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Trackways evidence of sauropod Dinosaurs Confronted by a Theropod found from middle Jurassic Samana Suk Limestone of Pakistan

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Abstract

The temporal distribution of sauropod trackways generally parallels the record of sauropod body fossils. The oldest sauropod trackways are found in Lower Jurassic deposits of Africa, North America, and Asia; trackways are abundant throughout the rest of the Jurassic and Lower Cretaceous, but fewer are recorded in the Upper Cretaceous rocks. The foot structures of the various dinosaur groups are usually fairly conservative within those groups. Trackways are particularly promising records of dinosaur locomotion because they represent the trace of an act-a moment in time- and therefore can provide information that is usually unavailable from skeletal morphology alone.

Remains of a diversified paleobiota are found in the middle Indus basin, which includes plants (gymnosperm), mollusks, reptiles (cranial and post cranial bones). The commonest vertebrate fossils belong to sauropod and theropod dinosaurs, and mesoeucrocodilian fauna that occur a wide geographic area. Recently the author have found footprints of sauropod confronted with a theropod, in the middle Jurassic Samana Suk Limestone of Surghar Range, Mianwali district, Punjab Province, Pakistan. Five species of Late Cretaceous and one species of Late Jurassic titanosaurian sauropod, and one species of Late Cretaceous Abelisauran theropod dinosaur from Pakistan have already been established. But one new genus and species ***Malasaurus mianwali*** of middle Jurassic sauropod and one new genus and species ***Samanadrinda surghari*** of large bodied theropod based on only ichnofossils, are tentatively erected. Large pes foot print having length/width about 1 metre are diagnosed only for a large bodied sauropod. The manus footprints are totally overlapped by the pes prints. These tracks suggest the gregarious behavior of narrow gauge locomotors defending the attack of predatory theropod. This is the reason these are not referred to previously erected species of titanosaurs from Pakistan, because they may belongs to wide gauge trackways. These footprints are surely assigned to sauropod, but its assignment to lower level is difficult.

Three slender toed foot prints having maximum length about 2 feet and width about 1.5 feet are diagnosed only for a large bodied theropod. These footprints are surely assigned to Theropod, but its assignment to lower level is difficult. Both the sauropod and theropod genera erected are named only to refer for future research work regarding locomotion, behavior, soft and hard tissues. This ichnotype reveal the scenario of confrontation among a carnivorous ***Samanadrinda surghari*** theropod and the groups of herbivorous ***Malasaurus Mianwali*** sauropods.

This ichnocoenosis consists of exposed about 15 footprints, and 4 short trackways. Three trackways are interpreted as mainly produced by sauropods which are obliquely confronted by a track of large Theropod. They are indicative of a sauropod herd, composed of 3 or more individuals and furnish evidence of gregariousness (herd). The ichnofossils are usually deep footprints probably due to good granolometric sorting and the high plasticity of the limy substrate. In the vicinity, some foot prints of possibly birds/ small body theropod/coelorusaurs are also present. The ichnofossils of sauropod dinosaurs confronting a theropod of upper Indus Basin are a unique record of a middle Jurassic dinosaurian fauna which inhabited the north western margin of Indo-Pakistan subcontinental plate.

Keywords: Footprints, sauropods, confronted a theropod, Middle Jurassic, Pakistan.

M. Sadiq Malkani

1. Introduction

The temporal distribution of sauropod trackways generally parallels the record of sauropod body fossils. The oldest sauropod trackways are found in Lower Jurassic deposits of Africa, North America, and Asia; trackways are abundant throughout the rest of the Jurassic and Lower Cretaceous, but fewer are recorded in the Upper Cretaceous rocks (Lockley, Meyer, Hunt, and Lucas 1994 and references therein). The foot structures of the various dinosaur groups are usually fairly conservative within those groups; footprints shapes are also pretty generic within a group. One may be able to say that a given footprint was made by a large theropod, or a big ornithopod, or a sauropod, but it is seldom possible to say exactly which species of theropod, ornithopod, or sauropod we are dealing with (Farlow, 2000). If the formation having foot prints may host skeleton of dinosaurs then we can argue that it was a trackmaker but we can not be completely sure. Fossilized tracks and trackways (ichnofossils) are the only direct evidence of what extinct animals did when they were alive. They are like snapshot from the animal's life and can provide us important information about locomotion (e.g., posture, kinematics), behaviour (e.g., herding), and even soft tissues (e.g., foot scales, body features). The ancestral dinosaurs and herraresaurids walked with all four toes on the hind feet touching the ground, advanced carnivorous dinosaurs (the Neotheropoda) walked on only the middle three toes (digits 2-4).

Footprints and trackways were among the first dinosaur remains to receive scientific attention (e.g., Hitchcock 1836) and have seen a renaissance of study in recent decades as an increasing number and diversity have been discovered (see Lockley 1986; Thulborn and Wade 1989). Trackways are particularly promising records of dinosaur locomotion because they represent the trace of an act-a moment in time- and therefore can provide information that is usually unavailable from skeletal morphology alone (Alexander 1976; Thulborn 1982, 1989; Gatesy and Middleton 1996). Despite these potential benefits, however footprints have been of limited use because of difficulties in identifying the trackmakers. This problem is underscored in depositional settings where footprints are preserved better than body fossils, and estimates of taxonomic diversity must depend solely on these tracks. This problem is partially mitigated by a system of ichnotaxonomy that categorizes types (e.g., ceratopsian, sauropod, hadrosaur), but this system precludes examining footprint data at any lower taxonomic levels. As a result analyses that attempt to integrate skeletal and ichnological data (Farlow 1992; Lockley, Farlow, and Meyer 1994) must focus on these broad taxonomic categories and generally can not examine within group patterns of locomotor diversity (Wilson and Carrano, 1999).

A common pattern displayed by trackways at dinosaur footprint sites is for about half of the trails to be heading in one direction and the other half in the opposite direction. If we think about the conditions under which footprints are likely to be formed and preserved, the reason for this pattern will be apparent. Footprints require soft substrates in order to be formed, but some such soft substrate situations are more likely to preserve prints than others. Footprints can easily be made in dry sands well away from water courses, but likely fate of such prints is that they will eventually be gone with the wind. Footprints have a much better chance of survival if they are made in wet sediments, along the margins of streams, lakes, or seas, where they can eventually be buried beneath other sediments. The mirror image pattern could readily be generated if groups of animals were to move in either direction along the shore over time. The famous Early Cretaceous dinosaur footprint sites of the Paluxy River, in what is now Dinosaur Valley State Park near Glen Rose, Texas, provide a good example of this for one kind of trackmaker. The great majority of footprints displayed in the limestone bed of the river are big three toed jobs likely made by large theropods. The trackways of big theropods nicely show the mirror-image pattern. (Farlow, 2001).

Extrapolating from living crocodilians and birds, it is plausible that some dinosaur groups were family structures, consisting of a parent and its young, or a group of juveniles that had become large enough to get by without their parents, but that stayed together, at least for a time, for mutual protection and foraging (Farlow, 2001).

Paleontologists have faced the problem of associating tracks and trackmakers since the earliest discoveries of dinosaur tracks (Hitchcock 1836). In subsequent decades, a diverse ichnotaxonomy flourished alongside a comparatively poor understanding of trackmaker identity (e.g., Lull 1915). In recent years, however a renaissance in dinosaur ichnology has led to the application of theoretical biomechanics (Alexander 1976), the mechanics of trackmaking in extant vertebrates (Pardian and Olsen 1989), and the effect of different substrates (Farlow 1989) for discriminating and interpreting dinosaur tracks (Wilson and Carrano, 1999). Farlow (1997,1998) data from birds (extant dinosaurs) show that even under idealized conditions of preservation, the tracks of certain major taxonomic group (i.e., most ground dewelling birds) can be difficult to distinguish between lower level non avian dinosaur taxa. Temporal and spatial coincidence can be used to draw more general and reasonable conclusions about potential dinosaur trackmakers. For example, Schulp and Brokx (in press) described a wide gauge sauropod trackway from the Maastrichtian of Fumanya, Spain. The authors noted that titanosaurs were the only sauropods known from the Maastrichtian of Europe and cited this as evidence that titanosaurs were the makers of wide gauge trackways. This is consistent with the currently known geographic and temporal distribution of titanosaur body fossils, although this association remains coincidental. Although direct trackmaker-trackway associations are known in the fossil records, they are exceedingly rare (Wilson and Carrano, 1999).

2. History of Dinosaur Discoveries in Pakistan

The firstever discovery of dinosaurs from Pakistan was made by author during early 2000 from the Latest Cretaceous dinosaur beds (Vitakri) member of Pab formation in Vitakri area, Barkhan district, Balochistan. First time in Pakistan I found a fossil of distal femur of Titanosaurian Sauropod dinosaur and first reported by Malkani and Anwar (2000). Professor Philip D. Gingerich, University of Michigan congratulated the GSP for this first ever dinosaur discovery from Pakistan and requested to DG, GSP for the visit of dinosaur locality. During late 2000, Professor Phillip D. Gingerich visited the Pakistan for previously running project of Eocene whale. On his visit to Vitakri dinosaur locality, I showed him the in-situ fragmentary bones. About 100 bones/pieces of bones of dinosaur Vitakri locality no one, are sent to Museum of Paleontology, University of Michigan, USA. I collected further 1500 bones/pieces of bones from 25 localities in Sulaiman foldbelt, administratively located in the areas of Barkhan, Kohlu, Dera Bugti, and Dera Ghazi Khan districts, Balochistan and Punjab Provinces during early 2001. Dr Jaffery A Wilson, Museum of Paleontology, University of Michigan, USA visited the GSP museum during March, 2001 and Dr. David A. Krauss of Bostan College, USA visited the GSP museum and Vitakri locality during mid of 2001. Second time dinosaur fossils are reported by Malkani, Wilson and Gingerich, (2001). I collected further 1200 bones/ pieces of bones during mid of 2001, from Sulaiman foldbelt. Third time dinosaur fossils are reported by Malkani, (2003a,b,c). Then the collected fossils of dinosaurs from Pakistan are documented by a continuous series of research papers by Malkani, (2004a,b,c, 2005a,b, 2006 a-h). The research on a braincase of titanosaurian sauropod dinosaur discovered by me from the Top Kinwa Kali Kakor locality of Vitakri area are also documented (Wilson, Malkani and Gingerich, 2005; Malkani, 2006h). The research on Paleobiogeography of titanosaurian and abelisaurian dinosaurs from Pakistan, wide gauge locomotion argued from skeletal morphology of Late Cretaceous Pakistani Titanosauria, localities of dinosaurs from the Late Cretaceous Pakistan, and confrontation scenario between two theropod dinosaurs argued from the discovery of a rostrum of *Vitakridrinda* found from the Late Cretaceous Park of Pakistan (Malkani, in review). The research on the finding of trackways of sauropod dinosaurs confronted by a theropod found from the Middle Jurassic Samanasuk Limestone of Pakistan is presented here.

3. Geological and Stratigraphic Setting

The study area of Surghar range is located in the upper Indus Basin of Pakistan **(Fig.1).** Trackways (footprints) of sauropod dinosaurs and a theropod are hosted by middle Jurassic Samanasuk Limestone of Surghar Range. The sediments of the study area underwent considerable tectonic deformation during the collision of Asian and Indo-Pakistan continental plates that commenced in the Late Cenozoic. As a result dinosaurs' foot print hosted beds along with other formations have been folded and faulted **Table -1.**

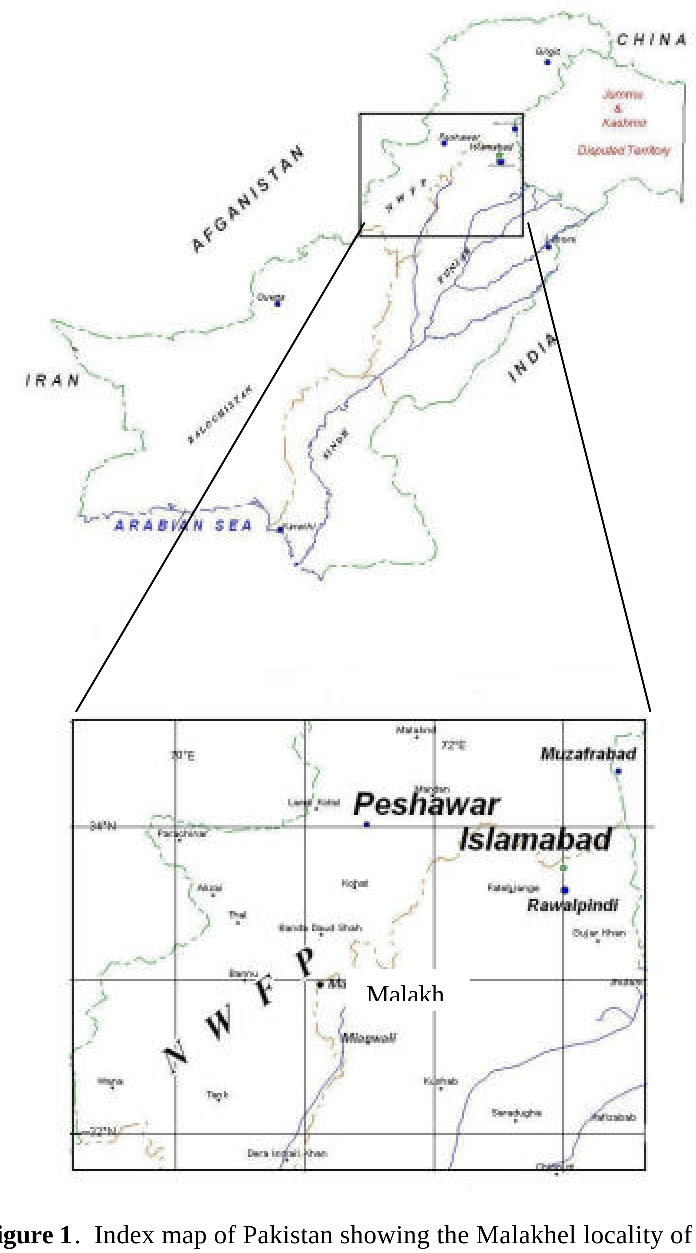

Figure 1. Index map of Pakistan showing the Malakhel locality of Mianwali District, which is the host of newly discovered footprints of herbivorous sauropod dinosaurs confronted by a carnivorous theropod dinosaur.

Table – 1: Stratigraphic Sequence of surghar range, Mianwali and Karak Districts, Punjab and N.W.F.P Provinces, Pakistan

Age			Formation	Lithology
CAINOZOIC	QUATERNARY	Recent	Modern channel deposits	Gravel, sand, silt and clay
			Sand, silt and clay deposits (cultivated lands)	Sand, silt and clay with minor gravel
		and	Sand, silt and clay deposits (non-cultivated lands)	Sand, silt and clay with minor gravel
			Colluvium deposits	Boulder, pebbles,cobbles,with sand silt and clay.
			Fan gravel deposits	Poorly consolidated gravel, sand, silt and clay.
		Sub-Recent	Terrace gravel deposits	Poorly consolidated gravel, sand, Silt and clay.
			-----------------Angular Unconformity -----------------	
	TERTIARY	Pliocene	Soan Formation	Clays, conglomerate and sandstone
			Dhok Pathan Formation	Clays with subordinate sandstone conglomerate
		Miocene	Nagri Formation	Sandstone with minor shale and conglomerate
			Chingi Formation	Red Clays, sandstone and conglomerate
			------------------------Disconformity------------------------	
			Kamlial Formation	Shale with subordinate sandstone and conglomerate
		Oligocene	Murree Formation	Sandstone, conglomerate and shale
			--------------------------Disconformity--------------------------	
			Habib Rahi Formation	Mainly limestone with marl and shale
			Kuldana Formation	Shale with minor sandstone and limestone
			Choregali Formation	Limestone and shale
		Eocene	Skesar Limestone	Limestone with subordinate shale and marl
			Nammal Formation	Marl with subordinate shale
			Patala shale	Mainly shale with marl
		Paleocene	Lockhart Limestone	Mainly limestone with minor shale
			Hungu Formation	Sandstone, coal, and shale
			-------------------------Disconformity-------------------------	
MESO	CRETACEOUS		Lumshiwal Formation	Sandstone & shale
			Chichali Formation	Glauconitic sandstone and shale
			------------------------Disconformity------------------------	
	JURASSIC		Samanasuk Formation	Mainly limestone with subordinate shale
			Shinawari Formation	Shale, limestone and sandstone.
			Data Formation	Mainly sandstone with minor shale
			--------------------------Disconformity--------------------------	

Z		Kingriali Formation	Dolomite and limestone with minor shale
O	TRIASSIC	Tredian Formation	Mainly sandstone
I		Mianwali Formation	Shale, limestone and sandstone
C		----------------------------Disconformity --	
PALEO-		Chiddro Formation	Shale and sandstone.
ZOIC	PERMIAN	Wargal Limestone	Limestone and dolomite
		-----------------------------Contact not exposed--	
PRECAMBRIAN		Salt Range Formation	Marl, gypsum, salt and shale

4. Materials and methods

Sedimentary strata of Pakistan are famous for Cenozoic vertebrate (Gingerich *et al.*, 2001). Recent dinosaur discoveries by me from Mesozoic of Pakistan have increased the temporal variation of its vertebrate fauna.

Remains of a diversified paleobiota are found in the middle Indus basin, which includes plants (gymnosperm), mollusks, reptiles (cranial and post cranial bones). The commonest vertebrate fossils belong to sauropod and theropod dinosaurs, and mesoeucrocodilian fauna that occur a wide geographic area. Five species of Late Cretaceous and one species of Late Jurassic titanosaurian sauropod, and one species of Late Cretaceous Abelisauran theropod dinosaur from Pakistan have already been established.

Recently I have found footprints of sauropod confronted with a theropod **(Figure 2-4),** in the middle Jurassic Samana Suk Limestone of Surghar Range, Mianwali district, Punjab Province, Pakistan. The research on these footprints and trackways of Sauropd dinosaur confronted by a theropod are presented here. The method applied here is the paleontological methods representing description, interpretation, discussion and conclusions.

Figure 2. Footprint of herbivorous sauropod dinosaurs found from Malakhel area, Mianwali District, Punjab, Pakistan.

For scale please see the hammer. Arrow shows movement direction.

Figure 3. Footprint of a large bodied theropod, found from Malakhel area of Mianwali District, Punjab, Pakistan.
For scale please see the hammer. Arrow shows movement direction.

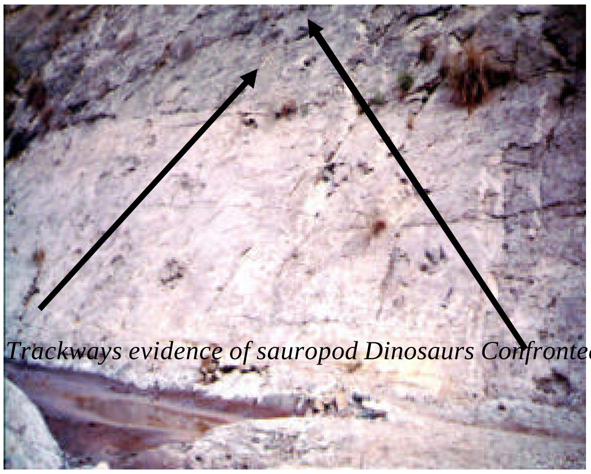

Figure 4. Footprints of sauropods confronted by a theropod,found from Malakhel area of Mianwali District, Punjab, Pakistan. Longer arrow shows the advancing movement of a Theropod, while the smaller arrow shows the advancing movements of sauropod dinosaurs. For scale please see the hammer.

