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Status assessment of the Indus River dolphin, *Platanista gangetica minor*, March–April 2001

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ABSTRACT

A survey was conducted in March and April 2001, to assess the status of the Indus River dolphin, *Platanista gangetica minor*, throughout its present range. A total of 1535 km of survey effort was conducted, consisting of 1375 km of the Indus River main channel, 136 km of Indus River secondary channels, and 24 km of the Panjnad River, a tributary of the Indus. The effective range of the Indus dolphin has declined by 80% since 1870. The sum of best group size estimates produced an abundance estimate of 965 dolphins. Extrapolation of encounter rates to un-surveyed channels and application of a correction factor to account for missed dolphins indicates that the metapopulation may number approximately 1200 individuals. Dolphins occur in five subpopulations separated by irrigation barrages. A pronounced increase in dolphin abundance and encounter rate was observed in each subsequent downstream subpopulation (except the last). The three largest subpopulations were between Chashma and Taunsa Barrages (84 dolphins; 0.28/km), Taunsa and Guddu Barrages (259 dolphins; 0.74/km) and Guddu and Sukkur Barrages (602 dolphins; 3.60/km). Reasons suggested for the high encounter rate between Guddu and Sukkur Barrages, include high carrying capacity, low levels of anthropogenic threat, effective conservation, and augmentation of the subpopulation by downstream migration of dolphins from upstream.

1. Introduction

1.1. Background

The Indus River dolphin, *Platanista gangetica minor,* is endemic to Pakistan and occurs only in the Indus River system. The Indus River has five main tributaries; the Jhelum, Sutlej, Chenab, Ravi and Beas Rivers. These rivers merge with one another to form the Panjnad River, which then joins the Indus mainstem (Fig. 1). The Indus leaves the Himalayan foothills and enters the plains at Kalabagh town; 3 km upstream of Jinnah Barrage. From Kalabagh it flows at a gentle gradient (averaging 13 cm/km), primarily SSW, for approximately 1600 km, to its confluence with the Arabian Sea. It runs through semi-desert and irrigated agricultural land, as well as some small remnant areas of native riverine scrub forest located between Guddu and Sukkur Barrages. Human habitation is sparse but increases with proximity to the delta. The only large towns are Dera Ismail Khan in North Western Frontier Province (NWFP), and Sukkur and Hyderabad in Sindh Province. The river is not used for commercial traffic, and the few vessels present are oar-powered ferries and fishing boats.

Historically, the Indus River dolphin occurred in approximately 3400 km of the Indus River and its five tributaries, from the estuary upstream into the foothills of the Himalayas, where distribution was limited by rocky barriers, high

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Fig. 1 – Indus River system, irrigation barrages and high dams in Pakistan.

velocities, or shallow water (Anderson, 1879). The Indus River dolphin now occupies approximately one fifth of this former range (Reeves et al., 1991) and was listed as 'Endangered' in the 2004 IUCN Red List (Braulik et al., 2004).

1.2. *Fragmentation*

The Indus River dolphin population was fragmented by construction of the Indus Basin Irrigation System (IBIS). The irrigation system, claimed to be the largest in the world, consists of 19 barrages, 12 inter-river link canals, and two million kilometers of tertiary watercourses (Hassan et al., 1999). The system has immense political and economic importance as its waters irrigate more than 180,000 km^2 of arid and semi-arid land, irrigated agriculture accounts for 90% of Pakistan's agricultural produce and agricultural goods for approximately 55% of Pakistan's exports (CIA, 2004; FBSP, 2003; Ahmad, 1993). Barrages are low, gated diversion dams comprised of a series of gates used to control the elevation of an upstream 'head pond'. The head pond is maintained not to store water, but to aid the diversion of water into lateral canals. Barrages also restrict the movement of river dolphins and other aquatic megafauna, thereby separating them into subpopulations. Reeves et al. (1991) questioned the degree to which dolphin subpopulations are isolated, suggesting that individuals may occasionally move downstream through barrages.

Dolphins in the Indus mainstem were split into two subpopulations, and isolated from those in the five Punjab tributaries, in 1932 when Sukkur and Panjnad Barrages were completed. Completion of Taunsa (1959) and Guddu (1962) Barrages, further fragmented the Indus mainstem population into four subpopulations. Dolphins have now been extirpated from the Indus mainstem upstream of Jinnah Barrage, downstream of Kotri Barrage and from the Indus tributaries. Today they occur in five subpopulations bounded by Jinnah, Chashma, Taunsa, Panjnad, Guddu, Sukkur and Kotri Barrages (Fig. 1).

1.3. *Habitat*

Indus River discharge is highly seasonal. Peak flows of approximately 20,000–22,500 m^3/s occur between June and August when the river is fed by Himalayan melt-water and monsoon run-off, while flows as low as 340 m^3/s occur in the dry season between December and April. The system is highly modified and managed, and the natural flow regime has been significantly disrupted. Large-scale diversion of river water for irrigation in the dry season causes discharge to diminish as the river flows towards the Arabian Sea. For part of the dry season the river is de-watered downstream of Kotri Barrage and no water flows through the delta into the Arabian Sea. Consequently, dolphins are no longer found downstream of Kotri barrage.

Following partition of British India in 1947, the Indus Waters Treaty of 1960 allocated water in the Ravi, Beas and Sutlej Rivers to India and the Indus, Chenab and Jhelum

Rivers to Pakistan. In the dry season, the three rivers allocated to India enter Pakistan virtually dry and almost all flow from the remaining two tributaries is utilised by Pakistan with the result that the lower reaches of all five Indus tributaries are frequently de-watered. While there were occasional reports of dolphin sightings in the Indus tributaries during the 1980s (Pelletier and Pelletier, 1980; Roberts, 1997) reports have ceased, and it is likely that dolphins have been completely extirpated from these rivers due to insufficient and inconsistent water supplies.

1.4. *Previous dolphin surveys*

Abundance monitoring of the three largest dolphin subpopulations has been conducted since the early 1970s, using direct visual counts from vessels or point counts from the riverbank. Methods were insufficiently recorded to evaluate bias, estimate precision, or reliably detect trends in abundance from the data. In addition, the Sindh and Punjab wildlife departments used different survey methods, precluding direct comparison of counts between Provinces. All published Indus River dolphin abundance estimates for the Guddu–Sukkur, Taunsa–Guddu and Chashma–Taunsa subpopulations are presented in Table 1. This table is an expansion and update to previous compilations of count data published by Reeves and Chaudhry (1998), Bhaagat (1999) and Gachal and Slater (2002). Where several counts were conducted in the same year and month, only the highest count is presented.

The survey data implies that each subsequent downstream subpopulation (except Sukkur–Kotri) is larger than the one above. The data also indicate that, since the 1970s, there has been a steady increase in abundance of the Taunsa–Guddu and Guddu–Sukkur subpopulations. This apparent increase may be due to differences in survey methods, a real increase, or a combination of these.

