keenjhar)	83.7	76.9	4.2	165
Forest (Pai)	9.0	0.9	20.8	286
Agriculture (Pai)	255	-		
Total	474	85.6	56.3	616

Source: *inflation adjusted figures based on WWF (2008) and Dehlavi and Adil (2010) (All values calculated using a 10% discount rate; assumes a limitless time horizon).*

First, DUVs, IUVs and NUVs are arithmetically summed to produce TEVs, which are the only values that are policy relevant. In the case of deltaic or coastal ecosystem, DUVs consisted of fisheries, while IUVs were those of the prevailing market values associated with carbon sequestration for stands of mangrove forest, both dense and sparse. The IUVs of Pai Forest in Shaheed Benazirabad also consisted of carbon market values for tree species in the forest. The NUV for the study is based on perceptions of a representative sample of Karachiites, interviewed in each of Karachi's 18 towns (Dehlavi *et al.*, 2010).

Second, values in Table 1 (above) need to be adjusted before being interpreted, among others by determining per hectare values, and selecting discount rates and time horizon assumptions to allow comparison and use. Thus, in the case of Keenjhar lake, the TEV of Pak Rs. 15 billion needs to be divided by 14,000 ha to produce a per hectare value of Pak. Rs. 1.05 million. The corresponding values for other ecosystems are Pak. Rs. 1.33 million (coastal), Pak. Rs.0.27 million (rangeland), Pak. Rs. (forest) and Pak. Rs. 22.9 million (agriculture).

Third, the WWF study methodology for the calculation of net present values (NPVs) listed in Table 1 uses an assumption of an infinite time horizon. That is, it is assumed that the benefits described, e.g., fish catches, are sustainable. Suppose we assume these benefits exist for only 50 years, then with a 10 % discount rate, the NPV is little affected. These values are obviously sensitive to the discount rate. For instance, if discount rates are assumed to be 20 %, this would halve the NPV. In Table 1, the 10 % discount rate is used because this corresponds to the average yield of the 6 - months Treasury Bill (T-Bill) for the past 15 - 20 years (about 10 % between March 1991 and April 2009, at the time the study was carried out). This is a conservative benchmark for the time value of money in Pakistan. Pakistan Investment Bonds probably would have been better instruments than 6 month T-Bills to obtain average yields for this purpose, but data are available only from 2001 onwards. A sensitivity analysis (for discount rates of 1 %, 5 %, 10 %, 15 %, and 20 %) has been presented in Dehlavi *et al.,* (2008).

Fourth, another important point to note for Table 1 is that the numbers presented are annual means from the authors' cluster sampling procedure. In the case of Keti Bunder, DUV figure in Table 1, the associated standard errors lead to a 95 % confidence interval ranging from 303,569,915 to 1,176,928,997. This means that gross margins in Keti Bunder are significantly different from zero. Only estimates which were significantly different from zero were included while calculating the total annual benefit values. Similar interval estimators exist for all the sites in Dehlavi *et al.,* (2008). To put this in layman›s terms, the figures are not meant to be interpreted as being exact, but lying within a range. This is a statistical point, but one worth emphasising to Pakistan›s planners and policy makers who need to be fully informed.

Fifth, methodology used to compute values relies on multivariate or econometric analysis. Most of the techniques in use were devised within the branch of economics known as welfare economics, each relying broadly on two types of streams of data. One technique, the "revealed preference" class of techniques,

relies on the tracking and recording of all relevant transactions and time allocations of respondents, producing a huge dossier of their movements and purchases, allowing modelers to use individual respondents' economic biographies to reveal the worth placed by the estimated total number of users of the ecosystem service in question. The other technique relies on the surface of it rather simply on peoples' own "stated preferences" as reported by them; but, it too relies on complicated techniques. These often establish a hypothetical market and within this exercise bear responsibility for demonstrating that standard strategic and other biases did not interfere while answers were volunteered.

Sixth, the standard methodological steps accompanying valuation studies, also described in detail in WWF (2010) are:

1. agree the aims and objectives of the valuation study to be commissioned by economic planners and policy makers;
2. define geographical and analytical boundaries while listing primary and secondary data requirements;
3. consult "rank tables" to prioritise assets, services and attributes and, for each, list preliminary information requirements;
4. choose revealed and stated preference technique(s) noting general / essential informational requirements of the specific technique (e.g., Market Value method). Also, consult "criteria tables" to apply the technique which is most appropriate for the given type of lake, forest, etc;
5. consult questionnaire design best practice guidelines separately for each technique since attitudes, opinions, knowledge, resource use, and demographic informational requirements vary by technique;
6. use Simple Random Sampling (or "probability sampling") where resources permit such an approach in order to get a genuinely random sample;
7. define the sample to be taken from the sampling frame (i.e., the entire population);
8. consult sampling statisticians appropriate to the needs of the method chosen;
9. test several functional forms and discuss their merits, noting that the functional form of a model has a strong effect on the magnitude of the results;
10. make a judgment on the desired accuracy of the TEV (or DUV, IUV, NUV) at the outset before commissioning the study;
11. apply a Benefits Transfer technique if resources are insufficient to carry out a satisfactory field-based valuation study (the World Bank 2006 study for example uses secondary data);
12. use a sensitivity analysis and make clear assumptions relating to the net present value; and, adopt different pathways for results dissemination: an academic / technical one (e.g., format of the present guidelines), a policy-level one, and one for stakeholders / public.

How does valuation help the conservation of wetlands?

In practice, how does one include ecosystem services into national policy? This refers to more precise inventorying of natural resources, assessments of costs of environmental degradation in terms of health or foregone incomes, but also use of TEV study results to argue for increased allocations to environmental sectors. The current system awards conservation budgets based on a given sector's share to gross domestic product and cannot be said to be the result of consultation among environment, economic, and resource ministries. An urgent overhaul of the old system is needed since it privileges goods and services production through land uses that fragment habitats and cause ecosystem damage.

The notion of man-made and natural capital management based on actuality must take into account concrete linkages between fiscal policy, monetary policy, industrial and natural resource extraction policies, the patterns of use of natural resources, and broader factors of national welfare. These linkages can be developed when the flows of services to people from ecosystems are monetized (marketed and non- marketed service flows such as flood protection), and that the results of such valuation studies are embedded within policy directives to achieve efficiency. Again, in layman's terms, imagine yourself setting money aside in your household budget (think national budget) for replacing light bulbs indoors (think man-made capital) and for maintaining trees and grass in your garden (think natural capital) that attracts beautiful bird species that sing and sit on branches for your delight. Further imagine that your household budget savings are decided jointly by yourself and your spouse (think different ministries), and that the trees somehow fuel the budget with which you purchase light bulbs (imagine you sold some of your garden plants to create savings!). Then valuation would be the good advice that allowed you to save efficiently to replace the right amount of plants sold, but did so by appealing to your sense of budget management by telling you proportional worth of the plants as a share of your total household budget.

Pakistan's Ministry of Climate Change and the National Forest Programme Facility have already taken a groundbreaking step in this direction by commissioning a set of national guidelines to assist statisticians and resource economists, among others, in conducting and overseeing forest valuation studies. The long-term journey is not a difficult one. In fact, it can be approached through a series of simple steps. The first step is to agree that monetization of the environment and environmental services is a necessary step in order to manage and improve resource allocation to the environment sector. Once this consensus has emerged, the lead ministry i.e. the Ministry of Climate Change in consultation with experts, civil society and other partners undertakes to identify important services in order of priority while consulting a broad spectrum of stakeholders will allow for a richer and more complete perspective.

The valuation studies would need to be outsourced by the Government of Pakistan to competent persons and groups. The consultants would in turn identify information needs and the on-ground valuing of ecosystem services together with those overseeing and commissioning the studies. Once these studies and assessments have been completed, there exist various ways that the results of these studies may be used to inform policy directives, decisions surrounding resource allocation and investment in natural capital, strategic utilisation of conservation benefits, or encourage provincial and district governments to use these findings to guide their planning and investment priorities.

Finally, the results of these studies, actionable findings, and associated policy formulations must be communicated to the necessary provincial and district line departments in order to shape current and future planning.

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Stream macroinvertebrate assemblages in the Bagrot Valley of Central Karakoram National Park, Pakistan

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K E Y W O R D S

Aquatic insects
Macroinvertebrate assemblages
High-altitude streams
Biodiversity
Species richness
Station
Bagrot Valley
Central Karakoram National Park

A B S T R A C T

The study was conducted in Bagrot Valley, in the buffer zone of Central Karakorum National Park, to assess diversity and distribution of zoo-benthic taxa in relation to habitat type and environmental factors. Fourteen stations were sampled twice in two field surveys. Nine stations were selected on the glacier fed streams (Kryal and Glacio-rhithral), one on a spring-fed stream (Krenal), and three on springs (Limnokrenal and Rheokrenal) and one in a glacial pond. In an additional "terrestrial" station, only adults were collected. At each station, environmental factor (air, temp, pH and conductivity) and faunal samplings (kick and drift samples) were carried out. Adults were collected by sweep net and by Malaise trap. In all stations, 7,991 aquatic specimens were counted of which Diptera and Ephemeroptera were abundant respectively 53 % and 29 % of individuals. Representatives of eight families of Diptera were found, among them family Chironomidea as dominant. Within non-insects, Oligochaeta and Crustacea (Amphipoda and Ostracoda) were best represented i.e. 54 % and 37 % of the non-insect fraction respectively. The highest number of individuals and taxa was recorded in the Krenal streams and springs respectively. Kryal and Rheokrenal habitats were dominated by Chironomidae, Glacio-rhithral and Krenal by Baetidae. The longitudinal pattern was analysed in Dubani stream, considering a distance of approximately four kilometers. Richness and abundance increased with increasing distance from the glacier, with Chironomidae remaining dominant within the first two kilometers downstream of the glacial snout. Baetidae prevailed more in the downstream regions. The highest diversity and abundance were recorded in autumn in the glacier-fed stream, while the contrary in springs. The changes were mainly due to a significant increase of Baetidae and the appearance of many other insects (mainly Plecoptera) in October and November.

Introduction

The class Insecta is composed entirely of insects and is the largest group in the animal kingdom, with 29 orders and 800,000 known species. It is estimated that there may be up to 50,000,000 species of insects on Earth, most of which have not yet been discovered (http://amazinginsects.org/). Benthic macro-invertebrates are considered one of the best biological indicators of water quality. At the beginning of this century, Kolwitz and Marsson (1902) clearly formulated the relationship of aquatic organisms to the purity and pollution of water. Since then, many methods are employed to assess biological water quality; using different organisms (viruses, bacteria, fungi, lichens, algae, plants, protozoa, macro-invertebrates and fishes). However, most of the methodologies are based on macro-invertebrates (Hellawell, 1986; DePauw *et al.,* 1992; Rosenberg and Resh, 1993; Ghetti, 1997). Their response to organic or inorganic pollutants has been used to develop biotic indices (Duran, 2006), because presence of particular species, taxa and/or communities reflects the environmental history and condition of an area (Fureder *et al.*, 2006). Benthic macro-invertebrates vary in their sensitivity and tolerance of pollutants occurring in surface water. These organisms respond to long-term impairments of stream water. Thus, as bio-indicators, aquatic insects are excellent and reliable determinants of stream health. Members of the orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) are mostly intolerant of pollutants; their relative abundance indicates good water quality. The biological index of Ephemeroptera -Plecoptera - Trichoptera also known as EPT, calculates the taxa richness of a sampling site. Midge flies, and Black flies (both are in the order Diptera) are tolerant of pollution; their occurrence in high numbers is indicative of organic water impairment (Bohlman *et al.,* 2009).

The importance of this research is revealed by the fact that it is the first ever scientific research on macro-invertebrates in upper Indus Basin (Gilgit-Baltistan). In Pakistan, especially in Gilgit-Baltistan, research on these organisms was neglected in the past, resulting in lack of scientific data and literature, but in developing countries a lot of progress has been achieved on macro-invertebrates on various aspects. The assemblage of freshwater macro-invertebrate with special regard to diversity and distribution of Diptera: Chironomidae (Insecta), the dominant taxon in all aquatic habitats is focused in Bagrot Valley (CKNP) in relation with environmental parameters is great intervention at Gilgit-Baltistan level rather at Pakistan's level. This data would help upcoming research programme on alpine stream, rivers, and springs and associated fauna and will serve as baseline information in Gilgit-Baltistan.

Material and Methods

Study area

CKNP is the largest Protected Area in Pakistan, stretches along the Karakoram mountain ranges located in four Districts, Gilgit, Hunza-Nagar, Skardu and Ghanche of Gilgit-Baltistan and covers an area of 10,000 km^2. A total of 231 villages with cultural and dialect diversity of indigenous communities inhabit these villages and dependent on the natural resources of park to meet their livelihood. Its main attractions are largest glacier's concentration, second largest peak K2, several other peaks are the most prestige destination for trekkers, mountaineers, and climbers. Beyond its scenic natural beauty, it also hosts great floral and faunal diversity.

The recent study was carried out in Bagrot Valley (Fig. 1) a buffer zone valley of CKNP. The valley lies at 36°1'4" N 74°33'19" E surrounded by Karakoram mountains. Outstanding physical features in the vicinity of the valley include the Rakaposhi (7,788m) and Diran (7,269m) peaks in the northwest and northeast

respectively, and Dubani peak (6,143m) in the east.

Bagrot valley forms part of the CKNP buffer zone and is the model region for CKNP, due to its socio-ecological significance. Bagrot valley is one of the potential buffer zone valleys in CKNP hosting productive summer pastures, glaciers, faunal and floral diversity. The biodiversity includes pine, birch, juniper and various herbs and shrubs, key wildlife species such as Snow Leopard, Ibex, Woolly Flying Squirrel, Stone Marten, Snow Partridge, Snow Cock and Chukar.

Data Collection

Record of Environmental Data

Before sampling, environmental parameters including water, air temperature, pH and conductivity were recorded; using different instruments like thermometer, Multiprobe Water Sampler.

Benthic Fauna (Sampling and identification)

Macro-invertebrates were collected by means of a pond net (250µm mesh size) with the technique of kick sampling according to Lencioni and Rossaro (2005). Samples were washed through a funnel with the same size to remove excess water and then preserved in 75 % ethanol. Other specimens were collected by tweezers and drift nets (100 µm mesh size).

Samples were transported to the Section of Invertebrate Zoology and Hydrobiology of the Natural Science Museum of Trento, Italy, and analysed by Dr. Valeria Lencioni and Dr. Alessandra Franceschini. Sorting was carried out to family or higher taxonomic level according to Campaioli *et al.,* (1994). Adults were collected by means of a sweep net and a Malaise trap.

Data analysis

The relative composition of the macro-invertebrate community of 14 stations was analysed. The longitudinal pattern was considered for the Dubani stream (st. 2,3,5), while a temporal pattern was considered for the station 3. Significant differences among stations were found by applying univariate parametric analysis (ANOVA-test), using the STATISTICA 6.0.

Results

Environmental data

The Kryal and Glacio-rhithral stations appeared to be colder from those located on small tributaries of the Hinarche stream (st. 9 in Fig. 1). This is due to the low discharge of the stream, and the high air temperature recorded especially in June (27.5°C at st. 9)

The highest temperature recorded was of station 9 (Fig. 2), which is a small and shallow pond with brighter sunshine resulting in increase in temperature of water. Station 6 is the one with lowest temperature i.e. about 10°C.

According to conductivity data collected, station 14 and station 15 have the highest conductivity measurements ranging from 540 to 580 (µS/cm). These two stations are the springs located on lowest altitude, while station 13 which is the highest station of our study area has lowest conductivity (Fig. 3.). pH data showed variation among stations except st. 4 Krenal and st. 5 Glacio-rhithral which are located close to each other and no significant change in pH in all 14 sampling stations of the study area was observed (Fig. 4).

Benthic fauna

In all, almost 8,453 individuals were collected from 15 stations (Fig. 5) of which 90 % belonged to Insects, mainly as larvae (about 7,000 specimens). In station 6 no animals were found in the sample. With the exclusion of terrestrial instars of Insects (adults

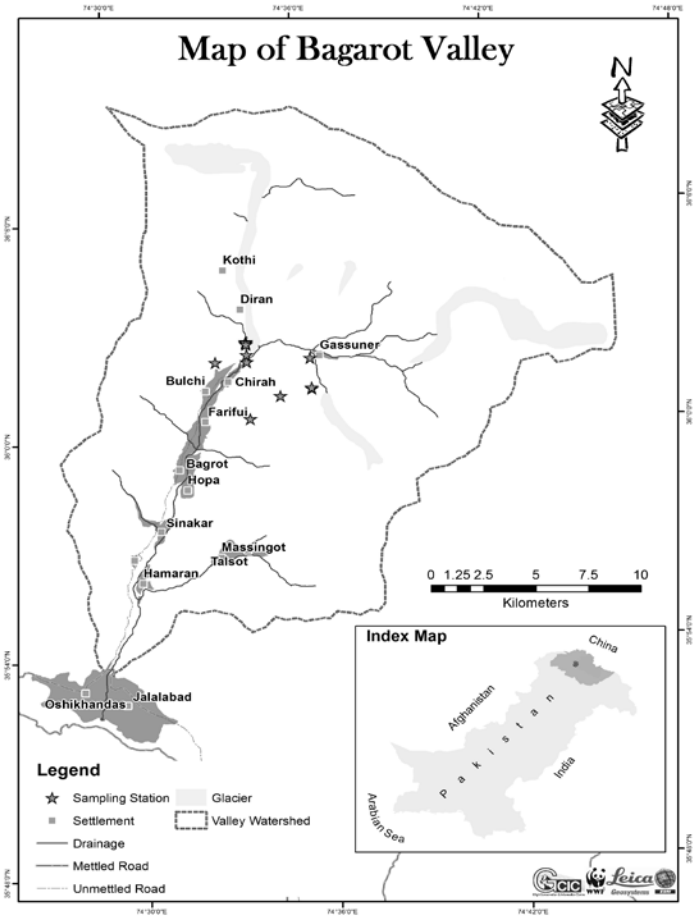


Figure 1: Map of Bagrot Valley, Central Karakoram National Park

of Diptera, Trichoptera, Plecoptera) and terrestrial taxa accidentally fallen in the water (Tysanoptera, terrestrial Coleoptera), 7,991 aquatic specimens were counted. In all, 25 taxa were identified, of which 22 were Insects. Diptera and Ephemeroptera form the two most abundant taxa, accounting respectively 53 % and 29 % of individuals. Within Ephemeroptera, two families were identified, of which Baetidae prevailed (= 29% of total fauna). Diptera was found with eight families (some specimens were not recognised as known family and were named as "other Diptera"). Among these, Chironomidae was dominant (= 39% of total fauna). Within non-Insects, Oligochaeta and Crustacea (Copepoda and Ostracoda) were the best represented (54 % and 37 % of the non-Insect fraction respectively) (Fig. 5).

The two stations with the highest number of individuals and taxa were st. 4 and 14, dominated by Ephemeroptera: Baetidae (30 %) and Chironomidae (59 %) (Fig. 6).

The highest number of individuals was collected in the Krenal streams, followed by the Glacio-rhithral habitats. The highest taxa richness was found at the springs (17) and in the spring-fed streams (16), followed by the Glacio-rhithral (15); the lowest in the glacier-fed streams (Kryal) (6). Finally, four taxa were found exclusively in the Rheokrenal springs: Dixiidae, Gastropoda, Hydrophilidae and Planariidae (Fig. 7 & 8).

The longitudinal pattern was analysed in the Dubani stream (Fig. 9) from st. 2 to st. 5. Richness and abundance increased with increasing distance from the glacier (st. 2, st. 3) with Chironomidae remaining dominant. Their dominant role remained at st. 5, where taxa coming from the spring-fed tributary occurred (tributary effect) such as Simuliidae, Tipulidae and Ostracoda (Fig. 9).

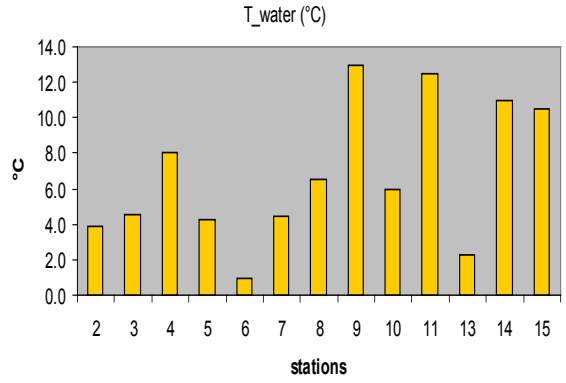


Figure 2: Results of water temperature at all sampling stations of the study area

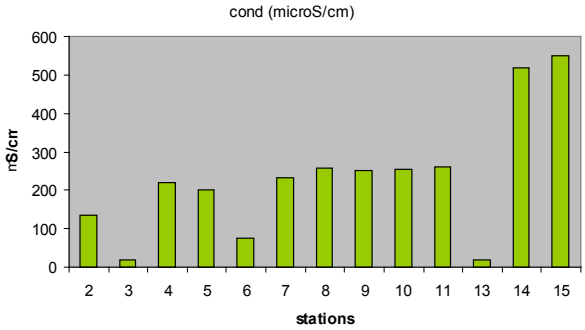


Figure 3: Results of conductivity at all sampling stations of the study area

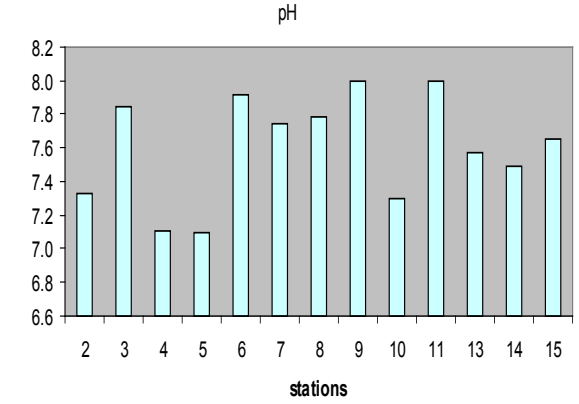


Figure 4: Results of pH in all 14 sampling stations of the study area

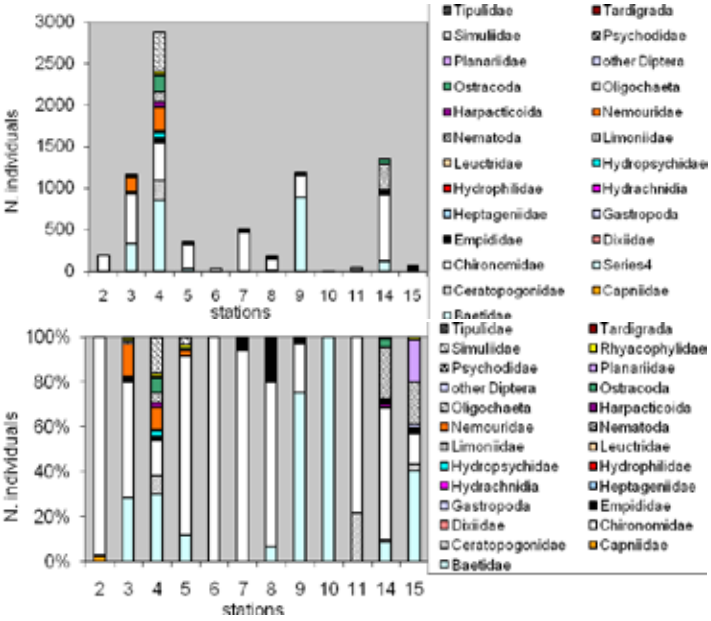
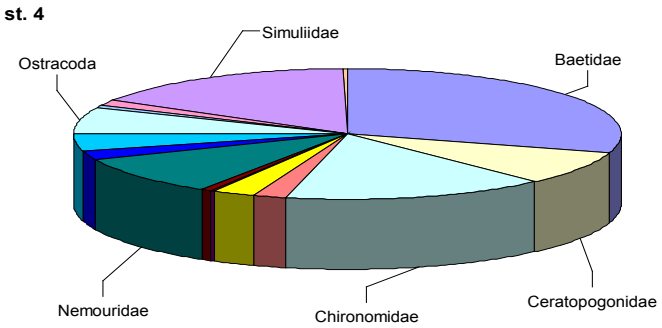