5. Footprints of Dinosaurs

Sauropod trackways are notable in that they document distinct gauges. Variation in track and trackway morphology of other dinosaur clades appears to be circumstantial rather than systematic, serving to differentiate speeds, sizes, or individual ichnotaxa. For example, although hadrosaur trackways may preserve either bipedal or quadropedal locomotor habit, all hadrosaur taxa are thought to have been capable of engaging in either form of locomotion; other widespread differences between group of hadrosaur treacks are not apparent. The same is true for identifiable tracks of other ornithopods, theropods, ceratopsians,and prosauropods-none of these groups show systematic within group clustering of trackway variation (Wilson and Carrano, 1999).

Sauropod has an easily recognizable, conservative morphology. Manus impressions are generally U shaped, subtending an arc of approximately 270 degrees. The median axis of the print (passing through digit III) is oriented anterolaterally relative to the line of travel, and atrace of large pollex claw is occasional preserved. Pes impressions are always larger in an area than those of the manus, and the manus to pes ratio (referred to as heterodonty) ranges from 1:2 to1:5 in sauropods (Lockley, Farlow, and Meyer 1994). Additionally pes prints are characteristically subcircular in outline, with a well developed heel print and impressions of three or four laterally directed claws. The pes impression can partially or totally obscure that of the manus in sauropod trackways, as the pes was apparently often placed in the same location following removal of the manus from the substrate. This overlap is common in short coupled forms (Leonardi 1987).

Wide-gauge trackways have been defined as those in which manus and pes impressions are well away from the trackway midline, whereas those of narrow gauge tracks are close to or even intersect the trackway midline (Farlow 1992) (Fig.1). Farlow has identified several additional ichnomorphological correlates of narrow and wide gauge trackways. For example, whereas claw impressions are occasionally preserved in narrow gauge manus prints, they are not typically associated with wide gauge trackways. Additionally manus prints are positioned closer to the midline than are pes prints in wide gaudge trackways, where as the opposite is true of narrow gauge trackways. Farlow (1992) also described identifications in the manus prints of Brontopodus (wide gauge) that indsicate aseparation of digits II-IV from the marginal digits. The morphology is not known to occur in narrow gauge tracks.

Footprint sites of Queensland, Australia tells the story of more than 100 small bipedal dinosaurs from the early cretaceous that were seemingly stampeded into mass flight by the approach of a much larger bipedal dinosaur, probably a carnivore. The paleontologists who originally describe the site thought that the small bipedal dinosaurs represented two different species, one a theropod and the other an ornithopod. If true, the co-occurrence of the two kinds of trackway at the same spot suggests that members of each species tolerated the presence of the other, at least at times. However some paleontologists have suggested the two trackway types may belong to members of same species, so our behavioral interpretation must be rather tentative. (Farlow, 2000).

Caveats duly noted, we can now consider what dinosaur trackways suggest about their makers' social behavior. At the famous Early Jurassic locality at dinosaur State Park near Hartford, Connecticut, numerous theropod track makers traveled every which way, with no obvious pattern to their courses. Quite possibly these dinosaurs were loners. At other sites, the pattern is very different. At an Early Jurassic dinosaur tracksite near Holyoke, Massachusetts (New England), at least 20 bipedal dinosaur, all theropod, were moving together as a group. The Early Cretaceous British Colombia Canada locality where four igaunodonts appear to have moved as a unit, changing directions at the same time. One of the worlds' best known set of dinosaur footprints from the Early Cretaceous sauropod trackways from Texas. Since every individual trackway is in the same direction and in close association with others the probability that the makers were moving together is high. The past claims that the young were in a protective center have not borne out (Farlow, 2001).

At the Paluxy River site, prints made by enormous quadrupeds, with the hindfoot impressions a yard or more in length. These foot prints are made by sauropods, and at least a dozen of them moved across the main tracksites in the park. Unlike the theropod trails, which go in both directions along the inferred ancient shoreline, nearly all of the sauropod trails head in only one directions, it may representing migratory path (Farlow, 2001).

If sauropd moves in groups, then we might often expect to find monospecific bonebeds dominated by a single kind of sauropod. A few such occurrences have been reported, but most such monospecific sauropod bonebeds have only a few individual animals in them, nothing like the enormous monospecific death assemblages known for some hadrosaurs and ceratopsians. Most bonebeds that have sauropods generally contain more than one sauropod species (Farlow, 2001). Patterns in the temporal distribution of narrow and wide gauge trackways have been identified by Lockley, Farlow and Meyer (1994) and Lockley, Meyer, Hunt, and Lucas (1994). The narrow gauge tracks do form the majority of Jurassic sauropod ichnocoenoses, wide gauge tracks are well represented, particularly in the late Jurassic. Their data do, however support predominance of wide gauge tracks in the Cretaceous, as such tracks consititute atleast 96% of total trackways and 97% of total tracksites. The data of Lockley, Meyer, Hunt and Lucas (1994) suggest a more complex pattern; a mix distribution of Jurassic track types followed by increasing rarity of narrow gauge tracks through the late Jurassic and Early Cretaceous, culminating in the complete absence of narrow gauge trackways by the late Cretaceous.

Yuansheng *et. al*. (2001) mentioned semicircle/ new moon shape of the manus, and ellipse/inverse taper/ taper shape as pes impression of sauropod from the Gansu Province of China. The divarication from midline to 30 degree is also mentioned. High angle divarication shows the forward movement as splayfooted gait. He also mentioned the footprint with three strong digits and large divarication angle representing ornithopod, footprint with three slender digits having sharp claw and little divarication representing theropod, footprint with twidactyl represent also theropod and footprint with quadrupedal, tridactyl with outward rotation probably belongs to Lizard.

6. Footprints of Sauropod Dinosaurs Confronted by a Theropod found from Middle Jurassic Samana Suk Limestone of Pakistan

Remains of a diversified paleobiota are found in the middle Indus basin, which includes plants (gymnosperm), mollusks, reptiles (bone, teeth and ichnofossils). The commonest vertebrate fossils and ichnofossils belong to sauropod (Figure 2,4) and theropod (Figure 3,4) dinosaurian fauna that occurs a wide geographic area. Environmental interpretation of ichnofossil bearing lithofacies/strata allows reconstruction of sea shore marine limestone. Of all ichnofossil localities in Pakistan, one displays the theropod track. In this locality, the sauropod herd is flanked by a theropod on the right. There are four trackways of sauropod and one trackway of theropod, having about 15 footprints in a 1500 square feet area. Further exploration of footprints in the Sammanasuk limestone in the upper Indus Basin, Loralai and Chiltan limestone in the middle and lower Indus basin are encouraging and can reveal the best results. Malkani previously recorded one foot print of juvenile sauropod from the Mula area, Khuzdar district, Balochistan.

The fossil tracks are found on the limestone bed of Middle Jurassic Sammana Suk Formation.The footprint bearing strata are found in the upper successions of Middle Jurassic Sammana Suk Formation **(Figure 2-5).** The upper succession consists of marine limestone, possibly deposited near the sea shore. It is no doubt the footprint bearing limestone is marine and footprints show the slight regression of sea and area was exposed as near sea shore and already deposited lime clay received the dinosaur footprints. The sauropod and theropod ichnofossils of upper Indus Basin are a unique record of a middle Jurassic dinosaurian fauna which inhabited the north western margin of Indo-Pakistan sub continental plate. A gregarious behavior is deduced from the analysis of these ichnocoenoses. At the time of dinosaur extinction, all of the dinosaur and few of others biota becamextinct. The extinction may be due to catastrophic flood, droughts and volcanic eruptions.

Figure 5. Footprints obirds/Avian/theropod dinosaurs, found on the middle Jurassic limestone of Malakhel area, Mianwali District, Balochistan, Pakistan.

Malkani (2005a, fig.69) have reported a foot print of a juvenile primitive Titanosauria found on the fragment of Chiltan Limestone (middle Jurassic) of Jhukkur area, Mardan nala of Mula Zahri Range (lower Indus basin/ Kirthar foldbelt). It is an ellipse of about 15 cm diameter. It has well preserved three small digits. The manus print is partially overlapped by the pes print. Remains of a diversified paleobiota are found in the middle Indus basin, which includes plants (gymnosperm), mollusks, reptiles (cranial and post cranial bones). The commonest vertebrate fossils belong to sauropod and theropod dinosaurs, and mesoeucrocodilian fauna that occur a wide geographic area. Recently the author have found footprints of sauropod confronted with a theropod (Figure 2-4) found from the middle Jurassic Samana Suk Limestone of Surghar Range, Mianwali District, Punjab Province, Pakistan. Footprints of birds/Avian/theropod dinosaurs **(Figure 5),** found on the middle Jurassic limestone, in the vicinity of dinosaurs' footprints locality, Malakhel area, Mianwali District, Balochistan, Pakistan. Many visitors visit Baroch section of Malakhel area every year due to easy accessibility and best stratigraphic exposure. But the recent studies have broadened their distribution to the upper Indus Basin of Punjab Province, Pakistan.

Sauropod dinosaurs were the largest animals to inhabit the land. Sauropoda has a global affinity. Five species of latest Cretaceous sauropod (Malkani, 2004a, Malkani, 2005a) and one species of Late Jurassic sauropod (Malkani, 2003c) from Pakistan have already been established. But one new genus and species ***Malasaurus mianwali*** of middle Jurassic sauropod is hereby tentatively erected. The holotype/ ichnotype belong to three tracks consisting of exposed 10 footprints (Figure 4). Ichnotype/ holotype footprints are found in middle Jurassic Samana Suk Formation of Baroch nala, Mala khel area, Mianwali District, Punjab Province, Pakistan (32^0 55.50" N; 071^0 09.00" E). Age of the ichnotype foot prints is deduced from the host formation which is middle Jurassic after Fatmi (1977). The dip of host limestone strata is 52^0 west and strike is north 5^0 east. The dip of the strata is high and creates problem to take measurement of the footprints and trackways. This limestone is white brown as weathered, and white to light grey as fresh, thin to thick bedded, interbedded with light grey to greenish grey calcarious shale.

The name ***Mala,*** honoring the dinosaurs' host Malakhel area; ***saurus*** means reptile. The species specific epithet ***mianwali*** is deduced from the name of footprint host district. Large pes foot print having length/width about 1 meter are diagnosed only for a large bodied sauropod (Figure 2,4). The manus footprints are totally overlapped by the pes prints. These tracks suggest the narrow gauge trackways. That is the reason these are not referred to previously erected species of titanosaurs from Pakistan, because they may belongs to wide gauge trackways. These footprints are surely assigned to sauropod, but its assignment to lower level is difficult.

Carnosaurian dinosaurs were the largest carnivorous animals to inhabit the land. Theropoda has global occurrences while tyranosaurids have Laurasian affinity and abelisaurids have Gondwanan affinity. The eleven named species from the Lameta formation of India actually represent at least three large bodied theropod (*Rajasaurus, Indosuchas, Indosaurus*) and a fourth, small bodied theropod (*Laevisuchas*) (Wilson, et al. 2003). But from Pakistan, there are some evidences of two large bodied theropod, and one small bodied theropod of Late Cretaceous age. Malkani (2004a) reported one species *Vitakridrinda,* of large bodied theropod and the other large bodied theropod evidences are based on only two types of vertebrae and teeth. One type of vertebrae is tall and other type is cylindrical. One type of teeth is D shape while the other is oval. The small bodied theropod is only based on a hollow surrouded by thin bone found on cross section of bone. One new genus and species ***Samanadrinda surghari*** of large bodied theropod based on only ichnofossils, is hereby tentatively erected. A track consisting of exposed 5 footprints is considered as holotype/ichnotype (Figure 3,4). Ichnotype/ holotype footprints are found in middle Jurassic Samana Suk Formation of Baroch nala, Malakhel area, Mianwali District, Punjab Province, Pakistan. Age of the ichnotype foot prints is deduced from the host formation which is middle Jurassic after Fatmi (1977). The name ***Samana,*** honoring the dinosaurs' host geologic formation; and ***drinda*** is a Seraiki and Urdu word means beast. The species specific epithet ***surghari*** is deduced after the name of Surghar Range which is the host of ichnotype area. Three slender toed foot prints having maximum length about 2 feet and width about 1.5 feet are diagnosed only for a large bodied theropod (Figure 3). The other toed are not marked on footprints. These footprints are surely assigned to Theropod, but its assignment to lower level is difficult. Because until now, no theropod fossils from these strata are collected. Both the sauropod and theropod genera erected are purely tentative and named only to refer for future research work regarding locomotion, behavior, soft and hard tissues. This ichnotype reveal the scenario of confrontation among a carnivorous ***Samanadrinda surghari*** theropo and the groups of herbivorous ***Malasaurus Mianwali*** sauropods.

This ichnocoenosis consists of exposed about 15 footprints, and 4 short trackways. Three trackways are interpreted as mainly produced by sauropods which are obliquely confronted by a track of large Theropod. They are indicative of a sauropod herd, composed of 3 or more individuals and furnish evidence of gargariousness (herd). The ichnofossils are usually deep footprints probably due to good granolometric sorting and the high plasticity of the limy substrate. In the vicinity, some foot prints of possibly birds/ small body theropod/coelorusaurs are also present. The footprint bearing strata are found in the upper successions of Middle Jurassic Sammana Suk Formation. The upper succession consists of marine limestone, possibly deposited near the sea shore. It is no doubt the footprint bearing limestone is marine and footprints show the slight regression of sea and area was exposed as beach and already deposited lime clay received the dinosaur footprints. Further exploration of footprints in the Sammanasuk limestone in the upper Indus Basin, Loralai and Chiltan limestone in the middle and lower Indus basin, and other Mesozoic strata are encouraging and can reveal the best results.

The sauropod and theropod ichnofossils of upper Indus Basin are a unique record of a middle Jurassic dinosaurian fauna which inhabited the north western margin of Indo-Pakistan sub continental plate. A gregarious behavior of herbivorous sauropods defending the attack of predatory theropod is deduced from the analysis of these ichnocoenoses.

7. Conclusions

The sauropod and theropod ichnofossils of upper Indus Basin are a unique record of a middle Jurassic dinosaurian fauna which inhabited the north western margin of Indo-Pakistan sub continental plate. A gregarious behavior of herbivorous sauropods defending the attack of predatory theropod is deduced from the analysis of these ichnocoenoses.

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Analysis of Integration Technology Adoption: a Case for Enterprise Application Integration for Healthcare Organisations

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Abstract

A continuous technological innovation in software has brought development in integration technologies that promise the real time enterprise-wide systems integration. Healthcare organisations continue to struggle with integration challenges. However, much confusion regarding the adoption of integration technologies still remains. To provide a clear perspective about integration technologies, a discussion is presented on these technologies such as Electronic Data Interchange (EDI), Enterprise Application Integration (EAI) and Web Services. EAI has emerged to provide significant benefits to organisations. From a technical perspective, EAI addresses integration problems at all integration levels (e.g. data level and process level) by providing a flexible and manageable IT infrastructure. From a business perspective EAI reduces the overall integration cost due to the reduction in integration time and maintenance cost. This paper attempts to present the advantages and disadvantages of these technologies. Furthermore, a comparative analysis of these technologies is presented. Thus, it can facilitate to healthcare organisations decision-makers during the adoption of integration technologies.

Keywords: Healthcare, Integration Technology, EAI

1. Introduction

The computerisation of healthcare records has been around since the early 1960s, when hospitals first started using computers. Since then, incremental developments have taken place within healthcare industry, with IT playing an increasingly significant role in the delivery of computerised patients records, adoption of Internet along with other networks (e.g. intranets and extranet), integration approaches asynchronous transfer mode (ATM) networks and telemedicine [1]. The extensive use of IT in healthcare organisations has resulted in the development of various information systems (IS). These have been deployed at different levels, ranging from computerised patients' record to department-specific decision support systems [2].

According to Xu *et al.*, [3] information systems that manage the healthcare organisations data and process have been developed with different technologies. This has resulted in healthcare organisations being left with the islands of technologies that are difficult to integrate. As a result, the need for integrating these systems has increased enormously [4]. Thus, several integration standards, systems, projects such as Health Level 7, CEN/TC251, Synergy Extranet (SynEx), and Synapses have been deployed in healthcare organisations to address integration problems. Implementation of these integration approaches has provided significant benefits to healthcare organisations [5] . However, there are still many problems relating to their adoption. Among other problems, the cost of healthcare integration standards is high and the level ofinteroperability remains very low according to Carr and Moore [6]. The integration of the heterogeneous IS in healthcare is needed to support various issues such as:

- ❖ Clinical and administrative tasks
- ❖ Reduced Medical Errors
- ❖ Reduced Cost

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- Patients' data security
- Healthcare process integration and
- Utilisation of valuable legacy systems

Many other organisations have adopted integration technologies such as EDI, EAI and web services. To make the proper decisions towards the adoption of the technology, that can be a well match to their systems. However, the decision is not simple since each of the integration technologies includes different IT strategies and characteristics. Enterprise application integration has emerged to overcome integration problems at all levels in a more flexible and manageable way [7]. It provides the infrastructure to rapidly connect and interface information between intra-organisational and inter-organisational applications [8]. EAI can support healthcare organisations to improve clinical and businesses processes. In this paper, the authors, have attempted to present description of integration technologies along with their advantages and disadvantages. After that a comparative analysis for the integration requirements is presented. The factors for the adoption of EAI in healthcare organisations are then discussed. Thereafter the integration of healthcare information systems with EAI is described with respect to the way they can be integrated at both an internal hospital level and externally with other hospitals, primary health care providers and with other stakeholders.

2. Description of Integration Technologies

In an attempt to provide a clear perspective about integration technologies, this section discusses integration technologies such as EDI, EAI and web services with their advantages and disadvantages presented in

Technology	Advantages	Disadvantages
Electronic Data Interchange	Increase closeness in supplier customer relationships [17] Quick response to trading partners [18] Reduced clerical error [19] Allows improvement in business performance and efficiency [20] Elimination of labor-intensive tasks [21]	Requires high initial capital investments [17] Requires compatible hardware at both ends [17] Increases the risk in the process of conducting commercial transactions [20]. Implementation is not simple [20] Difficulty of quantifying the return on Investment [22]
Enterprise Application Integration	Improve customer relationships [11] Achieve better return on investment [11] Increases the overall performance of the supply chain [23] Achieves businesses process integration [24] Reduced integration cost [24]	High level of investment [12] No single EAI product solve all integration problems [25] Complexity concerns [12] Requires EAI skill [25] Integration technologies are confusing [26]
Web Services	Reduce development and deployment time [27] Low implementation cost [28] Reduce the maintenance complexity [28] Require less programming skills [28] Less risk of project failure [29]	Requires high customisation [30] Lack of transaction support [28] Performance is not mature [30] Lack of user interface [15] Security is a problems [12]

Table 1.

2.1 Electronic Data Interchange

In the past many organisations have used EDI approach to exchange their business documents in an integrated way [9]. This refers to the computer-to-computer exchange of business documents electronically, between or within firms in a structured machine-retrievable data format that permits data to be transferred without re-keying from a business application in one location to an application in another location. Although, EDI achieves data integration but it is a complex and invasive technology that does not achieve process integration and does not provide the required flexibility and maintainability [10].