During the last 30 years, there have been occasional reports, but no consistent monitoring, of small dolphin subpopulations, in the Indus mainstem, at the up and downstream ends of the current known distribution. Between Jinnah and Chashma Barrage, from 1 to 4 dolphins were reported in the 1970s and 1980s (Pilleri and Bhatti, 1978; Pilleri and Pilleri, 1979; Niazi and Azam, 1988) and between Sukkur and Kotri Barrage 21 animals were reported in the mid 1980s (Khan and Niazi, 1989) and 30 in the early 1990s (Gachal and Slater, 2002).

There has been considerable international concern regarding the endangered status of the Indus River dolphin and the IUCN Cetacean Specialist Group has urged for cooperation between provincial wildlife departments and for range-wide surveys using accepted river dolphin survey techniques to comprehensively assess the status of the dolphin subspecies (Reeves and Leatherwood, 1994; Reeves et al., 2003). The survey presented in this paper was designed to address this need.

2. Methods

The survey was conducted between 12 March and 27 April, 2001, and covered 1375 km of the Indus River from Jinnah Barrage (N32° 55.0; E71° 30.9) to Kotri Barrage (N25° 26.7; E68° 18.7) (Fig. 1). This area was selected for survey as it included the location of all confirmed Indus River dolphin sightings since 1980. Early spring is the optimum time to conduct an abundance survey as Indus discharge is at its annual minimum and dolphins are concentrated into a narrower channel and are therefore easier to count. This survey was conducted during a period of extended drought in Pakistan, and dry season river discharge was therefore lower than average.

Survey methods generally followed those described by Smith and Reeves (2000) for Asian river dolphins in wide-channel habitat. Observers, consisting of provincial wildlife department and conservation Non-governmental Organisation (NGO) staff, were trained in dolphin survey techniques prior to the survey. Surveying was conducted from oar-powered wooden boats travelling at 5–7 km/h in a downstream direction. The vessel surveyed a single transect, following the deepest channel and moved from bank to bank as the channel meandered. Observers surveyed with the naked eye and Nikon 7×50 binoculars from a viewing platform approximately 3 m above the water surface. Surveys were conducted using three forward observers, one rear observer, and a data recorder. The rear observer was responsible for detecting animals missed by the primary observation team and also assisted the primary team in group size estimation and group tracking. Team members rotated positions every 30 min and received a rest period to maintain alertness.

Environmental conditions were recorded at the beginning and end of each period of surveying, when observers rotated positions and when conditions changed. The effect of wind on the river surface was evaluated according to the following scale: 0 = Water surface glassy; 1 = ripples without crests; 2 = small wavelets with crests but no white-caps; 3 = large wavelets with scattered white-caps; 4 = small waves with fairly frequent white-caps. Visibility was assessed as: 0 = clear; 1 = visibility less than 2 km; or 2 = visibility less than 1 km. When viewing conditions deteriorated to river surface state '3' or visibility code '2' surveying was postponed until conditions improved. Garmin 3+ GPS units were used to record the survey track and location of all sightings.

2.1. *Sightings*

Unlike many marine dolphins, Indus dolphins do not form easily defined, interacting groups. Instead, they are frequently observed in loose aggregations with little apparent interaction between individuals. For the purposes of this study, a dolphin group was defined as dolphins no more than 500 m apart, within an area of similar hydrological characteristics (Smith and Reeves, 2000). High turbidity of the Indus River prevented dolphins being sighted prior to surfacing.

When a dolphin was sighted, the vessel continued moving downstream but active surveying for new dolphin groups was temporarily suspended while observers focused on obtaining an accurate group size estimate. All sightings were confirmed by a second observer. Group sizes were evaluated with a best, high and low estimate of numbers to incorporate a degree of uncertainty. A low and best estimate of zero was used if the sighting was unconfirmed or if there was a possibility that the dolphin was following the vessel and might have already been counted (Smith, 1994). Good coordination between all

Table 1 – Published counts of Indus River dolphins between Chashma, Taunsa, Guddu and Sukkur Barrages

Guddu–Sukkur subpopulation			Taunsa–Guddu subpopulation			Chashma–Taunsa subpopulation		
Date	Count	Reference	Date	Count	Reference	Date	Count	Reference
Jan 1974	138	Pilleri and Zbinden (1973–74)	Apr 1979	36	Pilleri and Bhatti (1980)	Oct–Nov 1987	39	Niazi and Azam (1988)
Dec 1974	182	Kasuya and Nishiwaki (1975)	Dec 1983	72	Chaudhry and Khalid (1989)	Winter 1987	47	Chaudhry et al. (1999)
Feb 1977	171	Pilleri and Bhatti (1978)	Apr 1985	61	Khan and Niazi (1989)	Mar 1989	15	Chaudhry and Khalid (1989)
Apr–May 1977	187	Pilleri and Bhatti (1978)	Aug 1985	71	Chaudhry and Khalid (1989)	April 1990	20	Chaudhry et al. (1999)
May 1977	198	Pilleri (1977)	Sept–Oct 1985	62	Khan and Niazi (1989)	Nov 1991	35	Chaudhry et al. (1999)
Oct 1977	168	Pilleri and Bhatti (1978)	Oct–Nov 1987	62	Niazi and Azam (1988)	Nov 1992	49	Chaudhry et al. (1999)
Feb–Mar 1978	191	Pilleri and Bhatti (1978)	Mar 1989	83	Chaudhry and Khalid (1989)	Nov 1993	51	Chaudhry et al. (1999)
May 1978	241	Pilleri and Bhatti (1978)	Apr 1990	107	Chaudhry et al. (1999)	Mar 1994	34	Chaudhry et al. (1999)
Apr 1979	240	Pilleri and Bhatti (1980)	Nov 1991	108	Chaudhry et al. (1999)	Nov 1994	62	Reeves and Chaudhry (1998)
June 1979	292	Pilleri and Bhatti (1980)	Nov 1992	124	Chaudhry et al. (1999)	Apr 1995	38	Chaudhry et al. (1999)
Sept 1979	291	Pilleri and Bhatti (1980)	Nov 1993	111	Chaudhry et al. (1999)	Apr 1996	43	Chaudhry et al. (1999)
Feb 1980	291	Bhatti and Pilleri (1982)	Mar 1994	128	Chaudhry et al. (1999)	Winter 1997	39	Chaudhry et al. (1999)
Apr 1980	346	Bhatti and Pilleri (1982)	Nov 1994	100	Reeves and Chaudhry (1998)	Winter 1998	31	Chaudhry et al. (1999)
Mar–Apr 1982	360	Bhaagat (1999)	Apr 1995	117	Chaudhry et al. (1999)			
Mar 1986	429	Khan and Niazi (1989)	Apr 1996	124	Chaudhry et al. (1999)			
March 1987	450	Reeves and Chaudhry (1998)	Dec 1996	143	Reeves and Chaudhry (1998)			
Apr–May1989	368	Bhaagat (1999)	Winter 1997	90	Chaudhry et al. (1999)			
Mar–Apr 1990	387	Bhaagat (1999)	Winter 1998	100	Chaudhry et al. (1999)			
Mar–Apr 1991	398	Bhaagat (1999)						
Mar–Apr 1992	410	Bhaagat (1999)						
1992	439	Reeves and Chaudhry (1998)						
Mar–Apr 1993	426	Bhaagat (1999)						
Mar–Apr 1994	435	Bhaagat (1999)						
Mar–Apr 1995	447	Bhaagat (1999)						
Apr–May 1996	458	Mirza and Khurshid (1996)						
May 1999	104	Gachal and Slater (2002)						
June 1999	220	Gachal and Slater (2002)						
Aug 1999	367	Gachal and Slater (2002)						

