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An assessment of the olive ridley turtle (*Lepidochelys olivacea*) nesting population in Orissa, India

Kartik Shanker[a,*], Bivash Pandav[b], B.C. Choudhury[b]

[a]*Centre for Herpetology/Madras Crocodile Bank Trust, Post Bag 4, Mamallapuram, Tamil Nadu, 603104, India*
[b]*Wildlife Institute of India, PO Box 18, Chandrabani, Dehradun 248001, India*

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Abstract

Olive ridley mass nesting events or '*arribadas*' have been documented in Orissa, India since 1974. However, since standardised techniques have not been used to census turtles, actual population trends remain unknown. Herein, we summarise information on nesting populations in Orissa, using data from multiple sources to arrive at consensus estimates and to derive trends. We conducted a quantitative estimate of an arribada in March 1999, where nesting was estimated as ~180,000 turtles by the strip transect method. Non-linear (quadratic) fits for arribada data from 1976–1999 and a recent decrease in the size of adults suggest a potential or imminent decline, consistent with fishery-related mortality of at least 90,000 turtles since 1994. Though statistical support for the recent decline is equivocal, efforts to reduce mortality and close monitoring of the population would be prudent. The absence of reliable data on which to base conservation action highlights an urgent need to train management personnel in data collection and estimation techniques for effective monitoring of status, threats and trends.

Keywords: Arribada; Rookery; Fishery-related mortality; Strip transect; Population trend

1. Introduction

Olive ridley turtles (*Lepidochelys olivacea*) are a widely distributed species, and like the rarer Kemp's ridley (*Lepidochelys kempi*), exhibit the phenomenon of synchronous mass nesting, known as *arribadas* (or *arribazones*, which is the correct Spanish usage). While Kemp's ridleys consist of a single nesting population (Marquez, 1994), olive ridleys are considered the most abundant of the sea turtles (Pritchard, 1997). Nesting aggregates of over 100,000 females have been reported from Pacific Mexico, Pacific Costa Rica and Orissa on the east coast of India (Marquez et al., 1976; Pritchard, 1997; Pandav et al., 1998). Despite their seeming abundance and wide distributions, many populations have been greatly depleted by human activities including exploitation, habitat destruction and fishery-related mortality (Limpus, 1995; Pritchard 1997; Pandav et al., 1998). The Convention on International Trade in Endangered Species of Flora and Fauna (CITES) lists olive ridleys on Appendix I (prohibited from international trade) and the International Union for the Conservation of Nature (IUCN) currently lists the species as Endangered.

In the western Indian Ocean, olive ridley turtles nest along the east coast of Africa, and in Oman (Frazier, 1975), Pakistan (Asrar, 1999) and Gujarat, India (Kar and Bhaskar, 1982). Olive ridleys also nest on the east coast of India, Sri Lanka and Bangladesh (Kar and Bhaskar, 1982), and in other south east Asian countries (Limpus, 1995). In India, a few thousand olive ridleys nest in northern Tamil Nadu (Bhupathy and Saravanan, 2002), Andhra Pradesh (Tripathy and Choudhury, in press) and the Andaman and Nicobar islands (Andrews et al., 2001). However, the single most important breeding area for olive ridleys in the Indian Ocean is Orissa, which has three known arribada beaches at Gahirmatha, Devi River mouth and Rushikulya (Pandav et al., 1998). Recent genetic studies indicate that olive ridley rookeries on the east coast of India are distinct from other ridleys worldwide and might be ancestral to populations in other ocean basins, which

* Corresponding author. Tel.: +91-44-24405407; fax: +91-44-24934862.
E-mail address: kartikshanker@vsnl.net (K. Shanker).

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increases the conservation importance of this particular population, as an evolutionarily significant unit as well as a management unit (Shanker et al., 2000).