2.2 Enterprise Application Integration

EAI systems have emerged to overcome the limitation of enterprise resource planning (ERP) systems through providing an integrated organisational infrastructure. It has been introduced as a solution to intra and inter-organisational systems and process integration. For various reasons it results in more organised business process, achieves return on investment, increases collaboration among partners, achieves data, object and process integration and reduces the cost [11]. EAI aims at integrating individual applications into a seamless whole, enabling business process, and data to speak to one another across applications [12]. EAI can efficiently incorporate custom applications, packaged systems and e-business solutions into a flexible and manageable infrastructure[13].

2.3 Web Services

Web services approach is relatively new integration technology. It is a distributed computing paradigm and allows applications written in diverse languages, and running on multiple platforms to interoperate and integrate more easily and less expensively than other traditional methods [14]. The Web service protocols are built on top of application-level network protocols like hypertext transfer protocol, simple mail transfer protocol, and file transfer protocol. There are various problems that have been reported regarding web services adoption such as: Inexperience in architecting web services, changing internal organizational culture to embrace web services, multiple standards for implementation, immature technology and security concerns [15].

3. Comparison of the Integration Technologies

Given the focus of this paper i.e. the adoption of EAI technology, it is imperative to compare EAI with other integration technologies such as, EDI and web services. Themistocleous [16] presented several integration requirement factors, such as maturity, flexibility, scalability, portability, reusability, maturity, complicity, non-invasive, performance and real time. Theses factors are based on the characteristics of EAI technology, and provide the support to the organisation, when organisations are deciding to adopt the integration technologies. Description of these characteristics is illustrated in Table 2. In addition to these, from the literature in the area of integration technologies the authors have identified several other characteristics that can also provide support to draw the comparison between integration technologies, such as transaction, security and levels of integration. Description of these characteristics is illustrated in Table 2 as well. In addition to that, international standards organisations ISO-9126 standard, documents highlights software qualities including functionality, reliability, usability, efficiency, maintainability and portability. These qualities are proposed to measure the high-level software qualities. Thus, this applies to integration technologies software solutions as well. Thus, the authors have illustrated the comparative analysis of these technologies in **Table 2.**

		Technologies		
Characteristics	**Description**	**EAI**	**EDI**	**WS**
Maintainability	Britton and Doake [31] suggest that maintainability is an important characteristic of software technologies. It refers to the capability of software applications to allow changes without causing problems to other components or systems. In integration area, technologies should lead to the development of solutions that could be easily maintained.	✓		✓
Flexibility	There are three types of flexibility: flexibility in functionality, flexibility in modification, and flexibility in use [32]. The first two types of flexibility describe the capability of rapid adjustments with minimal effort and the capability to operate well in many different environments. In the context of integration technologies, flexibility supports both flexibility in functionality and modification.	✓		
Scalability	Scalability describes the ability of an information system to provide high performance as greater demands are placed upon it, through the addition of extra computing power [24].	✓	✓	✓
Portability	Portability allows a software solution developed for one platform to run on an entirely different platform. Portability is closely related to the concept standards and plays a significant role in the cost effectiveness of information systems	✓		✓
Reusability	Reusability refers to the capability of using existing components or software solutions to build new applications. Reusability, has an important role in application integration as it reduces the implementation time and cost. It results in more flexible, manageable and maintainable systems [33].	✓	✓	✓
Maturity	Maturity shows whether an integration technology is mature or not. The more mature an integration technology, the better it is. The reason for this is that analysts and developers trust more mature technologies than immature one.	✓	✓	
Complexity	Complexity describes whether an integration technology leads to complex or simple solutions. Often, complex integration solutions are not preferred as they increase development and maintenance costs.	✓		✓
Non-Invasive	Many organizations seek for non-invasive integration technologies and solutions. The reason for this is that invasive technologies (like RPC) extend the code of interconnected applications by adding new modules that support integration efforts. As a result, the less changes required the better value achieved for integration as cost, effort and complexities are eliminated and flexibility and maintainability are increased [34].	✓		✓
Performance	In some cases integration technologies achieve integration but the performance of the overall solution could be low. As a result, this requirement seeks to describe whether the performance of an integration solution is low or not.	✓		
Real Time	Real time requirement refers to the capability of integration technologies to support transactions that require up to the second data latency [24]. Data latency defines how current the information needs to be. As mentioned in previous paragraphs real time integration is important for e-business applications.	✓		✓
Security	Adoption of integration technologies have provided tremendous benefits to the organizations, and have also created significant and unprecedented risks to the organizations, such as security. Organizations heavily depend on IT security measures to avoid data tampering, fraud, inappropriate access, disclosure of sensitive information, and disruptions in critical operations.	✓	✓	
Transaction	Transaction refers to concurrent access of data shared amongst multiple components, to perform operations on that data. Such distributed access of a single resource of data, and access to distributed resources from a single application component be treated as one unit of work. Further more it implies to commercial activates e.g. ordering, invoicing, etc. in contract to pure information and knowledge sharing [35].	✓	✓	
Levels of integration	Integration refers to the sharing of information between dissimilar computing systems and applications. Linthicum [24] suggest that integration can be achieved at different levels	✓		

	(e.g. data level, object level, and process level).			

Table 2: Comparison of Integration Technologies

4. Motivations for the Adoption of Enterprise Application Integration

The advantages and disadvantages presented in Table 1 and the comparison of the integration technologies analyzed in Table 2 provides the support and clear concept regarding the adoption of EAI in healthcare organisation. Thus, to better understand the factors that motivate the healthcare organisations to adopt EAI, this section summarises these factors, which are influencing the adoption of EAI in healthcare organisations, like technical, cost, medical errors, decision support system, and security and confidentiality of patients' data. A description of these factors is presented below:

Technical: The various integration approaches adopted in healthcare organisations mainly focused on the technological aspects, solving the connection problems between applications and devices to exchange information. ERP systems have been used to solve integration problem but have many drawbacks. In addition, the integration approaches are based on massage-based technologies such as Message-Oriented Middleware (MOM) and XML. Since massages can only solve the basic communication problem between the systems. Thus, communication mechanism can not achieve integration of the systems and can not provide interoperability, without meeting the requirements of healthcare organization as a whole

Cost: To introduce new technology, one of the major concerns of senior management is the cost associated with the change. In this context, healthcare organisation have a lack of money for IT infrastructure. According to Anonymous [36] most hospitals have budgets between £3 to £15 millions for IT implementation. Therefore, the healthcare organisations are looking for cheap integration solutions, so that they can provide better healthcare services to the citizens. The integration efforts made so far, are based on customised interfaces [37]. Development and maintenance of customised interfaces to integrate diverse systems is very costly and time consuming. Each interface requires more time and high cost for the development and maintenance [38]. Therefore, there is a need for technology that reduces integration costs. However, Puschmann and Alt [38] states that a significant benefit of application integration is the reduction of overall integration cost.

Medical Errors: Patients' safety and medical errors are becoming one of the highest priorities in healthcare systems across the world. According to the Institute of Medicine (IOM) US report that, as many as 98,000 people die every year in US as a result of medical errors, which is more than the combined number of deaths from breast cancer, AIDS and motor vehicles [39], whereas in the UK according to a report by National Patients' Safety Agency (NPSA) it is estimated that 850,000 incidents and medical errors occurring every year. Likewise 64 persons die every day in UK hospitals due to medical errors. Most of the errors occur due to the limitations of information systems in healthcare organisations [40]. For instance, patients' are given inappropriate medications or doctors can not make accurate diagnosis, as important information can not be received, due to the non-integrated IT infrastructure.

Clinical Decision Support: In most of the organisations, decision support systems are used at the management level. In healthcare organisations decisions support systems are referred to as clinical decision support systems. Healthcare organisation needs to improve decision-making process for the patients' treatment in real time. This can be achieved through an integrated IT infrastructure. However, a number of clinical applications such as artificial intelligence, neural networks, and fuzzy logic techniques are being developed to provide support to physicians for clinical decision making [41]. As a result, hospitals must build hospital-wide infrastructure to obtain data from different sources and then convert into useful information and apply them for the decision making process [42]. In addition, decision support requires higher levels of integration for the exchange and sharing of patients' data between various decision support applications, to generate warnings, provide diagnostics suggestions and offer treatment advice [43].

Security and Confidentiality of Patients' Data: Huston [44] states that security and confidentiality of patients' data has always been important. In an open and distributed processing environment, accesses control and authentication mechanism have very important role in healthcare organisations [45]. As patients' data may contain some of the most sensitive information such as the emotional problems, psychiatric care, sexual behaviours, sexually transmitted diseases, HIV status, physical abuses and so on. Access to such information must be controlled because disclosure to irrelevant users can harm the patients'. Patients and citizens must be assured that their information is held securely and shared based on appropriate legal, ethical and technical processes. There is therefore a need for a technology that provides security approaches to the healthcare organisation.

5. EAI based Integration Approach for Healthcare Organisations

Enterprise application integration aims at integrating individual applications into a seamless whole, enabling business process, and data to speak to one another across applications [46]. EAI specifically addresses integration problems from a technical perspective, and provides a more flexible and maintainable IS infrastructure [47] . In addition to that Stal [12] states that EAI provides a flexible infrastructure to integrate heterogeneous platforms. All these literature evidences support that EAI can be used to create an integrated infrastructure in healthcare organisations. Raghupathi and Josph [41] report two key dimensions of systems integration in healthcare organisations (a) internal integration of the systems and (b) external integration of the systems. Irani *et al.*, [13] suggest that EAI provides solutions to intra and inter-organisational systems integration.

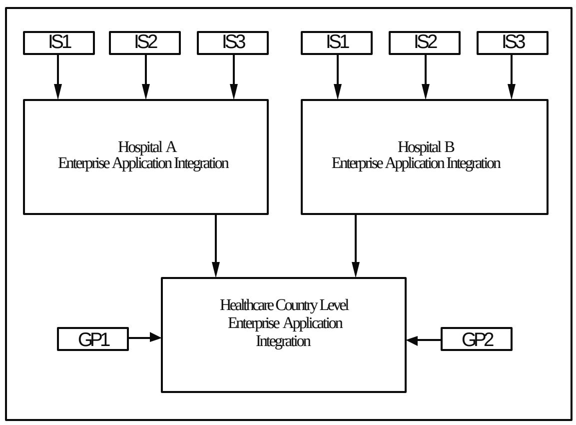

Figure1: Integrating Healthcare Information Systems through EAI Technology

Thus, in Figure 1 the authors have illustrate the integration of disparate and autonomous information systems that exist in healthcare organisations at (a) internal (hospital) level (b) at external country level with other hospitals, GPs and other stakeholders using EAI technology.

Internal systems integration represents the integration of internal systems of the hospitals by using EAI to improve clinical and businesses process that cross multiple departments and organisational boundaries and involve multiple healthcare professionals. Let us consider the complex network of tasks and applications involved in the inpatient medication management. The internal closed loop medication management process flow depicted in Figure 2 involves a triangle of professionals, physicians entering the medication order, pharmacists reviewing and verifying the order and nurses administrating the medications. All of them use different clinical applications that display the information in a format that is relevant to their specific purposes. In most of the cases the supporting applications are not integrated. The end result is a complex process that causes medical errors and results in the deaths of patients. Clearly an EAI that supports businesses process management can provide process and information integration [13].

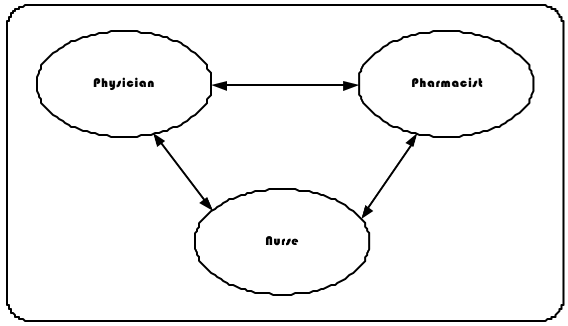

Figure: 2 Internal Medication Management Process

In addition to that internal hospitals integrated infrastructure provides the facility to share data among different applications connected with each other. Functioning of these applications eliminate the duplication of data entry at different department levels. Additionally, other complicated and data intensive healthcare process that can also benefit from the internal integration of healthcare information systems with EAI. Furthermore, physicians will be able to focus on healthcare delivery. By having the most relevant information including up-to-date medical evidence at the point of care, that will enrich care delivery. Physicians and patients will have more time together free of distractions such as searching for traditional paper records. The reporting that every physician has to do will be accurate and timely, but also simple and automated. Eexternal systems integration represents countrywide integration with other hospitals systems, GPs, government's bodies and other stakeholders. This type of integration can provide significant benefits to hospitals and the patients'.

External integration infrastructure can save the patients life, If hospitals are interconnected with each other and the record of all the patients' can be viewed form anywhere in real time, in such situations or the life of the patients' can be saved by appropriate and timely treatment. Additionally, healthcare processes that can benefit from EAI integration include claims clearinghouses, revenue cycle and other areas such as Supply Chain Management (SCM), Customer Relationship Management (CRM) and real time monitoring of clinical and businesses process.

6. Conclusions

The adoption of healthcare information systems at various levels in healthcare organisations are developed in different computer languages, compiled on different platforms, executed on different hardware, and have different data structures, types and formats. These information systems were not developed in a cordinated way but evolved as autonomus and hetrogenous systems. Thus, in most of the cases these information systems function independently and do not share their data and process. As a result, this rasises the need for integration. Therefore, several integration approches are adopted in healthcare organisations to overcome the integration problem. Integration of existing systems represents one of the most urgent priorities of health care information systems that allow the whole organisation to meet the increasing clinical, organisational and managerial needs.

In the description of integration technologies the authors have provided the detailed discussion on these technologies. In doing so, the advantages and disadvantages of the integration technologies have been presented. After that the comparative analysis of these technologies is presented. This analysis has been based on various integration factors such as maturity, flexibility, scalability, portability, reusability, maturity, complicity, non-invasive, performance security, integration level, transaction and real time. This analysis provides a clear vision that EAI is the technology, which can provide the support for all these factors. As a result, the authors have identified the factors such as technical, cost, medical errors, decision support system, and security and confidentiality of patients' data that motivate the adoption of EAI in healthcare organisations. EAI can support to integrate different information systems at the internal hospital level and at external country level with other hospital and GPs. The internal hospitals integrated infrastructure provides the facility to share data among different applications connected with each other. Functioning of these applications will help in reducing the medical errors and save the human lives. Further, healthcare organisations can benefit from using EAI to improve processes that cross multiple departments and organisations boundaries and involve multiple healthcare stakeholders

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Optimization of the stocking density of mud crab, *Scylla serrata* culture in Brackishwater earthen ponds in Bangladesh

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Abstract

A study on the optimization of stocking density of mud crab, *Scylla serrata* in the grow out system in brackishwater earthen ponds (400m^2 each) was carried out for a periods of five months. Crabs (40-50g) were stocked @ 2,500, 5,000, 7,500 and 10,000 /ha under four treatments T_1, T_2, T_3 of T_4, respectively, with three replications of each. The crabs were fed with slaughtered house waste at the rate of 5.10% of the biomass. Significantly (< 0.05) higher specific growth rate (SGR) of 0.09 % day, survival rate of 66.25% were observed in T_I followed by T_2, T_3 and T_4, but the total production of mud crab of 610 kg/ha was significantly (p< 0.05) higher in (7.500 nos/ha) followed by 569.64 kg/ha in T_4 (10,000 nos/has), 481.66 kg/ha in T_2 (5,000 nos/ha) and 328.48 kg/ha in T_1 (2,500 nos/ha). respectively. Considering the final weight, SGR and survival rate of mud crab, better performance of producing internationally accepted marketable size crabs (>180g) were achieved with the lower stocking density of 2,500 nos/ha though the total production was lower than the other socking densities.

Keywords: Stocking density, mud crab, Bangladesh.

1. Introduction

Among the cultivable shellfishes, mud crab *(Scylla serrata)*, a decapod crustacean, is considered as one on the important seafood items for aquaculture in Southeast Asian countries due to its larger size, delicacy and grater demand (Dorairaj and Roy 1996). In Bangladesh, the mud crab, *S. serrata* occurs throughout the costal districts of Cox's Bazar. Chittagong. Noakhali, Bhola, Barisal, Patuakhali, Bagerhat, Khulna and Satkhira (Ahmed 1992). Bangladesh has been earning a significant amount of foreign exchange every year by exporting crabs to the international market

The mud crab fishery in Bangladesh still depends on wild caught from mangrove area. Generally, female crabs of 180g with mature gonad (fattening) and male crabs of 400g with hard body (full of flesh/muscle; hardening) demand for high price and export to the foreign country. Female crabs below 180g have no international market value but large numbers are caught in our country which has a very narrow local market. Female crabs are cultured for fattening and male for hardening by the coastal people.

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The mud crab is yet not scientifically cultured in Bangladesh but extensively grown in ponds/ghers together with shrimps (Giasuddin and Alam 1992). The culture techniques have not been popularized among the peoples engaged in from Bangladesh is increasing rapidly and the interest in culture of mud crab is also increasing so, effort should be made to give maximum profit from this species. Success of culture of mud crab depends on a number of factors mainly on stocking density food and feeding resume etc. It is important to maintain a suitable stocking density to support mud crab aquaculture development in view of this present research was undertaken to optimize the stocking density of juvenile mud crab, *S. serrata* in the grow out system in brackishwater earthen pounds.

2. Materials and Methods

An experiment on the optimization of stocking density of mud crab, *Scylla serrata* in the grow out system (earthen ponds) of Brackishwater Station, Bangladesh Fisheries Research Institute (BFRI), was carried out for a period of five months from May to September. 2005.

3. Experimental design

A stocking density of 2,500, 5,000, 7,500 and 10,000 crabs/ha was maintained as Tretment-1 Treatment-2 Treatment-3 and Tretment-4, respectively. Each treatment had three replic ations.

4. Pond preparation

Twelve brackishwater ponds (400m^2 each) were used for this experiment. The ponds were sun dried for one week. Lime @ 125 kg/ha was applied in the ponds after drying, when the soil pH was 7.0-7.5 Immediately after the lining, the ponds were filled up with tidal water of Kapotaksha river and organic manure (cowdung) was applied @ 750 kg/ha after seven days, After four days, inorganic fertilizers @ 25kg/ha urea and 15 kg/ha TSP were applied. Depth of water of the pond was maintained at a level of about one meter. The inside of pond embankment was encircled with bamboo splits made fence covered with nylon net, one meter apart from the edge of water. The splits were pushed into the soil up to 50cm depth to prevent escape burrowing of crabs.

5. Stocking of crabs

Twelve Crabs (40-50g) were collected from the Sundarbans mangrove area through fishermen. These crabs were then acclimatized for about 30 minutes in plastic bucket containing
ponds water because abrupt change in physico-chemical factors may cause high mortality. After acclimatization. Crabs were stocked in the ponds with the ration of Male: Female: 1:1 following the experimental design of the experiment. Crabs were stocked after three days of applying the inorganic fertilizers.

5. Feeding and management

The crabs were fed daily with slalughtered house sate @5-10% of the biomass. About 50% of water was exchanged with tidal water at every new and full moon throughout the experimental period. The depth of the water was maintained between 1 and 1.5 meter.

7. Sampling

Growth performance in respect of carapace width (CW), bodyweight (BW) of crabs and physico-chemical parameters such as water temperature, salinity. pH. Dissolved oxygen and water transparency of the water were recorded fortnightly. Water temperature was measured with a mercury thermometer, salinity with a refractometer, the value of pH with a battery operated digital pH meter and water transparency with a secchi disk.