observers, especially forward and rear observers, was essential to obtain an accurate estimate of group size as the vessel moved downstream through the group.

Dolphin groups were generally sighted downstream of the survey vessel. When a group was sighted the 'detection' location was recorded via GPS, a second 'exact' location was recorded when the boat was located in the centre of, or perpendicular to the group. When the vessel was abeam of the group, channel width was recorded by adding the distance from the vessel to each bank, measured using laser range finders when less than 800 m or estimated visually, if greater.

The probability of double counting dolphins due to their movement from surveyed to un-surveyed reaches overnight, was considered to be balanced by the probability that an equal number of dolphins were missed due to their movements in the opposite direction.

2.2. *Survey of secondary channels*

Satellite images of the Indus River acquired by LANDSAT (30 m resolution) in November 2000 were georeferenced and used for survey planning and navigation. Recent images were essential, as the annual flood causes significant morphological changes of Indus River channels. Satellite images were examined to identify split channels, side channels and multi-threaded channels (hereafter termed collectively 'secondary channels'). In reaches where more than one channel was present, a decision, based on width and estimated proportion of discharge, was made as to which branch constituted the main channel. The primary survey vessel was always deployed on the main channel, resulting in unbroken main channel survey effort. In order to survey all potential dolphin habitat, a second survey boat was deployed to simultaneously survey significant secondary channels. Between Jinnah and Guddu Barrages, the Indus River was often highly braided and there were many mid-channel bars and islands, whereas downstream of Guddu Barrage the river changed character and became a single meandering channel. Consequently, most secondary channel survey effort was conducted between Jinnah and Guddu Barrages.

Geographic coordinates of the beginning and end points of each secondary channel were recorded. The primary survey vessel recorded all animals in the main channel as well as those located at the junctures of main and secondary channels. The second survey boat recorded only animals located exclusively in secondary channels. Two-way radio contact was maintained between survey vessels to avoid double counting at divergences and confluences.

2.3. *Correction of abundance estimate*

Availability and perception biases in direct count surveys result in underestimates of absolute abundance (Marsh and Sinclair, 1989). To quantify the number of dolphins missed during this survey, upstream of Guddu Barrage duplicate survey effort was opportunistically conducted from a vessel travelling from 1 to 5 km behind the primary survey vessel. Survey methods were identical on both vessels and observers rotated between teams. However, the second vessel travelled at greater speed (approximately 8 km/h) and used a motor. Primary and duplicate survey data were compared only when sighting conditions were good (i.e., river surface state <2) for both survey vessels. Sightings from the duplicate survey were considered as missed by the primary vessel if they were greater than 750 m from another group according to the 'exact' GPS position. The number and percentage of dolphin groups missed by the primary survey vessel was determined and this factor used to correct the abundance estimate to account for undetected animals. It was recognised that because of the time lag between the two surveys, there was potential for groups to move and be determined as missed by the primary team when they were actually sighted, resulting in a positively biased correction factor. However, there is evidence that Platanista form fairly stable aggregations in preferred habitat (Pilleri, 1970; Pilleri and Bhatti, 1978; Niazi and Azam, 1988; Smith, 1993) and that in general, except for possible seasonal migration, individuals do not move large distances along the river axis.

2.4. *River discharge*

Pakistan's Indus River System Authority (IRSA) calculates discharge daily at each barrage. The mean discharge for each river section during the survey period was calculated considering the daily discharge at the upstream barrage, the number of days spent surveying that river section and the flow pulse time (i.e., time required for water to flow from one barrage to the next) (Associated Consulting Engineers – ACE (Pvt.) Ltd., 1998) (Table 2).

2.5. *Data analysis*

Abundance was calculated by summing 'best' group size estimates. High and low estimates of group size were totalled to give high and low estimates of overall abundance. Unless stated otherwise, reported abundance always refers to the sum of best group size estimates. To investigate variations in dolphin encounter rate throughout the range of the Indus River dolphin, as well as within each subpopulation, a moving average of dolphins/km was plotted. Main channel sightings were plotted according to their 'river distance' (RD), along the main channel thalweg, from the immediate upstream barrage. Secondary channel sightings were assigned a mainstem river distance in order to present a realistic description of encounter rate across the whole width of the river. This was calculated according to the following equation:

$$\mathrm{RD}_{\mathrm{adj}} = \mathrm{RD}_{\mathrm{div}}\left(\frac{\lambda_{\mathrm{sc}}}{\lambda_{\mathrm{mc}}}\right)s_{\mathrm{sc}}$$

Table 2 – Dry season flow pulse time between barrages on the Indus River

River section	Pulse time (days) Nov–Mar
Jinnah–Chashma	1
Chashma–Taunsa	4
Taunsa–Guddu	4
Guddu–Sukkur	2
Sukkur–Kotri	5

where RD_{adj}, the adjusted main channel river distance of the secondary channel sighting; RD_{div}, the river distance at the point the secondary channel diverges from the main channel; λ_{sc}, the total length of the secondary channel; λ_{mc}, the length of the main channel segment between the point where the secondary channel diverged, and the point where the channels converged; and s_{sc}, the distance between the secondary channel divergence and the sighting as measured down the centre of the secondary channel.

A 20 km averaging interval was selected as an appropriate segment length as it consistently incorporated two full meander loops and therefore included a representative range of different habitat types (Gordon et al., 1992).

To investigate the null hypothesis that dolphins are evenly distributed within each subpopulation, the RD's of all dolphin groups were averaged to give a 'central position' for each subpopulation. The sum of the distances at which dolphins are found upstream of the central point is equal to the sum of the distances at which dolphins are found downstream of the point.