Figure 5: Relative abundance of macro-invertebrates at sampling stations



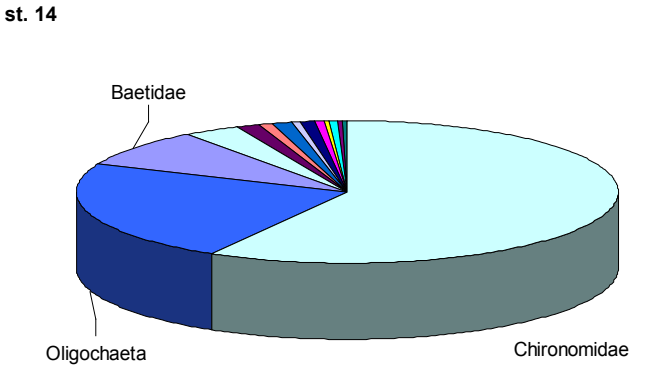


Figure 6: Relative composition of the two richest stations (labels only for taxa accounting >5% of individuals found in the station

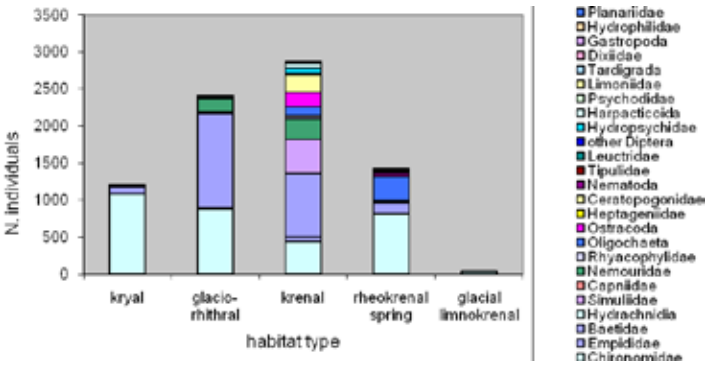


Figure 7: Habitat type characterisation

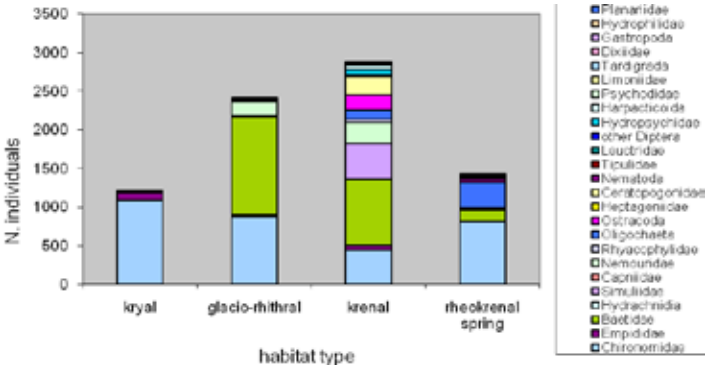


Figure 8: Habitat type characterisation

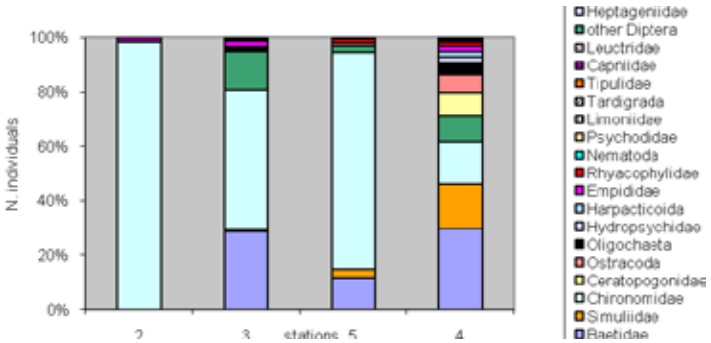


Figure 9: Longitudinal pattern (Dubani stream)

Temporal pattern was analysed in Stations 3 and 15 (Fig. 10), which were sampled twice. Significant differences ($p < 0.05$) were found between the macro-invertebrate community in terms of taxa, individuals and relative composition. In st. 3, a Glacio-rhithral site, highest diversity and abundance were recorded in autumn, whereas the contrary was observed in st. 15. Here only two taxa were collected in October and 8 in June, in st. 3, three taxa in June and 12 in November. In this station, the changes are mainly due to the significant increase ($p < 0.05$) of Baetidae and the appearance of many other insects (mainly Plecoptera) in November. Overall, higher abundance and diversity was recorded in autumn (3,410 individuals and 18 taxa in early summer, 4,581 individuals and 21 taxa in autumn) thus showing significant increase ($p<0.05$) in Baetidae, Ceratopogonidae, Simuliidae and Psychodidae.

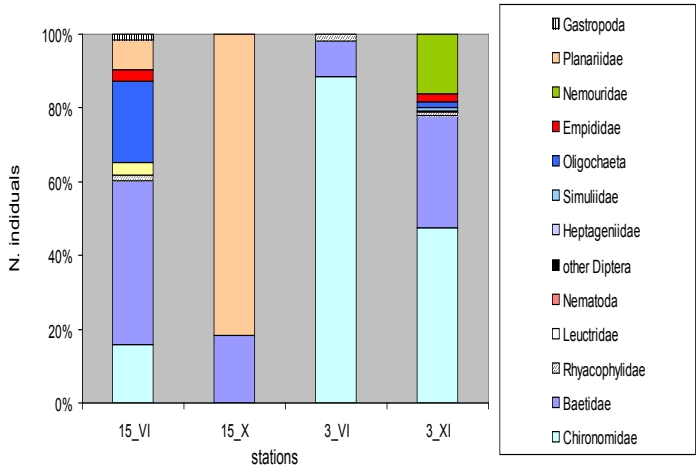


Figure 10: Temporal pattern (st. 15 and st. 3)

Discussion and conclusion

As expected (Lencioni, 2000; Castella *et al.,* 2001; Lencioni and Rossaro, 2005), Kryal habitats were characterised by the lowest faunal abundance and taxa richness, with Diptera: Chironomidae as the dominant taxon. The finding of *Hydrurus foetidus* was also expected. This chrysophyte was found, until now, common in the Alps as well as in Northern Scandinavia (Ward, 1994). It provides support, food source and protection from currents and abrasive sediments and can act as refugia for Diamesinae and Orthocladiinae in the Kryal section of glacial streams. The "glaciality" of the investigated sites was so highlighted. Always as expected (Ward, 1994), springs and springs-fed streams were richer, being characterised by milder environmental features than Kryal habitats in terms of lower channel instability, higher water temperature, lower discharge and lower flow fluctuations.

The key role of Diptera: Chironomidae was confirmed, as highlighted for many other arctic and alpine freshwaters (Lencioni and Rossaro, 2005; Lodsz-Crozet *et al.,* 2007). It is known that their relative abundance decreases with increasing distance from the glacier (Castella *et al.,* 2001). The second group for abundance was represented by Ephemeroptera: Baetidae, occasionally dominant but more typical of Rhithral habitats.

The seasonal trend of taxa such as Diptera: *Simuliidae* and Plecoptera: *Nemouridae* were comparable with the same families found in the Alps (Schutz, 1999; Lencioni, 2000). Mountain headwaters are traditionally characterised by low level of human impact, pristine and harsh landscapes and isolation from major industrial centres (Ward, 1994). All this has made these remote regions valued for the purity of their landscape and for their surface and groundwater quality. Today, this water purity is threatened by atmospheric acid deposition, and by erosion and pollution associated with water diversions for hydro-electric power developments, land use changes, road constructions and tourism development. Headwater regions, so fragile and sensitive to environmental changes, may also be of major importance as conservation areas for natural ecosystems and wildlife.

Few literatures are available for now on alpine streams and the associated fauna and flora located in East Asia, especially in the Karakoram mountain group. Some references were published on river fauna of Afghanistan and Pakistan (Kitamura and Yosii, 1966), and Nepal Himalaya (Roback and Coffmann, 1987). Most part refers to taxonomical descriptions of new species (Singh, 1958; Makarchenko and Kobayashi, 1997; Willassen, 2007), more than ecological surveys. This background makes our work original, describing spatial and seasonal trends of macro-invertebrate fauna in glacial and non-glacial streams, and in springs located in an unknown Valley from this point of view, the Bagrot valley. These data are preliminary (species identification remains the main goal for the future) but would implement the general knowledge on alpine fauna in streams, rivers and springs from Karakoram and give useful tools for management purposes in this protected but human-exploited area of the CKNP.

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The authors are very much grateful for support provided by the Ev-K2-CNR Committee, in collaboration with three Italian research Institutes: the University Bicocca of Milan, the Natural History Museum of Verona (MCSNV) and the Natural Science Museum of Trento (MTSN). We wish to extend our gratitude to Dr. Alessandra Franceschini (technician MTSN) for samples sorting. Our special thanks go to Mr. Garee Khan, GIS expert for map preparation and for entire WWF - Pakistan Gilgit staff for their cooperation. We would like to thank Mr. Yasir Abbas, ecologist CKNP and Mr. Riaz for extending cooperation and support during the field survey.

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Some Observations on Threatened and Near Threatened avifauna of Pakistan

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K E Y W O R D S

Threatened
Near Threatened
Avifauna
Midwinter waterfowl census
Classification
Wetlands
Baseline assessments
Pakistan

A B S T R A C T

Sixteen Threatened and Near Threatened species of birds belonging to 12 families and sub-families and 8 orders were recorded at 50 different sites from December 2006 to January 2012 during studies conducted under Pakistan Wetlands Programme for baseline assessments and midwinter waterfowl census in Pakistan. Of the total recorded species, nine are Near Threatened, five Vulnerable, one Endangered and one Critically Endangered. Classification of birds on the basis of their occurrence and visit to the study area shows that of the total recorded species, four are resident; four are winter visitors; passage migrant and irregular year round visitors; three are winter visitors; two are resident; passage migrant and year round visitors; two are passage migrant and irregular year round visitors and one is resident and winter visitor. Similarly of total bird species, nine are omnivorous and seven are carnivorous. A brief account of each species and their sightings is given. Recommendations are made to conserve the population of these threatened bird species.

Introduction

The article gives the account of the Threatened and Near Threatened bird species observed during different studies conducted under Pakistan Wetlands Programme for baseline assessments and midwinter waterfowl count in Pakistan. These species can be considered as indicators of ecosystem health. The IUCN/SSC (1999) classifies threatened species as "all full species categorised at the global level as Critically Endangered, Endangered or Vulnerable". Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) taxa are considered to be facing an extremely high, very high, and high risk of extinction in the wild, respectively.

Threatened species lists are designed to set priorities for resource allocation for species recovery, to inform reserve system design, to constrain development and exploitation, and to report on the state of the environment (Possingham *et al.,* 2002). Moreover, in many countries, there is a direct connection between threatened species lists and legislation [e.g. the Convention on International Trade in Endangered Species (UNEP-WCMC, 1998) and the US Endangered Species Act], leading to political and social considerations in the listing protocol. Conserving populations of threatened species often derives and simplifies reserve system planning. For example, Ceballos *et al*., (1998) and Noss (2000) recommend using threatened species lists as one of several factors identifying high-risk ecosystems. Given the social and legal importance of threatened species, protecting such species might take precedence over other criteria. In addition, a pragmatic view is that threatened species may serve best to attract public attention as well as funding (Williams *et al.,* 2000). A common presumption, shared by both global and national schemes for determining priority areas for conservation based on the occurrence of threatened species, will also prove appropriate to protect most of the other species within the target taxon (Bonn *et al.,* 2002).

In most countries, environmental impact processes evaluate the likelihood that development will affect any threatened species. Threatened species lists are one of the few tools at the disposal of regulatory agencies and the public to limit adverse environmental impacts of development. When a proposed development action is judged to increase risks to threatened species, that activity might be modified or postponed. If there is no evidence that listed species are present, or impacts are negligible, development can proceed (Possingham *et al.,* 2002). Listing might increase threats to a species. When the presence of a threatened species in an area is viewed as an impediment to a particular land use, land managers might destroy habitat, deny the presence of the species or deny access to the area for researchers or government officials. This is an unintended consequence of a threatened species list when incentives for landowners to conserve threatened species on their properties are lacking (Possingham *et al.,* 2002).

Although simplifying complex problems makes sense, there is no biological justification for using threatened species alone as an umbrella group for all biodiversity (Possingham *et al.,* 2002). The use of threatened species as surrogates for biodiversity is limited, because most invertebrate animals and nonvascular plants do not appear on any threatened species lists. The use of single threatened species as umbrella species for biodiversity conservation is particularly problematic (Berger, 1997; Andelman and Fagan, 2000; Rubinoff, 2001).

The global population sizes of species vary by many orders of magnitude. Amongst the birds, the rarest presently numbers just a handful of wild individuals (BirdLife, 2000), whilst the most abundant (Elliott, 1989) has many hundreds of millions. Numerous reasons can be suggested for these differences, including the influences of body size, life history, trophic group, phylogeny and history (Damuth, 1981; Peters & Wassenberg, 1983; Pimm, 1991; Brown, 1995; Blackburn *et al.,* 1996; Gaston & Blackburn, 1996; 2000).

One obvious potential reason for the limited progress in explaining variation in the abundance of bird species has been the heavy emphasis placed on their intrinsic characteristics, rather than on differences in extrinsic factors, such as the environments that they occupy and the influence that human activities have had on their populations. Of course, it is generally understood that environments differ in the opportunities that they provide for birds, because of variation in their productivity, temporal and spatial stability, and geographical extent (Blackburn and Gaston, 2002). However, many, arguably perhaps most, macroecological comparative studies have failed to take explicit account of such issues. Likewise, it is evident that the vast majority of those species presently regarded as having a high risk of becoming extinct in the near future are listed as such

because of the negative impacts that human activities have had on their global populations, and that such impacts extend to a large number of species that are not as yet threatened (Tucker & Heath, 1994; Lawton & May, 1995; BirdLife, 2000). The disproportionate attention paid to the characteristics of species rather than extrinsic factors when considering their abundance is echoed in attempts to understand the covariates and determinants of high risks of extinction (Blackburn and Gaston, 2002).

The objective of the current study was to carry out surveys at significant wetlands in Pakistan to provide information about the current distribution and status of bird species in general and Threatened and Near Threatened bird species in particular in Pakistan to contribute to the conservation of wetlands. The rationale behind this approach was to increase the knowledge of Threatened and Near Threatened avifauna of Pakistan. The study provides an ornithological baseline data for significant wetlands in Pakistan where future population trends can be compared.

Material and Methods

A 10x42mm Olympus binocular, 20x45-60mm Nikon spotting scope, Garmin Map 76 Global Position System receiver, Birds of Pakistan by Grimmett *et al.,* (2008), Pocket guide to the "Birds of Indian Subcontinent" by Grimmett *et al.,* (1998) and "A field guide to the Birds of the Indian Subcontinent" by Kazmierczak (2000) were used in the field for identification. A 4x4 Land Cruiser was used for transport purposes, whereas hand floatable and Ray marine Rib boats were used to collect data from different habitats of the region.

Surveys were conducted at 50 significant wetlands in Pakistan from December 2006 to January 2012 (Fig. 1). Sites covered during the count include all types of natural and manmade wetlands, including rivers, lakes, reservoirs, freshwater swamps, mangroves, rice fields and lagoons. Water birds counted during the census included all types of water birds regularly encountered at wetlands, including grebes, cormorants, pelicans, herons, egrets, storks, ibises, spoonbills, flamingoes, ducks, geese, cranes, rails, jacanas, shorebirds, gulls and terns etc. In addition, raptors, kingfishers and other wetland dependent birds were also covered. The official dates for the Asian Waterbird Count are during the second and third week of January every year. Data were collected on prescribed data forms. Direct field observations were made on different observation points of different habitats to count and collect information about distribution and status of waterfowl in Pakistan.The line transect method was usually used where it was possible to move through the habitat or on the edges of the area. A distance of about 30 - 40 m on both sides of the tract was maintained in the line transect surveys. At the beginning of the transect count the starting point was marked with GPS. As transect proceeded, observed species were recorded. The finishing point was also marked at the end of observation.

Point counts were conducted for areas where a moving transect was not possible since the open ground made birds unapproachable, or for areas where movement was restricted i.e. water courses with low water level which restricted linear movement in a boat. At the beginning of the point survey, the location was noted with a GPS along with the viewing bearing (using a compass) and the starting time. Normally point count survey was conducted for thirty minutes when the species and their abundance in a particular habitat was noted. Usually the radius of the point counts was 100 m.

The occurrence of the species in the country, their feeding habits and major food items and nomenclature used in this paper is adopted from Roberts (1991; 1992). The International Union for Conservation of Nature (IUCN) status of the species for 2011.2 is adopted from IUCN website (IUCN, 2011). The data of the global population sizes of all the species (Annex 1) are adopted from BirdLife International website (Birdlife International, 2012).

Results and Discussion

During the study, 16 Threatened and Near Threatened species of birds belonging to 12 families and sub-families and 8 orders were recorded at 50 different sites all over Pakistan (Fig. 1; Annex 1). According to IUCN criteria (IUCN, 2011), of the total recorded species, nine are Near Threatened, five Vulnerable, one Endangered and one Critically Endangered (Fig. 2; Annex 1). Classification of birds on the basis of their occurrence and their visit to the study areas given in Roberts (1991) shows that of the total recorded species, four are resident; four are winter visitors; passage migrant and irregular year round visitors; three are winter visitors; two are resident; passage migrant and year round visitors; two are passage migrant and irregular year round visitors and one is resident and winter visitor (Fig. 3; Annex 1). Similarly, classification of birds on the basis of their feeding habits as recorded in Roberts (1991) shows that nine species are omnivorous and seven are carnivorous (Fig. 4; Annex 1).

Bird fauna of Pakistan is predominantly Palearctic, especially in the winter time with an influx of migrant species. A total of 668 bird species are recorded in Pakistan (Roberts, 1991;1992), of which 36.6 % can be considered to have Oriental affinities and 63.4 % to be Palearctic or Holarctic and less than 0.5 % can be considered as truly cosmopolitan or pan-sub-tropical (Roberts, 1991). There is an influx of winter visiting birds from northern breeding grounds, or summer breeding visitors both from the northern mountain regions and from the Indus Plains, to warmer more southern latitudes (Ali, 2005). Of the total 668 Pakistan's bird species, 30 % visit the country for a significant period of the year as long distance migrants, 43 % are either Palearctic species visiting Pakistan only for breeding and 28 % are regular winter visitors, which breed extra-limitally and mainly in trans-Himalayan northern regions (Ali, 2005). About one-third of total 668 bird species in Pakistan use wetlands for food, shelter, and (or) breeding (Ali, 2005), however, the birds that visit or breed in poorer quality habitats will not contribute to a sustainable population through the years (Pulliam and Danielson, 1991).

A review of the individual status of bird species that are either wetlands dependent or associated with wetlands in Pakistan revealed that 25 bird species are of substantial economic importance and believed to need urgent attention of which nine bird species or subspecies are endangered or threatened (Khurshid, 2000; BirdLife, 2004; IUCN, 2011). In Pakistan wetlands related threatened species of birds that require priority action for conservation are, Siberian Crane *Grus leucogeranus,* Sarus Crane *Grus antigone,* Dalmatian Pelican *Pelicanus crispus*, Ferruginous Duck *Aythya nyroca,* White-headed Duck *Oxyura leucocephala,* Marbled Teal *Marmoronetta angustriostris,* Sociable Plover *Vanellus gregarious,* Jerdon's Moupinia or Sindh Babbler *Moupinia altirostris,* Lesser White-fronted Goose *Anser erythropus,* Long-tailed Grass Warbler *Prinia burnesii, and* Pallas Fish Eagle *Haliaeetus leucoryphus* (Khurshid, 2000).

The recent sightings of Threatened and Near Threatened bird species are significant in that these will help update the distribution of these species in Pakistan because there are many areas where the occurrence of these species is not mentioned in the past literature presented by Roberts (1991; 1992); Grimmett *et al.,* (1998); Kazmierczak (2000); Grimmett et *al.*, (2008). The distribution of Marbled Teal is not mentioned at Rangla Wetlands Complex in Punjab and Saji Dam area in Balochistan (Roberts, 1991; 1992; Grimmett *et al.,* 1998; Kazmierczak, 2000; Grimmett *et al.,* 2008); however it has been recorded at these places during the present study. Similarly, the occurrence of Ferruginous duck or White-eyed Pochard is not mentioned in Gawadar area (Roberts 1991; 1992; Grimmett *et al.,* 1998; Kazmierczak, 2000; Grimmett *et al.,* 2008), however, was recorded during the present study.