8. Harvesting

At the end of experiment, crabs were harvested by dewatering the pond. After harvesting, final body weight, final carapace width, specific growth rate, survival rate and total production of the crab were calculated.

9. Data analysis

The experimental data was analyzed by one way ANOVA and F Value were computed. Duncan's New Multiple Range Test (DNMRT) at 5% level was also employed for further analysis of the results.

10. Results and discussion:

Water quality analysis

Mean water quality parameters in all culture ponds throughout the experimental period are shown in **Table-1.**

Table 1. Mean (SD) water parameters in different treatments during experimental period.

parameters	Treatment-1 (T1)	Treatment-2 (T2)	Treatment-3 (T3)	Treatment-4 (T4)	F-value	Level of significance
Temperature (^{0}C)	29.34 ?0.27	29.56 ±0.47	29.21± 0.39	29.76 ±0.37	0.14	ns
Salinity(ppt)	9.24 ±5.83	9.42 ±5.01	9.0 ± 65.11	9.0 ±5.21	0.067	ns
pH	8. 1 ±1.37	8.0 ±0.97	8.2 ± 0.88	8.4 ±1.12	0.056	ns
DO (mg/1)	5.53 ± 0.13	5.76 ± 0.10	5.9 ±0.11	5.31± 0.09	0.812	ns
Transparency(cm)	29.12 ±1.16	9.69 ±1.17	8.76 ±1.07	30 ±2.30	1.023	ns

'ns' represents non-significance ($p > 0.05$)

The range of water temperature was from 28-33.5^0 Cwhich is conducive to the growth of crabs. Temperature difference among the treatments was not significant ($P>0.05$). Cholik and Hanafi (1992) suggested that the suitable water temperature for culture of the *Scylla serrata* ranges between 5 and 30^{o}C. Wide range of salinity (3-16ppt) was observed with its highest in late May and lowest in mid September and difference among the treatments were not significant ($p>0.05$). The range pf salinity 2-18ppt, was recorded by Saha *et al*. (1997). Cholik and Hanafi (1992) reported that 10-25ppt salinity is optimal for the growth of mud crab whereas Bhuiyan and Islam (1981) reported that the lower and upper lethal salinities were 10ppt and 50ppt, respectively, pH of water **Table .1** were within the suitable range (8.0-8.4) and values were not significantly different when compared using ANOVA. pH value of 8.4-8.6 was recorded by Saha *et al,*. (1997). Dissolved oxygen (DO) and water transparency (Table -1) were recorded within a range 5.31 -5.92 mg/1 and 28.76 – 35 cm. respectively. Dissolved oxygen (DO) and water transparency also did not vary significantly among the treatments. Dissolve oxygen 5.6-6.5 mg/l and transparency

3-40cm recorded by Saha *et al.* (1997) were more or less similar to the present study.

11. Growth and Production

September) is shown in **Fig.1.** Growth increment in T_2 T_3, and T_4 were more or less similar but in T_1, it was always higher than the other treatments. The higher body weight increment in T_1 might be due to the lower stocking density than other treatments. Body weight increment in all the treatments was higher during June and July. Significantly ($p<0.05$) highest carapace width (9.89 ± 0.57 cm) was found in T_1 followed by T_3 (8.96 ± 0.96 cm), T_2 (8.65 0.61cm) and T_4 (8.61± 0.61 cm), respectively Table 2. A growth of 0.04, 0.016. 0,108 and 0.017 cm per day was in T_1, T_2, T_3, and T_4, respectively. Difference in final body weight was significant ($p<0.05$) among the treatments but the difference was not significant ($P>0.05$) between T_2 and T_3. After five months of rearing, an average weight gain of 148.83, 199, 105.94 and 102.01g were recorded, at T_1, T_2, T_4 respectively **Table 2.**

Fig. 2. Increase in carapace width of juvenile mud crabs under different stocking density over the culture period

The Specific Growth Rate (SGR) of mud crab was 0.9, 0.80 0.77 and 0.69 (%/day) in T_1, T_2 and T_3. respectively. There was significant ($p<0.05$) difference among the treatments. The men survival of mud crab varied significantly ($p<0.05$) with higher men value of 66.5% in T_1 followed by 58.50 % in T, 52 .65% in T_3 and 41.8% in T_4. Chaiyakama and Parnchsuka (1977) studied the relation among the stocking, survival rate and production of mud crab and found survival rate of 57% and 36% incase of stocking density of 10,000 nos/ha and 20,000 nos/ha respectively. Raphel (1972) worked on the pond culture of mud crab in brackish water in Sri Lank and found 36% survival rate during eight months of culture period. He reported that cannibalism was the main cause for less survival Gunarto and Cholik (1990) observed increased mortality with increasing stocking density and found survival rate of 77.05%, 70% and 3.06% at stocking density of 10,000, 20,000, 30,000 and 50,000 crab/ha, respectively. Agbayani, *et al.* (1990) studied on monoculture of mud crab at different stocking densities 5000, 10000, 15,000 and 20,000/ha for 90 days. The highest mean weight, survival and relative growth

increment was obtained from a stocking density of 5000/ha. Trino *et al.* (1999) reported that

The loss of young crabs grown in ponds for a period of 3 to 8 months can be relatively high, from 40% to 60%, if the stocking rates are high. Trino *et a*l. (1999) made experiment on the effects of 3 levels of stocking density (5,000, 15,000 and 30,000 nos/ha) on the growth, survival and production of mixed species of mud crabs. They obtained the highest survival at a stocking density of 5,000 nos/ha In Indonesia, Juvenile crabs (15g) were stocked in ponds at 10,000 ,20,000 and 50,000 nos/ha and fed trash, fish, snails and clams @ 3% body weight/day. After 3 months, survival was 80%, 45% and 3.9% and average weights were 146. 159 and 158g. respectively (Allan and Fielder, 2004), Mud crabs with mean body weight ranging from 5-30g, are cultured in ponds and pens in mangroves at 5,000 – 15,000 ind./ha for over 4-6 months (Quinitio 2004) Samarasinghe *et al.* (1992) made experimental culture of mud crab (*S.serrata*) with 6000 crabs/ha, at Andriesz Mariculture Ltd, from Sri Lanka. After a grow out perio15days, 44.27 % marketable crabs were recovered. Low survival was observed in this study with consequent increase in stocking density. So the same effect of stocking density on survival rate of crab was confirmed by the present study. The lower survival rate in T_3 and T_4 could be due to the cannibalistic nature of crab. Mortality of crab due to cannibalism has been widely documented (Iversen 1986). Cannibalism is common in mud crab culture when high stocking densities (Baliao *et al.* 1981) and mixed sex culture (Cholik and Hanafi 1992) are used. Srinivasagam *et al.* (1984) observed the cannibalistic nature of crab over even the same species during and after moulting. Escritor (1972) concluded that cannibalism and the burrowing habitat of *S.serrata* should be controlled to minimize losses and to make the crab culture profitable. Survival in pond culture is generally lower as a result of cannibalism and escape (Liong 1992). The low survival is due to low salinity in the last two months of the experimental period.

The total production of mud crab of 610 Kg/ha was significantly ($p<0.05$) higher in T_3 followed by 569.64 kg/ha in T_4, 481.66 kg/ha in T_2 and 328.48 kg/ha in T_1, respectively (Table-2). Though the production was lowest in T_1 among the treatments but body weight of all the crabs gained internationally accepted which could be used further for fattening and hardening purpose. Samonte and Agbayani (1992) compared monoculture of mud crab, *S.serrata* at stocking density of 5,000, 10,000, 15,000 and 20,000 nos/ha worked out to 675kg/ha after 8 months (Dorairaj and Roy 1996). In Philippines, average survival rate of 67% and 1450 kg/h production of mud crab (average final wt. 15g) were recorded at a stocking density of 10.000 nos/ha within 130 days culture period (Allan and Fielder, 2004), Stocking density adopted varies widely and ranges from 5000 to 10000/ha in Taiwan to less than 10000/ha in the Philippenes (Chong, 1993).

12. Conclusion

The present study revealed that the higher final weight gain, specific growth rate and survival of mud crab could be obtained by culturing them with lower stocking density of 2,500 nos/ha. Considering the above view, it may be concluded that the optimum stocking density of 2,500 nos/ha might be practiced for culturing juvenile mud crab to produce internationally accepted size (>180g) crabs which can be further used for fattening and hardening purpose.

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Endosulfan exposure effects on health of farmers in Sindh Province of Pakistan

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Abstract

Endosulfan usage in agriculture sector may be related to the increasing rate of morbidity in exposed population. Many studies earlier reported its toxicity symptoms in the spray workers but the lack of national research and hard data on farmers has hindered efforts to improve their health. Therefore it was aimed to investigate this problem through some epidemiological and biochemical parameters. Farmers (n=158) exclusively working with endosulfan sprays in agriculture sector and volunteer controls (n=150) unexposed to any pesticides were selected and surveyed for protective measures and symptoms after exposure. Blood and urine samples of both groups were investigated and data obtained were statistically analyzed for t-test.

Present study revealed that 48.24% farmers adapted "respirator" and "sunglasses" for their protection during spray, while symptoms reported by them were remarkable. Findings of the biochemical analysis were highly significant. Total protein, urea, creatinine and calcium levels in the farmers' serum were different as compared to controls. Whereas in urine; protein, creatinine and sodium were also highly significant while calcium values in urine found different at significant level. That indicates the effects of endosulfan on health of the farmers. This work concludes the farmers at greater risk of health hazards in case of endosulfan exposures. Therefore, further use of this pesticide product may be avoided in either condition very intensive care is suggested.

Keywords: Endosulfan, Exposed farmers, Sindh Pakistan

1. Introduction

The massive use of pesticides like endosulfan in farming system in Sindh province, has produced higher yields and greater wealth but on the other hand created many health problems in farmers. Chabra *et al.*, 1970., Proctor and Hughes, 1978., Watterson, 1988., Malik ,1990., Osorio *et al.*, 1991., Pengali *et al.*, 1994., Nicolson 1995., SHEC, 1999, have reported toxicity symptoms often severe and/or lethal, induced by exposure of the pesticide products exclusively and in classified groups. Organochlorine pesticides including endosulfan were being used globally due to its efficacy against a variety of insects. However, due to its toxicity to humans it has been either restricted for use or banned in many countries. Despite this it is reported as the most used pesticide product in Sindh province of Pakistan (Soomro *et al.*, 2003a).

As observed the farmers being sprayworkers mostly avoid the protective equipments, therefore, are more prone to pesticide intoxication. Kidd and James, 1991. Smith, 1991, report highly toxic effects of endosulfan necessitating the solid protective measures. Insufficient data are available for sub-acute or chronic exposure to endosulfan in human subjects; however, such toxicity studies of endosulfan in animals suggest that the liver, kidneys, immune system, and testes are the main target organs (ATSDR, 2000). It also causes growth reduction and changes in blood chemistry (Stephen, 2001). Such risks produce the hazards to health, hence the introduction of endosulfan is found responsible for significant

number of death among the farmers (Ton, *et al.* 2000 and Tovignan, 2001).

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The lack of national research and data on farmers has hindered efforts to improve their health (NAC1993). This study was aimed at exploring the reasons of declining health status of the farmers. In this connection different approaches exist which detect the effects by epidemiological surveys and testing blood and urine of exposed and unexposed population. Hence the objective of this work was to find out the effects of endosulfan on the health of the farmers by conducting survey for protective measures, toxicity symptoms in the exposed farmers and biochemical investigation of blood and urine samples as ascertain the degree of toxicity (Bertell 1999).

2. Methodology

Farmers (n=158) those who were exclusively the spray workers for 'endosulfan' and the age matched normal volunteer controls (n=150) unexposed to any sort of pesticides were selected from various areas of Sindh province of Pakistan. Both groups were studied during cropping seasons in the year 2004-2005. Initially exposed farmers were interviewed with the help of a questionnaire; asked about the type and tools of protective measures taken by them. While keeping in view the common epidemic symptomatology, all the farmers were questioned about developing symptoms concurrently. Both the groups were mentally prepared and 5 ml of blood was collected by vein-puncture method, transferred to sterilized screw caped glass tubes. It was allowed to clot, and then centrifuged at 3000 G for serum biochemical tests. The farmers and controls were further advised to wash their groin properly and void mid stream urine. After voiding urine in sterilized 50 ml screw caped glass bottles, the samples were analyzed for the proposed tests.

Serum was analyzed for total protein, urea, creatinine and sugar levels while urine samples were analyzed for protein, urea, creatinine and sugar. Both serum and urine specimen were also investigated for the electrolytes which include the calcium, potassium and sodium concentrations.

All the chemical reagents and kits used for biochemical analysis were purchased from Merck Company Germany. Spectronic 20 (Bouch and Lumb) was used for manual determination of each parameters and company suggested protocols were followed accordingly. The electrolytes were determined by flame analyzer (Perkin-Elmer). The experimental data was processed on SPSS version 8.0

3. Results

Epidemiological data show that 48.24% of the exposed farmers adapted only two types of self protection tools during sprays; towel-mask as 'respirator' and 'sunglasses'. Distribution of the farmers for these protective measures is given in Figure 1. Health status of both groups of the farmers recorded in terms of specified symptomatology simultaneously, in existing similar environmental conditions. Table 1 shows number and percentage of farmers with and without symptoms which were observed by author and as stated by study groups. According to present data 94.93% exposed and 18% unexposed controls reported different symptoms during study.

Serum and urine samples of the farmers and controls were examined with help of some biochemical parameters and data obtained were analyzed statistically by t-test. Mean, standard deviation and probability for each test are summarized in Table 2 and 3.

Figure 1. Percentage of farmers for adapting the protective measures

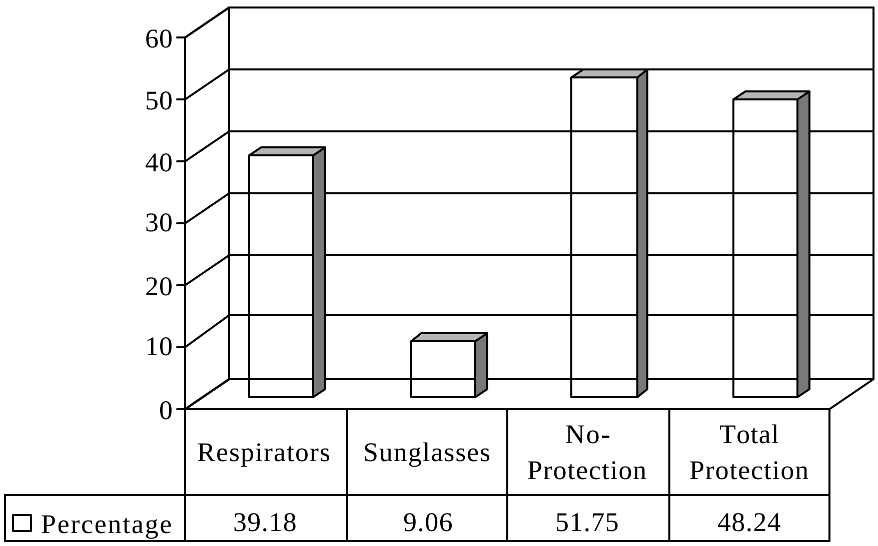

Table 1. Number and Percentage of farmers and Controls with and without Symptoms

Symptoms	Farmers (n=158)	Controls (n=150)
Body itching	13 (8.23)	00
Difficulty in breathing	14 (8.86)	04 (2.67)
Face burning	08 (5.06)	00
Fits	01 (0.63)	00
Flu	06 (3.80)	05 (3.34)
General weakness	15 (9.50)	08 (5.33)
Headache	20 (12.66)	07 (4.66)
Heavy head	20 (12.65)	01 (0.67)
Nausea	05 (3.16)	00
Sinking of heart	14 (8.86)	00
Unconsciousness	02 (1.27)	00
Vertigo	30 (18.98)	02 (1.34)
Vomiting	02 (1.27)	00
No symptoms	8 (5.06)	123 (82)

Table 2. Effect of endosulfan on Serum Biochemical Parameters

S. No.		Farmers Mean ± S.D	Controls Mean ± S.D	p – value
1	Total protein m/dl	2.88 ± 0.52	7.44 ± 1.33	0.001
2	Urea mg/dl	61.13 ± 11.54	29.70 ± 5.46	0.001
3	Creatinine mg/dl	3.32 ± 0.53	0.87 ± 0.21	0.001
4	Sugar mg/dl	95.91 ± 10.90	99.71 ± 16.10	N.S
5	Calcium mmol/l	1.40 ± 0.30	2.27 ± 0.25	0.001
6	Sodium mmol/l	146 ± 7.91	140 ± 4.17	N.S
7	Potassium mmol/l	4.95 ± 0.59	4.15 ± 0.88	N.S

N.S = Non-significant

Table 3. Effect of endosulfan on Urine Biochemical Parameters

S. No.		Farmers Mean ± S.D	Controls Mean ± S.D	p – value
1	Protein mg/24 hr	74.88 ± 5.75	38.53 ± 10.81	0.001
2	Urea g/24hr	37 ± 2.48	28 ± 6.25	N.S
3	Creatinine g/24hr	12.22 ± 2.34	1.67 ± 0.30	0.001
4	Sugar mg/dl	17.40 ± 1.73	9.98 ± 3.30	N.S
5	Calcium mmol/l	8.13 ± 1.88	9.78 ± 3.18	0.01
6	Sodium mmol/l	120.77 ± 21.09	142.4 ± 31.68	0.001
7	Potassium mmol/l	34.18 ± 3.81	58.70 ± 15.92	N.S

N.S = Non-significant

4. Discussion

Findings of this work show that the self protective measures were ignored by farmers. Figure 1 indicates that 48.24% of farmers protected themselves by cloth mask (respirator) and/or sunglasses only which indeed were insufficient, whereas rest of them did not apply any sort of protection during complete process of pesticide sprays. Hence, it was not possible to wear 'protective kit' that is commonly recommended and adapted in advanced countries. Therefore the poor protecting behavior shown by the local farmers was their compulsion that is commonly reported in third world countries (Kishi, *et al.*, 1995), though not encouraging.

Endosulfan dermal absorption is rapid and its bioaccumulation increases due to its lipophilic property. This could be one reason for change in biochemistry and development of symptoms in the exposed farmers. In present work thirteen symptoms were recorded in the farmers while control group has six similar symptoms which were in lower percentage. Therefore symptoms reported in the farmers under this work can be considered as effects of endosulfan consistent with the reports by Merck (1993) and Venkateswarlu *et al.* (2000).

In biochemical investigation, serum total protein and urine proteins were analyzed and their values found significantly different as

compared to the controls (Table 2 and 3). Proteins by their functions undergo variations in different physiological and pathological conditions as studied by some authors (Alper, 1974 and Anderson, *et al.* 1997). This work shows serum total proteins decreased, which indicate the disruption of protein metabolism in the farmers. Such depletion has been reported in line with many pesticides induced in various animals (Mehle, *et al.* 1971., Kozlovskaia, *et al.* 1979., Swarup, *et al.* 1981., Murthy, *et al.* 1982.)

However, the endosulfan exposures have increased the protein in urine with significant difference in its values (Table 3) in the farmers as compared to the controls. This appeared to indicate the effects of endosulfan on glomerular functions of the kidneys in farmers rather than the other organs.