Arribadas occur at many sites in Orissa, of which Gahirmatha, first reported by Bustard (1974, 1976) is considered the most important. This population has been simultaneously labeled as the 'world's largest' (from Bustard, 1976 to Patnaik et al., 2001) and as 'highly endangered' (from Davis and Bedi, 1978 to Patnaik et al., 2001). Arribadas have occurred almost every year from 1975 (Patnaik et al., 2001) and reported estimates have ranged from 100–800,000 nesting turtles. Despite the abundance of olive ridley turtles in Orissa, the death of over 90,000 turtles in the last 8 years (Pandav, 2000a; B. Mohanty, personal communication) has necessitated serious conservation efforts (Shanker and Mohanty, 1999; Kar, 2001). The main cause of mortality is illegal gill net and trawl fishing in the offshore waters where the turtles die as incidental catch (Pandav, 2000a; Rajagopalan et al., 2001). Despite bans on mechanised fishing in near-shore waters (5 km off the Orissa coast, 20 km in Gahirmatha), trawlers continue to operate and mortality has risen alarmingly over the past 10 years (Pandav, 2000a). The use of turtle excluder devices (TED) is mandatory, but has not been effectively enforced in this region (Shanker and Mohanty, 1999).

In the past 25 years, various groups of researchers, state Forest Department officials and non-government organisations have been involved in the conservation and monitoring of turtle populations in Orissa. Consequently, a variety of approaches and methods have been used to estimate female populations at arribada beaches, and the reliability of these estimates has been questioned (Pandav and Shanker, 2001), as has been the case with other arribada rookeries (Valverde et al., 1998).

This paper has three objectives with regard to assessing the status of the olive ridley population in Orissa. First, we review and summarise the arribada data available for Orissa, in particular for Gahirmatha. We extracted data from more than 20 publications over the past 25 years to reinterpret the data and analyse trends. Second, we use the strip transect method to quantify the 1999 arribada at Gahirmatha. Finally, we use data on sizes of breeding adults from a tagging program and review mortality data to evaluate the outlook for this population of olive ridley turtles.

2. Materials and methods

2.1. Study area

Orissa, on the east coast of India, has a coastline of 480 km, which is largely sandy and suitable for nesting, apart from the Balasore coast north of Gahirmatha which is shallow and muddy. Gahirmatha (21°N and 87°E) is the northernmost of the arribada beaches, ~35 km long, at the mouth of the rivers Brahmani and Baitarani (Fig. 1). It is part of the Bhitarkanika Wildlife sanctuary and the offshore waters (up to a distance of 20 km) have been declared as the Gahirmatha National Park. Until 1989, nesting occurred on a 10 km beach near the river mouth. In 1989, a cyclone cut off a 5 km spit from the mainland and subsequently, nesting has occurred on islands which are fragments of this spit. Since 1996, this island, known as *Ekakula Nasi*, has changed drastically from year to year. In 1997, it became fragmented into two islands, 1.1 km and 2.8 km long and a few hundred metres wide (Prusty et al., 2000). In 1999, arribadas occurred on two islands which were 2 km long and 50–100 m wide (K. Shanker and B. Pandav, personal observation). After the cyclone in October 1999, the islands became narrower and further fragmented (Pandav, 2000b).

Rushikulya (19°N and 85°E), located 320 km south of Gahirmatha, is the southernmost of the arribada rookeries and was discovered in 1994 (Pandav et al., 1994). Nesting occurs on a 4 km beach north of the Rushikulya River mouth. The rookery at Devi River mouth (20°N and 86°E), located north of Puri, was discovered in 1981 (Kar, 1982). Nesting at this rookery occurs on the mainland as well as on dynamic sand bars that change from year to year. Nesting beaches at this site have been severely reduced by introduced *Casuarina* plantations that dominate much of the Orissa coast