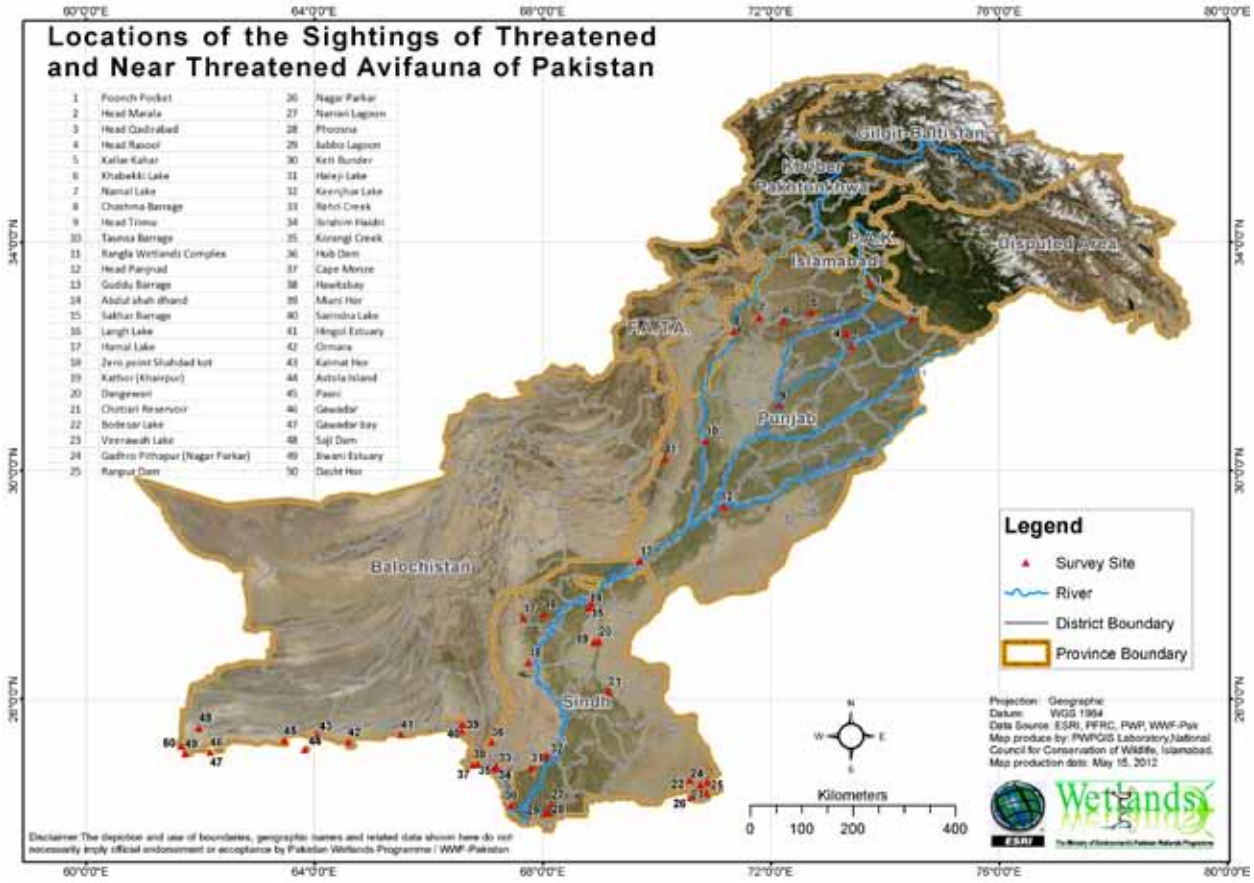

Figure 1: Locations of the sightings of Threatened and Near Threatened avifauna of Pakistan

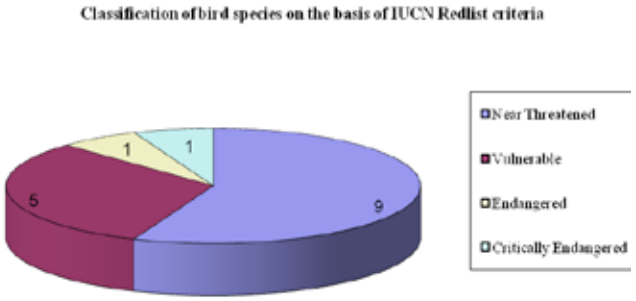

Figure 2. Classification of sixteen bird species on the basis of IUCN Red list criteria 2011.2

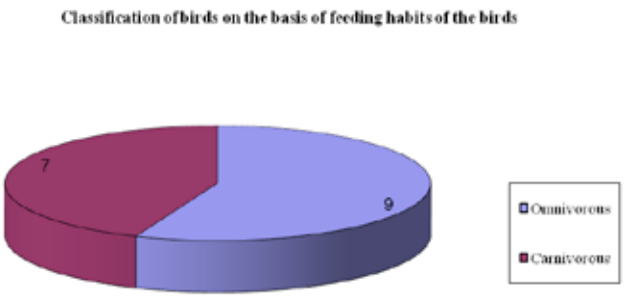

Figure 4: Classification of sixteen birds on the basis of feeding habits of the birds

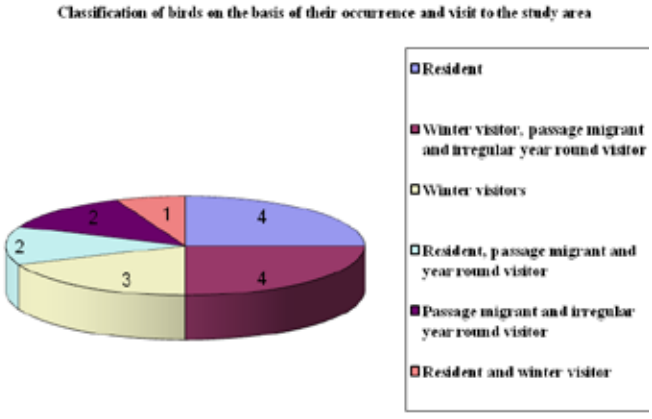

Figure 3. Classification of sixteen birds on the basis of occurrence and visit to the study area

Brief account of the species and their sightings

1. Marbled Teal *Marmaronetta angustirostris*

This species is resident in Balochistan, Punjab and Sindh provinces of Pakistan (Roberts, 1991; Grimmett *et al.,* 1998; Kazmierczak, 2000; Grimmett *et al.,* 2008). Its population has declined as a result of extensive habitat destruction. It, therefore, qualifies as Vulnerable (BirdLife, 2012). Grimmett *et al.,* (2008) are of the view that there are no breeding or wintering records of this species in Punjab Province. However, 19 adult individuals were observed during surveys from April 13-16, 2010 at Rangla Wetlands Complex (RWC) in district Muzaffargarh of Punjab province. Similarly, a flock of 32 individuals including six nestlings of about one week old and two empty nests were observed at RWC during surveys from June 2-4, 2010. Further, two adult individuals were seen on January 18th, 2011 and four adult individuals were seen on January 15th, 2012 at the same site. A total of two individuals were seen at Dangewari Lake in district Khairpur on January 21st, 2012. A total

of 31 adult individuals were seen on January 22nd, 2010 and 12 adults were seen on January 24th, 2012 at Saji Dam in Balochistan. This sighting is important as the distribution of Marbled Teal is not mentioned in Gawadar and Jiwani areas in Roberts (1991) and Grimmett *et al.,* (2008). A total of 11 birds were seen at Zero point, Sahahdad Kot, on January 15th, 2010.

2. Ferruginous Duck or White-eyed Pochard *Aythya nyroca*

This species breeds at Zangi Nawar Lake, Balochistan when water conditions are favourable, however, is also a winter visitor, passage migrant and irregular year round visitor in Pakistan (Roberts 1991; Grimmett *et al.,* 2008). It qualifies as Near Threatened and its population has declined by the degradation and destruction of well-vegetated shallow pools and other wetland habitats (BirdLife, 2012). During midwinter waterfowl counts in January 2010, a total of 444 adult individuals were observed at 9 sites i. e. Haleji Lake (10), Hawkesbay (30), Hab Dam (32), Keenjhar Lake (20), Narrari Lagoon (70), Phoosna (8), Poonch Pocket (161), Head Qadirabad (100) and Ranpur Dam (13). Similarly, during midwinter waterfowl counts in January 2011, a total of 67 adult individuals were seen at three sites i.e. Chashma Barrage (24), Khabeki Lake (34) and Taunsa Barrage (9). However, during midwinter waterfowl counts in January 2012, a total of 177 adult individuals were observed at nine different sites i.e. Abdul Shah Dhand (38), Dangewari (04), Gadhro Pithapur (17), Hamal Lake (42), Head Rasool (54), Kathor (08), Langh Lake (4), Ranpur Dam (4), and Saji Dam (6).

3. Pallas's fish Eagle *Haliaeetus leucoryphus*

This species is resident in Pakistan (Roberts, 1991; Grimmett *et al.,* 2008) and its population has declined due to habitat loss, degradation and disturbance of wetlands and breeding sites throughout its range. It, therefore, qualifies as Vulnerable (BirdLife, 2012). During midwinter waterfowl counts in January 2010, an adult pair was seen at Taunsa Barrage on January 11th, 2010. Further, during breeding midwinter waterfowl counts in January 2011, a single adult male was seen at Taunsa Barrage on January 17th, 2011. Similarly, during midwinter waterfowl counts in January 2012, one adult male was observed at Taunsa Barrage on January 13th, 2012 and one adult male was observed at Chotiari Reservoir on January 26th, 2012.

4. Sociable Lapwing *Vanellus gregarius*

This species is winter visitor from September-October to March-April in its non-breeding plumage in Pakistan (Roberts, 1991; Grimmett *et al.,* 2008) and is considered to have undergone significant and rapid decline in the second half of the 20th century and is designated as Globally Threatened (Critically Endangered) bird species (BirdLife, 2012). On October 18th, 2011, two adult individuals were seen at Dera Malik Bashir Pannuan Mouza Bakhri near Head Panjnad. Similarly, next day on October 19th, 2011, a total of 05 adult individuals were seen at the same place. This area is a part of Satluj River and included in the Panjnad Wildlife Sanctuary.

5. Sarus Crane *Grus antigone*

This species is resident breeding in Pakistan (Roberts, 1991). One pair was found breeding in 2004 in Nagar Parkar of district Thar Parkar. Its population has declined, due to the loss and degradation of wetlands as a result of drainage and conversion to agriculture land, ingestion of pesticides, the hunting of adults and collection of eggs and chicks for trade, food and medicinal purposes. It qualifies as Vulnerable (BirdLife, 2012). On December 21st, 2012, an adult pair was seen at Abasar Talab near Nagar Parkar town. The pair continued to stay at this pond till March 18th, 2012 and then moved to Saanga Talab near Veera Wah. The pair was seen last time at this place on March 31st, 2012. Similarly, one pair was seen at Bando Goth Talab near Nagar Parkar in September 2011. A pair was breeding in 2004 at Bhansar Talab near Nagar Parkar.

6. Dalmatian Pelican *Pelecanus crispus*

This species is winter visitor, passage migrant and irregular year round visitor in Pakistan (Roberts, 1991; Grimmett *et al.,* 2008). Its population has decreased due to habitat loss, disturbance, water pollution, collision with overhead power-lines and hunting. It qualifies as Vulnerable (BirdLife, 2012). During midwinter waterfowl counts in January 2010, a total of 1,199 individuals were seen at 12 different sites i.e. Gawadar (98), Miani Hor (176), Narrari Lagoon (175), Pasni (132), Phoosna (12), Saji Dam (43), Astola Island (7) Hawkesbay (6), Hingol Estuary (342), Jiwani Estuary (98), Jubbho Lagoon (15) and Kalmat Hor (87). During midwinter waterfowl counts in January 2011, a total of 12,656 individuals were seen at five different sites i.e. Narrari Lagoon (1,523), Ormara (5), Sakar Tali near Nagar Parkar (10,112), Jiwani Estuary (107) and Jubbho Lagoon (909). During midwinter waterfowl counts in January 2012, a total of 2,060 individuals were seen at 6 different sites i.e. Narrari Lagoon (92), Saji Dam (490), Sankar near Nagar Parkar (1,266), Gawadar (22), Hingol Estuary (18) and Jiwani Estuary (172).

7. Black-bellied Tern *Sterna acuticauda*

This species is resident and winter visitor in Pakistan. The species is almost extinct in a large part of its range, but remains locally common throughout the Indian subcontinent (Roberts, 1991; Grimmett *et al.,* 2008). Its population has declined qualifying the species as globally Near Threatened (BirdLife, 2012). During midwinter waterfowl counts in January 2010, a total of 150 individuals were seen at seven different sites i.e. Taunsa Barrage (14), Narrari Lagoon (70), Rehri Creek (30), Sukhur Barrage (12), Haleji Lake (4), Hub Dam (8) and Keenjhar Lake (12). During midwinter waterfowl counts in January 2011, a total of 311 individuals were seen at 5 different sites i.e. Taunsa Barrage (48), Head Trimmu (16), Keti Bunder (22), Head Marala (5) and Sakar Tali near Nagar Parkar (220). Further, during midwinter waterfowl counts in January 2012, a total of 136 individuals were seen at seven different sites i.e. Hub Dam (22), Ormara (6), Head Panjnad (06), Sarindra Lake (27), Sukhur Barrage (35), Guddu Barrage (21) and Taunsa Barrage (19).

8. Black-headed Ibis *Threskiornis melanocephalus*

This species is resident, passage migrant and irregular year round visitor in Pakistan (Roberts, 1991; Grimmett *et al.,* 2008). It faces the full gambit of threats, from hunting and disturbance at breeding colonies to drainage and conversion of foraging habitats to agriculture. It is undergoing a population reduction and qualifies as globally Near Threatened (BirdLife, 2012). During midwinter waterfowl counts in January 2012, only two individuals were observed at Veerawah Lake in district Tharparkar on January 18th, 2012.

9. Black-necked Stork *Ephippiorhynchus asiaticus*

This species is very rare, irregular year round visitor to major lakes in both Sindh and Punjab provinces of Pakistan (Roberts, 1991; Grimmett *et al.,* 2008). Formerly, it bred in mangroves in Indus Delta but not recorded since late 1970's (Grimmett *et al.,* 2008). Its population has declined and therefore qualifies as globally Near Threatened (BirdLife, 2012). During midwinter waterfowl counts in January 2010, only two individuals were seen at Head Marala on January 12th 2010.

10. Black-tailed Godwit *Limosa limosa*

This species is winter visitor in Pakistan (Roberts, 1991; Grimmett *et al.,* 2008). Its population has declined rapidly in parts of its range owing to changes in agricultural practices, therefore, qualifies as Near Threatened (BirdLife, 2012). During midwinter waterfowl counts in January 2010, a total of 1,812 individuals were seen at 10 different sites i.e. Cape Monze (33), Hawksbay (380), Hingol Estuary (14), Jubbho Lagoon (180), Keenjhar Lake (32),

Miani Hor (241), Narrari Lagoon (490), Phoosna (25), Ranpur Dam (04) and Rehri Creek (413). During midwinter waterfowl counts in January 2011, a total of 202 individuals were seen at three different sites i.e. Chashma Barrage (45), Jiwani Estuary (147) and Kallar Kahar Lake (10). Further, during midwinter waterfowl counts in January 2012, a total of 72 individuals were seen at four different sites i.e. Miani Hor (49), Narrari Lagoon (6), Pasni (11) and Veerawah Lake (6).

11. Eurasian Curlew *Numenius arquata*

This species is winter visitor, passage migrant and irregular year round visitor in Pakistan (Roberts 1991; Grimmett *et al.,* 2008). Its decline has been recorded in several key populations and overall a moderately rapid global decline has been reported, therefore, it qualifies as Near Threatened (BirdLife, 2012). During midwinter waterfowl counts in January 2010, a total of 1,154 individuals were seen at 18 different sites i.e. Astola Island (35), Bodesar Lake (2), Cape Monze (36), Gawadar (138), Hawkesbay (40), Head Trimmu (5), Hingol Estuary (28), Jiwani Estuary (102), Jubbho Lagoon (23), Kalmat Khor (36), Keenjhar Lake (5), Keti Bunder (90), Miani Hor (328), Narrari Lagoon (26), Pasni (116), Rehri Creek (97), Saji Dam (43) and Sarinda Lake (04). Similarly, during midwinter waterfowl counts in January 2011, a total of 1,310 individuals were seen at seven different sites i.e. Gawadar (136), Hingol Estuary (172), Jiwani Estuary (492), Kalmat Hor (190), Keti Bunder (30), Miani Hor (281) and Ormara (9). Further, during midwinter waterfowl counts in January 2012, a total of 7,091 individuals were seen at 21 different sites i.e. Chashma Barrage (17), Dasht Hor (43), Gawadar Bay (22), Gawadar (15), Hawkesbay (2050), Hingol Estuary (57), Hub Dam (27), Ibrahim Haidri (125), Jiwani Estuary (62), Kallar Kahar (01), Keti Bunder (450), Korangi Creek (3,670), Miani Hor (177), Namal Lake (3), Ormara (81), Pasni (177), Head Panjnad (2), Saji Dam (12), Sarinda Lake (21), Veerawah Lake (4) and Zero point Shahdad Kot area (75).

12. Great Knot *Calidris tenuirostris*

This species is rare winter visitor in Pakistan (Roberts, 1991; Grimmett *et al.,* 2008). It is qualified as Vulnerable owing to rapid population decline caused by reclamation of non-breeding stopover grounds (BirdLife, 2012). During midwinter waterfowl counts in January 2010, 15 individuals were seen at Miani Hor. During midwinter waterfowl counts in January 2012, six individuals were seen at Chotiari Reservoir and two individuals were seen at Phoosna.

13. Lesser Flamingo *Phoenicopterus minor*

This species is resident in district Badin in Pakistan (Roberts, 1991; Grimmett *et al.,* 2008). It qualifies as Near Threatened because populations appear to be undergoing a moderately rapid reduction (BirdLife, 2012). During midwinter waterfowl counts in January 2010, 150 individuals were seen at Narrari Lagoon. During midwinter waterfowl counts in January 2011, 518 individuals were seen at Narrari Lagoon and 350 individuals in Nagar Parkar area. Further, during midwinter waterfowl counts in January 2012, 112 individuals were seen at Narrari Lagoon and 52 individuals in Nagar Parkar area.

14. Oriental Darter *Anhinga melanogaster*

This species is resident in Pakistan (Roberts, 1991; Grimmett *et al.*, 2008). It is qualified as Near Threatened because its population has declined due to pollution, drainage, hunting and collection of eggs and nestlings (BirdLife, 2012). During midwinter waterfowl counts in January 2010, a total of 16 individuals were seen at four different sites i.e. Hub Dam (4), Keenjhar Lake (2), Narrari Lagoon (8) and Phoosna (2). However, during midwinter waterfowl counts in 2011 and 2012, no individuals were seen.

15. Painted Stork *Mycteria leucocephala*

This species is resident and winter visitor in Pakistan (Roberts, 1991; Grimmett *et al.,* 2008). Its population has declined due to hunting, drainage and pollution and therefore qualifies as Near Threatened (BirdLife, 2012). During midwinter waterfowl counts in January 2010, two individuals were seen at Head Marala. During midwinter waterfowl counts in January 2011, six individuals were seen at Keti Bunder. Further, during midwinter waterfowl counts in January 2012, eight individuals were seen at Pasni.

16. White-headed Duck *Oxyura leucocephala*

This species is winter visitor in Pakistan (Roberts, 1991; Grimmett *et al.,* 2008). Its population has rapidly declined and therefore qualifies as globally Endangered (BirdLife, 2012). A total of 14 individuals were seen at Khabeki Lake in Salt Range area in December 2006.

Conclusion and Recommendations

Threatened species lists fulfill important political, social and scientific needs. For example, lists of endangered species are very useful in explaining to people the importance of recovery or loss of species. In most circumstances, they are the only tools available that have a clear social mandate and that rest on substantial sound ecological knowledge. This study provides an ornithological baseline data of Threatened and Near Threatened species for significant wetlands in Pakistan where future population trends can be compared. Therefore, we recommend that the sites where Threatened and Near Threatened bird species were recorded should be monitored regularly in future especially during midwinter waterfowl counts. Further, these areas should be declared as Protected Areas and rules and legislations should be reviewed for putting these species under protected category. There is need to increase the watch and ward mechanism and to launch awareness campaigns especially during migratory seasons to control illegal hunting.

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Annex: 1. Final checklist of Threatened and Near Threatened bird species observed during the study from December 2006 to January 2012 in Pakistan

#	Scientific Name	Common Name	Feeding habit	Major food items	Occurrence in Country	Global population size	IUCN 2011.2 Red list criteria
				FAMILY-ANHINGIDAE			
1	*Anhinga melanogaster*	Oriental Darter	Carnivorous	Fish, water snakes, insects	Resident, Passage migrant and irregular year round visitor	11,000 mature individuals	Near Threatened
				FAMILY-PELECANIDAE			
2	*Pelecanus crispus*	Dalmatian pelican	Carnivorous	Birds, fish, amphibians, small snakes, insects and invertebrates	Winter visitor, passage migrant and irregular year round visitor	10,000-13,900 mature individuals	Vulnerable
				FAMILY-CICONIIDAE			
3	*Mycteria leucocephala*	Painted Stork	Carnivorous	Fish, amphibians, reptiles,	Resident and winter visitor	25,000 mature individuals	Near Threatened
4	*Ephippiorhynchus asiaticus*	Black-necked Stork	Carnivorous	Birds, fish, amphibians, reptiles and invertebrates	passage migrant and irregular year round visitor	10,000-21,000 mature individuals	Near Threatened
				FAMILY-THRESKIORNITHIDAE			
5	*Threskiornis melanocephalus*	Black-headed Ibis	Carnivorous	Fish, amphibians, insects and invertebrates	Resident, passage migrant and irregular year round visitor	20,000 mature individuals	Near Threatened
				FAMILY-PHOENICOPTERIDAE			
6	*Phoenicopterus minor*	Lesser Flamingo	Omnivorous	Algae, shrimp, plant seeds, larvae of crustaceans, small insects	Resident	2,200,000-3,240,000 mature individuals	Near Threatened
				FAMILY-ANATIDAE			
7	*Marmaronetta angustirostris*	Marbled Teal	Omnivorous	Insects, invertebrates, seeds,	Resident	14,000 -26,000 mature individuals	Vulnerable
8	*Aythya nyroca*	Ferruginous Pochard	Omnivorous	Seeds, roots, aquatic plants, invertebrates, insects, small fish and amphibians	Winter visitor, passage migrant and irregular year round visitor	e 160,000-257,000 mature individuals	Near Threatened
9	*Oxyura leucocephala*	White-headed Duck	Omnivorous	Insects, aquatic invertebrates, seeds, aquatic plants	Winter visitor	7,900-13,100 mature individuals	Endangered
				FAMILY-ACCIPITRIDAE			
10	*Haliaeetus leucoryphus*	Pallas's fish Eagle	Carnivorous	Fish	Resident	2,500-9,999 mature individuals	vulnerable

#	Scientific Name	Common Name	Feeding habit	Major food items	Occurrence in Country	Global population size	IUCN 2011.2 Red list criteria
				FAMILY-GRUIDAE			
11	*Grus antigone*	Sarus Crane	Omnivorous	Insects, aquatic plants, fish, amphibians, birds, invertebrates, seeds	Passage migrant and irregular year round visitor	19,000-21,800 mature individuals	vulnerable
				FAMILY-CHARADRIIDAE			
12	*Vanellus gregarius*	Sociable lapwing	Omnivorous	Insects, plant matter, grains, leaves, flowers, invertebrates	Winter visitor, passage migrant and irregular year round visitor	11,000 mature individuals	Critically Endangered
				SUB-FAMILY CALIDRIDINAE			
13	*Calidris tenuirostris*	Great Knot	Omnivorous	Plant material, berries, insects, spiders, invertebrates	Winter visitor	290,000 mature individuals	Vulnerable
				SUB-FAMILY TRINGINAE			
14	*Limosa limosa*	Black-tailed Godwit	Carnivorous	Insects, invertebrates, fish eggs, tadpoles of frog, plant material, berries and seeds	Winter visitor	630,000-805,000 mature individuals	Near Threatened
15	*Numenius arquata*	Eurasian Curlew	Omnivorous	Insects, invertebrates, berries, seeds, small fish, amphibians, lizards, birds and small rodents	Winter visitor, passage migrant and irregular year round visitor	770,000-1,065,000 mature individuals	Near Threatened
				FAMILY-STERNIDAE			
16	*Sterna acuticauda*	Black-bellied Tern	Omnivorous	Insects, invertebrates, fish eggs, tadpoles of frog, berries, seeds, grains	Resident	630,000-805,000 mature individuals	Near Threatened

Hydrological assessment of significant lakes in Broghil and Qurumbar Valleys, Northern Alpine Wetlands Complex

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K E Y W O R D S

Broghil lakes
Bathymetry
Water quality
Thermocline
Aquatic productivity
Migratory waterfowl species
Land use and climate change
Qurumbar Lake
Surkheng Lake

A B S T R A C T

Vital hydrological investigations about significant lakes of Broghil and Qurumbar Vallies were made, which mainly comprised of bathymetric, water quality, aquatic flora and micro-fauna. These were the first intensive and technical assessment ever made for wetlands of the area and its buffer zones. The major explorations include: maximum, average depths, lake volume and surface to volume ratio and discharge. Apart from bathymetric investigations, the water quality of lakes was also being monitored in correlation with lake's morphometry, and topography was developed to envisage their status of vulnerability to land use change and climate change. The hydrological parameters were mostly observed as habitat for waterfowls and their extent of biological aquatic productivity. Qurumbar Lake is one of the highest biologically active water bodies present on earth and there have been sightings of a broad spectrum of biological life, from phyto and zooplankton to important migratory waterfowl species, but, enigmatically, no fish. The investigation revealed that the valley has been bestowed with unique ecosystems, which still up to some extent are virgin and needs attention from conservation agencies. The information being gathered is preliminary and, therefore, further investigation are required for developing management plans and conservation strategies.