Urea the end product of protein metabolism, excreted out in urine, falls in acute renal impairment while its concentration at serum level rises rapidly. In the intrinsic renal disease, the glomerular filtration rate diminishes and leads to urea retention that may rise its serum level. Decrease in serum urea is seen in severe liver disease with destruction of cells leading to impairment of the urea cycle (Alan, 1996). Endosulfan turn up the serum urea increase in the farmers at highly significant level ($p<0.001$) as shown in Table 2, hence urea values in urine statistically were not affected (Table 3). Therefore, this reveals the toxic effect of endosulfan on renal functions only. That is seen in animal studies indicating kidney damage with increased level of urea in serum samples (Shakoori, *et al.* 1987).

Above parameters indicated the renal effects of endosulfan in the exposed farmers since creatinine is more a reliable guide of renal function as it is almost completely filtered at the glomerulus and is not reabsorbed in renal tubules. Reduction in creatinine values is caused by conditions of acute glomerulonephritis, shock, hypovolumea and nephrotoxic chemicals. In present work the serum and urine creatinine concentration is shown increased in the endosulfan exposed farmers at highly significant level ($p<0.001$) as revealed in Table 2 and 3. In comparison with control values this increase has confirmed the renal impairment in the farmers under this study.

Glucose is main carbohydrate substrate, stored as glycogen in muscle and liver. When peripheral tissues need it the glycogen is converted to glucose and transported to them via blood. The endosulfan intoxication has been reported for hyperglycemic effects in animals (Bhatia, *et al.* 2002) and in the suicide attempting farmers (Soomro, *et al.* 2003b). Satish, *et al.* (1972) studied the organochlorines group of pesticides and reported the impairment in the uptake of glucose by the tissues during acute intoxication in rats. Both the reported conditions indicate significant toxicity, whereas this study on farmers dismantles the endosulfan effects as non-significant (Tables 2 and 3). Therefore previous reports and present results indicate that the chronic and/or continuous exposure to endosulfan do not induce gluconeogenesis or glycogenolysis which may change its blood concentrations.

Among electrolytes; calcium is an important constituent of blood, its ionized form is of great value in the function of heart, nerves and in permeability of membrane (Nicholas, 1932. and Logan, 1940). Kanis (1996) reported that 'stress' causes transient increase in plasma parathromone and calcium. Presently, reduced calcium concentrations in farmers' serum and urine were at significant level as shown in Tables 2 and 3. This recorded effect may be due to endosulfan exposures.

Sodium is major action, which maintains the osmotic pressure of body fluids and regulates the acid base balance thus protects the body against excessive fluid loss (Harper, 1971). Hamilton (1982) reported that total body fluids volume depends on sodium and potassium ions present in fluids. Table 2 shows that the endosulfan exposures have not affected the sodium concentration in serum. But the differences in its values in urine found highly significant ($p<0.001$) as shown in Table 3, which indicates the physiological changes towards the toxic effects of this pesticide in the farmers.

Serum potassium increases in adrenal cortical insufficiency, renal failure, anemia, dehydration and cellular break down. Its greater concentration (hyperkalemia) was seen as a direct complication of acute poisoning. In an animal study Rangwaswamy (2002) reported significant alterations in the ionic compositions of the blood including potassium at sub-lethal doses of endosulfan. In this work no significant differences in the values of serum and urine potassium were detected between farmers and the controls as revealed in the Tables 2 and 3.

5. Conclusion

Farmers under study were seen at greater risk of health hazards in case of endosulfan exposures. Increasing rate of toxic effects was due to inadequate protective measures, which can be observed from the reported symptoms and significant biochemical changes in the studie d population. Therefore this work may be considered as indicator to avoid further use of endosulfan, in either condition very intensive care is suggested.

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Natural productivity of fish ponds in relation to physico-chemical parameters at Chilya hatchery Thatta, Sindh, Pakistan

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Abstract:

The analysis of physico-chemical and biological parameters of two fish ponds; brooder rearing pond (Pond-I) and fry stocking pond (Pond-II), at Chilya fish hatchery were carried out during January - December 2006. Ranges of temperature of water 14-35.2°C, 14.5-34.7°C; dissolved oxygen 7.69-12.71 mg/l, 7.82-12.3 mg/l; pH 7.2-7.9, 7.87-8.4; total alkalinity 75-142 mg/l, 106-181 mg/l; total hardness 83-120, 102-189 mg/l; total dissolved solids (TDS), 270-348, 226-3920 mg/l; total nitrogen 0.15-0.47, 0.528-1.47 mg/l and orthophosphate 0.12-0.372, 0.74-1.21 mg/l respectively were recorded at the ponds.

Algal flora in Pond-I consisted of 7 species of Cyanophyta, 11 species of Chlorophyta while in Pond-II 12 species of Cyanophyta, 13 species of Chlorophyta and 2 species of Bacillariophyta were found,7 species of aquatic plants, *Hydrilla verticillata*, *Najaz minor*, *Potamogeton pectinatus*, *Nymphia sp*. *Typha domingensis* and *Phragmites vallatorn* were also recorded from pond -II.

Among zooplankton the brooder pond had the population of rotifers (5 species) and micro crustaceans (3 species). In fry pond, 4 species of rotifers and 7 species of micro crustaceans were present.

The results revealed that the water quality variables of Chilya fish hatchery were suitable for fish culture. No known source of pollution enters the ponds. On the northern side there is an outlet channel of Keenjhar lake which supplies water to fish ponds. Rich algal flora and zooplanktons were observed in Pond-II (fry pond). This may be due to the artificial feeding and availability of macrophytes which maintain the water temperature, light penetration, nitrates, phosphates and total dissolved solids (TDS).

Keywords: Limnology of ponds, Chilya fish hatchery, Plankton, Algae.

1. Introduction

Artificial breeding places such as hatcheries incorporate biotic interrelations with socio-economic benefits for human society. The developing countries are facing shortage of protein in diet; therefore much attention is given to aquaculture which provides a cheap source of protein in the shape of fish.

The first fish hatchery in Sindh was established near village Chilya, in district Thatta to cater the requirements of fish seed in lower Sindh. The hatchery is situated on National Highway, 10km from Thatta towards Hyderabad. It spreads over an area of 0.74/s km^2 consisting of 12 circular holding tanks, 45 nurseries, 9 brooder ponds and 20 fry stocking ponds.

This hatchery is a technical unit aimed at production of high quality fish seed and carrying out research activities to boost fish production. Many varieties of fish including indigenous as well as exotic species breed in this hatchery during various periods of the year. The breeding of major carps including *Catla catla*, *Labeo*

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rohita, *Cirrhinus mrigala*, *Ctenopharyngodo idella* and *Hypothalmichthyes molitrix* starts from May and ends in mid August whereas *Cyprinous carpio* breeds during February to March.

The primary productivity of the aquatic habitats depends on the physico-chemical conditions in relation to other environmental factors. Hence, considering the importance of the studies on the limnological aspects, the present study of the two fish ponds was undertaken.

2. Materials and Methods

Samples of water, planktons and macrophytes were collected four times, in January, April, August and December, 2006 from the two ponds, i.e. brooder rearing (pond-I) and fry stocking (pond-II). The area of these earthen ponds was 0. 25 km^2 each and depth of 1.5meter.

Water samples from both the ponds were collected in sterilized plastic bottles for analysis of chemical parameters. The temperature, TDS, pH and dissolved oxygen of water were in site recorded with WTW 320 conductivity meter, Ecoscan pH digital meter, and Oxy. 315i/SET meter respectively. Alkalinity and hardness were determined by titration with standard HCl 0.01N with methyl orange and phenolphthalein as indicators. Total nitrogen Kjeldhal was determined using mercuric oxide red as catalyst. Orthophosphate was evaluated by reducing phosphomolybdic acid (formed with ascorbic acid to molybdenum blue on Hitachi 880 model A. spectrophotometer). All parameters were determined according to the recommended methods of APHA (1992).

Zooplankton samples were collected with the help of plankton net (mesh size 55µ). For quantitative analysis, 50 liter of water sample was filtered in same plankton net from both the ponds and the specimens were preserved in 3-5% formalin solution in. The enumerations of the plankton were done in counting tray under the binocular microscope at x100.

Phytoplankton samples were collected with plankton net (mesh size 30µ) and preserved in 2-4 % formalin solution. For the analysis of seasonal variation of phytoplankton, the samples were centrifuged at 1000rpm for 10-15 minutes. Residues of phytoplankton were counted in Sedgwick Rafter counting chamber by drop method. Macrophytes were collected with hand net and plant-gripner. Identification was confirmed according to Shameel (2001) and Kazmi (2002). In the brooder pond the fish feed exclusively on natural food while in the fry pond artificial feed is provided to the young fish.

3. Results and Discussion

Temperature of the ponds water was found vary to seasonally, minimum (14- 14.5 °C) in the winter month (January) and maximum (34.7-35.2°C) in the summer (August) (Fig.1). The role of temperature in controlling chemical and metabolic reactions is well known as pulses of productivity occur with rise and fall of temperature (Das and Singh, 1992). A slight seasonal variation in temperature was observed in the ponds, but no thermal stratification was observed between surface and bottom.

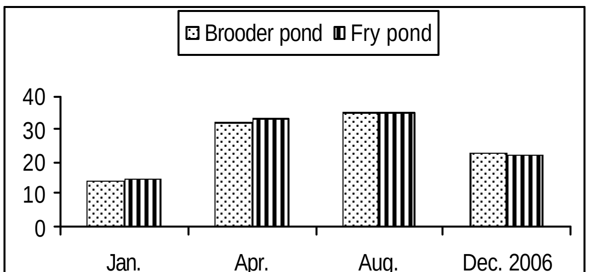

Fig.1. Seasonal variation of water temperature (ºC) in the brooder and fry pond

Dissolved oxygen is one of the most important ecological parameters to assess the productivity of an aquatic habitat. Its fluctuation depends upon the temperature and algal population. It was low (7.69-7.82 mg/l) in summer and high (12.3-12.71mg/l) in winter during the abundant both phyto and zooplankton population **(Fig.2).** The dissolved oxygen contents were even higher than 5mg/l in both ponds due to the high photosynthetic activity and air currents.

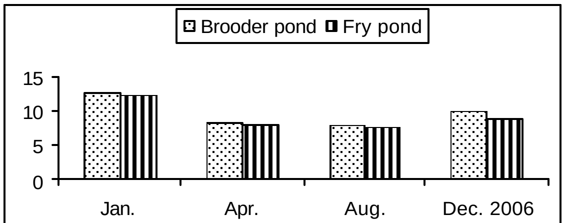

Fig.2. Seasonal variation of dissolved oxygen (mg/L) in the brooder and fry pond

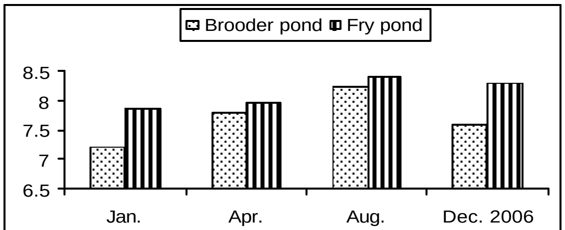

Fig.3. Seasonal variation of pH in the brooder and fry pond

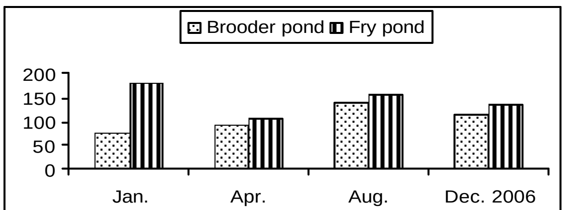

Fig.4. Seasonal variation of alkalinity (mg/L) in the brooder and fry pond

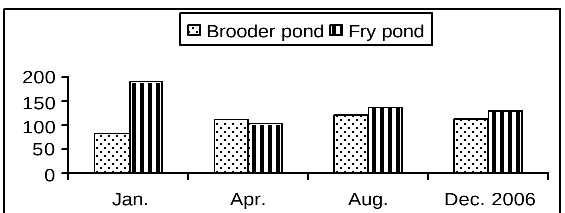

Fig. 5. Seasonal variation of hardness (mg/L) in the brooder and fry pond

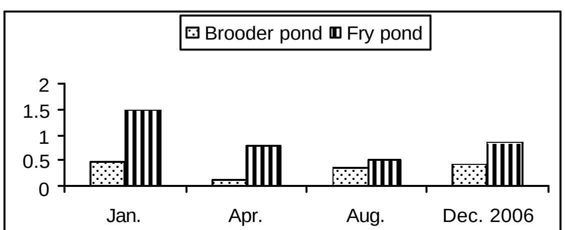

Fig.6. Seasonal variation of nitrogen (mg/L) in the brooder and fry pond

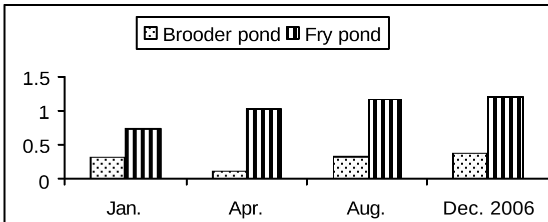

Fig.7. Seasonal variation of orthophosphate (mg/L) in the brooder and fry pond

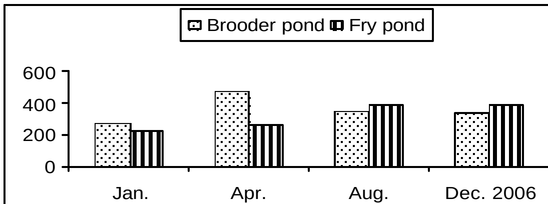

Fig.8 Seasonal variation of total dissolved solids TDS (mg/L) in the brooder and fry pond

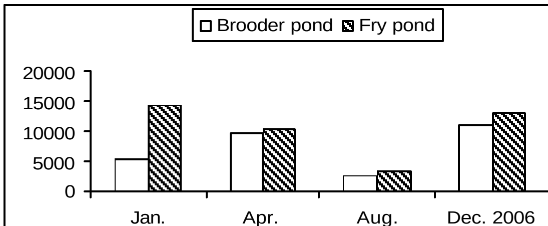

Fig.9. Seasonal variation of algal flora (No.of individuals/5L)

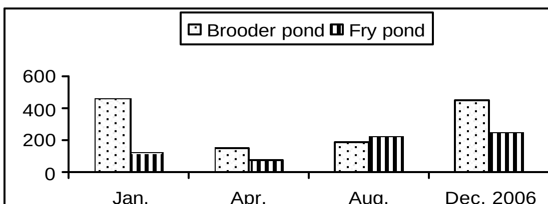

Fig.10. Seasonal variation of zooplankton (No.of individuals/50L)

The high pH ranges (7.87 to 7.9) in ponds were observed in August due to high rate of photosynthetic activities by aquatic macrophytes and rich algal and phytoplankton population, on other hand the low pH values in January and April may be attributed to low photosynthetic activity. Total alkalinity (106-181 mg/l) and total hardness (102-189 mg/l) in pond-II were higher due to the photosynthesize process. Clarke (1954) stated that more carbonate is formed when free CO_2 is drawn up from the water by photosynthesis.

High values of total dissolved solids (TDS) were 473 mg/l in April pond-I conceivably due to the application of supplementary feeding to fish.

A positive co-relationship between phytoplankton population and nutrients (total nitrogen 0.15-0.47 & 0.528-1.47 mg/l, and orthophosphate 0.12-0.372 & 0.74-1.21 mg/l) was observed in the ponds.

Seasonal density fluctuation of 18 algal species including 7 species of Cyanophyta, 7 Chlorophyta, 3 of Euglenophyta and 1 belonging to Charophyta in brooder pond is given in **Table-1**. Cyclic variation in phytoplankton population was strongly effected by seasonal and ecological influences. In tropical regions dry and rainy climate showed distinct variations (Harris, 1986).*Aphanocapsa gravillei* dominated from April to December, *Chroococcus limneticus*, *C. minor, C. tenax* were present in January and December and early August. *Coelosphaerium kuetzingianum* was recorded in April and December, while *Merismopedia glauca* and *Oscillatoria* species were frequent throughout the year. Palmer (1969) concluded that *Oscillatoria* species were more likely present than other species when organic pollution exists. *Cosmarium granatum, C. formosulum, C. leave and Phacus acuminatus* were widespread from August to December. Temperature plays an important role in the periodicity of bluegreen algae as emphasized by earlier workers (Hutchinson, 1967; Rao, 1972 and Nazneen, 1980).

Table 1. Seasonal abundance of algal flora in the brooder pond (Pond-I)

	Taxa	January	April	August	December
	Cyanophyta				
1	*Aphanocapsa gravillei*	00	3142	104	2700
2	*Chroococcus limneticus*	120	00	00	445
3	*C. minor*	528	00	00	347
4	*C. tenax*	1262	3068	00	1487
5	*Coelosphaerium kuetzingianum*	00	1196	00	938
6	*Merismopedia glauca*	1292	00	226	748
7	*Oscillatoria jasorvensis*	918	1038	860	628
	Chlorophyta				
8	*Cosmarium granatum*	9	00	598	620
9	*C. formosulum*	00	00	78	220
10	*C. leave*	00	00	109	00
11	*Phacus acuminatus*	82	0	227	0
12	*Scenedesmus bijugatus*	75	38	0	102
13	*S. dimorphus*	20	00	90	284
14	*Stigeoclonium tenue*	00	1172	00	1324
15	*Coelastrum microporum*	00	28	87	00
16	*Euglena proxima*	24	00	00	28
17	*Enteromorpha salina*	1210	00	00	1442
18	*Paranema trichophorum*	0	00	108	00
19	*Chara zeylanica*	6	0	0	83
	Total	**5546**	**9682**	**2487**	**11396**

Table 2. Seasonal abundance of algal flora in the fry pond (Pond-II) at Chilya hatchry

	Taxa	January	April	August	December
	Cyanophyta				
1	*Anabaena limnetica*	00	00	220	2921
2	*A. planktonica*	00	00	00	67
3	*Chroococcus limneticus*	1207	00	00	805
4	*C. tenax*	109	2027	00	1925
5	*Coelosphaerium kuetzingianum*	00	00	637	468
6	*Merismopedia glauca*	929	00	230	560
7	*M. elegans*	105	00	00	372
8	*Oscillatoria jasorvensis*	467	00	520	82
9	*O. limosa*	220	70	0	00
10	*O. formosa*	00	00	204	00
11	*Nostoc spongiforme*	00	00	320	337
12	*Spirulina major*	468	00	20	597
	Chlorophyta				
13	*Cosmarium undulatum*	97	00	209	65
14	*C. formosulum*	123	185	00	00
15	*C. leave*	00	102	00	00
16	*Mougeotia sphaerocarpa*	00	00	758	1853
17	*Phacus acuminatus*	00	00	64	38
18	*Rhizoclonium sp.*	5362	6728	00	2922
19	*Scenedesmus dimorphus*	00	00	78	43
20	*Spirogyra subsalse*	2930	486	00	00
21	*Stigeoclonium tenue*	203	89	00	00
22	*Coelastrum microporum*	4	480	30	00
23	*Euglena proxima*	66	00	00	40
24	*Enteromorpha salina*	940	204	00	00
25	*Chara zeylanica*	30	40	00	2
	Bacillariophyta				
26	*Cyclotella kuetzingana*	520	00	35	00
27	*Cocconeis pediculus*	536	00	00	90
	Total	**14316**	**10411**	**3325**	**13187**

Table 3. Higher aquatic plants (Macrophytes) in the fry pond (Pond-II)

	Taxa	January	August	December
1	*Najas minor*	+	+	+
2	*Hydrilla verticillata*	+	+	+
3	*Potamogeton pectinatus*	-	+	+
4	*Scirpus nodulus*	+	+	+
5	*Typha domingensis*	+	+	+
6	*Phragmites vallatorn*	+	+	+
7	*Nymphia sp.*	-	+	-
8	*Nylimbo sp.*	-	+	-

In the fry pond, **27** species of algae were recorded **Table - 4.** The species of genus *Anabaena, Coelosphaerium, Mougeotia, Nostoc, Phacus, and Scenedesmus* were dominant in August and December while *Chroococcus, Cocconies* and *Spirulina* were common in January and December. The genera of *Merismopedia, Oscillatoria, Cosmarium, Rhizoclonium* was rarely recorded in January, August and December. Seenayya and Raju (1972) observed that phosphates were high just prior to the

Table 4. Zooplankton density (Individuals/50L) in the brooder pond (Pond-I) at Chilya hatchery

Taxa		January	April	August	December
Rotifera					
1	*Brachionus quadridentatus*	130	0	0	85
2	*B. falcatus*	46	0	0	77
3	*Keratella tropica*	112	0	0	39
4	*Lecane luna*	54	7	2	14
Cladocera					
5	*Alona rectangula*	8	2	65	12
6	*Bosmina longirostrus*	36	21	40	122
7	*Ceriodaphnia reticulata*	0	16	0	0
8	*Daphnia lumholtzi*	2	0	4	0
Copepoda					
9	*Cyclops affinus*	0	28	38	6
10	*Microcyclops varicans*	8	3	20	0
11	*Thermocyclops hylinus*	6	1	0	0
Miscellaneous		52	76	18	89
Total		**454**	**154**	**187**	**444**

Table 5. Zooplankton density (Individuals/50L) in the fry pond (Pond-II)

Taxa		January	April	August	December
Rotifera					
1	*Brachionus quadridentatus*	24	17	0	0
2	*B. calyciflorus*	15	0	0	47
3	*Keratella tropica*	0	26	13	0
4	*K. quadrata*	0	0	18	0
5	*Monostyla pygmae*	8	0	0	132
Cladocera					
6	*Alona rectangula*	23	0	0	24
7	*Bosmina longirostris*	18	0	0	27
8	*Chydorus poppei*	2	0	0	0
Copepoda					
9	*Cyclops affinus*	12	0	8	0
Miscellaneous		16	34	178	19
Total		118	77	217	249

development of bloom of *Anabaena raciborski*. Nazneen (1980) also reported the occurrence of *Anabaena* only during spring and early summer in Keenjhar lake. The variations in algal community may probably be due to the change of temperature and other chemical parameters. Hutchinson (1967) emphasized that the distribution of phytoplankton in lakes is regulated mainly by temperature, light, nutrients, toxicants, parasitism, grazing and inter-specific competition.