3. Results

3.1. Distribution and abundance

A total of 1534.2 km of survey effort was conducted, consisting of 1374.8 km of the Indus River main channel, 135.6 km of secondary Indus River channels, and 23.7 km of the Panjnad River upstream from its confluence with the Indus. Sighting conditions were generally excellent, with 90% of effort conducted in river surface state 0% or 1% and 100% with clear visibility. All potential dolphin habitat was surveyed, including main and secondary channels, except for two reaches between Guddu and Sukkur Barrages. A 33.1 km reach of the Indus River main channel, and 22 km of a large secondary channel were not surveyed due to security concerns. At the time of the survey, there was no water release from the Panjnad Barrage and the Panjnad River immediately downstream of the barrage was dry. Therefore, the Panjnad River was surveyed only when it became navigable, from approximately 10 km downstream of the barrage to its confluence with the Indus.

Dolphins were observed in approximately 1000 km of the Indus River and were present in five subpopulations separated from one another by barrages. Approximately 99% of the dolphin population occurred in 690 km of river length. No dolphins were seen in the Panjnad River. Dolphins were occasionally sighted in secondary channels, but generally encounter rates were very much lower than those in the main channel (Table 3).

An abundance estimate of 965 Indus River dolphins was produced from the sum of the best estimates of group size. The sum of the low estimates and the high estimates of group size were 843 and 1171 animals, respectively. Encounter rates increased as the survey proceeded downstream to Sukkur Barrage (Fig. 2 and Table 4). Only two dolphins were recorded in the furthest upstream subpopulation between Jinnah and Chashma Barrages. The sum of best group size estimates between Chashma and Taunsa Barrages, was 84 dolphins (0.28 dolphins/km), between Taunsa to Guddu Barrages, 259 (0.74 dolphins/km) and between Guddu and Sukkur Barrages, 602 dolphins (3.60 dolphins/km) were recorded. In the final downstream subpopulation, located between Sukkur and Kotri Barrages, only 18 dolphins were observed. A summary of survey results for each dolphin subpopulation is presented in Table 4.

Table 3 – Dolphin encounter rates in main and secondary Indus River channels

Subpopulation	Mean number of dolphins/km	
	Main channel	Secondary channels
Chashma–Taunsa	0.27	0.04
Taunsa–Guddu	0.68	0.26
Total	0.49	0.18

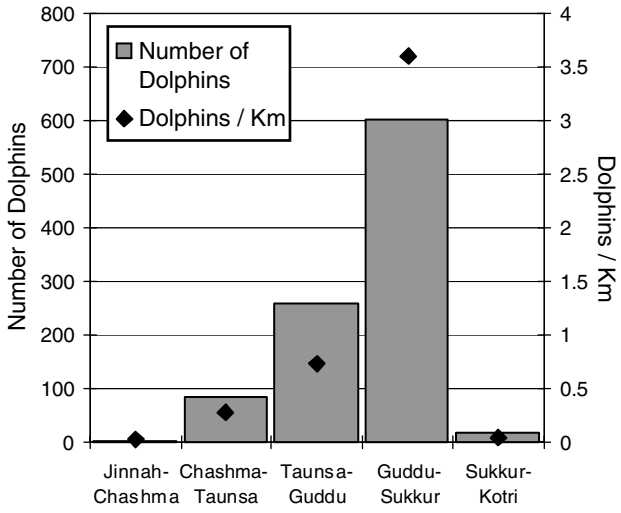

Fig. 2 – Encounter rate and abundance of Indus dolphins in each subpopulation.

3.2. Correction of abundance estimate

Between Guddu and Sukkur Barrages, survey coverage was incomplete and dolphin abundance in this subpopulation was therefore assumedly underestimated. To estimate the number of animals present in the un-surveyed reaches and give a realistic indication of the size of the Guddu to Sukkur subpopulation, dolphin encounter rates were extrapolated to the un-surveyed reaches from those recorded in similar habitat, elsewhere in the subpopulation. In a reach of high dolphin encounter rate, between Guddu and Sukkur, 33.1 km (16.7%) of the main channel were not surveyed. Examination of satellite images showed that the un-surveyed reach (105.6–138.7 km downstream from Guddu Barrage) consisted of a single sinuous channel. Therefore, the mean encounter rate for single channel survey effort between Guddu and Sukkur Barrages (3.60 dolphins/km) was extrapolated to the un-surveyed reach. This indicated that approximately 120 dolphins may have been missed. At a point 70 km downstream of Guddu Barrage, a large secondary channel diverged from the Indus, rejoining a further 31.8 km downstream. Only

Table 4 – Summary of Indus River dolphin, *Platanista gangetica minor*, survey results – Mar–Apr 2001

#	Section of the Indus River	Discharge (m^3/s)	Abundance	Distance surveyed (km)	Dolphins/km	Mean group size (Group size range)	% of Population
1	Jinnah to Chashma	360	2	68.2	0.03	–	0.2
2	Chashma to Taunsa	470	84	303.5	0.28	1.87 (range = 1–7)	8.7
3	Taunsa to Guddu	400	259	348.8	0.74	2.07 (range = 1–11)	26.8
4	Guddu to Sukkur	360	602[a]	160.1[b]	3.60[c]	4.39 (range = 1–25)	62.4
5	Sukkur to Kotri	110	18	494.3	0.04	2.25 (range = 1–4)	1.9
6	Total for Indus River	–	965	1374.8	–	3.02 (range = 1–25)	100.0

a Thirty four dolphins opportunistically sighted in 33.1 km of un-surveyed main channel are included in this estimate but excluded from all other analyses.
b Does not include 33.1 km of mainstem that was not surveyed.
c Calculated only using data where all parallel main and secondary channels were surveyed.

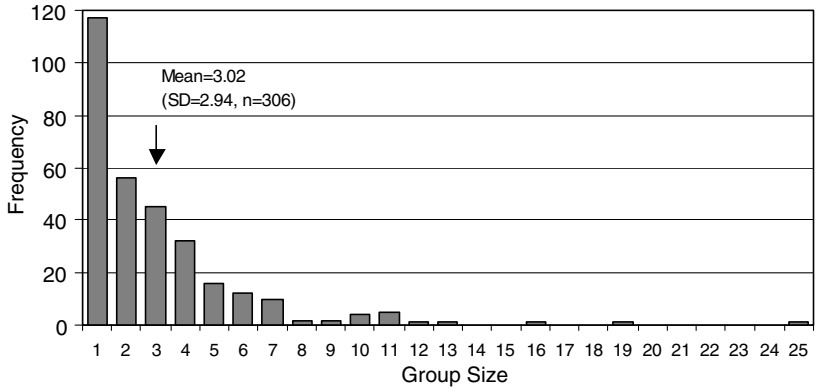

Fig. 3 – Size of Indus dolphin groups encountered on the Indus River, March–April 2001.

the downstream 12 km of this secondary channel was surveyed, leaving 19.8 km un-surveyed. Examination of satellite images showed the secondary channel to be morphologically similar throughout and therefore the encounter rate of 1.92 dolphins/km recorded in the surveyed part of the channel was extrapolated to the un-surveyed portion. This indicated that approximately 38 dolphins may have been missed. Inclusion of extrapolated estimates to the survey results indicate that abundance of the Guddu to Sukkur subpopulation is approximately 725, and for the entire metapopulation approximately 1100.