Introduction

Broghil valley is located at a distance of 250 km from main Chitral town and is the northern most valley of Chitral district in Khyber Pakhtunkhwa province of Pakistan (Fig. 1). By virtue of its strategic location having both internal and international borders, Broghil is one of the most important valleys in the region. Towards the north, the valley is connected with famous Wakhan strip of Afghanistan through the famous "Broghil Pass". Another important pass "Darwaza" connects Broghil with Afghanistan in the northwest. Broghil pass for the large part of the year remains open for the back and forth motion of the communities, as the population from both sides have familial and tribal relationship with each other since centuries. In the southeast direction, the valley is connected with Yasin valley of Gilgit-Baltistan region via Darkot Pass. Towards east, the valley joins the Qurumbar valley through famous Qurumbar pass towards Ghizer district of Gilgit-Baltistan. In the south, Broghil joins the main valley of Yarkhun towards Mastuj and Chitral town. The valley runs narrowly from southwest to northeast along the Broghil River with high mountains on both sides. The stable and somehow open slopes on both sides of the river provide space for settlement and agriculture practices. The valley is comprised of high mountain peaks, wide plains, steep slopes and deep canyons inhabited by "Wakhi" people. It covers a total area of 124,964ha. The history of Broghil dates back to centuries when communities from different tribal backgrounds i.e. Wakhan, Tajikistan, China etc. started pouring into the Broghil valley while searching for rich pastures and safe refuge (Cited in Said *et al*., 2007).

The area mostly comprises of mountainous tracts. The elevation of the area ranges from 3,280m at Kishmanjah village to 4,304m at Qurumbar Lake in northeast. The terrain of the area is undulating comprising of steep mountains, wide stretch grassy plains and narrow valleys. Broghil valley is characterised by snow clad mountains, narrow passes and fairy meadows. There are more than 30 small and large lakes in the valley and the total area covered by peatlands and lakes is almost 3,400 ha (PWP, 2010).

All large and small streams drain ultimately into the Chitral River that itself originates mainly from Chiantar glacier and Qurumbar Lake's adjacent glaciers and watersheds.

The Broghil River collects numerous tributaries from Chiantar to Darband, locally called Xerao meaning stream. The most important Xeraos (stream/tributaries) that feed into Broghil River from Lashkargaz (last village of Broghil valley) to Kishmanjah (first village) are Rabat Xerao, Kahsherdoor Xerao, Ganj Xerao, Yok Xerao, Warsing Xerao, Kishmanjah Xerao, Chokzard Xerao and Sakhir Xerao (Cited in Said *et al*., 2007).

The climate of area is characterised as Dry Temperate. It is hot in summers (July-August), ranging from very hot in lowlands to warm in the uplands and cool in the higher elevations. Located at height above 3,000 m, the Broghil is haunted by harsh climatic conditions. The temperature remains below freezing point for larger part of the year. The average precipitation in the area has been recorded about 1,000mm.

The unique climatic conditions and extreme variation in altitude and geographic aspect has resulted in diverse ecosystems and vegetation zones in Broghil valley. This diverse range of vegetation and ecological zones also support a rich floral and faunal diversity. The Broghil valley is of high importance in maintaining a great diversity of wetlands including high altitude alpine lakes and ponds, peatlands areas, alpine pastures, riparian areas, Birch, Salix and Juniper forests and riparian vegetation. Beside the habitat of other wildlife species, these resources collectively provide breeding ground to waterbirds and staging ground to waterfowl mostly in autumn and spring seasons. The Pakistan Wetlands Programme's Northern Alpine Wetlands Complex under the mandate to establish the NAWC conservancy, proposed the area to the custodian Khyber Pakhtunkhwa (KP) Wildlife Department for an appropriate protected status. After the baseline studies of the wetlands resources conducted in 2007 and 2008, the valley was explored as one of the potential area for a national or even for an international protected status. Through the joint efforts of the KP Wildlife

Department, the Pakistan Wetlands Programme and the custodian community organisation (Chiantar Welfare Society, Broghil), the Broghil Valley was notified as National Park under the KP Wildlife (Protection, Preservation, Conservation and Management) Act, 1975. The final notification was made on August 25th, 2010, and was circulated to all the concerned departments/organisations from the office of the Environment Department, Government of KP. In future, this wetlands based National Park will be managed by the Wildlife Department of KP with the active participation of the Broghil valley community in Chitral district. After the Chitral GoI National Park, this is the second National Park in Chitral district and the phenomenon is very new to the lowest educated Wakhi community of the district. This designation of the area has also served as a benchmark for the trans-boundary protected area initiatives which resulted in the notification of Qurumbar National Park by the Government of Gilgit Baltistan, and has the potential to link other regions of the bordering Wakhan corridor in Afghanistan at international level (Said *et al*., 2007).

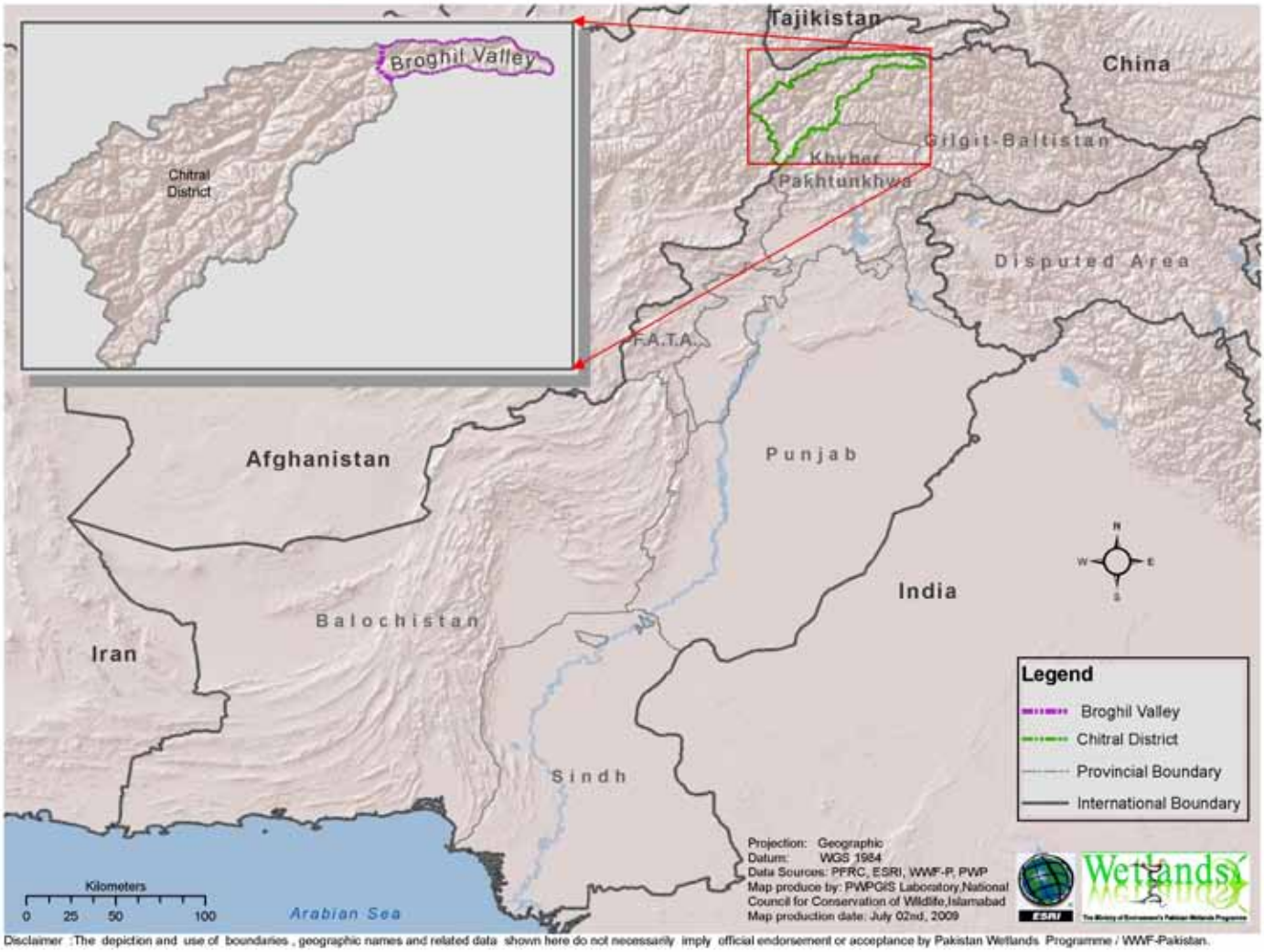

Figure 1: Location map of Broghil Valley, Northern Alpine Wetlands Complex

Material and Methods

Bathymetry

Bathymetric maps are maps that show the topography of the bottom of a lake. The topography is shown in the same way that topographic maps describe terrestrial landscape with contours. The maps are based on depth soundings taken from a boat floating on the surface of the water body. These maps are used to calculate a variety of parameters for a lake such as area, perimeter, maximum depth, littoral area, and volume. Bathymetric maps are used for a wide variety of environmental assessment purposes (BC MoE, 2009).

State of the art incarnations like GIS, GPS and Sounder technologies provided means to record the bathymetry of all selected lakes of the region. For further traversing on the surface of lake, Depth Sounder and GPS assembly were installed on the *SOAR* inflatable boat, which was powered by an eco-friendly four-stroke *Yamaha 4 HP* outboard motor. Transect lines were cruised on the surface area of selected lakes with 50m resolutions which took us approximately five days for each lake (Khan, 2010).

Outline maps of selected lakes

Outline maps of each lake were developed using *Google Earth* images and polygons from previous surveys. Outline information maps were uploaded to Depth Sounder's memory for display in the screen for navigation purposes. Depth data were acquired using transducer and automatically logged in the built in data-loggers in the system (Garmin Sounder Map 298). The logged data were being downloaded on daily basis using *MapSource* software. For data enhancement, we processed and cleaned the information using *MapSource* and *Microsoft Excel*. Later on, the partially processed data were further transferred to GIS interfaces e.g. *ArcGIS 9.2.1*.

Boat and Sounder Requirement

A self-propelled vessel called SOAR canoe was employed; the most common setup is a boat of minimum draft (i.e. inflatable) fitted with a short-leg outboard (petrol) motor for safe operation on the lake. The configuration was suitable for use in relatively shallow water conditions when near the shoreline but also large enough to handle any weather and water conditions. *SOAR Canoe* was chosen and the transducer was mounted in a way that it remained at a constant depth (which was later on accounted during the data manipulation phase) and was also far enough away from the propeller to avoid turbulence and potential interference in the sonar signals. The sounder/GPS unit was also capable of digitally logging (recording) the collected X, Y (surface location), and Z (depth) data for subsequent downloading and import into a GIS package. The positioning system was configured to record the coordinates in a standardised format that can be easily translated into UTM co-ordinates (BC MoE, 2009).

Boat and Sounder Operation

Excessive speed was avoided during surveys for not causing turbulence under the transducer, which could result in poor soundings. Many other good rules-of-thumb were followed like not cruising too quick near the shoreline as it increases the likelihood of damaging the boat, motor, or transducer by striking the lake bottom (rocks), submerged flora, or other debris and going too close to the shore is also counterproductive because the sounder will often lose the signal in shallow water.

The following principles were followed for using the sounder equipment:

a. The unit was tested before going in the field to become familiar with its operation and to ensure that the unit is tracking and recording both the location and depth data correctly;

b. The operating frequency of the sounder was wet in order to provide the best resolution and detail in the soundings. PWP's unit feature dual frequency 50kHz and 200kHz. The 200kHz setting would be for water less than 100m deep and the 50kHz setting for deeper water because it has a wider cone angle. The instrument was set with 200kHz as the lakes are less than 100m deep;

c. The sensitivity (also known as gain) was tested in order to ensure that enough echoes are being picked up by the receiver. If the sensitivity is set too low, the signal from the bottom of the lake will be weak; if the sensitivity is set too high, the receiver will collect too much noise and it may be difficult to differentiate detail from the signals. In setting the sounding frequency, a good rule of thumb was followed i.e. recording rate of one data point per second;

d. Manually spot soundings were also conducted at the beginning of the survey and also calibrated the sounder accordingly. Spot soundings are depths taken manually using a metre stick or weighted measured line, depending on the depth (Khan, 2010)

Field Procedure and Data Collection

Shoreline Cruise

In the beginning of the depth sounding process, we cruised around the lake shoreline and formed an electronic outline of the lake on the sounder screen. We tried our level best to get as close as possible to the shoreline without hitting bottom or submerged rocks. During shoreline cruise, we noted all the key limnological features like inlets and outlets and marked them on the GPS (Khan, 2010).

E-line

After shoreline cruising, we traversed the lake doing sounding crossing the middle by cruising horizontally and vertically in the lake, which is termed as E-line. These E-lines were used as reference point for transects coverage (Khan, 2010).

Transect Coverage

As the shoreline cruising completed, we began doing transects back and forth across the lake, perpendicular to the E-line and working from one end of the lake to the other. Exact locations of transects were not needed to be predetermined, but some general rules was ensured to have good coverage of the lake. This in turn affects the quality and quantity of the data gathered and, therefore, the final bathymetric map. The following guidelines were observed when planning the layout of transects:

a. Transects were roughly parallel to each other and as close to perpendicular to the shore as possible;

b. The distance between transects was discretionary, but was always close enough to allow for reasonable interpolation by the 3-D surface generating application during the final mapping process;

c. The more transects, the more accurately the depth contours can be mapped. Generally, the smaller the lake, the closer are transects. In the case of an irregular lake like Surkheng Zhui, more transects are required to determine the shape of the lake bottom and water volume;

d. All areas of the lake were mapped.

Data analyses and presentations

Bathymetric maps

Final bathymetric maps were produced using series of techniques. Data were downloaded from Sounder's internal data logger into a laptop machines using *MapSource* package. The dataset were then imported into MS Excel spreadsheet where data were sorted based on the Depth Valid field and then deleted all the false values and the Position Valid Field was used for deleting all bad recorded data. This exercise reduced the number of rows in the sheet. Formulae applied for converting coordinates system into UTM and decimals.

The depth values were converted from positive meters to negative values and added a 20 cm for transducer depth technically called *the Draft*. The sheets were saved on the lake name.

For developing a 3-D model of the lake, the collected three dimensional coordinates (x, y and z) were used as basic information for a very specific, special and spatial model called TIN *(Triangulated Irregular Network)*, which is generally used in GIS for representation of irregular distributed physical land and sea or lake-bottom. This model actually arranges irregular distributed lines or nodes with three dimensional coordinates and shape them in a network of non-overlapping triangles. GIS infrastructure provides ample means and ways for more in depth and accurate information (BC MoE 2009).

Lake volume computation

Mean depth of the lakes was multiplied by the lake surface area. Mean depths were obtained by averaging depth soundings. For a reliable average, the soundings were spaced in a uniform grid pattern. Depth soundings for very shallow water (e.g., close to shore) was omitted as it is very common source of error in this method.

All soundings of the lake were summed and then were divided by the number of soundings to obtain mean depth. Lake volume equals mean depth times lake area (Taube, 2000).

Lake Volume = Mean Depth X Lake Area
Hydraulic Residence Time of Lakes

Hydraulic Residence Time = Volume / Flow Rate (Holdren *et al*., 2001).

Water Quality (*In-situ* Monitoring)

Hydrolab Multiprobe MS 5 was used for *in-situ* monitoring of water quality. The *Hydrolab* being connected with 25m long data cable and used to lower for vertical profiling of lakes with a meter resolution. The data being monitored were logged in the Toshiba laptop machine using *Hydras 3LT* software. The reading interval was set at 3 seconds and for further QC, three reading were recorded at same depth. The Multiprobe equipment senses and monitor the Water Temperature, pH, Electric Conductivity (EC), Salinity, Total Dissolved Solids (TDS), Sensor's Depth, Oxidation Reduction Potential (ORP), Luminescence Dissolved Oxygen (LDO) and Percent Saturation of Oxygen (% Sat).

The *Hydrolab* unit uses internal and external batteries, both were properly checked and extra backup were taken along for any emergency purpose. For better results, Dura Cell and Energisers battery cells were used as an external power to avoid any inconvenience in the field.

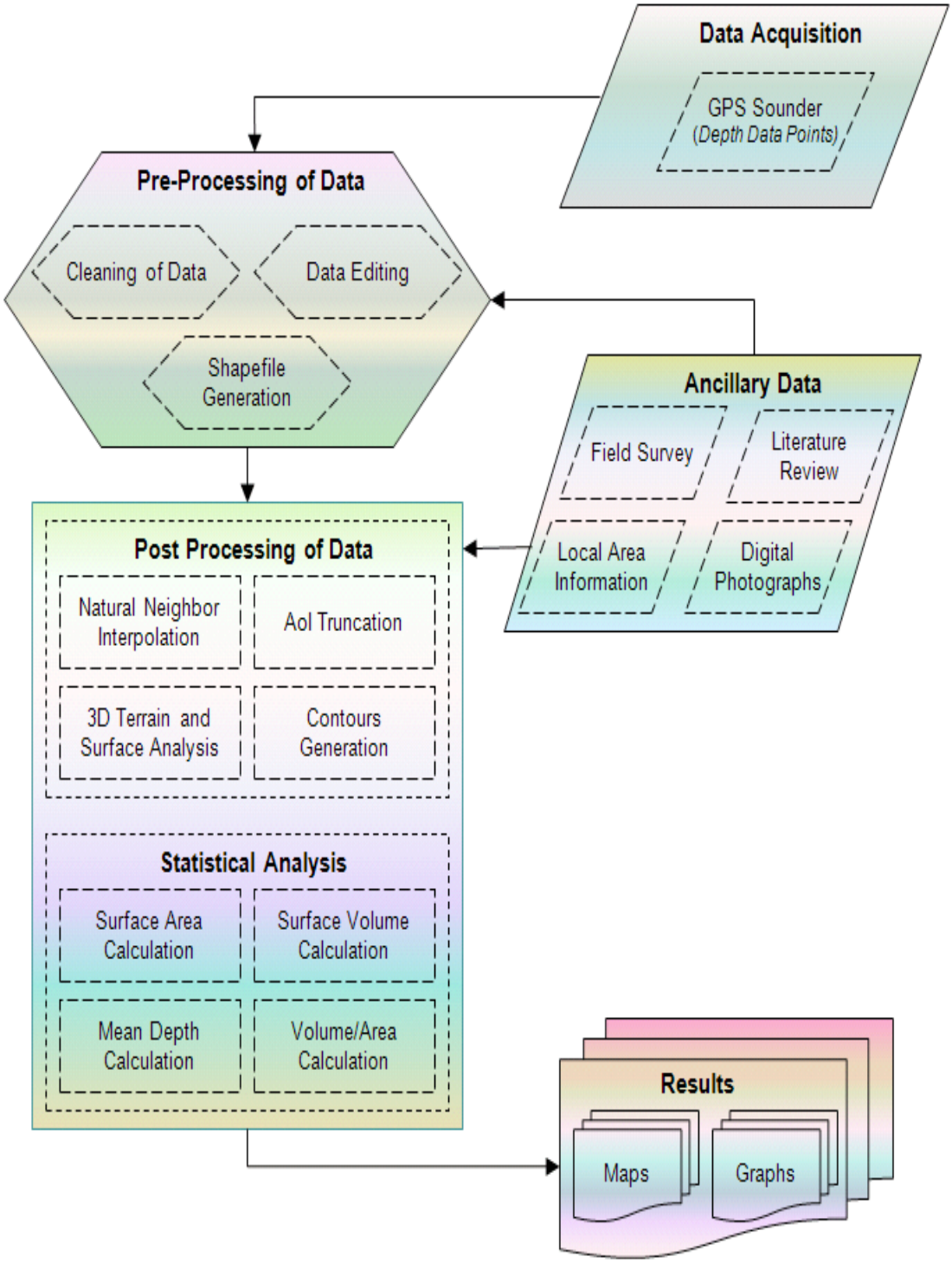

Figure 2: Methodology employed in development of bathymetric maps

Hydrolab Calibration

The *Hydrolab* units used was calibrated with standard solutions after every 25 readings in the field. The standard solution with required parameters and known values were taken along and were used to calibrate all the sensors with regular interval. Even though the instrument was properly calibrated before plunging into field but for safety and QC/QA purposes, the practices being repeated with recommended interval.

Water Quality Sensing Assembly

The water quality sensing unit comprises of Hydrolab MS 5, extra data cable of length 25m, a Laptop and a spray gun of distilled water being set on the SOAR Canoe boat along with two trained persons. We cruised to required depth location and hence *in-situ* monitoring was conducted with aforementioned methodology. For QC/QA purposes, the monitoring were conducted and data was logged while descending and ascending the *Hydrolab* as the unit also log depth of the sensing point, in order to compare both the readings. The Hydras 3LT software package offers the facility to export the readings to an Excel Spreadsheet, which was the easiest way to edit and clean the data on site.

Results and Discussion

Surkheng Zhui Lake

Morphology of Surkheng Zhui Lake

Surkheng Zhui is morphologically a fish shaped lake and located at the border of the Broghil Valley, Pakistan with the Wakhan Corridor of Afghanistan. It is a mountain pass and the local communities use it for going back and forth to Afghanistan. It is a bluish green lake and appears as blue gemstone from the very top of the mountain. The trail is very steep and therefore, very tricky for the horses and donkeys to transport the gears, food stuffs and even the staff.

Surkheng Zhui is a vernacular name; where *Surkheng* mean Reddish and *Zhui* mean Lake. Actually the lake water is not reddish but the mountain towards Wakhan appears as red from the far away distance. It is surrounded by three mountains and study reveals that the lake is 24m deep in south western portion, where the gorge intrudes into the lake. Anthropogenic affects are negligible. The water quality and bathymetric information depict key facts about the limnological aspects of the lake.

Water Quality of Surkheng Zhui Lake

Because of the current law and order situation, access is limited to the area and therefore, the lake is protected and untouched. The *Secchi* Depth recorded is 13 m, which is pretty high transparency and is therefore, can be classified as Oligotrophic. Lake bottom in the littoral zone is rocky and appeared sandy on the western side because of the shore area. Aquatic vegetation observed are emergent such as *Polygonum* and *Juncus* and submerged appeared in few spots are Chara. Thermocline seems have been developed and a unique attribute is that the deepest portion of lake have dissolved oxygen all the way up to 20m. No fish life was observed and amphibians like toad and frog have rarely been sighted. The lake shore was full of larvae and zooplanktons, and therefore, was very attractive for birds. ORP value is pretty high and therefore should be further investigated.

Dynamisms is a beauty of wetlands ecosystems, status of any lake varies across the seasons and even within day period. Apart from the temporal variation, the spatial variation within a lake (horizontally and vertically), are other key attributes that support the dependant biodiversity. Among all selected parameters, DO and temperature are very important for keeping ecological integrity alive within the lake ecosystem. The vertical distribution of temperature and DO up to 20m depth were highlighted of the lake and the results are very supportive for life. The graph in vertical distribution shows that thermocline has been developed from 8 – 12m (Table 1; Fig. 3).