Seasonal variation in densities of three groups of zooplankton (Rotifera, Cladocera and Copepoda) in the brooder pond and in the fry pond are given in **Table 6 and 7**. *Brachionus*, *Keratella*, and *Monostyla* species were dominant in January and December. *Alona rectangular* and *Bosmina longirostrus* were dominant and commonly occurred throughout the year in Brooder pond, while both species were absent in the fry pond in April and August. The present findings conform to the observations of Choubey (1992) that a restricted occurrence of *Alona rectungula* and *Bosmina longirostris* in the month of September, November and December. Bosmina longirostris has been considered a good indicator of trophic conditions (Swar and Fernando, 1980). *Ceriodaphnia reticulate*, *Chydorus poppei* and *Daphnia lumholtzi* were rare in both the ponds. Seasonal succession of cladoceran in Lake Ikeda (Japan) showed different rate of succession in different months, and no two species were found to be alike in their succession behavior (Baloch, 1995). *Cyclops affinus* and *Microcylops varicans* were common during summer season (April and August). *Microcyclops varicans* was absent in December. Dad (1981) reported the highest population of cyclopoids in the month of June from clear water area of Chambal river. The results showed the higher populations of cyclopoids in the brooder pond due to clear water as macrophytes were absent. *Thermocyclops hylinus* was found in January and April. In Fry pond the presence of *Cyclops affinus* was observed during January and August. The analysis of zooplankton samples from the brooder pond showed the abundance of rotifers in winter (January and December). *Brachionus quadridentatus* was found abundant in February and April in Gandhi Sager reservoir (Nayar, 1970). Green (1972), Chengalth *et al*., (1974), Pejler (1977), Fernando (1980) and Sharma (1983) mentioned the importance of genus *Brachionus* in tropical rotifer communities. It was also commonly recorded from Manchar lake (Mahar *et al*., 2000). *Brachionus* and *Monostyla* are regarded as indicators of eutrophication (Gannon and Stemberger 1978, Maemets 1983 and Mahar *et al.*, 2004). The present findings agree with the above observation. Artificial feed is the major cause of organic pollution and eutrophication. *Lecane* was recorded throughout the year in the brooder pond with slight variation. Dussart *et a*l., (1984) reported the presence of many species of *Lecane* in the tropical water bodies of Asia and Australia. *Keratella* was abundant in the brooder pond during January and December while in the fry pond these species were commonly recorded in April and August. Pejler (1983) mentioned that along a trophical scale, the number of planktonic rotifer species successively increases up to mesoeutrophic condition after which the number declines till hyper-eutrophic stage. The differences in biological parameters of two ponds reflect the ecological conditions affected by seasonal changes.

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Water quality assessment and flora study of desert Thar and Nagarparkar District Tharparkar, Sindh, Pakistan

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Abstract:

A number of water samples (24) were collected from wells, water pumps, natural and artificial depressions from Naukot, Vajuto, Mithi, Islamkot, Virawah and Nagarparkar area and analyzed on the site and at the laboratories for 18 different parameters. There was a wide variation in water quality; conductivity157 to 41400 µS/cm and total dissolved solids 100 to 26500 mg/L. The highest values were observed at Virawah area and lowest at an artificial depression of rainwater within Nagarparkar town. The higher vegetation of Thar region consists mainly of thorny or prickly shrubs and perennial herbs capable of drought resistance as *Calligonum polygonoides, Aerva javanica, Salvadora oleoides, Acacia senegal, Capparis decidua, Tamarix aphylla, Prosopis spicigera, Leptadenia pyrotechnica* and *Zizyphus nummularia.* During rainy season when dunes are covered with grasses and other herbs *Salvadora oleoides, Capparis decidua,* and *Tamarix aphylla* were found scattered in Thar area.

Acacia leucophloea, Acacia senegal, Salvadora oleoides, Commiphora mukul, Barleria prionitis, Blepharis sindica, Euphorbia caudicifolia were found on dry and rocky area. Rainwater pools contain total 83 algal sp; 37 sp belonging to Cyanophyta; 23 sp Volocothyta; 10 sp Chlorophyta; 3 sp Charophyta; 10 sp Bacillarophyta; some algal species found epiphytic on aquatic plants such as *Chaetophora pisiformis, Stigeoclonium subsecundum, Oedogonium* sp. *Spirogyra rhizobrachialis, S. fluviatilis* and *Gloeotrichia natans* attached to *Najas minor, Nymphaea stellata, and Typha domingensis.*

Keywords: Water quality assessment, flora study of Thar and Nagarparkar

1. Introduction

Thar Desert of Tharparkar district occupies southeast corner of Pakistan. Towards the south is the sandy salt marsh of Kach. The area is divided into sandy hills, flat alluvial plains and rocky hill tract. The area is dry and arid with low rainfall. The people depend upon rain for agriculture and livestock. Rainfall is low and is highly variable. The area is thinly populated with low vegetation. Eastern Nara supplies some water for irrigation upto Naukot. The main source of water in the region are underground water (wells) and rainwater. The water is collected within depressions between sand dunes. The underground water in Mithi, Islamkot upto Variwah is brackish while fresh in Nagarparkar area (Panhawar, 1986). Recently high deposits of coals have been detected within the region, which increases the economical importance of the area (Fassett & Durrani, 1994). The hard granite stones and China Clay found in the Nagarparkar area are also of considerable importance (Panhwar, 1986 Fassett & Durrani, 1994).

As systematic water quality of the region has not been reported, the present work is a preliminary study to evaluate the water quality and flora of Thar and Nagarparkar area.

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2. Sampling Scheme

The water samples were collected from Mithi, Islamkot and Nangarparkar area. The water sources within the area are wells and natural depressions (Tarai) where the rainwater is collected and remains as a source of water for both, the humans and animals for 2 to 8 months. The wells also vary significantly in depth and water quality. Twenty four (24) water samples were collected from Mithi, Islamkot and different villages in between Islamkot and Nagarparkar. 12 samples were of wells from (1) Village Lakhi Tobo, (2) Lonri yoon Saman (3) Adi jo Tar, (4) Kisaraki Paro Islamkot, (5) Tarho jo Goth about 10 Km from Mithi to Islamkot, (6) Nanukot to Vajuto, in between Mithi and Islamkot and (7) ground water boring from China Clay factory near Verawah (8) collected from whell Wajoto.

5 wells were sampled from Mithi area 9 Wahar wells, 10 Lal shah wells from village Sobharo shah, 11 well of village Kharo Bajer, 12 well from Mithi used for animals and 13 well from Mithi used for human consumptions.

A sample of rainwater was collected in depression about 1km from Adi jo Tar and a sample of water stream near Soothan Jo Wandhion before Nagarparkar area were also collected.

Ten samples were collected from Nagarparkar area. Six samples were collected from water ponds (1) Grhitari pond of about 1 acre area, half km outside Nagarparkar town, (2) Lorai Tarai pond with covered area of 4 acres, (3) Naryasoo Dam, (4) Ram Sar pool about 35 Km out side Nagarparkar town toward Rann of Kach, (5) Pond near village Phulpoyo and (6) Bhodasir reservoir behind historic Mosque of Munja, (7) from water supply of town Nagarparkar, (8) Piyao well about 1 km north of town Nagarparkar, (9) Inchile sar spring within Karonjhar mountains and (10) Punwah about 20km from Nagarparkar.

The samples were collected from the surface at the depth of 3 to 9 inches from the depressions, water pools and Dam about 2 to 6 feet from the side. The wells were sampled by lowering the buckets up to the bottom and filled buckets were pulled out. The samples from the water supply of Nagarparkar was collected after allowing water to flow for 5 min. The water sample from Inchile Sir Spring was collected from a small pool of water filled with continuous seepage of the mountain from creeks. The water samples were collected in 1.5L plastic bottle, rinsed several times with water before collection of samples taken in July 2005.

3. Material and Method

Water temperature, conductivity, salinity and total dissolved solids (TDS) were measured with WTW conductivity meter at the sampling site. The pH was measured with Orion 420 pH meter. Chloride, alkalinity and hardness were determined by titration with standard silver nitrate, hydrochloric acid and EDTA respectively. Nitrate, nitrite and phosphate were determined by spectrophotometry using Hitachi 220 spectrophotometer. Nitrate was determined using brucine sulphate as derivatizing reagent. Total phosphate was determined by persulphate digestion method fallowed determination as orthophosphate by reducing phosphomolybdic acid formed with ascorbic acid to molybdenum blue. Sulphate was determined by turbidiometry using barium chloride (APHA, 1992).

Sodium, potassium, calcium and magnesium were determined by Varian Spectra AA-20 atomic absorption spectrometer with air acetylene flame using standard burner at conditions recommended by the manufacturer. Sodium, potassium, calcium and magnesium were determined at 589.0nm, 766.5 nm, 422.7 nm and 285.2 nm respectively with integration time 3 sec and delay time 3sec.Higher plants and Algal flora were identified with the help of taxonomic keys Jafri (1966), Islam and Sheikh (1966), Bhandri (1978), Desikachary (1959) and Prescott (1961).

4. Results and Discussion

Tharparkar district is covered with sand dunes, up to 80 meter thick. The Nagarparkar part of Thar district is only a rocky texture, which dominantly consists of granite with minor amount of Rhyolite and other metamorphic rocks (Fassett and Durrani, 1994).

The water quality of the study area may be divided into two parts (1) Mithi and Islamkot area and (2) Nagarparkar area.

Six wells were examined within Islamkot area upto Mithi which indicated conductivity of 1653-14730 µS/cm and TDS 9427 mg/L (Table-1 samples III to VIII). The sample with highest conductivity and TDS is used as a source of water for cattle, but wells III, IV,V,VI, and VIII are used as a source of water for both human and animals. The pH of all the wells was observed within acceptable limits i.e. 7.55 to 8.3. The chloride contents were observed within 283-1525 mg/L except sample 7 which indicated 3722-mg/L. Nitrate, nitrite and total phosphate were present only in traces and were within the safe limits. Among the metal ions the sodium was dominant followed by calcium, magnesium and potassium.

Table 1. Samples collected from Thar, District Tharparkar
Date of Collection 22-07-2005

Parameters	I*	II*	III*	IV*	V*	VI*	VII*	VIII*
Time	8.08	8.30	16.25	19.12	9.45	11.55	12.50	13.40
Temperature of Water in ^{o}C	25	27.6	30.5	30.2	27.1	31.3	36.6	36.9
pH	7.41	7.90	7.55	7.77	7.85	8.0	8.23	8.0
Conductivity µS /cm	2340	36100	4340	1653	6387	5383	14730	3140
Salinity g/L	1.2	25.8	2.60	4.3	3.6	3.6	7.5	1.3
TDS mg /L	1497	23104	2777	1057	4087	3445	9427	2009
M. alkalinity as Ca CO_3 mg /L	200	480	150	200	425	350	400	200

Chloride mg /L	354	6286	818	283	1691	1525	3722	670
Hardness as Ca CO_3 mg /L	450	3700	800	500	440	800	650	310
Acid Hydrolysable Phosphate µg /L	980	80	40	90	80	50	60	50
Nitrite µg / L	10	15	B.D	B.D	B.D	B.D	B.D	B.D
Nitrate µg /L	150	350	30	500	B.D	10	30	300
Sulphate mg /L	150	600	280	40	450	680	612	210
Na mg /L	209	2750	322	189	826	1053	2546	241
K mg /L	25	240	44	10	56	56	34	10
Ca mg /L	101	850	190	69	214	179	137	172
Mg mg /L	54	417	87	41	147	119	70	94

*Sampling stations

(I) Natural depression, 1 km ahead Adi Jo Tar rain water (II) Stream near Soothan Jo Wandhio standing water in bed of the stream (III) well of village Lakhi Jo Wandhio (IV) Well Haroon Samo (In between Nagarparkar and Islam Kot) (V) Well Adi Jo Tar (About 75 ft in depth (VI) Well of Kasarai Paro Islam Kot (About 150ft in depth). (VII) Well of Tarho Jo Goth (About 10km from Mithi to Islam Kot) (VIII) Well of Wajutoo (In between Naokot and Mithi and Islamkot).

Five more samples around Mithi indicated highly variable salt contents. Wahar well of village Kharo Bajer and well from Mithi town, used for both human and animals indicated conductivity within 2.04- 4.83 mS/cm and TDS of 1305-3091 mg/L. However the pH of Mithi well was on the higher side 8.99. Lal Shah well and well from Mithi used for animal indicated high conductivity and TDS within the range 11.01- 11.58 mS/cm and of 7046–7411 mg/L respectively; Nitrite was below the detection limits in all the samples **(Table 2).**

Table 2. Samples collected from Mithi, district Tharparkar.
Date of Collection 16-07-2005

Parameters	I*	II*	III*	IV*	V*
Temperature of Water in ^{o}C	36.9	36.7	36	36.4	36.4
pH	7.92	7.31	7.94	8.90	8.99
Conductivity µS/cm	2.04	11.58	4.83	11.01	3.80
TDS mg /L	1305	7411	3091	7046	2432
P. alkalinity as Ca CO_3 mg/L	B.D	B.D	B.D	50	80
M. alkalinity as Ca CO_3 mg /L	100	200	180	210	140
Chloride mg / L	300	2470	580	1646	428
Hardness as Ca CO_3 mg /L	280	650	380	640	310
Acid Hydrolysable Phosphate µg /L	0.06	0.09	0.08	0.3	0.3
Ortho phosphate µg /L	20	48	40	150	210
Sulphate mg /L	85	330	120	250	170
Nitrate µg /L	.35	B.D	0.20	0.10	0.10
Na mg /L	170	1310	148	730	182
K mg /L	24	57	42	46	28
Ca mg /L	73	303	106	334	98
Mg mg /L	46	71	80	88	54

*Sampling stations

I. Wahar well from village Sobharo Shah.
II. Lal Shah well from village Sobharo Shah
III. Well of village Kharo bajeer
IV. Well from Mithi (used for animals)
V. Well from Mithi town.

The rainwater collected in depression (Table-1 sample-I) used as a source of water for human and cattle indicated conductivity of 2340 µS/cm and TDS 1497 mg/L with acceptable pH 7.41. In Isalamkot, Mithi and Wajuto area, well water is hard water and is not suitable for human beings, but is suitable for animals and washing. The well water of moist surrounding soil area covered *Phormidium favosum* ,*Phormidium ceylanicum, Oscillatoria chalybea*, *Oscillatoria brevis*, *Oscillatoria lemmermannii, Gloeocapsa magma* belonging to Cyanophyta. Other two sources of water, ground water of China Clay factory Virawah and stream near Soothan Jo Wandhion, indicated extreme values of conductivity due to high amount of salt contents. China Clay ponds are full of *Oscillatoria amoena*, *Scenedesmus armatus*, *Spirogyra subsalsa* and *Glenodinium pulvisculus* are the dominant flora **(Table-3).**

Table - 3. Samples collected from central Thar district Tharparkar
Date of Collection 22-07-2005

Parameters	I*	II*
Temperature of Water in ^{o}C	29.7	30.5
pH	7.39	6.77
Conductivity µS / cm	1097	41400
TDS mg /L	702	26496
M. alkalinity as Ca CO_3 mg /L	210	250
Chloride mg /L	190	1168
Hardness as Ca CO_3 g/L	300	1200
Acid Hydrolysable Phosphate mg /L	0.04	0.08
Sulphate mg / L	90	500
Nitrate µg /L	B.D	0.12
Na mg /L	106	450
K mg /L	25	65
Ca mg /L	60	281
Mg mg /L	35	142

* Sampling stations.

I. Punwah well (45 ft in depth)
II. Ground water (By bording from about 100ft in depth) China Clay factory Virawah.

The well and rain water are used for human consumption, but the sources cross the safe limits of TDS 1000 mg/L. Samples III, IV, V, IV & VIII collected from wells even cross the maximum permissible limits of 1500 mg/L.

The second water resource observed within the Nagarparkar area indicated conductivity within 157 to 1487 µS/cm and TDS 100 to 951 mg/L except water collected from a depression near village Phulpoyo which indicated conductivity 3390 µS /cm and TDS of 2169 mg/l may be because of extensive evaporation from the surface or due to dissolution of the salts at the bottom (**Table – 4)**.

The collected sample at Bhodasir reservoir behind historic Mosque of Munja indicated the lowest electrical conductivity and TDS because the water was collected at the foot of the hard granite mountains having low dissolved solids.

Chloride, alkalinity, hardness, Sulphate, nitrite and phosphate were within the limits set for drinking water. Here also sodium was higher in concentration followed by calcium, magnesium and potassium in the decreasing order.