Duplicate survey effort and concurrent dolphin counts were conducted on 170 km of the Indus main channel, during which 51 dolphin groups were sighted. Analysis indicated that only 5 dolphin groups, corresponding to 9.8% of the total, were missed by the primary survey vessel. If this correction factor is applied to the abundance estimate above of 1100 then the corrected estimate of abundance for the subspecies population is approximately 1200 individuals.

3.3. *Group size*

Group size ranged from 1 to 25 individuals with single animals most frequently encountered (Fig. 3). As dolphin encounter rate and subpopulation abundance increased, there was a corresponding increase in mean group size. Between Chashma and Taunsa Barrages 1.87 (SD = 1.16) dolphins/group were recorded, between Taunsa and Guddu, 2.07 (SD = 1.7) dolphins/group, and the largest mean group size, 4.39 (SD = 3.76), were recorded between Guddu and Sukkur Barrages (Table 4). The largest dolphin group, which comprised 25 animals, was located in a large pool immediately downstream of Guddu Barrage. Between Guddu and Sukkur Barrages, dolphin encounter rate was extremely high and dolphins were distributed almost continuously along the river channel with no distinct separation between aggregations. We used 'groups' to facilitate counting in this river section, but reported group sizes do not necessarily reflect social organisation or affiliations of this subpopulation.

3.4. *Encounter rates*

Encounter rates varied considerably both between and within subpopulations. To illustrate this variation graphically, encounter rates were averaged over a 20 km interval and plotted according to their river distance from each barrage (Fig. 4). Where survey effort was incomplete encounter rates from similar habitat (described fully in Section 3.2) were inserted. The following describes the variation in dolphin distribution and encounter rates recorded within each subpopulation.

Between Jinnah and Chashma Barrages, two dolphins were sighted 24.4 km (36% of the river distance) downstream from Jinnah Barrage. Between Chashma and Taunsa Barrages, encounter rates peaked at approximately 160 and 220 km below Chashma. Very few dolphins were sighted within the first 100 km downstream of Chashma Barrage and the central point of dolphin distribution was biased downstream, 62% of the distance from Chashma.

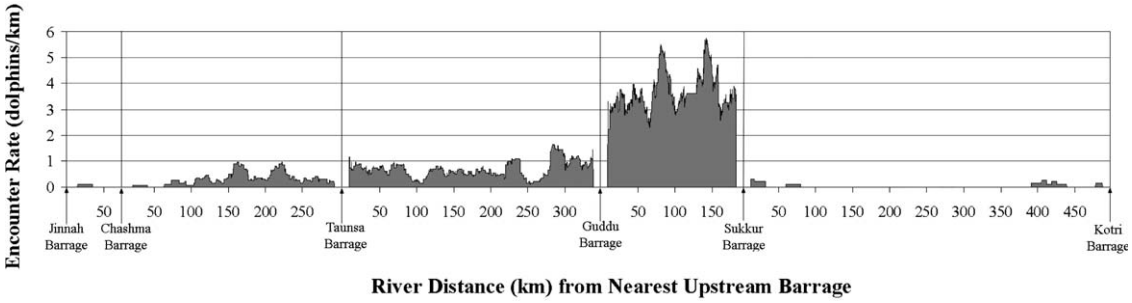

Fig. 4 – Twenty kilometres moving average encounter rate of Indus River dolphins between Jinnah and Kotri Barrages.

Between Taunsa and Guddu Barrages, dolphin encounter rates peaked immediately downstream of Taunsa Barrage and between the Panjnad River confluence and Guddu Barrage. Low dolphin encounter rates in the vicinity of Chacharan, 250–270 km from Taunsa, were probably due to high winds encountered in that area and may not truly reflect low dolphin abundance. In general, dolphin encounter rates in this subpopulation showed a gradual downstream increase and the central point of dolphin distribution was biased downstream, 54% (187 km) of the distance between Taunsa and Guddu Barrages.

Dolphin encounter rates in the Guddu to Sukkur dolphin subpopulation were consistently very high, peaking at 5.05 dolphins/km between 139 and 159 km from Guddu Barrage. The central point of dolphin distribution in the Guddu to Sukkur subpopulation was not calculated due to the lack of continuous survey effort throughout the section.

Between Sukkur and Kotri Barrages, dolphins were seen within 70 km of Sukkur Barrage and 150 km of Kotri Barrage, and no dolphins were observed for 275 km in the middle of this river section. While hydrological characteristics of the river were not measured during the survey, it was noted that deeper water was found close to the barrages.

4. Discussion

4.1. *Distribution*

The linear extent of occurrence of the Indus River dolphin has declined from approximately 3400 km of the Indus mainstem and its tributaries in the 1870s (see Anderson, 1879) to approximately 1000 km of only the mainstem today. This decline is primarily due to fragmentation of the dolphin population by irrigation barrages combined with habitat degradation caused by large-scale water abstraction from the Indus River system. An estimated 99% of the dolphin population occurs in only 690 km of river, which corresponds to almost an 80% reduction in effective range from 1870 (Anderson, 1879).

4.2. *Abundance*

The corrected abundance estimate (1200 dolphins) is likely to be an underestimate, but close to the absolute abundance of the subspecies. Comprehensive geographic survey coverage resulted in almost all potential dolphin habitat, including secondary channels, being surveyed. Where small sections of river were not surveyed, data were extrapolated to estimate the number of individuals in those reaches. In the field, measures were taken to increase detection opportunities by using experienced observers, non-motorized vessels travelling at a relatively slow mean survey speed, a rear facing observer to detect animals missed by the forward facing observer team and by surveying only during excellent or good viewing conditions. Despite the efforts taken to maximise detection of dolphins during the survey, some quiescent animals were likely missed during infrequent windy weather. In addition, the correction factor generated may be an underestimate as the duplicate survey vessel travelled at higher speed than the primary vessel and was therefore less likely to detect dolphin groups. In future surveys, employing independent observer teams on a single vessel would likely reduce bias in the correction factor.

4.2.1. *Metapopulation*

The abundance estimate of 965 Indus River dolphins from this survey is the highest estimate of abundance reported for the subspecies since surveys began approximately 30 years ago. The different survey methods employed, absence of fully reported methodology or lack of standardisation in previous surveys does not allow for abundance estimates to be compared. The higher abundance estimate of this survey can in part be attributed to more intensive survey methods and greater geographic survey coverage. The corrected metapopulation abundance estimate of 1200 is approximately double that suggested previously (Reeves, 1998).