Bathymetry of Surkheng Zhui Lake

Surkheng Zhui Lake is second deepest lake in Broghil valley with the maximum and mean depth of 24m and 6.06m respectively. The surface area is 20.8ha and the total lake volume is 1,019.85 acres feet.

The lake surface to the lake volume ratio is 6.06, which means that each square meter of the lake contain 6.06m^3 of water. The

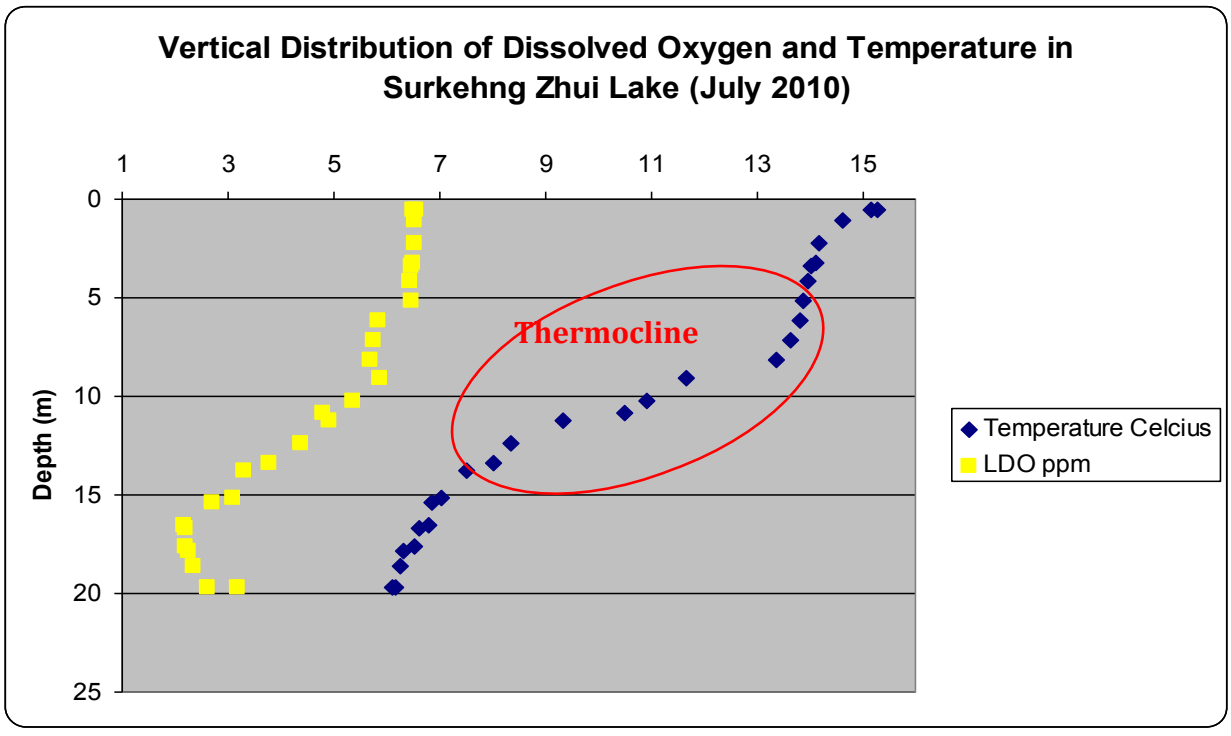

Figure 3: Vertical distribution of Dissolved Oxygen and Temperature in Surkheng Lake

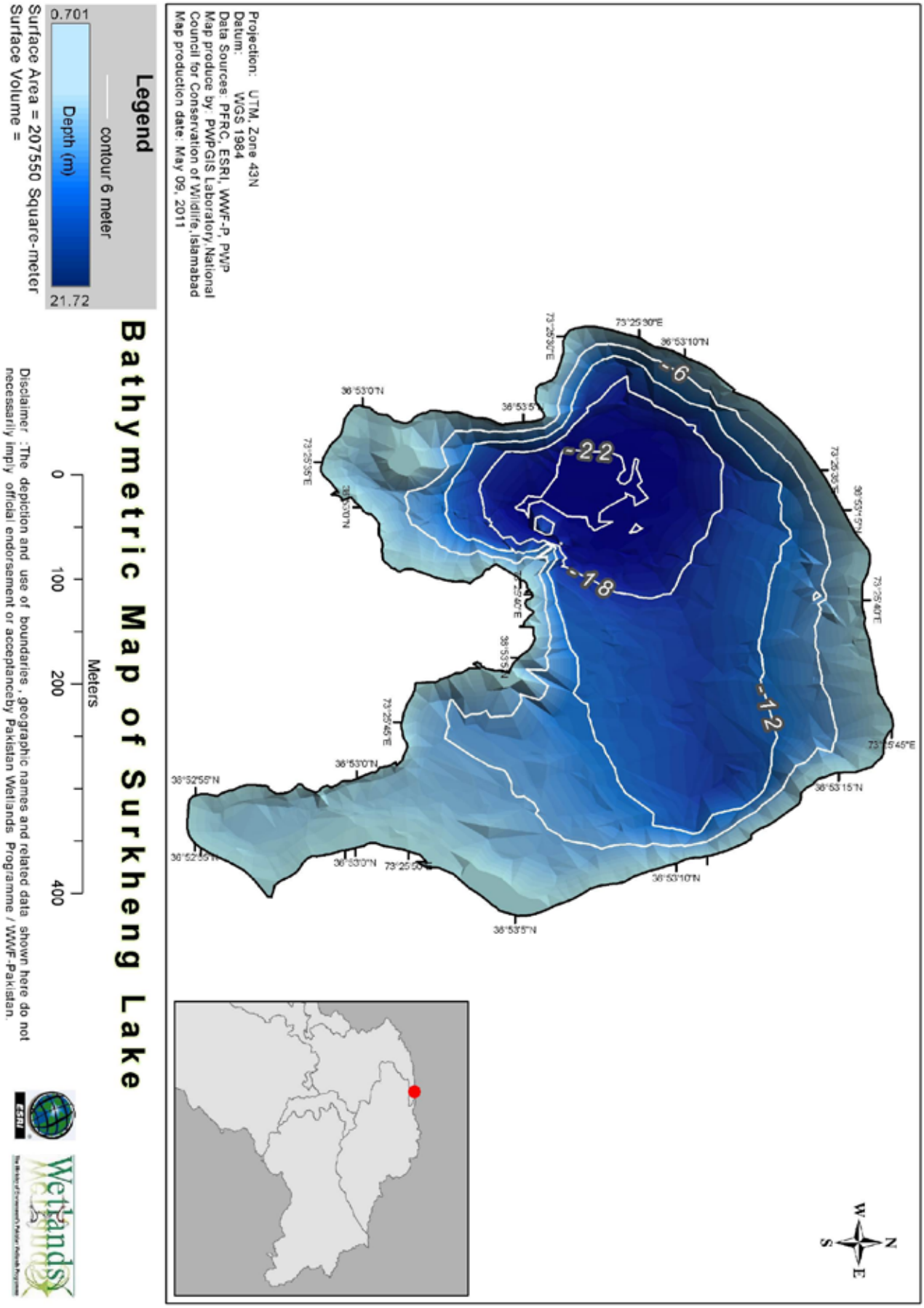

Figure 4: Bathymetric map of Surkheng Zhui Lake

lake's profundal zone is not uniformly distributed but is confined to southwest of the body. The south-eastern littoral zone consist of sand, gravels and rocks, and therefore support aquatic vegetation, both emergent and submerged. Waterfowls were sighted in the marginal zones of south-eastern portion of the lake (Fig. 4).

Qurumbar Lake

Morphology of Qurumbar Lake

Qurumbar Lake's vernacular name, as pronounced by the Wakhi community of Broghil Valley, is *"Qarumbura Zhui",* where *Qarumbura* means "a heap of boulders" and *Zhui* is the word for "lake". This seems entirely appropriate as the forces of glaciation formed the lake during a colder era, scouring out huge depression in the earth, and then filling it with ice. As the climate warmed up, the ice mass melted, leaving a barrier of *moraine* across the valley like a massive dam wall that confined the glacial melt water and formed the lake. *Moraine* is a technical term used for accumulated earth and rocks carried and finally deposited by a glacier. Surrounded by towering peaks, it is a breathtakingly beautiful panorama that rewards any hiker who is intrepid enough to climb up to 4,300m to see it.

Water Quality, bathymetric and other limnological features

The lake surface water temperature while undertaking the survey varied from 5-8° C daily. The water clarity level was 13.75m (Secchi Disc Reading), which is highest value ever recorded or seen in the available literature of lakes in Pakistan. The maximum and mean depth is 55 m and 17.08m respectively, the lake surface area is 265 ha and volume is 36,695.13 acre feet. The surface to volume ratio of the lake is 17.09 which means that there are 17.09m^3 water under 1m^2 area of the lake. The lake water quality was vertically profiled up to 25m and was strange to observe that the variation in temperature, pH, EC and DO is almost nil. The pH and DO of the lake is 7.08 and 7ppm respectively (Fig. 5 & 6).

Discharge from Qurumbar Lake

Qurumbar Lake has many inlets including glaciers mouth in the lake. The depth and central elongated trench (Fig. 5) also reveals that there is substantial quantity of base flow in the lake. The discharge therefore, is more than the recharge from surface inlets and glacial melt. The actual discharge at the mouth of the outlet was measured and the figure calculated as *3.2 Cusec (m^3/second)*. The time of measurements was 11:30 am, July 25th, 2010.

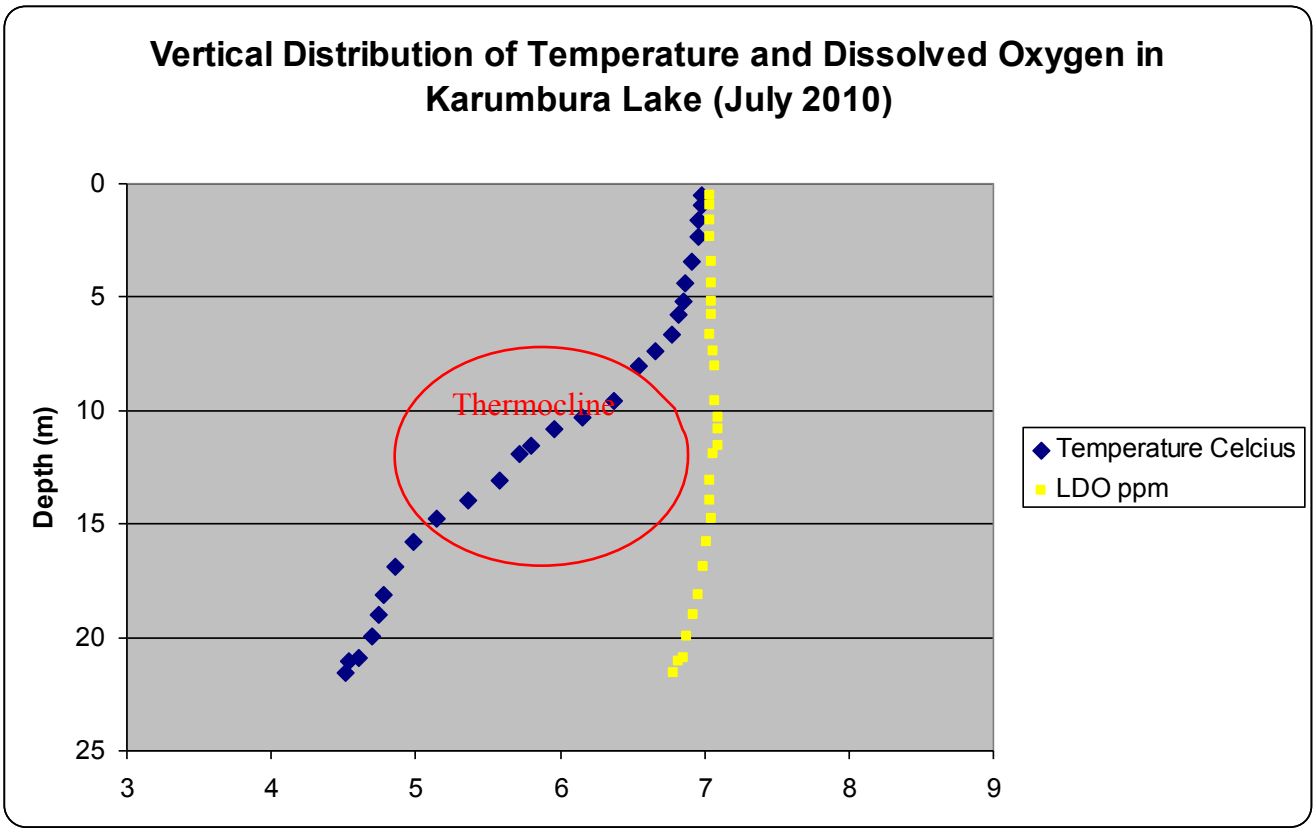

Figure 5: Vertical profile of Temperature and DO in Qurumbar Lake

Table 1: Volumetric and area details of Broghil Lakes

Lake	Lake Parameter	Values	Units	Lake Surface Area into Lake Volume Ratio
Qurumbar Lake	Surface Area	2,648,960	m^2	
	Mean Depth	17.09	m	17.09
	Volume	45,262,782.17	m^3	
Surkheng Lake	Surface Area	207,550	m^2	
	Mean Depth	6.06	m	6.06
	Volume	1,257,967.19	m^3	

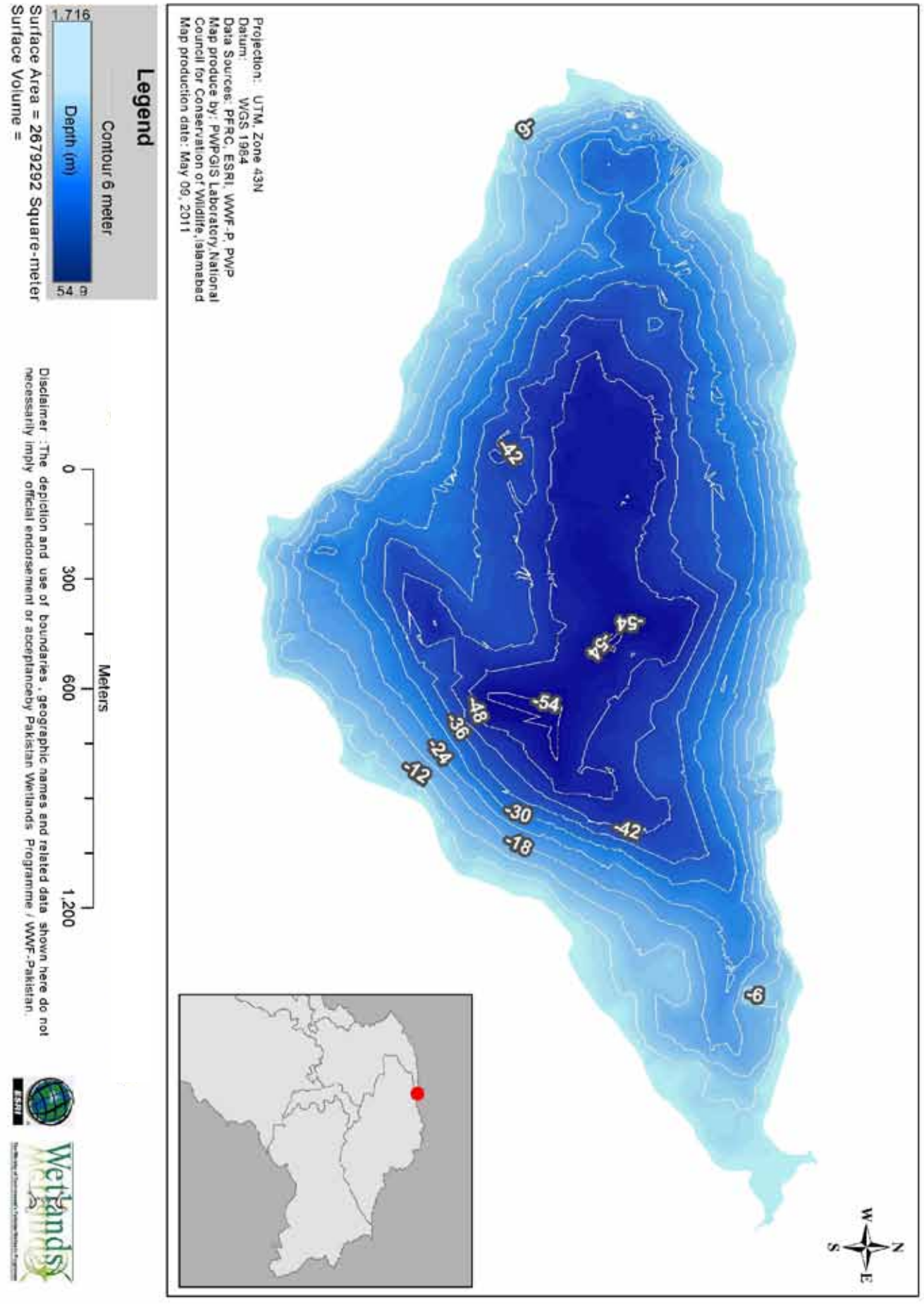

Figure 6: Bathymetric map of Qurumbar Lake

Hydraulic Residence Time of Qurumbar Lake

Average time required to completely renew a lake's water volume is called the hydraulic residence time. If the lake basin volume is relatively small and the flow of water is relatively high, the hydraulic residence time can be so short (10 days) that algal cells produced in the water column are washed out faster than they can grow and accumulate. An intermediate water residence time allows both an abundant time for algae to assimilate, grow and then accumulate. Longer water residence time from 100 days to several years provide plenty of time to algal biomass to accumulate if sufficient nutrients are present. The hydraulic residence time of Qurumbar Lake is 163.7 days.

Lake Surface Area Vs Volume Comparison of Broghil Lakes

Qurumbar Lake is the deepest lake in the valley with a maximum and mean depth of 55m and 17.08m respectively and is spread over a surface area of 26,48,960 m^2 and discharges into Qurumbar valley of Gilgit Baltistan. The discharge is 3.2m^3/second.

Surkheng Zhui Lake is the second deepest after Qurumbar with maximum and mean depth of 24m and 6.06m respectively. The lake surface area is 207,550m^2.

Recommendations

No doubt Broghil is a far flung and very remote area and is not easy to be accessed in most time of the year. Summer is best time for visiting the valley and so is for exploring the unveiled facts and information about the virgin ecosystems. The present study was deficient in assessing number of parameters and specifically recommends the followingl for future studies:

– As there is limited information available on meteorological and hydrological aspects at the country level, therefore, robust, unattended and telemetric based observatories are strongly recommended for long term monitoring. Ecosystems in the valley are very fragile and virgin hence are very prone to climate change;

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Conservation of Indus River Dolphin *(Platanista gangetica minor)* in the Indus River system, Pakistan: an overview

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K E Y W O R D S

Indus River Dolphin
Endangered
Mortality
Illegal fishing practices
By catch
Fragmentation
Sub-population
Indus Dolphin Reserve

A B S T R A C T

The Indus River dolphin (*Platanista gangetica minor*) is one of the world's most threatened cetaceans. It is endemic to the Indus River System in Pakistan. Its population is fragmented into five sub-populations due to six irrigation barrages on the Indus River. The largest sub-population of this subspecies is found between Guddu and Sukkur barrages, legally designated as the Indus Dolphin Reserve. The habitat of this subspecies is reduced to one fifth of its historic distribution range. The main threats to the Indus Dolphin are illegal fishing, water pollution and stranding in irrigation canals. There is also a potential risk of inbreeding due to the confined population in the Indus Dolphin Reserve. Escalating illegal fishing activities in Sindh Province are the consequences of revised fisheries legislation, which subsequently increased dolphin mortality in its high density areas. Illegal fishing practices include overnight netting across the river and use of poisonous pesticides to maximise fish catches, and both of these activities have increased dolphin bycatch in Sindh Province.

Introduction

The Indus River Dolphin (*Platanista gangetica minor*) is a global priority, endangered subspecies of freshwater cetacean endemic to the Indus River System in Pakistan (Rice, 1998; Smith and Braulik, 2008). The Indus River Dolphin is the second most endangered obligate freshwater dolphin population, falling only after the 'functionally extinct' Yangtze River Dolphin. The demise of the Yangtze River Dolphin is a tragic reminder of the river dolphin's sensitivity to anthropogenic activities occurring in and around its habitat, and the need for its formal protection and conservation on a national level (Smith and Braulik, 2008). The South Asian River Dolphins, Family Platanista, were first described in 1801 by Lebeck. The Indus and Ganges River Dolphins were regarded as a single species until 1970. Further studies were conducted based on differences in skull structure, vertebrae and lipid composition and hence scientists declared the two populations as separate species in early 1970's (Pilleri *et al.,* 1982). In 1998, the validity of the earlier studies was questioned and the classification reverted to the pre-1970 consensus of a single species containing two subspecies until the taxonomy could be resolved using modern techniques such as molecular sequencing. Hence, presently, there are two subspecies recognised in the genus *Platanista*; *Platanista gangetica minor* (the Indus River Dolphin) and *Platanista gangetica gangetica* (the Ganges River Dolphin) (Kasuya, 1972)

The Indus River Dolphin is characterised by a long beak, rounded belly, stocky body, very small dorsal fin and large flippers. Although its eye has not developed a lens (this subspecies is also referred to as the "blind dolphin"), the dolphin still uses its eyes to differentiate between light and dark. It relies on echolocation to find fish, shrimp, and other prey in, or near, the bottom mud (Smith and Braulik, 2008). The Indus River Dolphin swims on its side, at times enabling it to move in water as shallow as 30 cm. As it swims on its side, it trails a flipper along the bottom of the river. After 30 to 60 seconds or more, it swims to the surface, rotates upright to take in air, and then rotates 90 degrees again as it swims back to the bottom. This unique side swimming behaviour is not consistently seen in any other dolphin, except the Ganges River Dolphin. Before the dolphin habitat became permanently fragmented, dolphins migrated upstream into the smaller tributaries during the monsoon rains and migrated downstream to the main channels in the dry season (Bhaagat, 1999). The Indus River Dolphin weighs 70-110kg (155-245lbs). The maximum size is approximately 2.5m (8.2ft), with males slightly smaller than females (Kasuya, 1972).

The current distribution range of the Indus River Dolphin comprises of 1500km from Jinnah Barrage to Kotri Barrage. The largest population consisting of about 1200 individuals exists only in about 200km of the Indus River in Sindh Province, making the existing population extremely vulnerable to risks such as disease outbreak, water pollution and inbreeding depression. The habitat of Indus River Dolpin is reduced to one fifth of its historical range (Reeves *et al*., 1991) and this remaining habitat is degraded primarily due to shortage of water caused by its diversion to meet growing agricultural needs in a semi arid country. This also reduces the flow in the river, thus concentrating pollutants and increasing the chances that they will accumulate in the dolphins blubber. The population of the Indus River Dolphin is divided in sub-populations because of the six barrages constructed on the River Indus. Canal stranding, contamination due to industrial waste and agrochemicals, unsustainable fishing and net entanglements also contribute to the species endangerment. Dolphins are often caught in fishing nets accidently. In the past these animals were targeted and harpooned by local fisherman for bait, medicine, and meat and oil for consumption (Anderson, 1879; Pilleri, 1972; Bhatti & Pilleri, 1982).