Table 4. Samples collected from Nagar parkar, district Tharparkar.
Date of Collection 22-07-2005

Parameters	I*	II*	III*	IV*	V*	VI*	VII*	VIII*	IX*
Time	10.30	10.40	10.54	12.50	14	15.55	18.30	19.25	8.20
Temperature of Water in ^{o}C	27.7	30.5	30.6	32.5	32.1	33.4	30.7	30.4	30
pH	7.71	7.70	7.80	8.51	7.48	7.54	7.99	7.07	7.18
Conductivity µS / cm	887	236	237	255	1030	3390	157	1487	1298
Salinity g/ L	0.5	0.3	0.3	0.3	0.4	2.0	0.1	0.9	0.5
TDS mg / L	567	151	152	163	659	2169	100	951	830
M.Alkalinity as $CaCO_3$ mg/ L	250	100	75	75	50	100	50	250	400
Chloride mg/ L	292	118	142	148	269	1095	44	276	202
Hardness as $CaCO_3$ mg / L	240	250	230	210	290	620	150	290	300
Acid Hydrolysable Phosphate µg/L	80	50	50	50	50	90	100	500	50
Nitrate µg /L	150	250	500	B.D	200	350	360	320	320
Sulphate mg /L	60	40	60	61	170	400	25	130	100
Na mg /L	138	46	86	65	128	534	20	119	163
K mg /L	36	14	12	17	15	31	8	29	37
Ca mg /L	76	32	44	57	89	235	34	81	120
Mg mg /L	45	23	21	24	51	71	14	46	40

*Sampling stations
(!) Water supply of town Nagarparkar
(II) Grhitari pond of about 1 acre and half km outside Nagarparkar
(III) Lorai Taraie pond (covered area of 4 acre)
(IV) Naryashoo Dam
(V) Ram Sir pool about 35 km out side Nagar parkar town toward Rann of Katch
(VI) Pond near village phulpoyo (160 sq ft)
(VII) Bhodasir reservoir behind historic Mosque of Munja (4000sq ft and 20-25 in depth)
(VIII) Inchile Sir Spring within Karonjar mountains
(IX) Piyao well (36ft in depth) about 1 km north of town Nagarparkar.

Panhwer (1986) has reported potable water between Naukot and Nangarparker to contain high salt contents, because of being part of the sea. However for Nangarparkar area it has been suggested that fresh water floats over brackish heavier water.

The results of chemical analysis indicate sodium chloride concentration higher than calcium carbonate. Thus it does support that the area might have remained under the influence of seawater. However at Nagarparkar area hard granite mountain and strong bed with low water soluble salts have proved a shield to retain fresh water for longer time within the area. Thinly populated area has maintained natural balance with precipitation and the extraction of underground water. In Thar area relative humidity is quite high ranging between 40-48% where the higher plants are *Salvadora persica, Acacia Senegal, Zizyphus nummularia, Tecomella undulata, Calotropis procera*, and *Acacia jacquemontii*, also covered with the grasses which is used for the cattle farming. Nagarparkar where the rainfall is 7-21 % is comparatively higher then the other area and predominant plants were *Commiphora mukul, Leptadenia spartium, Capparis decidua, Cassia angustifolia, Crotalaria burhia* and *Tamarindus indica.* The grasses and other vegetation are comparatively higher in the area and is use for cultivation and cattle forming. The pools of rain water were full with the *Najas graminea and Najas minor* alongwith Algalflora..

CYANOPHYTA

Aphanocapsa elachista
A.halophytica
A.littoralis
A. pulchra
Aphanothece saxicola
A.halophytica
Chroococcus tenax
C. minimus
C. minor
C. turgidus
Lyngbya aestuarii
L.limnetica.
Microcoleus chthonoplastes
Microcystis aeruginosa.
M. flos-aquae
M.marginata
M.pulverea
Oscillatoria amoena
O. angusta
O. chalybea
O. chlorina.
O. curviceps,.
O. formosa
O. salina

O. sancta
O. brevis
O. kuetzingiana
Phormidium ambiguum
P. ceylanicum
P. fragile
P. tenue
P. faveosum
Spirulina major
S. subsalsa
S. Laxa
Merismopedia glauca
Anabaena sp.

VOLVOCOPHYTA
Chlorococcum humicola
Golenkinia radiata
Pediastrum simplex
P. duplex
P. tetras
Tetraedron muticum
T. pentaedricum
Lagerheimia longiseta
Chlorella vulgaris
Gloeotaenium loitels bergerianum
Oocystis crassa
O. elliptica
Botryococcus braunii
Ankistrode mus falcatus
A. spiralis
Coelastrum microporum
Crucigenia tetrapedia
Scenedesmus dimorphus
S. arcuatus
S. abundans
Cosmarium leave
C. granatum

CHLOROPHYTA
Stigeoclonium lubricum
Cladophora fracta
C. glomerata
Pithophora oedogonia
Rhizoclonium hieroglyphicum
Oedogonium oviforme
Spirogyra rhizobrachialis
S. subsalsa
S. rhizopus
Zygnemopsis indica

CHAROPHYTA
Chara setosa
C. zeylanica
Nitella hyalina

BACILLAROPHYTA
Amphora ovalis
Gyrosigma sp
Navicula pygmaea
N.viridulla
Navicula sp
Cymbella sp
Nitz schia vermiculuis
Cyclotella operculata
C. kutzingiana
Cocconeis pedeculus

The Thar and Karonjhar hilly area during rainy season were covered with grasses; *Scirpus littoralis, Chenopodium album, Digera arvensis, Aerva javanica, Amaranthus viridis* used as food, fodder for the domestic and wild animals. *Arva javanica* is used for filling the pillows and chairs seats**.**

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Trackways evidence of sauropod Dinosaurs Confronted by a Theropod found from middle Jurassic Samana Suk Limestone of Pakistan

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Abstract

The temporal distribution of sauropod trackways generally parallels the record of sauropod body fossils. The oldest sauropod trackways are found in Lower Jurassic deposits of Africa, North America, and Asia; trackways are abundant throughout the rest of the Jurassic and Lower Cretaceous, but fewer are recorded in the Upper Cretaceous rocks. The foot structures of the various dinosaur groups are usually fairly conservative within those groups. Trackways are particularly promising records of dinosaur locomotion because they represent the trace of an act-a moment in time-and therefore can provide information that is usually unavailable from skeletal morphology alone.

Remains of a diversified paleobiota are found in the middle Indus basin, which includes plants (gymnosperm), mollusks, reptiles (cranial and post cranial bones). The commonest vertebrate fossils belong to sauropod and theropod dinosaurs, and mesoeucrocodilian fauna that occur a wide geographic area. Recently the author have found footprints of sauropod confronted with a theropod, in the middle Jurassic Samana Suk Limestone of Surghar Range, Mianwali district, Punjab Province, Pakistan. Five species of Late Cretaceous and one species of Late Jurassic titanosaurian sauropod, and one species of Late Cretaceous Abelisauran theropod dinosaur from Pakistan have already been established. But one new genus and species ***Malasaurus mianwali*** of middle Jurassic sauropod and one new genus and species ***Samanadrinda surghari*** of large bodied theropod based on only ichnofossils, are tentatively erected. Large pes foot print having length/width about 1 metre are diagnosed only for a large bodied sauropod. The manus footprints are totally overlapped by the pes prints. These tracks suggest the gregarious behavior of narrow gauge locomotors defending the attack of predatory theropod. This is the reason these are not referred to previously erected species of titanosaurs from Pakistan, because they may belongs to wide gauge trackways. These footprints are surely assigned to sauropod, but its assignment to lower level is difficult.

Three slender toed foot prints having maximum length about 2 feet and width about 1.5 feet are diagnosed only for a large bodied theropod. These footprints are surely assigned to Theropod, but its assignment to lower level is difficult. Both the sauropod and theropod genera erected are named only to refer for future research work regarding locomotion, behavior, soft and hard tissues. This ichnotype reveal the scenario of confrontation among a carnivorous ***Samanadrinda surghari*** theropod and the groups of herbivorous ***Malasaurus Mianwali*** sauropods.

This ichnocoenosis consists of exposed about 15 footprints, and 4 short trackways. Three trackways are interpreted as mainly produced by sauropods which are obliquely confronted by a track of large Theropod. They are indicative of a sauropod herd, composed of 3 or more individuals and furnish evidence of gregariousness (herd). The ichnofossils are usually deep footprints probably due to good granolometric sorting and the high plasticity of the limy substrate. In the vicinity, some foot prints of possibly birds/ small body theropod/coelorusaurs are also present. The ichnofossils of sauropod dinosaurs confronting a theropod of upper Indus Basin are a unique record of a middle Jurassic dinosaurian fauna which inhabited the north western margin of Indo-Pakistan subcontinental plate.

Keywords: Footprints, sauropods, confronted a theropod, Middle Jurassic, Pakistan.

1. Introduction

The temporal distribution of sauropod trackways generally parallels the record of sauropod body fossils. The oldest sauropod trackways are found in Lower Jurassic deposits of Africa, North America, and Asia; trackways are abundant throughout the rest of the Jurassic and Lower Cretaceous, but fewer are recorded in the Upper Cretaceous rocks (Lockley, Meyer, Hunt, and Lucas 1994 and references therein). The foot structures of the various dinosaur groups are usually fairly conservative within those groups; footprints shapes are also pretty generic within a group. One may be able to say that a given footprint was made by a large theropod, or a big ornithopod, or a sauropod, but it is seldom possible to say exactly which species of theropod, ornithopod, or sauropod we are dealing with (Farlow, 2000). If the formation having foot prints may host skeleton of dinosaurs then we can argue that it was a trackmaker but we can not be completely sure. Fossilized tracks and trackways (ichnofossils) are the only direct evidence of what extinct animals did when they were alive. They are like snapshot from the animal's life and can provide us important information about locomotion (e.g., posture, kinematics), behaviour (e.g., herding), and even soft tissues (e.g., foot scales, body features). The ancestral dinosaurs and herraresaurids walked with all four toes on the hind feet touching the ground, advanced carnivorous dinosaurs (the Neotheropoda) walked on only the middle three toes (digits 2-4).

Footprints and trackways were among the first dinosaur remains to receive scientific attention (e.g., Hitchcock 1836) and have seen a renaissance of study in recent decades as an increasing number and diversity have been discovered (see Lockley 1986; Thulborn and Wade 1989). Trackways are particularly promising records of dinosaur locomotion because they represent the trace of an act-a moment in time- and therefore can provide information that is usually unavailable from skeletal morphology alone (Alexander 1976; Thulborn 1982, 1989; Gatesy and Middleton 1996). Despite these potential benefits, however footprints have been of limited use because of difficulties in identifying the trackmakers. This problem is underscored in depositional settings where footprints are preserved better than body fossils, and estimates of taxonomic diversity must depend solely on these tracks. This problem is partially mitigated by a system of ichnotaxonomy that categorizes types (e.g., ceratopsian, sauropod, hadrosaur), but this system precludes examining footprint data at any lower taxonomic levels. As a result analyses that attempt to integrate skeletal and ichnological data (Farlow 1992; Lockley, Farlow, and Meyer 1994) must focus on these broad taxonomic categories and generally can not examine within group patterns of locomotor diversity (Wilson and Carrano, 1999).

A common pattern displayed by trackways at dinosaur footprint sites is for about half of the trails to be heading in one direction and the other half in the opposite direction. If we think about the conditions under which footprints are likely to be formed and preserved, the reason for this pattern will be apparent. Footprints require soft substrates in order to be formed, but some such soft substrate situations are more likely to preserve prints than others. Footprints can easily be made in dry sands well away from water courses, but likely fate of such prints is that they will eventually be gone with the wind. Footprints have a much better chance of survival if they are made in wet sediments, along the margins of streams, lakes, or seas, where they can eventually be buried beneath other sediments. The mirror image pattern could readily be generated if groups of animals were to move in either direction along the shore over time. The famous Early Cretaceous dinosaur footprint sites of the Paluxy River, in what is now Dinosaur Valley State Park near Glen Rose, Texas, provide a good example of this for one kind of trackmaker. The great majority of footprints displayed in the limestone bed of the river are big three toed jobs likely made by large theropods. The trackways of big theropods nicely show the mirror-image pattern. (Farlow, 2001).

Extrapolating from living crocodilians and birds, it is plausible that some dinosaur groups were family structures, consisting of a parent and its young, or a group of juveniles that had become large enough to get by without their parents, but that stayed together, at least for a time, for mutual protection and foraging (Farlow, 2001).

Paleontologists have faced the problem of associating tracks and trackmakers since the earliest discoveries of dinosaur tracks

(Hitchcock 1836). In subsequent decades, a diverse ichnotaxonomy flourished alongside a comparatively poor understanding of trackmaker identity (e.g., Lull 1915). In recent years, however a renaissance in dinosaur ichnology has led to the application of theoretical biomechanics (Alexander 1976), the mechanics of trackmaking in extant vertebrates (Pardian and Olsen 1989), and the effect of different substrates (Farlow 1989) for discriminating and interpreting dinosaur tracks (Wilson and Carrano, 1999). Farlow (1997,1998) data from birds (extant dinosaurs) show that even under idealized conditions of preservation, the tracks of certain major taxonomic group (i.e., most ground dewelling birds) can be difficult to distinguish between lower level non avian dinosaur taxa. Temporal and spatial coincidence can be used to draw more general and reasonable conclusions about potential dinosaur trackmakers. For example, Schulp and Brokx (in press) described a wide gauge sauropod trackway from the Maastrichtian of Fumanya, Spain. The authors noted that titanosaurs were the only sauropods known from the Maastrichtian of Europe and cited this as evidence that titanosaurs were the makers of wide gauge trackways. This is consistent with the currently known geographic and temporal distribution of titanosaur body fossils, although this association remains coincidental. Although direct trackmaker-trackway associations are known in the fossil records, they are exceedingly rare (Wilson and Carrano, 1999).

2. History of Dinosaur Discoveries in Pakistan

The firstever discovery of dinosaurs from Pakistan was made by author during early 2000 from the Latest Cretaceous dinosaur beds (Vitakri) member of Pab formation in Vitakri area, Barkhan district, Balochistan. First time in Pakistan I found a fossil of distal femur of Titanosaurian Sauropod dinosaur and first reported by Malkani and Anwar (2000). Professor Philip D. Gingerich, University of Michigan congratulated the GSP for this first ever dinosaur discovery from Pakistan and requested to DG, GSP for the visit of dinosaur locality. During late 2000, Professor Phillip D. Gingerich visited the Pakistan for previously running project of Eocene whale. On his visit to Vitakri dinosaur locality, I showed him the in-situ fragmentary bones. About 100 bones/pieces of bones of dinosaur Vitakri locality no one, are sent to Museum of Paleontology, University of Michigan, USA. I collected further 1500 bones/pieces of bones from 25 localities in Sulaiman foldbelt, administratively located in the areas of Barkhan, Kohlu, Dera Bugti, and Dera Ghazi Khan districts, Balochistan and Punjab Provinces during early 2001. Dr Jaffery A Wilson, Museum of Paleontology, University of Michigan, USA visited the GSP museum during March, 2001 and Dr. David A. Krauss of Bostan College, USA visited the GSP museum and Vitakri locality during mid of 2001. Second time dinosaur fossils are reported by Malkani, Wilson and Gingerich, (2001). I collected further 1200 bones/ pieces of bones during mid of 2001, from Sulaiman foldbelt. Third time dinosaur fossils are reported by Malkani, (2003a,b,c). Then the collected fossils of dinosaurs from Pakistan are documented by a continuous series of research papers by Malkani, (2004a,b,c, 2005a,b, 2006 a-h). The research on a braincase of titanosaurian sauropod dinosaur discovered by me from the Top Kinwa Kali Kakor locality of Vitakri area are also documented (Wilson, Malkani and Gingerich, 2005; Malkani, 2006h). The research on Paleobiogeography of titanosaurian and abelisaurian dinosaurs from Pakistan, wide gauge locomotion argued from skeletal morphology of Late Cretaceous Pakistani Titanosauria, localities of dinosaurs from the Late Cretaceous Pakistan, and confrontation scenario between two theropod dinosaurs argued from the discovery of a rostrum of *Vitakridrinda* found from the Late Cretaceous Park of Pakistan (Malkani, in review). The research on the finding of trackways of sauropod dinosaurs confronted by a theropod found from the Middle Jurassic Samanasuk Limestone of Pakistan is presented here.

3. Geological and Stratigraphic Setting

The study area of Surghar range is located in the upper Indus Basin of Pakistan **(Fig.1).** Trackways (footprints) of sauropod dinosaurs and a theropod are hosted by middle Jurassic Samanasuk Limestone of Surghar Range. The sediments of the study area underwent considerable tectonic deformation during the collision of Asian and Indo-Pakistan continental plates that commenced in the Late Cenozoic. As a result dinosaurs' foot print hosted beds along with other formations have been folded and faulted **Table -1.**

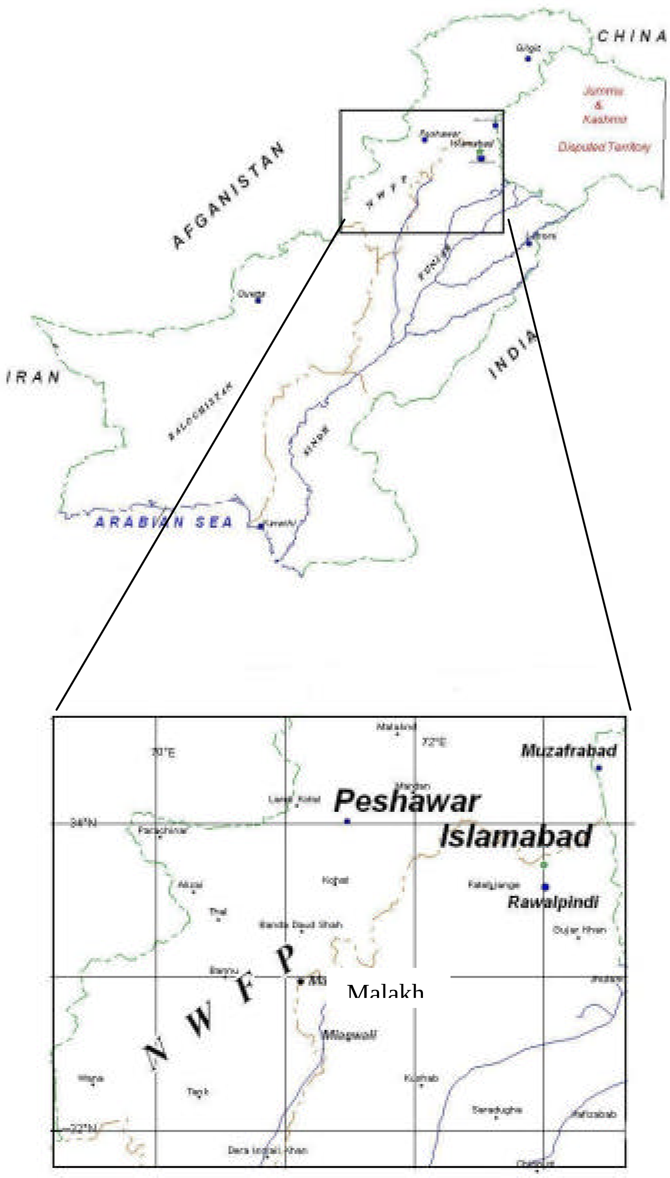

Figure 1. Index map of Pakistan showing the Malakhel locality of Mianwali District, which is the host of newly discovered footprints of herbivorous sauropod dinosaurs confronted by a carnivorous theropod dinosaur.