4.2.2. *Subpopulation abundance*

The Indus River dolphin exists as five subpopulations, the largest estimated as at least 725 individuals and the smallest as two. As population size decreases, the risk of extinction increases due to the effects of inbreeding, loss of genetic diversity and the Allee effect, as well as demographic and environmental stochastic events (Rosel and Reeves, 2000; Fowler and Baker, 1991). Due to the influence of these processes it is probable that the two smallest subpopulations – Jinnah–Chashma (2 individuals) and Sukkur–Kotri (18 individuals) – are too small to persist in the long-term. In addition, a third subpopulation, that between Chashma and Taunsa Barrages (84 individuals) is extremely vulnerable. These three subpopulations would likely qualify for listing as 'critically endangered' by the IUCN due to their small effective population sizes. The long-term survival of the Indus River dolphin may therefore rest on our ability to safeguard the two largest

subpopulations, those between Guddu–Sukkur and Taunsa–Guddu Barrages. The Guddu–Sukkur subpopulation is already protected in the Sindh Dolphin Reserve by the Sindh Wildlife Department, however, further efforts need to be made to support and expand their conservation work.

Subpopulation abundance estimates recorded by this survey were higher than any previous estimates (Table 1). There are many possible reasons for the differences. Abundance estimates of the Chashma–Taunsa and Taunsa–Guddu dolphin subpopulations from this study were approximately double those reported by Punjab Wildlife Department (PWD) in the 1990s (Chaudhry et al., 1999). Survey methods used by PWD were described sufficiently to conclude that the higher abundance estimate from the 2001 survey is at least partially due to its slower survey speed, absence of motor and higher viewing platform.

The first comprehensive surveys of the Guddu–Sukkur dolphin subpopulation during the 1970s consistently counted less than 200 individuals (Pilleri and Zbinden, 1973–74; Kasuya and Nishiwaki, 1975; Pilleri, 1977; Pilleri and Bhatti, 1978) (Table 1); the corrected abundance estimate of 725 dolphins recorded in this study implies a four-fold increase in abundance since that time. This apparent large increase may be due to differences in methodology, or it may reflect a real upward trend in abundance. If abundance has been increasing it may reflect increased survivorship following implementation of a ban on hunting in 1972, changes in habitat causing an increase in carrying capacity, or augmentation of the subpopulation by permanent immigration of dolphins from upstream subpopulations (see Section 4.4.3).

4.3. *Encounter rate*

Dolphin encounter rate in the Guddu–Sukkur subpopulation was almost five times greater than in any other Indus River dolphin subpopulation. Given the paucity of scientific studies on the ecology or hydrology of the Indus River it is not possible to evaluate habitat differences that may influence dolphin density. However, the slight downstream skew in dolphin distribution within both the Chashma–Taunsa and Taunsa–Guddu subpopulations, as well as the general downstream increase in dolphin abundance and encounter rate, suggests that dolphin habitat improves in a downstream direction and perhaps is optimal between Guddu and Sukkur Barrages. The Guddu–Sukkur subpopulation has been legally protected in the Sindh Dolphin Reserve since 1974. This legal protection combined with the fact that there is little human disturbance in the area due to the insecure conditions (lack of law and order) may mean that the rate of anthropogenic mortality of dolphins is lower here than in other subpopulations. Another factor that may contribute to the high dolphin abundance and encounter rate between Guddu and Sukkur Barrages is the permanent downstream migration of dolphins from upstream subpopulations (see below).

Dolphin encounter rate recorded between Guddu–Sukkur Barrages (averaging 3.60 dolphins/km, peaking at 5.05 dolphins/km), were several times greater than those recorded for the closely related Ganges River dolphin, *Platanista gangetica gangetica*, (0.9–1.36 dolphins/km), in rivers of India and Bangladesh (Sinha et al., 2000; Smith et al., 2002). It was also many orders of magnitude greater than those recorded for other Asian River dolphins, such as Irrawaddy dolphins, *Orcaella brevirostris*, in the Ayeyarwady River, 0.16 dolphins/km (Smith and Hobbs, 2002), the Mahakam River, 0.142 dolphins/km (Kreb, 2002) and the Mekong River, 0.197 dolphins/km (Beasley, I., personal communication). River dolphin encounter rate between Guddu and Sukkur Barrages approximates that recorded for Amazon River dolphins, *Inia geoffrensis*, only in their preferred, highly localised, 'meeting of waters' habitat (Martin et al., 2004), in a tropical river system that is much more productive than those of the arid South Asian subcontinent. While caution should be applied when comparing results of different studies, the methods used in the studies cited in this paragraph were broadly similar and it is unlikely that such a large difference in encounter rate could be explained by greater sighting efficiency and an unrecognised bias.

4.4. *Threats*

4.4.1. *Water abstraction*

Much of the range reduction of the Indus River dolphin can be attributed to the removal of water and the population fragmentation caused by barrages. The range of the dolphin will continue to decrease as the smaller upstream subpopulations are extirpated and as escalating demands for water, which already outstrip supply, further deplete groundwater reserves and reduce dry-season river discharge. There is perennial flow between Sukkur and Kotri Barrages but discharge is severely reduced (110 m^3/s) in the dry season. Low dolphin abundance between Sukkur and Kotri Barrages may be caused by large-scale water withdrawal, which renders the area marginal as dolphin habitat for part of the year. To ensure that sufficient water remains for the extant subpopulations, the minimum river flow required to maintain critical Indus River dolphin habitat should be assessed and the assessment results promoted to the Pakistani government and water management authorities.

4.4.2. *Pollution*

More than three quarters of all Indus dolphins occur in the Indus below the Panjnad River confluence and are downstream of cities inhabited by more than 100 million people (FBSP, 2003). The Panjnad River drains the densely populated and industrialised Punjab and this river and its tributaries are highly polluted with untreated sewage and toxic effluents of medium and heavy industry that originate in the industrialised cities of Lahore, Sheikpura, Faisalabad and Multan (Ghaznavi, 1999). The Ravi River alone, receives 47% of Pakistan's considerable municipal and industrial effluents, and during the dry season it has insufficient dissolved oxygen to support aquatic life (Khan and Yamin, 2004). Dolphins located downstream of the Indus–Panjnad confluence, which includes the whole Guddu–Sukkur subpopulation, are vulnerable to acute upstream pollution events in the Punjab, and may also be subject to the long-term chronic effects of unregulated upstream pollutant discharges.