WWF – Pakistan has been working with Punjab, KP and Sindh Wildlife Departments in collaboration with communities to conserve the species. WWF – Pakistan especially worked on Indus River Dolphin Conservation Project and the Pakistan Wetlands Programme to help conserve the endangered species in its entire range. This work focused on the root causes of biodiversity loss, specifically linking the protection of the Indus River Dolphin with measures in the agricultural and fisheries sectors. The purposes of these projects and programmes was to work in close coordination with key stakeholders and local communities particularly those living along the main river.

Material and Methods

Study Area

The Indus River is one of the world's largest rivers, extending from the Himalayas to the Arabian Sea. In its upper reaches, the river

runs a course through the Ladakh region of Jammu and Kashmir, Gilgit and Baltistan. After leaving behind the mountains, it flows in a southerly direction along the entire length of Pakistan to merge into the Arabian Sea near the port city of Karachi in Sindh. The total length of the river is 3,180 km (1,980 mi).

Assessments

Indus River Dolphin population assessment surveys were conducted in 2001 (Braulik, 2006), 2006 (Braulik *et al.,* 2012) and 2011 (WWF unpublished). General methods followed to assess dolphin population were those described by Smith and Reeves (2000), subsequently modified and improved to correct for missed animals (Braulik *et al*., 2012). Standardised survey protocols were adopted including tandem direct count surveys and mark recapture analysis. The surveys included a direct count, an estimate of absolute abundance, a correction factor to account for missed animals and estimate of encounter rate dolphins/km.

Dolphin mortality data were collected using wildlife offence record, dolphin stranding record, direct observations and through community-based information.

Results

Abundance of dolphins in 2001, 2006 and 2011

In 2001, dolphin direct counts obtained from five Indus Dolphin subpopulations were: Jinnah – Chashma (2); Chashma – Taunsa (84); Taunsa – Guddu (259); Guddu – Sukkur (725) and Sukkur – Kotri (18) (Braulik, 2006). The metapopulation was estimated to number approximately 1200.

In 2006, a more complex survey method was adopted which generated both direct counts and those corrected for missed individuals. Direct counts recorded in each Indus Dolphin subpopulation were as follows: Jinnah – Chashma (1); Chashma – Taunsa (82); Taunsa – Ghazi Ghat (44); Guddu – Sukkur (1,289) and Sehwan – Kotri (4). The corrected estimates for the three largest Indus River Dolphin subpopulations were estimated 101 (CV=44.1%) between Chashma and Taunsa barrages, 52 (CV=14.9%) between Taunsa barrage and Ghazi Ghat, and 1,289 (CV=33.4%) between Guddu and Sukkur barrages. The metapopulation was estimated as 1,550 – 1,750 individuals in 2006 (Braulik *et al.,* 2012). Figure 1 & 2 show results of population abundance in various sections of the Indus River.

The complete statistical analysis is yet to be conducted on the 2011 survey data but direct counts of Indus River Dolphins between Guddu to Sukkur were lower than in 2006 and 2001. While a non standardised direct count survey method adopted for the section between Taunsa to Guddu counted more dolphins than the previous survey in 2001.

Canal stranding and rescues of Indus River Dolphins

Dolphin movement is not restricted to the main stretch of the Indus River only. It frequently moves back and forth in irrigation canals and other tributaries of the Indus River. Stranding occurs when canal gates are closed and due to sudden decrease in water level, dolphin gets stuck in small water pools. The level of water during rescue operation significantly affects its success. The lower the water level, higher the chances of successful rescues. Timely reporting of the stranded dolphin is highly important for its successful rescue. Dolphin can suddenly die due to stress and shock during rescue operations. Dolphin rescue operations were started in 1992 in collaboration with the Sindh Wildlife Department. A total of 137 stranding cases were reported from 1992 to 2012. Out of 137 stranded dolphins, 103 dolphins were rescued successfully, while, 34 dolphins died during the rescue. Figure 3 shows percentage of successful rescue operations from 1992 to 2012.

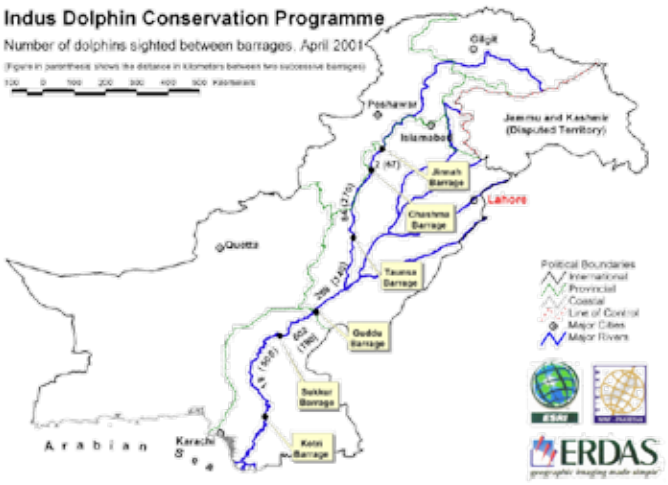

Figure 1: Estimate of dolphin population in various sections of the Indus River, 2001

Figure 2: Estimate of dolphin population in various sections of the Indus River, 2006

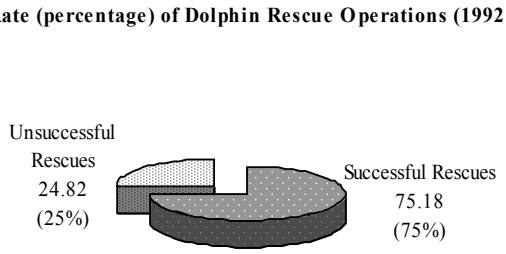

Figure 3: Success rate (percentage) of dolphin rescue operation from 1992 to 2012

Increased mortality of Indus River Dolphins

The Indus River Dolphin mortality has increased dramatically after the devastating flood in 2010. Most of the dead dolphins were found in the mainstream of the Indus River, either along the banks or trapped against the Sukkur Barrage. The local fishermen and fish contractors (who are mostly among the influential lords living along the river) have intensified the fishing practices using illegal means violating laws of fisheries and wildlife. There are also some unconfirmed reports of more deaths along the river stretch particularly between Guddu and Sukkur barrage. Figure 4 shows

the total number of dolphins died from 1993 to 2011. The highest mortality is recorded in 2011 with a total number of 45 dead dolphins. A total of 15 dolphins are recorded dead till May 2012.

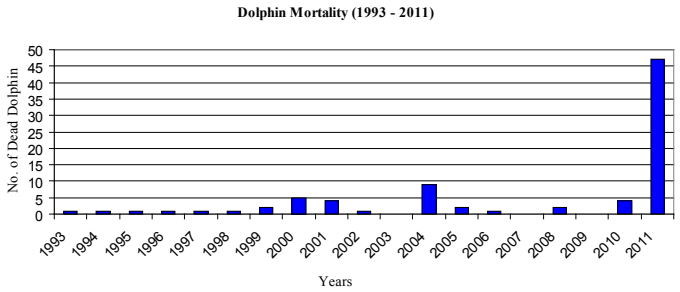

Figure 4: The total number of dead dolphins each year from 1993 to 2011

Discussion

The recent flood in 2010 in Pakistan has severely affected the socio-economic condition of indigenous communities consequently escalating their dependence on natural resources for their likely survival. Many native and local people of the Indus Dolphin Reserve are dependent on fishing for their subsistence. Fishing is legally banned in the Indus Dolphin Reserve. Currently, temporary lakes, water channels along the Indus River and permanent irrigation canals are declared as open water areas for fishing by the Sindh Fisheries Department. Temporary lakes and water channels become active during high water level and when the water level recedes, these become perfect places for fishing. These lakes and channels are found connected to the main river in most cases. It is assumed that dolphins are attracted to such areas due to the availability of fish, and they become vulnerable to different illegal means of fishing.

Change in the fishing system from contract to license, only for SIndh province, has resulted in over harvesting of fish resources, and an increase in illegal fishing practices, such as overnight netting, pesticide poisoning, and fishing without a legal permit. Fishing licenses are issued at district level at a very low cost, for a period of one year. Moreover, the traditional contract fishing systems still prevails in this protected area, where some water areas are auctioned for fishing by the fisheries authorities. The contractors either hire local people for fishing or their fishing teams consist of fishermen from other cities.

In the low water season, in addition to fishermen, turtle hunters also join the harvest, resulting in increased pressure on the natural resources of the Indus Dolphin Reserve. An illegal trade in river turtle body parts is at its peak in the entire country. Turtle capturing groups use overnight hook-lines and pesticide poisoning to catch turtles. These illegal activities adversely affect the Indus dolphin. Pollution loads in the river and irrigation canals also add up to threats to the aquatic animals during low water season.

WWF – Pakistan has taken up the issue of dolphin mortality on a high priority level and contacted relevant government authorities and line departments to take serious actions in order to control dolphin mortality. Establishing liaison with distant communities of this area is a key to developing improved community based mortality monitoring and reporting system for stranded or dead dolphins. WWF – Pakistan is contacting the influential local people in the project area as an effective means of controlling accidental mortality of dolphins. A community outreach programme has also been launched to create environmental awareness among native communities with the help of influential local people. An improved Sindh fisheries legislation is imperative for likely benefits of fishermen and for the sustainable conservation of all natural resources of the area. Inter-departmental coordination and effective implementation and enforcement of provincial wildlife and fisheries legislation are essential for successful management of the Indus Dolphin Reserve, and protecting endemic biodiversity of the Indus River.

The Fisheries Department needs to take strict actions to stop the illegal modes of fishing that have deteriorated the situation for Indus Dolphin. There is an urgent need for patrolling and monitoring to keep check on these fishing nets and practices. There is also need of dialogues with those fish contractors and card holders and strong message may be conveyed to stop the destructive fishing practices that are posing direct threats to Indus dolphin.

Conclusion

The Indus River Dolphin is one of the most threatened obligate freshwater species found only in the Indus River system of Pakistan. According to the population surveys of 2001 and 2006 the population trend was increasing but the recent 2011 population survey, revealed less dolphins numbers compared to 2001 and 2006. The Indus River Dolphin mortality has significantly increased after the devastating flood in 2010, which is the highest mortality rate in a year. The flood has severely affected the socio-economic conditions of indigenous communities consequently escalating their dependence on natural resources for their likely survival. Change in the fishing system from contract to license for this province and ever increased illegal fishing practices such as overnight netting, pesticide poisoning, and fishing without legal permit has resulted in over harvest of fish resources. Beside the mortalities, WWF - Pakistan and Sindh Wildlife Department have rescued 75 % of the stranded dolphins from 1992 to 2012.

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Effect of River Indus flow on low riparian ecosystems of Sindh: a review paper

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Riverine areas
Coastal areas

ABSTRACT

The present study is focused on the threats to low riparian ecosystems of Indus River emanating from deteriorating river flow regime coupled with associated anthropogenic activities. Indus River which serves as the lifeline of freshwater in the country is not only significant for the agricultural production and drinking water for the human, animals and plant survival but also for the perpetuity of riverine and deltaic ecology. The water flow pattern of the Indus River has been constantly changing with the changing climatic conditions and the human activities especially in the upstream areas. Substantial water diversion in the upper riparian zone has resulted in serious threats to the low riparian ecosystems and the sustenance of the associated local communities. This has led to the problems of over-exploitation of the ground water resources and degradation of quality of water. Formulating and ensuring effective implementation of sustainable strategies for the management of Indus River flow can only solve these issues.

Introduction

Water being a vital component for life is facing serious issues in Pakistan, whereas the lower Sindh is among the mainly affected areas. Indus River is the sole source of freshwater supply in the country both for ecosystems, agriculture and human consumption. It extends from the Himalayas to the Arabian Sea, with a unique range of geographical and geological features and biodiversity, covering mountains, plains and deltaic environments. The Indus has also great global significance from archaeological point of view, as Mohenjo Daro is one of the oldest civilisations along the river. The river provides 80% of all the water consumed in Pakistan. More than 70% of water in Indus comes from the glaciers and high altitude wetlands (Pakistan Water Gateway, 2008). It has the total drainage area of 1,165,000km^2, out of which 712,000km^2 is in Pakistan. Its annual flow is 207 billion cubic metres, which is twice as that of Nile and thrice as that of Tigris and Euphrates combined. It helps in irrigation of about 45 million acres of land, which accounts for 80% of the total arable land of the country. Almost 170 million human population is directly or indirectly dependent on the Indus River System (WWF, 2011).

The change in the flow rate of river directly affects the low riparian areas of Indus basin. The Indus basin is one of the largest river basins in Asia, which is covering an area of 1 million km^2 approximately. The basin spreads over north eastern China, eastern India, north western Afghanistan and plains of Punjab, Sindh and Khyber Pakhtunkhwa in Pakistan. About 56% of Indus basin covers 70% of area in the country (International River Symposium, 2005). The Indus delta has international significance as it is listed under the Ramsar Convention on Wetlands, 1971, and is classified as the fifth largest delta of the world (Abbasi, 2002).

Indus delta is an ecological and cultural landmark and is the most significant part of the Indus Ecoregion. It covers an area of 600,000ha, stretching from Kashmore to Indus Delta. It is the 40th most significant ecoregion, with major ecosystems including coastal areas/mangrove forests, riverine forests, freshwater lakes, desert, irrigated landscapes and brackish and salt lakes. It is an important and unique region because of the rich biodiversity such as the Indus blind dolphin, migratory waterfowl, riverine and mangrove forests and amazing landscape (Memon, 2005).

Unfortunately, the upstream diversions of River Indus by unchecked development of water infrastructure during 20th century have caused gradual reduction in the water flow of river. It is ultimately affecting its uniqueness and economic value and has seriously affected the riverine and coastal ecologies and their associated and dependent communities. Over the past 60 years, the freshwater flow in Indus River has reduced from 150 to 1 Million Acre Feet (MAF) annually (Kazi, 2003), thus reducing deltaic ecosystem from 3000 km^2 to 250 km^2 (Inam *et. al.,* 2007). Moreover, reduced river flow particularly in the downstream areas of the Indus River is causing a serious dispute between all the provinces. Realising this situation, based on a study, IUCN (2004a) has recommended an essential release of 27 MAF for the continued well being of the deltaic ecosystem. Likewise, Water Accord in 1991 recommended at least 10 MAF perpetual water supply in the Indus River for the downstream deltaic ecosystem. These recommendations, however, could not be materialised, so far. The flow of Indus River remains constantly below 2 MAF all over the year except between the months of July and September mainly because of monsoon season (Abbasi, 2002) or during peak floods. Due to its overexploitation, Indus River is now in the list of top 10 rivers of the world at risk (Pakistan Tribune, 2007).

This paper presents the causes of the effects of Indus River flow on low riparian ecosystems and the associated biodiversity. The paper also outlines some recommendations and interventions, which are required to improve the conditions.

River Flow and Its Impacts on Socio-economic Development

The historical studies on the coastal areas revealed that the past changes in Indus River flow rate have affected the coastal ecosystems of Pakistan in many ways. There have many factors that have affected the discharge pattern of Indus River. The major reduction in river flow has been recorded during the period between 1890 and 1998. Consequently, the primary productivity of coastal ecosystems reduced to almost one-third. Almost 70% of the total coastal fishing is done in Indus delta leading to significant contribution in the economy of the country. Annual fish catch has declined from 5000 tonnes in 1951 to merely 295 tonnes and the shrimp catch decreased by 47% over the last 10 years (Khan and Akbar, 2012). However, it is expected that the changes in the river

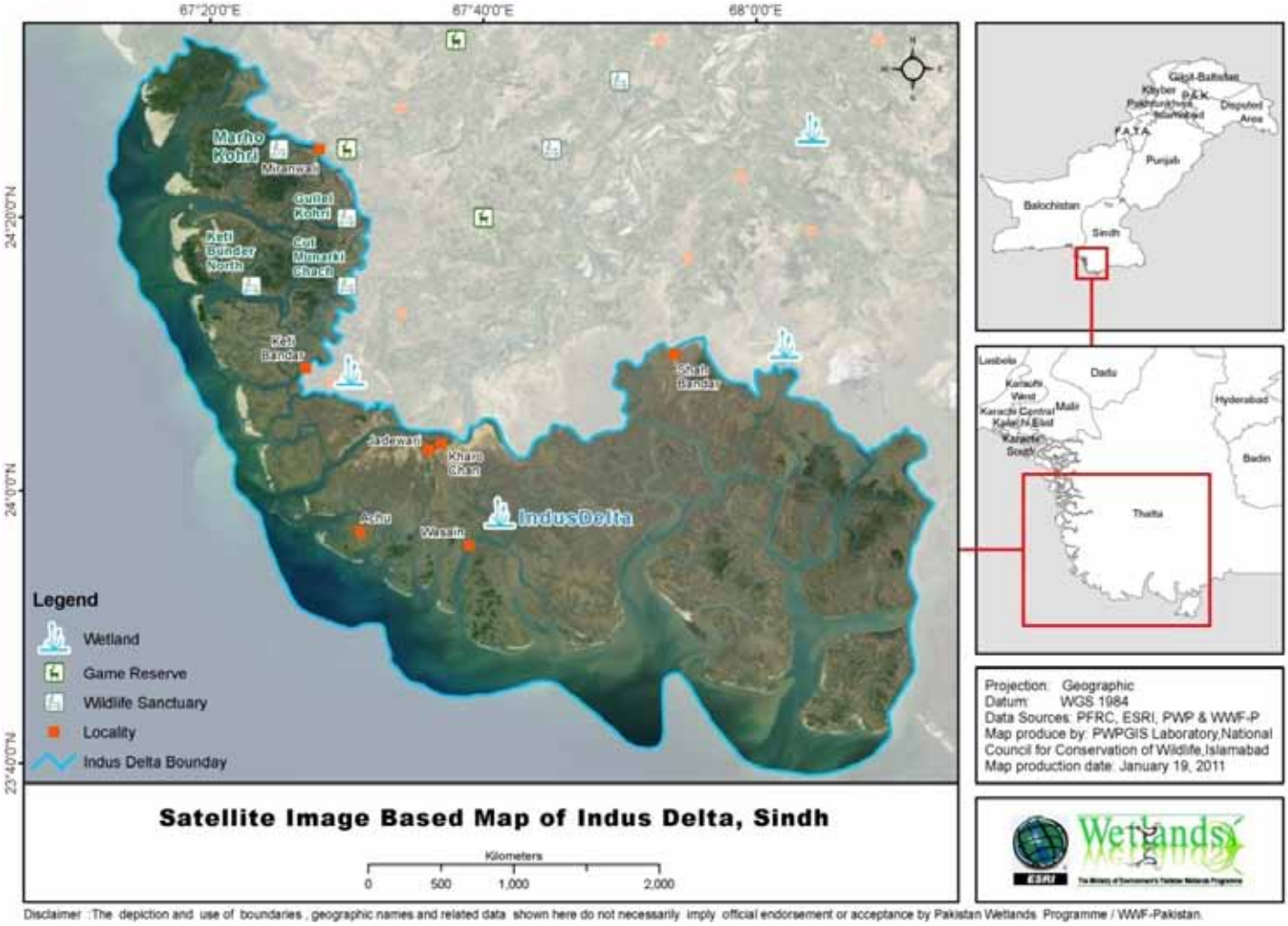

Figure 1: GIS map of Indus Delta, Sindh (PWP - WWF, 2011).

flow will ultimately affect fish catch in the coastal waters adversely affecting the economic benefits from the area. The coastal areas of Sindh inhabit almost over two million people, majority of them are directly or indirectly dependent on fisheries resource for sustenance. People live nearby the fishing grounds to fish in the sea, creeks, lakes, ponds and drainage channels. Annual fish catch from the coastal area of Sindh is about 770 metric tonnes in addition to 83 metric tonnes of shrimps. An export of about 85,000 metric tonnes of fish in the year 2000 accounted for Rupees 7.9 billion to the fish industry (Memon, 2008a).

Sindh is the 2nd largest province in terms of agriculture production in Pakistan occupying a total cultivated command area (CCA) of 5.1 million ha. The cultivable waste land in the province is about 1.3 million ha. More than 78% of the irrigated land in Sindh is underlain with saline or brackish water, which is unfit for agriculture. Therefore, the exploitation of groundwater in the area has increased due to shortage of irrigation water, drought conditions, and the unpredictability of canal water. Most of the groundwater in the area is drawn from the left bank of Indus River. This is also putting more pressure on the river (WWF, 2007; WWF, 2008; Azad, 2003).

The problem of water logging and salinity in Sindh has aggravated due to accumulation of riverbeds, insignificant gradient, conventional watering of crops and improper salt exit. These issues pose a significant threat to the sustainability of irrigated lands of Sindh. Therefore, the irrigation system is not efficient enough (Chandio *et al.,* 2011b). The increase in irrigated area is causing rise in salinity of soil in Sindh (Azad, 2003). The salinity is estimated to have increased from the year 1988 to 1995 from 900-940ppm in fresh ground water areas (Pakistan Water Gateway, 2002).

Ecological Ramifications

In the past, the freshwater flow from Kotri downstream was 150 MAF and it carried over 400 million tonnes of silt toward the delta. However, later on the flow reduced to only 20 MAF with 36 million tonnes of silt per year. Eventually, based on the recommendations of 1991 Accord, this ratio further reduced to 10 MAF. The silt deposited ratio was also reduced below 30 million tonnes per year. Ironically, even 10 MAF river flow is not achieved. This huge shortage of freshwater in River Indus has a large number of impacts. The shortage of freshwater from Kotri since last two decades and the increasing salinity are affecting the mangroves, which are already fighting for their survival. These forests are of great importance as they are regarded as protective shield for the coast against sea storms, cyclones and tsunamis. Currently, mangrove forests of Pakistan are facing many natural and anthropogenic pressures. The main cause of all these pressures is the low and uncertain water flow in River Indus. It is converting the fertile land into a saline desert. The local inhabitants are out-migrating from the area (Chandio *et al.,* 2011b).

About 38% area of mangroves forest has been reduced over the last twenty years. It is observed that four different species of mangroves have already been vanished from the area. The species still surviving are *Avicennia marina, Ceriops tagal, Agiceros corniculatum* and *Rhizophora mucronata.* According to experts, at least 6% of water flowing in the river is required for

the survival of these forests as this water may reduce the wave action at the coast thus reducing the impacts of advancing sea (Chandio *et al.,* 2011b; WWF, 2007).

It is important to realise that mangroves provide critical habitat for many species of wildlife of terrestrial and marine origin, including many fish and crustacean species. The Green turtles are found on the shores of Karachi coast. The area is habitat for at least 138 bird species, 34 animal species, 24 reptile species and 200 fish species. The migratory birds also use these coastal wetlands as their habitat, including 56 species of birds which belong to six orders and fourteen families. Fish and shrimp catch is reducing in the coastal water due to loss of mangrove habitat and change in seasonal water availability (WWF, 2007; Saito, 2008). The endemic Indus blind dolphin that also thrives in the Indus River is also under severe threat due to fluctuations in the river flow. Other fish species include *Indus Baril, Indus Garua* and *Golden Mahasheer* (IUCN, 2004a).

Sindh province was once famous for its riverine forests on either side of the Indus River covering an area of about 0.27 million ha. These forests need annual inundation for their survival. Riverine forests are not only a source of livelihood for the local people, providing them with fodder, honey, fuelwood, timber and tannin but also serve as important habitat for species like Hog deer, Fishing cat, Wild boar and Foxes and a number of small mammals. These forests are also an important sink and reduce the severity of flood water (WWF, 2007).