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Age			Formation	Lithology
CAINOZOIC	QUATERNARY	Recent	Modern channel deposits	Gravel, sand, silt and clay
			Sand, silt and clay deposits (cultivated lands)	Sand, silt and clay with minor gravel
		and	Sand, silt and clay deposits (non-cultivated lands)	Sand, silt and clay with minor gravel
			Colluvium deposits	Boulder, pebbles,cobbles,with sand silt and clay.
			Fan gravel deposits	Poorly consolidated gravel, sand, silt and clay.
		Sub-Recent	Terrace gravel deposits	Poorly consolidated gravel, sand, Silt and clay.
-----------------Angular Unconformity ---				
	TERTIARY	Pliocene	Soan Formation	Clays, conglomerate and sandstone
			Dhok Pathan Formation	Clays with subordinate sandstone conglomerate
		Miocene	Nagri Formation	Sandstone with minor shale and conglomerate
			Chingi Formation	Red Clays, sandstone and conglomerate
------------------------Disconformity--				
			Kamlial Formation	Shale with subordinate sandstone and conglomerate
		Oligocene	Murree Formation	Sandstone, conglomerate and shale
--------------------------Disconformity---				
			Habib Rahi Formation	Mainly limestone with marl and shale
			Kuldana Formation	Shale with minor sandstone and limestone
			Choregali Formation	Limestone and shale
		Eocene	Skesar Limestone	Limestone with subordinate shale and marl
			Nammal Formation	Marl with subordinate shale
			Patala shale	Mainly shale with marl
		Paleocene	Lockhart Limestone	Mainly limestone with minor shale
			Hungu Formation	Sandstone, coal, and shale
-------------------------Disconformity---				
MESOZOIC	CRETACEOUS		Lumshiwal Formation	Sandstone & shale
			Chichali Formation	Glauconitic sandstone and shale
------------------------Disconformity---				
	JURASSIC		Samanasuk Formation	Mainly limestone with subordinate shale
			Shinawari Formation	Shale, limestone and sandstone.
			Data Formation	Mainly sandstone with minor shale
--------------------------Disconformity--				
	TRIASSIC		Kingriali Formation	Dolomite and limestone with minor shale
			Tredian Formation	Mainly sandstone
			Mianwali Formation	Shale, limestone and sandstone
----------------------------Disconformity ---				
PALEO-ZOIC	PERMIAN		Chiddro Formation	Shale and sandstone.
			Wargal Limestone	Limestone and dolomite

	----------------------------Contact not exposed--	
PRECAMBRIAN	Salt Range Formation	Marl, gypsum, salt and shale

4. Materials and methods

Sedimentary strata of Pakistan are famous for Cenozoic vertebrate (Gingerich *et al.*, 2001). Recent dinosaur discoveries by me from Mesozoic of Pakistan have increased the temporal variation of its vertebrate fauna.

Remains of a diversified paleobiota are found in the middle Indus basin, which includes plants (gymnosperm), mollusks, reptiles (cranial and post cranial bones). The commonest vertebrate fossils belong to sauropod and theropod dinosaurs, and mesoeucrocodilian fauna that occur a wide geographic area. Five species of Late Cretaceous and one species of Late Jurassic titanosaurian sauropod, and one species of Late Cretaceous Abelisauran theropod dinosaur from Pakistan have already been established.

Recently I have found footprints of sauropod confronted with a theropod **(Figure 2-4),** in the middle Jurassic Samana Suk Limestone of Surghar Range, Mianwali district, Punjab Province, Pakistan. The research on these footprints and trackways of Sauropd dinosaur confronted by a theropod are presented here. The method applied here is the paleontological methods representing description, interpretation, discussion and conclusions.

Figure 2. Footprint of herbivorous sauropod dinosaurs found from Malakhel area, Mianwali District, Punjab, Pakistan.

For scale please see the hammer. Arrow shows movement direction.

For scale please see the hammer. Arrow shows movement direction.

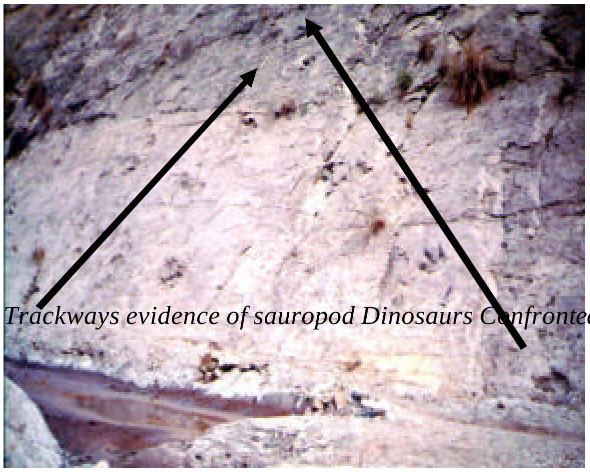

Figure 4. Footprints of sauropods confronted by a theropod,found from Malakhel area of Mianwali District, Punjab, Pakistan. Longer arrow shows the advancing movement of a Theropod, while the smaller arrow shows the advancing movements of sauropod dinosaurs. For scale please see the hammer.

5. Footprints of Dinosaurs

Sauropod trackways are notable in that they document distinct gauges. Variation in track and trackway morphology of other dinosaur clades appears to be circumstantial rather than systematic, serving to differentiate speeds, sizes, or individual ichnotaxa. For example, although hadrosaur trackways may preserve either bipedal or quadropedal locomotor habit, all hadrosaur taxa are thought to have been capable of engaging in either form of locomotion; other widespread differences between group of hadrosaur treacks are not apparent. The same is true for identifiable tracks of other ornithopods, theropods, ceratopsians,and prosauropods-none of these groups show systematic within group clustering of trackway variation (Wilson and Carrano, 1999).

Sauropod has an easily recognizable, conservative morphology. Manus impressions are generally U shaped, subtending an arc of approximately 270 degrees. The median axis of the print (passing through digit III) is oriented anterolaterally relative to the line of travel, and atrace of large pollex claw is occasional preserved. Pes impressions are always larger in an area than those of the manus, and the manus to pes ratio (referred to as heterodonty) ranges from 1:2 to1:5 in sauropods (Lockley, Farlow, and Meyer 1994). Additionally pes prints are characteristically subcircular in outline, with a well developed heel print and impressions of three or four laterally directed claws. The pes impression can partially or totally obscure that of the manus in sauropod trackways, as the pes was apparently often placed in the same location following removal of the manus from the substrate. This overlap is common in short coupled forms (Leonardi 1987).

Wide-gauge trackways have been defined as those in which manus and pes impressions are well away from the trackway midline, whereas those of narrow gauge tracks are close to or even intersect the trackway midline (Farlow 1992) (Fig.1). Farlow has identified several additional ichnomorphological correlates of narrow and wide gauge trackways. For example, whereas claw impressions are occasionally preserved in narrow gauge manus prints, they are not typically associated with wide gauge trackways. Additionally manus prints are positioned closer to the midline than are pes prints in wide gaudge trackways, where as the opposite is true of narrow gauge trackways. Farlow (1992) also described identifications in the manus prints of Brontopodus (wide gauge) that indsicate aseparation of digits II-IV from the marginal digits. The morphology is not known to occur in narrow gauge tracks.

Footprint sites of Queensland, Australia tells the story of more than 100 small bipedal dinosaurs from the early cretaceous that were seemingly stampeded into mass flight by the approach of a much larger bipedal dinosaur, probably a carnivore. The paleontologists who originally describe the site thought that the small bipedal dinosaurs represented two different species, one a theropod and the other an ornithopod. If true, the co-occurrence of the two kinds of trackway at the same spot suggests that members of each species tolerated the presence of the other, at least at times. However some paleontologists have suggested the two trackway types may belong to members of same species, so our behavioral interpretation must be rather tentative. (Farlow, 2000).

Caveats duly noted, we can now consider what dinosaur trackways suggest about their makers' social behavior. At the famous Early Jurassic locality at dinosaur State Park near Hartford, Connecticut, numerous theropod track makers traveled every which way, with no obvious pattern to their courses. Quite possibly these dinosaurs were loners. At other sites, the pattern is very different. At an Early Jurassic dinosaur tracksite near Holyoke, Massachusetts (New England), at least 20 bipedal dinosaur, all theropod, were moving together as a group. The Early Cretaceous British Colombia Canada locality where four igaunodonts appear to have moved as a unit, changing directions at the same time. One of the worlds' best known set of dinosaur footprints from the Early Cretaceous sauropod trackways from Texas. Since every individual trackway is in the same direction and in close association with others the probability that the makers were moving together is high. The past claims that the young were in a protective center have not borne out (Farlow, 2001).

At the Paluxy River site, prints made by enormous quadrupeds, with the hindfoot impressions a yard or more in length. These foot prints are made by sauropods, and at least a dozen of them moved across the main tracksites in the park. Unlike the theropod trails, which go in both directions along the inferred ancient shoreline, nearly all of the sauropod trails head in only one directions, it may representing migratory path (Farlow, 2001).

If sauropd moves in groups, then we might often expect to find monospecific bonebeds dominated by a single kind of sauropod. A few such occurrences have been reported, but most such monospecific sauropod bonebeds have only a few individual animals in them, nothing like the enormous monospecific death assemblages known for some hadrosaurs and ceratopsians. Most bonebeds that have sauropods generally contain more than one sauropod species (Farlow, 2001). Patterns in the temporal distribution of narrow and wide gauge trackways have been identified by Lockley, Farlow and Meyer (1994) and Lockley, Meyer, Hunt, and Lucas (1994). The narrow gauge tracks do form the majority of Jurassic sauropod ichnocoenoses, wide gauge tracks are well represented, particularly in the late Jurassic. Their data do, however support predominance of wide gauge tracks in the Cretaceous, as such tracks consititute atleast 96% of total trackways and 97% of total tracksites. The data of Lockley, Meyer, Hunt and Lucas (1994) suggest a more complex pattern; a mix distribution of Jurassic track types followed by increasing rarity of narrow gauge tracks through the late Jurassic and Early Cretaceous, culminating in the complete absence of narrow gauge trackways by the late Cretaceous.

Yuansheng *et. al.* (2001) mentioned semicircle/ new moon shape of the manus, and ellipse/inverse taper/ taper shape as pes impression of sauropod from the Gansu Province of China. The divarication from midline to 30 degree is also mentioned. High angle divarication shows the forward movement as splayfooted gait. He also mentioned the footprint with three strong digits and large divarication angle representing ornithopod, footprint with three slender digits having sharp claw and little divarication representing theropod, footprint with twidactyl represent also theropod and footprint with quadrupedal, tridactyl with outward rotation probably belongs to Lizard.

6. Footprints of Sauropod Dinosaurs Confronted by a Theropod found from Middle Jurassic Samana Suk Limestone of Pakistan

Remains of a diversified paleobiota are found in the middle Indus basin, which includes plants (gymnosperm), mollusks, reptiles (bone, teeth and ichnofossils). The commonest vertebrate fossils and ichnofossils belong to sauropod (Figure 2,4) and theropod (Figure 3,4) dinosaurian fauna that occurs a wide geographic area. Environmental interpretation of ichnofossil bearing lithofacies/strata allows reconstruction of sea shore marine limestone. Of all ichnofossil localities in Pakistan, one displays the theropod track. In this locality, the sauropod herd is flanked by a theropod on the right. There are four trackways of sauropod and one trackway of theropod, having about 15 footprints in a 1500 square feet area. Further exploration of footprints in the Sammanasuk limestone in the upper Indus Basin, Loralai and Chiltan limestone in the middle and lower Indus basin are encouraging and can reveal the best results. Malkani previously recorded one foot print of juvenile sauropod from the Mula area, Khuzdar district, Balochistan.

The fossil tracks are found on the limestone bed of Middle Jurassic Sammana Suk Formation.The footprint bearing strata are found in the upper successions of Middle Jurassic Sammana Suk Formation **(Figure 2-5).** The upper succession consists of marine limestone, possibly deposited near the sea shore. It is no doubt the footprint bearing limestone is marine and footprints show the slight regression of sea and area was exposed as near sea shore and already deposited lime clay received the dinosaur footprints. The sauropod and theropod ichnofossils of upper Indus Basin are a unique record of a middle Jurassic dinosaurian fauna which inhabited the north western margin of Indo-Pakistan sub continental plate. A gregarious behavior is deduced from the analysis of these ichnocoenoses. At the time of dinosaur extinction, all of the dinosaur and few of others biota becamextinct. The extinction may be due to catastrophic flood, droughts and volcanic eruptions.

Figure 5. Footprints obirds/Avian/theropod dinosaurs, found on the middle Jurassic limestone of Malakhel area, Mianwali District, Balochistan, Pakistan.

Malkani (2005a, fig.69) have reported a foot print of a juvenile primitive Titanosauria found on the fragment of Chiltan Limestone (middle Jurassic) of Jhukkur area, Mardan nala of Mula Zahri Range (lower Indus basin/ Kirthar foldbelt). It is an ellipse of about 15 cm diameter. It has well preserved three small digits. The manus print is partially overlapped by the pes print. Remains of a diversified paleobiota are found in the middle Indus basin, which includes plants (gymnosperm), mollusks, reptiles (cranial and post cranial bones). The commonest vertebrate fossils belong to sauropod and theropod dinosaurs, and mesoeucrocodilian fauna that occur a wide geographic area. Recently the author have found footprints of sauropod confronted with a theropod (Figure 2-4) found from the middle Jurassic Samana Suk Limestone of Surghar Range, Mianwali District, Punjab Province, Pakistan. Footprints of birds/Avian/theropod dinosaurs **(Figure 5),** found on the middle Jurassic limestone, in the vicinity of dinosaurs' footprints locality, Malakhel area, Mianwali District, Balochistan, Pakistan. Many visitors visit Baroch section of Malakhel area every year due to easy accessibility and best stratigraphic exposure. But the recent studies have broadened their distribution to the upper Indus Basin of Punjab Province, Pakistan.

Sauropod dinosaurs were the largest animals to inhabit the land. Sauropoda has a global affinity. Five species of latest Cretaceous sauropod (Malkani, 2004a, Malkani, 2005a) and one species of Late Jurassic sauropod (Malkani, 2003c) from Pakistan have already been established. But one new genus and species ***Malasaurus mianwali*** of middle Jurassic sauropod is hereby tentatively erected. The holotype/ ichnotype belong to three tracks consisting of exposed 10 footprints (Figure 4). Ichnotype/ holotype footprints are found in middle Jurassic Samana Suk Formation of Baroch nala, Mala khel area, Mianwali District, Punjab Province, Pakistan (32^0 55.50" N; 071^0 09.00" E). Age of the ichnotype foot prints is deduced from the host formation which is middle Jurassic after Fatmi (1977). The dip of host limestone strata is 52^0 west and strike is north 5^0 east. The dip of the strata is high and creates problem to take measurement of the footprints and trackways. This limestone is white brown as weathered, and white to light grey as fresh, thin to thick bedded, interbedded with light grey to greenish grey calcarious shale.

The name ***Mala,*** honoring the dinosaurs' host Malakhel area; ***saurus*** means reptile. The species specific epithet ***mianwali*** is deduced from the name of footprint host district. Large pes foot print having length/width about 1 meter are diagnosed only for a large bodied sauropod (Figure 2,4). The manus footprints are totally overlapped by the pes prints.

These tracks suggest the narrow gauge trackways. That is the reason these are not referred to previously erected species of titanosaurs from Pakistan, because they may belongs to wide gauge trackways. These footprints are surely assigned to sauropod, but its assignment to lower level is difficult.

Carnosaurian dinosaurs were the largest carnivorous animals to inhabit the land. Theropoda has global occurrences while tyranosaurids have Laurasian affinity and abelisaurids have Gondwanan affinity. The eleven named species from the Lameta formation of India actually represent at least three large bodied theropod (*Rajasaurus, Indosuchas, Indosaurus*) and a fourth, small bodied theropod (*Laevisuchas*) (Wilson, et al. 2003). But from Pakistan, there are some evidences of two large bodied theropod, and one small bodied theropod of Late Cretaceous age. Malkani (2004a) reported one species *Vitakridrinda,* of large bodied theropod and the other large bodied theropod evidences are based on only two types of vertebrae and teeth. One type of vertebrae is tall and other type is cylindrical. One type of teeth is D shape while the other is oval. The small bodied theropod is only based on a hollow surrouded by thin bone found on cross section of bone. One new genus and species ***Samanadrinda surghari*** of large bodied theropod based on only ichnofossils, is hereby tentatively erected. A track consisting of exposed 5 footprints is considered as holotype/ichnotype (Figure 3,4). Ichnotype/ holotype footprints are found in middle Jurassic Samana Suk Formation of Baroch nala, Malakhel area, Mianwali District, Punjab Province, Pakistan. Age of the ichnotype foot prints is deduced from the host formation which is middle Jurassic after Fatmi (1977). The name ***Samana,*** honoring the dinosaurs' host geologic formation; and ***drinda*** is a Seraiki and Urdu word means beast. The species specific epithet ***surghari*** is deduced after the name of Surghar Range which is the host of ichnotype area. Three slender toed foot prints having maximum length about 2 feet and width about 1.5 feet are diagnosed only for a large bodied theropod (Figure 3). The other toed are not marked on footprints. These footprints are surely assigned to Theropod, but its assignment to lower level is difficult. Because until now, no theropod fossils from these strata are collected. Both the sauropod and theropod genera erected are purely tentative and named only to refer for future research work regarding locomotion, behavior, soft and hard tissues. This ichnotype reveal the scenario of confrontation among a carnivorous ***Samanadrinda surghari*** theropo and the groups of herbivorous ***Malasaurus Mianwali*** sauropods.

This ichnocoenosis consists of exposed about 15 footprints, and 4 short trackways. Three trackways are interpreted as mainly produced by sauropods which are obliquely confronted by a track of large Theropod. They are indicative of a sauropod herd, composed of 3 or more individuals and furnish evidence of gargariousness (herd). The ichnofossils are usually deep footprints probably due to good granolometric sorting and the high plasticity of the limy substrate. In the vicinity, some foot prints of possibly birds/ small body theropod/coelorusaurs are also present. The footprint bearing strata are found in the upper successions of Middle Jurassic Sammana Suk Formation. The upper succession consists of marine limestone, possibly deposited near the sea shore. It is no doubt the footprint bearing limestone is marine and footprints show the slight regression of sea and area was exposed as beach and already deposited lime clay received the dinosaur footprints. Further exploration of footprints in the Sammanasuk limestone in the upper Indus Basin, Loralai and Chiltan limestone in the middle and lower Indus basin, and other Mesozoic strata are encouraging and can reveal the best results.

The sauropod and theropod ichnofossils of upper Indus Basin are a unique record of a middle Jurassic dinosaurian fauna which inhabited the north western margin of Indo-Pakistan sub continental plate. A gregarious behavior of herbivorous sauropods defending the attack of predatory theropod is deduced from the analysis of these ichnocoenoses.

7. Conclusions

The sauropod and theropod ichnofossils of upper Indus Basin are a unique record of a middle Jurassic dinosaurian fauna which inhabited the north western margin of Indo-Pakistan sub continental plate. A gregarious behavior of herbivorous sauropods defending the attack of predatory theropod is deduced from the analysis of these ichnocoenoses.

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