4.4.3. *Downstream migration*

Reeves et al., 1991) suggested that dolphins sometimes move through barrage gates and thus between subpopulations. It is

generally assumed that such movement would be uni-directional, downstream through barrages, and that upstream movement would be precluded by high gradient, rapid and turbulent flow, and frequently shallow water in, and downstream of, the gates. The result would be the gradual attrition of upstream subpopulations. Even a low downstream migration rate could dramatically affect the persistence of upstream subpopulations over time. Downstream migrants would not survive below Kotri Barrage where the Indus River is dry for much of the year. There have been no published sightings of dolphins moving through barrage gates either in Pakistan or India (Sinha, 1997), however there is circumstantial evidence supporting the theory:

(1) Each subsequent downstream subpopulation, except the last, is larger than the preceding one, despite a continually diminishing river flow. The exception to this trend is the small subpopulation furthest downstream (Sukkur–Kotri) that persists in severely degraded habitat. It is possible that this subpopulation is augmented by, or consists solely of, migrants from the upstream subpopulation (Guddu–Sukkur).
(2) Each year Indus River dolphins enter irrigation canals through flow regulating gates that are very similar to barrage gates. Between January 2000 and December 2002, for example, 34 dolphins were reported in canals originating from Sukkur Barrage (Bhaagat, 1999; Braulik, 2000; Sindh Wildlife Department and WWF-Pakistan, unpublished data). Once dolphins enter canals they are unable to travel back upstream through the canal gates and return to the Indus River. As dolphins are known to pass downstream through canal gates regularly, it seems likely that they also pass through similar barrage gates.

The magnitude of downstream dolphin migration at each barrage would likely vary based upon differences in engineering design, operational cycle, diversion capacity and location. Barrage permeability would determine subpopulation immigration and emigration rates, and therefore whether migration results in a net attrition or augmentation of that subpopulation. For example, if the downstream migration rate at a barrage is high, the subpopulation upstream would suffer rapid attrition. Alternatively, if the downstream migration rate at a barrage were low, the upstream subpopulation would contribute few migrants downstream and may instead exhibit its own net increase from upstream immigrants. Sukkur Barrage diverts more water than other Indus Barrages and its gates are therefore lowered, or closed, for a larger part of the year. High dolphin abundance between Guddu and Sukkur Barrages may therefore be the result of high immigration through Guddu Barrage and low emigration through Sukkur Barrage, resulting in an overall augmentation of the subpopulation by downstream migration.

It is important to clarify whether Indus River dolphins do move through barrages and to evaluate the magnitude of any such movement. This may be addressed by placing trained observers on each barrage to document instances of individuals passing through the gates. In addition, the gradual downstream population shifts that would be associated with permanent downstream dolphin migration may be revealed by regular, standardised population abundance monitoring.

4.5. *Conclusions*

A comprehensive evaluation of Indus River dolphin status is compromised by the inability to reliably identify trends in abundance due to lack of suitable baseline data. This survey has generated a robust baseline distribution and abundance dataset. It is now essential that it be replicated at appropriate intervals to reveal abundance trends in each subpopulation and the metapopulation as a whole.

The Indus River dolphin remains one of the world's most threatened cetaceans, despite the higher abundance estimate generated by this survey. The large range decline, population fragmentation, small size of several subpopulations and continuing habitat degradation, as well as our poor understanding of some potential threats, make the future very uncertain for the Indus River dolphin.

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REFERENCES

Ahmad, N., 1993. Water resources of Pakistan and their utilization. Shahzd Nazir, 61-B/2, Gulberg-3, Lahore, Pakistan.

Anderson, J., 1879. Anatomical and Zoological Researches: Comprising an Account of the Zoological Results of the Two Expeditions to Western Yunnan in 1868 and 1875; and a Monograph of the Two Cetacean Genera *Platanista* and *Orcella* [sic]. Quaritch, London.

Associated Consulting Engineers – ACE (Pvt.) Ltd., 1998. Evaluation report of safety of major irrigation installations/structures, vol. 1, Jinnah Barrage, Irrigation and Power Department, Government of the Punjab, Lahore, Pakistan.

Bhaagat, H.B., 1999. Introduction, distribution, conservation and behavioral ecology of Indus blind dolphin (*Platanista indi*) in River Indus (dolphin reserve), Sindh, Pakistan. Tiger Paper 26, 11–16.

Bhatti, M.U., Pilleri, G., 1982. Status of the Indus dolphin population (*Platanista indi* BLYTH, 1859) between Sukkur and Guddu Barrages in 1979–1980. Investigations on Cetacea 13, 245–262.

Braulik, G.T., 2000. Entrapment of Indus dolphins (*Platanista minor*) in irrigation canals: incidence, implications and solutions. International Whaling Commission, Scientific Committee Document SC/52/SM9, Cambridge, UK.

Braulik, G.T., Smith, B.D., Chaudhry, A.A., 2004. *Platanista gangetica* ssp. *minor*. 2004 IUCN Red List of Threatened Species, IUCN, Gland, Switzerland and Cambridge, UK.

Chaudhry, A.A., Khalid, U., 1989. Indus dolphin population in the Punjab. Proceedings of the Pakistan Congress of Zoology 9, 291–296.

Chaudhry, A.A., Maan, A.M., Akbar, M., 1999. Conservation of Indus dolphin in the River Indus, Punjab – Pakistan. Punjab Wildlife Research Institute, Faisalabad, Pakistan.

Central Intelligence Agency (CIA), 2004. The World Factbook 2004. Central Intelligence Agency, Washington, DC, USA. 698pp.

Federal Bureau of Statistics of Pakistan, 2003. Pakistan Statistical Yearbook 2003. Federal Bureau of Statistics, Government of Pakistan, Islamabad, Pakistan, 680pp.

Fowler, C.W., Baker, J.D., 1991. A review of animal population dynamics at extremely reduced population levels. Report of the International Whaling Commission 41, 545–554.

Gachal, G.S., Slater, F.M., 2002. A holistic approach to the conservation of the Indus river dolphin (*Platanista minor*) (Owen, 1853). Pakistan Journal of Science Industry and Research 45, 53–58.

Ghaznavi, D.N., 1999. Effect of agricultural, municipal and industrial pollution on the Indus ecosystem. In: Meadows, A., Meadows, P.S. (Eds.), The Indus River: Biodiversity, Resources, Humankind. Oxford University Press, Karachi, Pakistan, pp. 42–46.

Gordon, N.D., McMahon, T.A., Finlayson, B.L., 1992. Stream Hydrology. Wiley, London.

Hassan, M.S., Raoof, A., Shadid, M.A., Skogerboe, G.V., ur-Rehman, S., Aslam, M., 1999. Monitoring and evaluation of agro-economic benefits and project impact for Fordwah eastern Sadiqua (South) irrigation and drainage project. Watercourse monitoring and evaluation directorate, WAPDA, International Irrigation Management Institute, Lahore, Pakistan.

Kasuya, T., Nishiwaki, M., 1975. Recent status of the population of Indus dolphin. Scientific Report of Whales Research Institute 27, 81–94.