Riverine forests are victim of gradually decreasing flow of river water as the frequency and intensity of annual inundation especially during monsoon season has considerably reduced after the construction of upstream hydraulic structures. The species disappearing in the area include the less salt tolerant plants. The illegal encroachment of forests areas and their conversion into agricultural land and massive cutting of trees are the major threats to these forests. The poor state of decreasing riverine forests in Sindh is also the result of poor governance and lack of political will (WWF, 2007).

Sindh is home of over 300 small and large lakes. Out of 19 Ramsar sites in the country as a whole, 10 are situated in Sindh such as Haleji and Keenjhar. A large number of migratory birds visit these water bodies for wintering. The migratory bird fauna include flamingos, cormorants, ducks, geese, egrets, ibises, coots and other shorebirds. Many of these species have become endangered. These lakes are significant source of drinking water and fisheries for local population, as well. About 120 species of freshwater fish are found in these lakes. They make up 65% of total freshwater fisheries in the country. It is worthwhile to mention that wetlands serve as biological filter to remove the pollutants thus purifying the water of lakes and rivers (IUCN, 2005; Chandio, 2012). The wetlands in Sindh are either connected with River Indus or seasonal streams. These water bodies are being seriously affected by the fluctuations in the river flow.

Yet another potential threat to wetlands is the climate change that is apt to impose great pressure to freshwater ecosystems, primarily through changes in water temperature, quantity and quality, as well as through changes in the timing and duration of flows. Climate change can also result in indirect impacts by making existing threats worse or diminishing the ability of an ecosystem to deal with these threats. According to an estimate, the sea level in coastal areas of Pakistan is increasing at 1.1mm/year. It may result in 20-50cm further rise in sea level in next 50 to 100 years (UNESCAP, 1996). The Indus Delta is facing the affects of rise in sea level due to climate change. If the sea level rises up to 2m in future then it will submerge 7,500km^2 area of the Indus Delta. Studies have indicated that the subsidence rates at the delta must have increased due to lack of sediment flux. The projected figure for sea level rise at the delta is of 8-10mm/yr. The lack of sediment inputs and high energy waves may result in the formation of transgressive beach (Saito, 2008). Thus the life on the delta is facing a lot of troubles, especially the deltaic flora and fauna. Many species are facing significant challenges, as they are very dependent on a steady flow of freshwater.

Recommendations

It is evident from the foregoing discussion that the status of low riparian ecosystem is dependent on the rate of flow in the River Indus. However, regulation and management of river flow is essentially a responsibility of the concerned government authorities. One cannot over-emphasise the importance of raising awareness both at national and provincial levels about the requirements for the conservation and protection of freshwater ecosystems in Pakistan. As described earlier, freshwater habitats of Indus River ecosystem are rich in biodiversity. They also provide valuable ecological services and possess great potential to maintain resilience and adaptive capacity. The cost of loosing these wetlands is enormous and hence it is imperative to convince the federal and provincial governments for ensuring sustainable environmental flow on the one hand and to support the local communities in developing their ownership for restoration of degraded ecosystem through variety of interventions, on the other hand. The following interventions are thereby essentially required to improve the situation.

1. Realising the ecological significance of low riparian ecosystems particularly that of Indus Delta, the government of Pakistan must consider an Indus Delta rehabilitation programme ensuring regular environmental flow downstream Kotri. Such programme must consider revival of lost species and protection of mangrove forests.
2. An integrated coastal zone management plan must be developed along with appropriate legislation.
3. A team comprising representatives of the four provinces and supported by relevant water and biodiversity experts must determine the volume of water required for ecological and economic well being of the Indus Delta.
4. Sindh Forest Department needs to be strengthened in terms of human and material resources to effectively manage the Riverine belt along River Indus and revival of the riverine forests.
5. Disaster Risk Reduction strategies need to be developed to minimise the losses occurring due to outcomes of climate change such as prolonged droughts, sudden floods or sea storms.
6. Due consideration is required for self sustaining natural regenerative processes through effective floodplain management and developing resilience of the communities to adapt to other natural disasters such as climate change. The impacts of climate change should be recognised and also the potential negative impacts from human responses.

The irregular river flow especially in the lower Indus has caused some irreversible damage to the ecosystems in the region. The significant upstream water and sediment blockage in Indus River due to anthropogenic activities has caused reduction in the active delta and degradation of surrounding ecosystems. The coastal infrastructure, encroachment of lands, weak institutional framework and lack of political stability has led to serious ecological and social problems in the lower Indus. The survival of the delta depends on the availability of annual water

flow. The development of an integrated management plan for the sustainability of this ecosystem is essential. There is need of realistic assessments of the situation, along with effective implementation of the recommended strategies, to protect the low riparian ecosystem of Sindh.

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Distribution and status of significant freshwater fishes of Pakistan

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K E Y W O R D S

Fish fauna
Indigenous species
IUCN status
Cold water
Warm water
Aquaculture
Commercial importance.

A B S T R A C T

Present paper deals with the fish fauna of special importance with regard to endemism, IUCN status, commercial importance and the rarity of species. A total of 86 species have been identified as the fish fauna of special concern. Out of the total, 34 species have been categorised as endemic in the country, 11 species have special IUCN status, 31 species are commercially important while 8 species are identified as very rare in Pakistan. IUCN status of major component of freshwater fish species of Pakistan and mainly that of the endemic fauna has not yet been determined. Population of some of the economically important species is declining due to overexploitation, pollution and habitat fragmentation and therefore needs some conservation measures for its sustainable use. Major causes of high endemic component of the fish fauna in the river systems of the country have also been highlighted.

Introduction

Pakistan, and associated parts of Kashmir, is the land of geological and geographic diversity. The Indus Plain constitutes the eastern parts and the folds of mountains occupy the western and northern parts of the country, with valleys and plateaus of varying sizes falling between these mountain folds. The altitudes range between the coastlines in the south and the world highest mountain peaks (K-2, 8,611m above sea line and Nanga Parbat 8,126 m) in the north, holding many of the world's largest glaciated highland valleys. The gradual change in the altitude provides a natural slope to the area. Subtropical location of the country and its falling in the western-most reaches of the summer monsoons provides a gradual variation in temperature and precipitation. The southern and western parts of the country receive very low precipitation and have high summer temperatures, creating hot deserts with undulating sand dunes. The northeastern parts receiving high precipitation and low temperatures, where the glaciers and snow capped peaks dominate.

The general physiographic variation is equally reflected in hydrographical features of the country. Pakistan has substantially large natural inland water resources in the form of rivers and their tributaries, network of canals and natural and man-made lakes. Based upon pattern of the flow of its rivers and streams, Pakistan can be divided into three major drainage systems: the Indus drainage, Balochistan coastal drainage and landlocked drainage. Indus drainage is the largest river system of the country, consisting of the main Indus River and all its associated rivers and streams in Gilgit-Baltistan, Khyber Pakhtunkhwa, Punjab, northern and eastern Balochistan and Sindh. The Balochistan coastal drainage system consists of a number of relatively small and shallow rivers, namely Hub, Porali, Hingol, Basol and Dasht. All these rivers emerge from southwestern hills and independently fall into the Arabian Sea. The landlocked drainage is constituted by a number of small and shallow landlocked rivers and streams of central and western Balochistan. The Pishin River, Lora River and Shirin Aab end up in the Hamun-i-Lora and Rekhshan River, Mashkel stream and Tahlab River drain into Hamun-i-Mashkel. The available geologic, geographic, ecological and hydrographic variations has attributed to a diverse fish fauna of the country. The variation in fish fauna can also be attributed to the fact that the areas under Pakistan constitutes a transient zone between the Oriental, Palearctic and Ethiopian zoogeographical regions and fish fauna of Pakistan is influenced with all these geographical entities (Mirza, 1994).

The fish fauna of water bodies located in the areas under Pakistan is known through a number of comparatively recent studies conducted at different places and times (Mirza, 1975, 1978, 1980, 1990, 2003, Rafique and Qureshi, 1997; Rafique, 2000; Rafique, 2001; Rafique *et al.,* 2003). These studies are useful in providing baseline information on species distribution and diversity in different areas, yet are deficient in many ways as none of these studies exclusively encompass the species of special importance and their conservation status. Present study has been initiated to cover the most important aspect of commercial as well as conservation aspect of the fish fauna of Pakistan.

Results

The freshwater fish fauna of Pakistan is represented by a minimum of 193 fish species. These species belong to class Actinopterygii, sub-class Teleostei, 3 cohorts, 6 superorders, 13 orders, 30 families and 86 genera (Rafique, 2007; Rafique and Mian, 2012). This diversity also includes the exotic species introduced in wild or fish farming system of Pakistan during the recent past. Among the total fish fauna of Pakistan, 86 species (8 exotic and 78 indigenous) have been identified as "species of special importance" (Table 1) on the basis of endemism, IUCN status, economic importance and rarity. Among the indigenous species of special importance, 43 species have been identified as endemic to Pakistan and Kashmir. The IUCN conservation status of none of the endemic fish fauna, however, has yet been determined except one species, *Glyptothorax kashmirensis*, which is declared as 'Critically Endangered'. Among the rest 35 indigenous fish species of special importance, one species (*Tor putitora*) is declared Endangered, 6 species (*Ompok bimaculatus*, *Ompok pabda*, *Wallago attu, Ailia coila, Chitala chitala, Bagarius bagarius*) Near Threatened, one species (*Schizothorax plagiostomus*) Vulnerable, 12 species Least Concern while IUCN status of 7 species has not been determined. Rest of the indigenous species viz., *Danio rerio*, *Megarasbora elonga*, *Schizopygopsis stoliczkai*, *Triplophysa stoliczkai*, *Nandus nandus*, *Badis badis, Monopterus cuchia*, and *Macrognathus aral* are very rare in Pakistan.

Among the species of special importance in Pakistan, at least 31 species are economically important. Major component of the

economically important species belong to warm water fish fauna and are found in the Indus Plain while 8 species *Oncorhynchus mykiss*, *Salmo trutta fario*, *Schizothorax plagiostomus*, *Diptychus maculates*, *Ptychobarbus conirostris*, *Racoma labiata*, and *Schizopyge esocinus* are distributed in cold waters of Himalayas, Hindukush and Karakoram. Some of the indigenous commercially important species like *Labeo rohita*, *Cirrhinus mrigala* and *Gibelion catla* are being exploited in aquaculture while all the commercially important exotic species are part of fish aquaculture in Pakistan.

Table 1: Species of special importance found in Pakistan

Sr. No.	Species	Common Names	Distribution	Distributional status	IUCN Status	Maximum Length (cm)	Maximum weight (kg)	Commercial value
1	*Salmophasia punjabensis* (Day, 1872)	Punjab razorbelly minnow	KP, Punjab, Sindh	Endemic	Not evaluated	-	-	-
2	*Barilius naseeri* (Mirza, Rafique and Awan, 1986)	Naseeri baril	Punjab	Endemic	Not evaluated	-	-	-
3	*Barilius Pakistanicus* (Mirza and Sadiq, 1978)	Pakistani baril	AJK, Balochistan, KP, Punjab, Sindh	Endemic	Not evaluated	-	-	-
4	*Labeo caeruleus* (Day, 1877)	Blue rahu	Balochistan, Punjab, Sindh	Endemic	Not evaluated	-	-	-
5	*Labeo nigripinnis* (Day, 1877)	Days' labeo	Sindh Hills	Endemic	Not evaluated	-	-	-
6	*Labeo gedrosicus* (Zugmayer, 1912)	Balochistan labeo	Balochistan	Endemic	Not evaluated	-	-	-
7	*Labeo macmahoni* (Zugmayer, 1912)	Macmahons' labeo	Balochistan	Endemic	Not evaluated	-	-	-
8	*Naziritor zhobensis* (Mirza, 1967)	Zhob mahasheer	Balochistan, KP	Endemic	Not evaluated	-	-	-
9	*Puntius punjabensis* (Day, 1871)	Punjab barb	Balochistan, KP, Punjab, Sindh	Endemic	Not evaluated	-	-	-
10	*Puntius waageni* (Day, 1872)	Salt Range barb	Punjab	Endemic	Not evaluated	-	-	-
11	*Garra wanae* (Regan, 1914)	Wana garra	South Waziristan	Endemic	Not evaluated	-	-	-
12	*Botia javedi*, (Mirza and Syed, 1995)	Javeds' loach	KP	Endemic	Not evaluated	-	-	-
13	*Schistura afasciata* (Mirza and Banarescu, 1981)	Havelian loach	KP	Endemic	Not evaluated	-	-	-
14	*Schistura alepidota* (Mirza and Banarescu, 1981)	Swat loach	AJK, KP, Punjab	Endemic	Not evaluated	-	-	-
15	*Schistura anambarensis* (Mirza and Banarescu, 1970)	Anambar loach	Balochistan	Endemic	Not evaluated	-	-	-
16	*Schistura arifi* (Mirza and Banarescu, 1981)	Arifs' loach	Balochistan	Endemic	Not evaluated	-	-	-
17	*Schistura baluchiorum* (Zugmayer, 1912)	Panjgur loach	Balochistan	Endemic	Not evaluated	-	-	-
18	*Schistura curtistigma* (Mirza and Nalbant, 1981)	Kurram loach	Kurram Agency	Endemic	Not evaluated	-	-	-
19	*Schistura fascimaculata* (Mirza and Nalbant, 1981)	Hangu loach	KP	Endemic	Not evaluated	-	-	-
20	*Schistura harnaiensis* (Mirza and Nalbant, 1969)	Harnai loach	Balochistan	Endemic	Not evaluated	-	-	-
21	*Schistura kessleri* (Gunther, 1889)	Pishin loach	Balochistan	Endemic	Not evaluated	-	-	-
22	*Schistura lepidocaulis* (Mirza and Nalbant, 1981)	Parachinar loach	KP, Punjab	Endemic	Not evaluated	-	-	-
23	*Schistura kohatensis* (Mirza and Banarescu, 1981)	Kohat loach	KP	Endemic	Not evaluated	-	-	-
24	*Schistura machensis* (Mirza and Nalbant, 1970)	Mach loach	Balochistan	Endemic	Not evaluated	-	-	-
25	*Schistura macrolepis* (Mirza and Banarescu, 1981)	Dera loach	KP	Endemic	Not evaluated	-	-	-

Sr. No.	Species	Common Names	Distribution	Distributional status	IUCN Status	Maximum Length (cm)	Maximum weight (kg)	Commercial value
26	*Schistura microlabra* (Mirza and Nalbant, 1981)	Khyber loach	KP	Endemic	Not evaluated	-	-	-
27	*Schistura nalbanti* (Banarescu and Mirza, 1972)	Rawlakot loach	AJK, KP, Punjab	Endemic	Not evaluated	-	-	-
28	*Schistura pakistanica* (Mirza and Banarescu, 1969)	Zhob loach	Balochistan	Endemic	Not evaluated	-	-	-
29	*Schistura parashari* (Hora, 1933)	Pakhtunkhwa loach	KP, Punjab	Endemic	Not evaluated	-	-	-
30	*Schistura shadiwalensis* (Mirza and Nalbant, 1981)	Chenab loach	Punjab	Endemic	Not evaluated	-	-	-
31	*Triplophysa hazaraensis* (Omer and Mirza, 1975)	Hazara Loach	KP	Endemic	Not evaluated	-	-	-
32	*Triplophysa kashmirensis* (Hora, 1922)	Verinag triplophysaloach	AJK	Endemic	Not evaluated	-	-	-
33	*Triplophysa naziri* (Ahmad and Mirza, 1963)	Nazir triplophysaloach	KP	Endemic	Not evaluated	-	-	-
34	*Triplophysa yasinensis* (Alcock, 1898)	Yasin triplophysaloach	Gilgit-Baltistan	Endemic	Not evaluated	-	-	-
35	*Batasio pakistanicus (*Mirza and Jan, 1989)	Pakistans' batasio	Punjab	Endemic	Not evaluated	-	-	-
36	*Mystus horai (*Jayaram, 1955)	Horas' mystus	Punjab	Endemic	Not evaluated	-	-	-
37	*Gagata pakistanica (*Mirza, Perveen and Javed, 1999)	Pakistani gagata	KP, Punjab	Endemic	Not evaluated	-	-	-
38	*Glyptothorax naziri* (Mirza and Naik, 1969)	Naziri catfish	AJK, Balochistan, KP, Punjab	Endemic	Not evaluated	-	-	-
39	*Glyptothorax punjabensis* (Mirza and Kashmiri, 1971)	Punjab catfish	AJK, Balochistan, KP, Punjab	Endemic	Not evaluated	-	-	-
40	*Glyptothorax stocki* (Mirza and Nijssen, 1978)	Bhed catfish	AJK, KP, Punjab	Endemic	Not evaluated	-	-	-
41	*Nangra robusta (*Mirza and Awan, 1973)	Kalabagh nangra	Punjab	Endemic	Not evaluated	-	-	-
42	*Ompok Sindhensis* (Day, 1877)	Sindh catfish	Sindh	Endemic	Not evaluated	-	-	-
43	*Glyptothorax kashmirensis* (Hora, 1923)	Kashmir catfish	AJK	Endemic	Critically Endangered	-	-	-
44	*Tor putitora* (Hamilton, 1822)	Golden mahasheer	AJK, Balochistan, KP, Punjab, Sindh	Indigenous	Endangered	275	54	Very high
45	*Ompok bimaculatus* (Bloch, 1794)	Butter catfish	KP, Punjab, Sindh	Indigenous	Near Threatened	-	-	-
46	*Ompok pabda* (Hamilton, 1822)	Pabdah catfish	AJK, Balochistan, KP, Punjab, Sindh	Indigenous	Near Threatened	-	-	-
47	*Wallago attu* (Bloch and Schneider, 1801)	Freshwater shark	AJK, Balochistan, KP, Punjab, Sindh	Indigenous	Near Threatened	-	-	Very high
48	*Ailia coila* (Hamilton, 1822)	Gangetic ailia	Punjab, Sindh	Indigenous	Near Threatened	-	-	-
49	*Chitala chitala* (Hamilton, 1822)	Humped featherback	Punjab, Sindh	Indigenous	Near Threatened	120	10.5	High
50	*Bagarius bagarius* (Hamilton, 1822)	Gangetic goonch	Punjab, Sindh	Indigenous	Near Threatened	200	110	High
51	*Oreochromis mossambicus* (Peters, 1852)	Mozambique tilapia	AJK, Balochistan, KP, Punjab, Sindh	Exotic	Near Threatened	35	1.10	High

Sr. No.	Species	Common Names	Distribution	Distributional status	IUCN Status	Maximum Length (cm)	Maximum weight (kg)	Commercial value
52	*Schizothorax plagiostomus* (Heckel, 1838)	Himalayan snow trout	AJK, Gilgit-Baltistan, KP, Northern Punjab, Northern Balochistan	Indigenous	Vulnerable	60	2.5	High
53	*Cyprinus carpio* (Linnaeus, 1758)	Common carp	AJK, Balochistan, KP, Punjab, Sindh	Exotic	Vulnerable	110	40	High
54	*Tenualosa ilisha* (Hamilton, 1822)	Hilsa Shad	Sindh, Balochistan	Indigenous	Not evaluated	60	2.5	Very High
55	*Oncorhynchus mykiss* (Walbuam, 1792)	Rainbow trout	AJK, Gilgit-Baltistan, KP	Exotic	Not evaluated	120	25	Very High
56	*Salmo trutta fario* (Linnaeus, 1758)	Brown trout	AJK, Gilgit-Baltistan, KP,	Exotic	Least Concern	100	20	Very High
57	*Cirrhinus mrigala* (Hamilton, 1822)	Mrigal	Balochistan, KP, Punjab, Sindh	Indigenous	Least Concern	100	12.7	Very High
58	*Gibelion catla* (Hamilton, 1822)	Catla	AJK, Balochistan, KP, Punjab, Sindh	Indigenous	Least Concern	182	36.6	Very High
59	*Labeo dyocheilus pakistanicus* (Mirza and Awan, 1976)	Thicklip labeo	AJK, Balochistan, KP, Punjab, Sindh	Indigenous	Least Concern	90	5	High
60	*Labeo calbasu* (Hamilton, 1822)	Orangefin labeo	KP, Punjab, Sindh	Indigenous	Least Concern	90	4	High
61	*Labeo gonius* (Hamilton, 1822)	Kuria labeo	Punjab, Sindh	Indigenous	Least Concern	70	2.5	High
62	*Labeo rohita* (Hamilton, 1822)	Rahu	AJK, Balochistan, Punjab, Sindh	Indigenous	Least Concern	200	45	Very High
63	*Diptychus maculatus (*Steindachner, 1866)	Scaly osman	AJK, Gilgit-Baltistan	Indigenous	Not evaluated	50	3	High
64	*Ptychobarbus conirostris* (Steindachner, 1866)	Indus snowtrout	Gilgit-Baltistan	Indigenous	Not evaluated	30	1	High
65	*Racoma labiata* (McClelland and Griffith, 1842)	Kunar snowtrout	AJK, KP, Gilgit-Baltistan, Northern Punjab, Northern Balochistan	Indigenous	Not evaluated	30	1.5	High
66	*Schizopyge esocinus* (Heckel, 1838)	Chirruh snowtrout	AJK, KP, Gilgit-Baltistan, Northern Punjab	Indigenous	Not evaluated	47	2	High
67	*Carassius auratus* (Linnaeus, 1758)	Goldfish	AJK, KP, Balochistan, Punjab, Sindh	Exotic	Not evaluated	-	-	High
68	*Ctenopharyngodon idellus* (Valenciennes, 1844)	Grass carp	KP, Punjab, Sindh	Exotic	Not evaluated	150	45	Very High
69	*Aristichthys nobilis* (Richordson, 1844)	Bighead carp	KP, Punjab, Sindh	Exotic	Not evaluated	146	40	Very High
70	*Hypophthalmichthys molitrix* (Valenciennes,1844)	Silver carp	KP, Punjab, Sindh	Exotic	Not evaluated	105	50	Very High
71	*Sperata seenghala* (Sykes, 1839)		AJK, Balochistan, KP, Punjab, Sindh	Indigenous	Least Concern	150	10	Very High
72	*Rita rita* (Hamilton, 1822)	Rita catfish	Balochistan, KP, Punjab, Sindh	Indigenous	Least Concern	50	2	Very High
73	*Clupisoma garua* (Hamilton, 1822)	Garua bachcha	AJK, Punjab, Sindh	Indigenous	Least Concern	60	1	Very High
74	*Clupisoma naziri (*Mirza and Awan, 1973)	Naziri bachcha	AJK, KP, Punjab	Indigenous	Not evaluated	60	1	Very High
75	*Clarias batrachus* (Linnaeus, 1758)	Walking Catfish	Restricted areas of Punjab	Indigenous	Least Concern	47	1.2	High
76	*Channa marulius* (Hamilton, 1822)	Great snakehead	Balochistan, KP, Punjab, Sindh	Indigenous	Least Concern	180	30	Very High

Sr. No.	Species	Common Names	Distribution	Distributional status	IUCN Status	Maximum Length (cm)	Maximum weight (kg)	Commercial value
77	*Mastacembelus armatus* (Lacepede, 1800)	Zig-zag eel	AJK, Balochistan, KP, Punjab, Sindh	Indigenous	Least Concern	90	0.5	High
78	*Danio rerio* (Hamilton, 1822)	Zebra fish	Once in KP, Punjab, Sindh	Indigenous	Least Concern/ Very rare	-	-	-
79	*Megarasbora elonga* (Hamilton, 1822)	Bengala barb	Once in KP, Punjab, Sindh	Indigenous	Least Concern/ Very rare	-	-	-
80	*Schizopygopsis stoliczkai* (Steindachner, 1866)	Ladakh snowtrout	Upper Indus	Indigenous	Not evaluated/ Very rare	-	-	-
81	*Triplophysa stoliczkai* (Steindachner, 1866)	Stoliczka triplophysaloach	Deosai plateau	Indigenous	Not evaluated/ Very rare	-	-	-
82	*Sisor rabdophorus* (Hamilton, 1822)	Whiptail Catfish	Once in Punjab and Sindh	Indigenous	Least Concern/ Very rare	-	-	-
83	*Nandus nandus* (Hamilton, 1822)	Gangetic leaf fish	Once in Punjab and Sindh	Indigenous	Least Concern/ Very rare	-	-	-
84	*Badis badis* (Hamilton, 1822)	Chameleon fish	Once in Punjab and Sindh	Indigenous	Least Concern/ Very rare	-	-	-
85	*Monopterus cuchia* (Hamilton, 1822)	Gangetic mud eel	Once in Punjab and Sindh	Indigenous	Least Concern/ Very rare	-	-	-
86	*Macrognathus aral* (Bloch and Schneider, 1801)	One-stripe spiny eel	Once in Punjab and Sindh	Indigenous	Not evaluated/ Very rare	-	-	-

Discussion

The freshwater fish fauna has a high proportion of endemics. Major component of the endemic species belong to three genera (*Triplophysa*, *Schistura* and *Glyptothorax*). Fish species in these genera are not very agile or migratory in nature and mostly confined to their respective river systems. Moreover, these species are mainly cold water fauna and confined in headwater hilly streams and rivers and isolated from other such populations by the warm water stretches in between them. This natural isolation of different populations due to ecological barriers provides a fair chance of adaptations and evolution. The species of these taxa seem to have evolved after the creation of present day hydrography of the region, in response to orogeny of Himalayas and Tibetan Plateau. After the uplift of Himalayas and the Tibetan Plateau, the ancestors of these groups of fishes had to face the harder conditions of glacier-fed cold waters and the torrential rivers. The fishes of genera *Triplophysa* and *Schistura* reduced their body size and became thin and rounded to be able to hide in crevices and underneath the stones to save themselves from slipping away in the fast moving water, while those of *Glyptothorax* fishes developed different thoracic suckers in the abdominal region. Thus, anchorage to substratum was the prime factor for the survival of this group of fishes. These fishes have, therefore, developed numerous types of adhesive devices in response to water velocity and nature of river bed (Jayaram, 1982).