Khan, M.K., Niazi, M.S., 1989. Distribution and population status of the Indus dolphin, *Platanista minor*. Biology and conservation of the river dolphins. In: Perrin, W.F., Brownell, R.L., Kaiya, Z., Jiankang, L. (Eds.), Proceedings of the Workshop on Biology and Conservation of the Platanistoid Dolphins, Wuhan, People's Republic of China, 28–30 October 1986. IUCN – The World Conservation Union, Gland, Switzerland, pp. 71–77.

Khan, H.N., Yamin, M.T., 2004. South Asia water analysis network: a case study of River Ravi. In: Presented at the South Asia Water Analysis Network (SAWAN) Workshop, 29 June to 2 July 2004, Kathmandu, Nepal.

Kreb, D., 2002. Density and abundance of the Irrawaddy dolphin, *Orcaella brevirostris*, in the Mahakam River of East Kalimantan, Indonesia: A comparison of survey techniques. In: Jefferson, T.A., Smith, B.D. (Eds.), Facultative Freshwater Cetaceans of Asia: their Ecology and Conservation. The Raffles Bulletin of Zoology, Supplement No. 10, pp. 85–96.

Marsh, H., Sinclair, D.F., 1989. Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. Journal of Wildlife Management 53, 1017–1024.

Martin, A.R., da Silva, V.M.F., Salmon, D.L., 2004. Riverine habitat preferences of botos (*Inia geoffrensis*) and tucuxis (*Sotalia fluviatilis*) in the central Amazon. Marine Mammal Science 20 (2), 189–200.

Mirza, A.H., Khurshid, S.N., 1996. Survey of the Indus dolphin *Platinista minor* in Sindh. World Wide Fund for Nature – Pakistan, Ferozepur Road, Lahore Pakistan, and Sindh Wildlife Department, Karachi, Pakistan, pp. 17.

Niazi, M.S., Azam, M.M., 1988. Population status of Indus dolphin in the river Indus above Sind. Records Zoological Survey of Pakistan 11, 111–114.

Pelletier, C., Pelletier, F.X., 1980. Report sur l'expedition delphinasia (Septembre 1977–Septembre 1978). Annales de la societe des sciences naturelles de la charaente maritime 6, 647–679.

Pilleri, G., 1970. Observations on the behaviour of *Platanista gangetica* in the Indus and Brahmaputra Rivers. Investigations on Cetacea 2, 27–59.

Pilleri, G. 1977. Project 1221 Indus dolphin ecological study – WWF Grant 1977. In: WWF Yearbook. 1977–1978. WWF–Pakistan, Ferozepur Road, Lahore, Pakistan.

Pilleri, G., Bhatti, M.U., 1978. Status of the Indus dolphin population (*Platanista indi*, BLYTH, 1859) between Guddu Barrage and Hyderabad in 1978. Investigations on Cetacea 9, 25–40.

Pilleri, G., Bhatti, M.U., 1980. Status of the Indus dolphin population (*Platanista indi* BLYTH, 1859) between Sukkur and Taunsa Barrages. Investigations on Cetacea 13, 245–252.

Pilleri, G., Pilleri, O., 1979. Observations on the dolphins in the Indus delta (*Sousa plumbea* and *Neophocaena phocaenoides*) in winter 1978–1979. Investigations on Cetacea 10, 129–135.

Pilleri, G., Zbinden, K., 1973–74. Size and ecology of the dolphin population (*Platanista indi*) between Sukkur and Guddu Barrages, Indus River. Investigations on Cetacea 5, 59–70.

Reeves, R.R., 1998. Status of the Indus River dolphin in Pakistan. IBI Reports 8, 1–13.

Reeves, R.R., Chaudhry, A.A., 1998. Status of the Indus River dolphin *Platanista minor*. Oryx 32, 35–44.

Reeves, R.R., Leatherwood, S. (Eds.), 1994. Dolphins, Porpoises and Whales: 1994–1998 action plan for the conservation of cetaceans. IUCN – The World Conservation Union, Gland, Switzerland.

Reeves, R.R., Chaudhry, A.A., Khalid, U., 1991. Competing for water on the Indus plain: is there a future for Pakistan's river dolphins? Environmental Conservation 18, 341–349.

Reeves, R.R., Smith, B.S., Crespo, E.A., Notarbartolo di Sciara, G. (compilers), 2003. Dolphins, Whales and Porpoises: 2002–2010 Conservation action plan for the worlds cetaceans. IUCN/SSC Cetacean Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. Xi + 139pp.

Roberts, T.J., 1997. The Mammals of Pakistan: Revised Edition. Oxford University Press, London, Tonbridge, UK.

Rosel, P.E., Reeves, R.R., 2000. Genetic and demographic considerations for the conservation of Asian river cetaceans. In: Reeves, R.R., Smith, B.D., Kasuya, T. (Eds.), Biology and Conservation of Freshwater Cetaceans in Asia. IUCN, Gland, Switzerland, Cambridge, UK, pp. 144–152.

Sinha, R.K., 1997. Status and conservation of Ganges River dolphin in Bhagirathi–Hooghly River systems in India. International Journal of Ecology and Environmental Sciences 23, 343–355.

Sinha, R.K., Smith, B.D., Sharma, G., Prasad, K., Choudhury, B.C., Sapkota, K., Sharma, R.K., Behera, S.K., 2000. Status and distribution of the Ganges Susu (*Platanista gangetica*) in the Ganges River system of India and Nepal. In: Reeves, R.R., Smith, B.D., Kasuya, T. (Eds.), Biology and Conservation of Freshwater Cetaceans in Asia. IUCN, Gland, Switzerland, Cambridge, UK, pp. 54–61.

Smith, B.D., 1993. 1990 Status and conservation of the Ganges River dolphin *Platanista gangetica* in the Karnali River, Nepal. Biological Conservation 66, 159–169.

Smith, B.D., 1994. Status of Ganges River dolphins (*Platanista gangetica*) in the Karnali, Mahakali, Narayani and Sapta Kosi Rivers of Nepal and India in 1993. Marine Mammal Science 10 (3), 368–375.

Smith, B.D., Hobbs, L., 2002. Status of Irrawaddy dolphins *Orcaella brevirostris* in the upper reaches of the Ayeyarwady River, Myanmar. In: Jefferson, T.A., Smith, B.D. (Eds.), Facultative Freshwater Cetaceans of Asia: their Ecology and Conservation. The Raffles Bulletin of Zoology, Supplement No. 10, pp. 67–74.

Smith, B.D., Reeves, R.R., 2000. Survey methods for population assessment of Asian River dolphins. In: Reeves, R.R., Smith, B.D., Kasuya, T. (Eds.), Biology and Conservation of Freshwater Cetaceans in Asia. IUCN, Gland, Switzerland, Cambridge, UK, pp. 97–115.

Smith, B.D., Ahmed, B., Edrise, M., Braulik, G.T., 2002. Status of the Ganges River dolphin or shushuk *Platanista gangetica* in Kaptai Lake and the southern rivers of Bangladesh. Oryx 35, 61–72.