Owing to dispersal limitation, the endemic fish species have relatively localised distributions and are restricted in localised areas (Rosenfeld, 2002). If IUCN conservation status of the endemic fish fauna is determined, most of the species will be determined critically endangered or threatened with extinction due to restricted range of distribution, declining of their population and narrowing chances of their reproductive success. High levels of human pressure, overexploitation of resources, habitat loss and degradation of breeding grounds has lead to unrecorded extinction of the restricted range species (Magurran, 2009). Only assessed endemic species, *Glyptothorax kashmirensis*, on the basis of IUCN criteria has been declared Critically Endangered. It is found in Jhelum River drainage. The river is currently being dammed at several locations. This will impact this fast flowing river species due to habitat loss. A predicted decline of more than 80% over the next five to ten years is expected due to the above severe, irreversible threats (IUCN, 2011). A comprehensive strategy, therefore, needs to be evolved for conservation of this extinction prone group of fishes. Major component of endemic fish fauna of Pakistan is restricted to mountainous and sub-mountainous areas. This area, being the main centre of damming and blocking of rivers and streams, may be ecologically altered to such an extent that could eventually lead to extinction of this important component of freshwater biodiversity (Regnier *et al*., 2009).

The commercially important fishes are a vital component in the livelihoods of people of Pakistan. A total of 31 economically important fish species in the water bodies of Pakistan is apparently good number. It provides high quality protein, essential nutrients and minerals that are often difficult to obtain from other food sources. It is also used for recreation rather than for food production, another avenue to economic development and growth. Population of many commercially important species is declining due to various anthropogenic factors. As a result of severe population decline, the species, *Tor putitora* has been declared Critically Endangered. It is under severe threat from overfishing, loss of habitat and decline in quality of habitat resulting in loss of breeding grounds. In addition, with several dams planned for construction in the future in the Himalayan region, they could have a more drastic effect on its populations blocking their migrations and affecting their breeding. It is estimated that population of the species has already declined by more than 50% in the past and if the current trends continue, the population may decline even up to 80% in the future (IUCN, 2011).

The species, *Ompok pabda, Wallago attu, Ailia coila, Chitala chitala, Bagarius bagarius* and *Oreochromis mossambicus* have been declared Near Threatened (IUCN, 2011). This status is given mainly as a result of overexploitation in case of *Ompok pabda, Wallago attu, Ailia coila.* Significant decline of population due to pollution and overharvesting has occurred in case of *Chitala chitala*. The population of *Bagarius bagarius* has declined due to heavy harvesting of species as food fish and for ornamental trade and as sport. A rapid decline in the population of species *Oreochromis mossambicus* is expected due to its hybridisation with closely related and rapidly spreading *Oreochromis niloticus*.

In response to the above impacts on inland fisheries, special enhancement programmes need to be initiated for sustainable use of fisheries resources. One common form of enhancement is the stocking of natural water bodies with the fish seed produced in fish hatcheries. Thus, fishery production can be maintained not by natural recruitment but by the release of hatchery-raised individuals. Similarly, bringing more indigenous species in aquaculture net will boost the fish production in the country. The potential candidates being the *Tenualosa ilisha, Chitala chitala*, *Labeo calbasu*, *Labeo dyocheilus, Wallago attu*, *Sperata seenghala*, *Rita rita*, *Clupisoma garua*, *Clarias batrachus*, *Channa marulius* and the cold water schizothoracid snow carps.

Population of some of the species is declining due to habitat loss and degradation, water abstraction, drainage of wetlands, dam construction, pollution and eutrophication. These factors have caused substantial declines and/or changes in inland fish species. Consequently distributional ranges of some of the species have shrunk tremendously over the last three decades and are restricted to localised areas. The species *Danio rerio*, *Megarasbora elonga*, *Rita rita, Nandus nandus*, *Badis badis*, *Monopterus cuchia*, and *Macrognathus aral* have been severely affected by the environmental deterioration and habitat loss. Once quite common in river systems of Pakistan are now at the verge of extinction and hardly encountered in their natural habitats.

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Short Communications

Pakistan National Wetlands Policy

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1. Introduction

In 1976, Pakistan joined the Ramsar Convention, which stresses the importance of developing a National Wetlands Policy as a key feature in the implementation of the concept of "Wise Use" of wetlands promoted by the Convention. A Wetlands Action Plan was prepared and approved in 2000, but it is now considered to be "wholly inadequate for comprehensive application"; thus, "in the absence of a pragmatic and living policy framework, the existing national and site level initiatives are likely to have little sustainable impact upon the conservation of globally important wetlands and their associated biodiversity in Pakistan".

2. Pakistan National Wetlands Policy

Pakistan has no designated definition of wetlands, so for this policy the definition of the Ramsar Convention is used:

"*…areas of marsh, fen,[1] peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres."*

In case of Pakistan, all future legislations will consider the adaptation of this definition to include glaciers and the areas of wetlands that fluctuate in size to include the 10-year high water levels.

Pakistan's National Wetlands Policy recognises the importance of Pakistan's wetlands, which include valuable ecosystem services, such as: water regulation, wetlands and climate, biodiversity importance, human health and livelihoods.

Threats to wetlands: The policy addresses a number of threats including loss and degradation of wetlands, demands for water, land and natural resources, lack of awareness, lack of co-ordination, lack of capacity and resources, and lack of policies, laws and regulations

Opportunities for wetlands: The policy encourages many opportunities that exist for increasing the value of wetlands for human use without damaging or degrading the wetland natural resources. These include: enhancing wetland productivity for water supply and food production, using wetlands for water treatment, optimising multiple uses of man-made wetlands, using wetlands as an educational resource and using wetlands for recreation and tourism.

3. The Need For A National Wetlands Policy

Starting with the adoption of the National Conservation Strategy (NCS) in 1992, Pakistan has developed a number of environmental and natural resource policies, and incorporated environmental concerns into ongoing and future national plans.

These policies are fundamental to the overall National Vision 2030 prepared by the Pakistan Planning Commission in 2007. They contain elements supporting wetlands conservation and management, but are inadequate in their scope and have gaps in their coverage. They highlight the importance of water availability and water resources rather than wetlands.

Climate change is a big issue for both Pakistan and its wetlands. Models show that Pakistan will grow warmer by about 1°C by 2030 (CICERO, Report 2002-2), and could even rise up to 4-5°C higher in the last three decades of this century. The Indus basin depends heavily on the western Karakorum and Himalayan glaciers that act as a reservoir, maintaining the rivers that feed the irrigation system of the country. Rising temperatures will increase the melting of glaciers over the next 50 years.

Precipitation during Pakistan's summer monsoon is likely to increase substantially between 20 to 30%, but the rainfall will be poorly distributed temporally and spatially; much of the additional rainfall is likely to occur as high-intensity storm events. Climate change will have an adverse impact on wildlife and their habitats. Wetlands and their biodiversity will be under even greater threat. Policies encouraging adaptation to climate change for wetlands and wetland users are urgently required,

These policies do not specifically address wetland issues and there is a growing concern that wetlands conservation may "fall through the gaps" of other environmental and conservation policies. There is already a National Forest Policy, even though forest cover amounts to only 5 % of the land area of Pakistan compared with 10 % covered by wetlands. The National Environment Policy highlights the need for developing a separate national wetlands policy.

There is a clear need for a separate wetland policy that is focused on rehabilitation, restoration, sustainable management and wise use of wetlands. It must be closely co-ordinated with other environmental, water and natural resource use policies. There is also a legal obligation under the Ramsar Convention to formulate a National Wetlands Policy.

4. National Wetlands Policy

Vision Statement: The Vision Statement for the future of Pakistan's wetlands provides a goal for all wetland conservation and management work for the future:

"Pakistan manages its wetlands for effective performance of ecological functions and services; and for realising opportunities for sustainable livelihoods, recreation and culture, research and education."

Policy principles: A wide range of different principles underlie the design of the Pakistan National Wetlands policy; these can be summarised as:

1. **Ecosystem approach** – endorsed by the Convention on Biological Diversity, the ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies that encompass the essential processes, functions and interactions among organisms and their environment. It recognises that humans, with their cultural diversity, are an integral component of ecosystems;

1 Fen = Alkaline marsh.

2. **Equity** – the aim of sustainable management of wetlands is an equitable sharing of water and wetland resources at community, district and provincial levels;
3. **Good governance –** the implementation of the national wetland policy is based upon good governance, transparency, informed decision-making and accountability;
4. **Stewardship** – the policy aims to engender a sense of stewardship in wetland management so that the wetlands of Pakistan may be used and enjoyed by future generations;
5. **Integration with other policies and development planning decisions** – the policy aims to ensure that wetland issues, risks and opportunities are incorporated into decision-making and planning of all major developments;
6. **Transboundary co-ordination –** the policy aims to facilitate transboundary co-ordination in the management of wetlands and upstream/downstream impacts of developments upon wetlands;
7. **No net biodiversity loss** – in the long term, the policy aims at halting further loss of wetland biodiversity and enhancing biodiversity values wherever possible. The policy will consider the concept of wetland biodiversity offsets, in which loss of wetlands in one area is offset by gains and improved management in another area;
8. **Knowledge-based –** wetland policies, plans and management are based upon on best available knowledge and understanding; the policy encourages easy access to such information for wetland users, managers and stakeholders;
9. **Implementation** – the policy aims to act as a guide for the implementation of a range of initiatives to promote sustainable use of wetland resources, address the loss and degradation of wetlands, and reduce the poverty and vulnerability of wetland users;
10. **Involving stakeholders –** implementing the policy is the responsibility of all wetland stakeholders – wetland users, including both men and women, riparian communities, wetland managers, local government officials, provincial and federal agencies, private sector companies, academia and research organisations, community-based organisations and non-governmental organisations (NGOs) – recognising their different roles and responsibilities;
11. **Resourcing** – sustainable financing for implementing the policy will be raised through a variety of different sources, and will not rely solely upon government budgets and donor funds.

Policy objectives: The seven objectives detailed below have been specified for Pakistan's Wetland Policy to address the principal issues. These objectives are

1. **Addressing primary threats to Pakistan's wetlands –** providing for direct action to tackle the principal threats to Pakistan's wetlands, covering water availability and quality issues, unplanned land use change, overuse and illegal use of natural resources and climate change induced degradation of wetlands.
2. **Creating and implementing a regulatory framework for the conservation and sustainable use of wetlands –** addressing the issue of conflicting and overlapping policies, laws and regulations, and envisaging the enactment of new legislation covering wetland conservation and sustainable use.
3. **Greater co-ordination and collaboration between agencies and sectors on wetland issues encouraged from local to international levels –** addressing the lack of co-ordination between different agencies and sectors at provincial and national levels, and encouraging greater collaboration at the international level.
4. **Promoting wetland research, education and data management** – recognising that further research is required to increase understanding of wetland resources and processes, and the valuation of wetland services. Wetland education is needed to extend this knowledge base about wetlands to build the capacity for wetlands management for future generations. Improved data management is required for monitoring changes in wetlands, and for more effective site management.
5. **Building Pakistan's capacity for sustainable wetland management** – building the capacity for current and future management of wetlands at site level and among provincial and national agencies. Strengthened capacity will lead to improved decision-making about specific wetlands as well as improved implementation of wetland policies and sectoral development plans.
6. **Promoting improved understanding, perceptions and attitudes towards wetlands conservation and wise use** – creating a broad understanding and awareness of wetlands, their importance and threats at all levels – the general public, wetland stakeholders and users, including vulnerable communities that are dependent on wetland resources, and specific influential groups (e.g., industries that use or have an impact on wetlands, government officials, politicians and senior decision makers).
7. **Securing financing mechanisms for sustainable management of wetlands** – recognising that without adequate financing, all efforts envisaged by this policy will be undermined. A range of sources of financing, such as environmental funds, government budgets, corporate sector funding and donor funded projects, are identified.

5. Implementing The Policy

Strategies for Action: For each objective, the policy framework outlines a number of strategies for action. These are indicative and further actions in line with the objectives will be added as the policy matures. The strategies explain the meaning and intentions of the policy objectives and their implementation.

1. Addressing primary threats to Pakistan's wetlands.

1.1. Ensuring water availability for priority wetlands in Pakistan
1.2. Ensuring water quality in Pakistan's wetlands, especially rivers, lakes and coastal zones
1.3. Managing land-use change to protect Pakistan's wetland resources
1.4. Encouraging sustainable use of Pakistan's wetland resources
1.5. Addressing issues of climate change and natural disasters affecting wetlands

2. Creating and implementing a regulatory framework for the conservation and sustainable use of wetlands

1.1 Harmonising national wetland policy with other policies
1.2 Clarifying legal status for the protection and sustainable use of wetlands and developing new wetland legislation

3. Greater coordination and collaboration between agencies and sectors on wetland issues achieved from local to international levels

3.1 Ensuring greater coordination between institutions with wetland responsibilities
3.2 Developing site-level collaborative wetland management
3.3 Establishing co-ordination, collaboration and support

mechanisms for wetlands at the provincial level

3.4 Developing collaboration with other provinces on wetland issues

3.5 Developing international collaboration on wetland issues

4. Promoting wetland research, education and data management

1.1 Encouraging wetland education at all levels from primary to tertiary education

1.2 Improving the understanding of wetlands science – processes, use, threats and management

1.3 Developing and improving wetland maps and data management

1.4 Valuing the benefits and services of Pakistan's wetlands

1.5 Providing access to wetland information

5. Building Pakistan's capacity for sustainable wetland management

5.1 Building the capacities for site-level wetland management

5.2 Building the capacity for addressing wetland issues among provincial government agencies

5.3 Building the capacity for addressing wetland issues among federal government agencies

6. Promoting improved understanding, perceptions and attitudes towards wetlands conservation and wise use

Creating awareness about wetlands among:

- *The public*
- *Wetland stakeholders and users*
- *Specific influential groups*
- *Government officials*
- *Senior decision makers.*

7. Securing financing mechanisms for sustainable wetlands management

7.1 Sourcing wetland finance from various environmental funds

7.2 Ensuring specific wetland allocations in government budgets

7.3 Developing corporate sector finance for wetlands

7.4 Developing donor-funded projects

Pakistan's National Biodiversity Clearing House Mechanism

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Pakistan's National Clearing House Mechanism (CHM) is a network that provides information on the biodiversity in Pakistan in support of the UN Convention on Biological Diversity (CBD). The National Focal Point (NFP) of CBD and NFP of CHM has jointly set up a national CHM in the Forestry Wing of Ministry of Climate Change through the financial assistance of Global Environment Facility (GEF) through United Nations Environment Programme (UNEP) and with the technical support of WWF - Pakistan. The CHM aims to contribute significantly to the implementation of the CBD by promoting and facilitating technical and scientific cooperation among Parties, other Governments and stakeholders at the national level. The main objectives of the Pakistan's CHM are as under:

1. Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society
2. Reduce the direct pressures on biodiversity and promote sustainable use
3. Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity
4. Enhance the benefits to all from biodiversity and ecosystem services
5. Enhance implementation through participatory planning, knowledge management and capacity building

A national level CHM technical Committee was constituted and notified by the NFP CHM with the following Terms of References:

1. Review the requirements of CHM – PoW and to provide technical guidance accordingly.
2. Identify sources of biodiversity data and information and gaps
3. Provide technical backstopping for establishing world-class CHM of Pakistan
4. Define terms of partnership for data sharing, data specification and standards
5. Ensure full and timely implementation of CHM component of BEAP project

Pakistan's National Biodiversity CHM has two major components:

- CHM Data Repository Center
- CHM Website

Data Repository Center will be established under the NFP - CBD. Data that is held by Centre includes both manual and electronically held data, and comes from a variety of sources, including species via data exchange agreements, habitat & species surveys, national reports, reference materials, historic biodiversity reports, historic maps, photographs etc.

The national CHM website administered by the national CHM Focal Point, contains all national biodiversity-related information to assist policy makers and interested stakeholders to meet obligations under the CBD and to conserve and ensure sustainable use of biodiversity. The Pakistan's CHM website is serving as a gateway to all available biodiversity information at the National level.

Ministry of Climate Change through the NFP of CBD and NFP of CHM is the custodian of the Pakistan's National CHM and WWF – P is assisted the Ministry of Climate Change in establishing the CHM through this project. Ministry of Climate Change will officially acquire, authenticate and make available necessary documentation and data required for the Pakistan's National CHM.

An inception workshop on Pakistan's national biodiversity Clearing House mechanism was organised in Islamabad from May 7-8, 2012 with the following major objectives:

1. Provide information on the Convention on Biological Diversity (CBD) and its implementation in Pakistan
2. Share information on the status of biodiversity in Pakistan
3. Disseminate draft National CHM Strategy document with the stakeholders
4. Share design and layout of the National CHM website
5. Develop links to Internet-based biodiversity information in Pakistan
6. Offer a window for scientific and technical cooperation in the field of biodiversity
7. Integration of Biodiversity conservation issues and principles into national policies and plans

Three working groups were defined to give suggestions for the improvement of CHM Strategy and Website and how this could effectively address Pakistan's commitment to CBD and also share information with the global community about the biodiversity status of Pakistan.

Group 1: Identification of Stakeholders and Terms of Partnership

The main responsibility of the Group 1 was to identify the stakeholders that are not included in the draft CHM Strategy, and to edit the terms of partnerships between the data producers and data users.

Group 2: Data Standards

This group discussed about the spatial data specifications. The main purpose of this working group discussion was to identify the number of spatial data layers and their standards.

Group 3: Strategy Implementation Working Group

This working group discussed about the implementation phase of the CHM project and identified the stakeholders as the resource persons in the provinces. This group was also assigned the duty of compiling the Terms of References for the data users.

It was concluded in the workshop that due to large volume of data, CHM data repository center will only have the lists/electronic catalogue of the data available with different organisations. This can also be achieved by uploading the list of historic datasets and literature on biodiversity on relevant organisation's website or CHM website. Website design and layout was finalised with the suggestions from stakeholders.

After the launching of national CHM website, capacity building workshops will be organised in all provinces, AJ&K and Gilgit Baltistan. GIS Nodes established by Pakistan Wetlands Programme in provincial headquarters will be used for CHM capacity building workshops. Representatives of provincial nodes will be trained on Content Management System (CMS) programme, which can be used to set up and maintain website for national CHM database building. As part of this activity, participants are trained to database management system, web portal use, data/metadata entry processes, metadata standards, use of open source applications for data sharing and spatial data handling in open source web GIS interface. Encourage the use of CHM website as a means of dialogue between civil society, the stakeholders and policy makers.

Instructions to Authors

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Abstract should hold a summary of not exceeding 200-300 words including the question investigated, the methods used, the principal results and conclusions. It should not contain any undefined abbreviations or references. At the end of the abstract, there should be at least five keywords that may highlight the subject matter. The journal's language is English. British English spelling and terminology may be used. We appreciate your efforts that you make to ensure that the language is corrected before submission. Manuscript should contain titles such as: Abstract, Introduction, Materials and Methods, Results and Discussion, Conclusion, Recommendations and finally References. Manuscripts should be typewritten on A4 paper, with a font Helvetica of 12 pt size, one side only, leaving adequate margins on all sides to allow for reviewers' remarks. Please use single space for all the text and number the pages consecutively. The article should range from 7-10 pages (3500-5000 words).

All photographs, graphs, maps and diagrams should be referred to as a 'Figure' and they should be numbered consecutively (1, 2, etc.). Multipart figures ought to be labelled with lower case letters (a, b, etc.). Please mention figure caption in the end of figure (e.g. Figure 1) with bold. Please insert keys and scale bars directly in the figures. Provide a detailed legend (without abbreviations) to each figure, refer to the figure in the text and note its approximate location in the margin. The resolution of figure must at least be 300 dpi. Figures that are prepared by excel should be sent along with their source of data. Each figure should stand alone. Each table should be numbered consecutively (1, 2, etc.). In tables, footnotes are preferable to long explanatory material in either the heading or body of the table. Such explanatory footnotes, identified by superscript letters, should be placed immediately below the table. Please provide a caption (without abbreviations) to each table, refer to the table in the text and note its approximate location in the margin. The same data should not be presented simultaneously in tables and figures. Table captions must be at the top of table with 10 pt Helvetica.

Acknowledgements of people, grants, funds, etc. should be cited in a separate section before the References. In case of single author (Stephenson, 1990) and for more than one author, citation should be mentioned (Hassan & Abdullah, 2009). All publication cited in the text should be presented in the list of references following the text of the manuscript. In the text refer to the authors' name and year of publication (e. g. Arshad, 2012). For three or more authors use the first author followed by "et al.," in the last (Firdous *et al.*, 2009). The list of references at the end of the manuscript should be arranged alphabetically like "Ullah, S., R. Frasier, L. Pelletier, Moore, T. R. (2009). Greenhouse gas fluxes from boreal forest soils during the snow-free period, Quebec. Can. J. Fore. Res. 39:666-680"

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