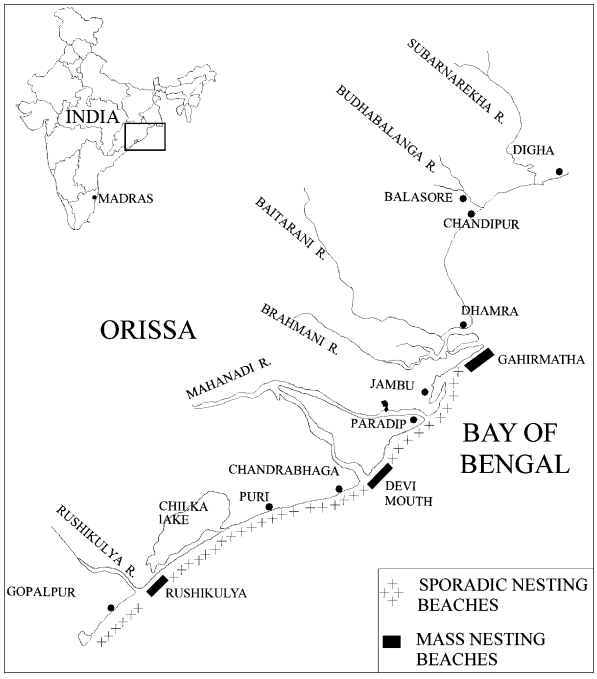

Fig. 1. The three principal mass nesting beaches in Orissa at Gahirmatha, Devi River Mouth and Rushikulya. Solitary takes occurs the entire east coast of India.

(Pandav, 2000a). The natural beach vegetation on the sand dunes includes psammophytes such as *Ipomea pescaprae*, *Spinifex littoreus*, *Gisekia phranacoides* and *Hydrophylax maritima*. Mangroves occur near the Gahirmatha and Devi rookeries.

2.2. Field methods

The Wildlife Institute of India studied inter-nesting behaviour, migration and other aspects of turtle biology along a coastline of 282 km south of the Brahmani–Baitarani River mouth from 1995 to 1999 (Pandav, 2001a). The beaches were patrolled by foot nightly during the nesting season (January–April) to monitor turtle activities at the three arribada rookeries; 13,000 nesting female turtles and mating pairs were tagged. Dead and live turtles were measured from 1996 to 1998 and 2001 to 2002. Curved Carapace Length (CCL) was measured from the anterior point at midline (nuchal scute) to the posterior tip of the supracaudal. Curved Carapace Width (CCW) was measured at the widest part of the shell.

Turtles were counted during an arribada between 25 and 31 March 1999 at Nasi 2 island, Gahirmatha, using a method modified from Valverde and Gates (1999). A total of 17 strip transects were established, one each at every 100 m, over the entire length of the beach (1.8 km). Each 20-m wide transect was marked by wooden poles and extended from the high tide mark across the entire width of the island to the riverine face of the island. Transect lengths depended on the width of the island and therefore were unequal. Each transect was walked hourly from 1800 to 0600 and all ovipositing turtles within the strip were counted. During this period, an arribada also occurred on the adjacent island of Nasi 1. Though the beach was not censused, we documented the area and period of nesting. The duration of oviposition for 20 nesting turtles gave an average value to estimate population size during the arribada.

2.3. Literature review

We reviewed 22 publications for accounts of arribadas in Orissa (Table 1). Many recent publications provided identical estimates obviously derived from the same source. However, these were not consistent with older published estimates, and many earlier estimates did not match with each other (Table 2). One difference between accounts was that estimates from successive arribadas within a season had been added cumulatively in some instances. These numbers are not necessarily additive as recent studies have shown that the same turtles nest in successive arribadas (Kalb, 1999), even at beaches separated by over 300 km (Pandav, 2000a). If a large proportion of the population nests at the same site, the total number of nests per season may serve as a good index of population size, once adjusted for clutch frequency and remigration interval. In Orissa, however, tag returns (Pandav, 2000a) and genetic data (Shanker et al., 2000) suggest that a large proportion of the Gahirmatha turtles re-nest in arribadas at other rookeries, which have not been regularly censused (see also Section 3.3). Hence, in many earlier reviews, multiple arribadas have been added only in years when both arribadas took place at Gahirmatha. Therefore, in this review, if multiple arribadas were reported for a particular year, the value of the largest arribada for that year or 'Minimum Number Known Alive (MNKA)' (Krebs, 1966) was assumed to be the best index of nesting population size. We derived a consensus estimate for each arribada, using concordant data from different sources (see Appendix).

2.4. Data analysis

Estimates of nesting and variance were derived using equations from Valverde and Gates (1999). (see also Gates et al., 1996). Nesting was estimated as follows:

$$\text{Estimate of Nesting} = \frac{\begin{array}{c}\text{Total Area available for nesting } (m^2)\times \\ \text{Duration of arribada (min)}\times \\ \text{sum total of egg laying turtles counted}\end{array}}{\begin{array}{c}\text{Width of the transect (m)}\times \\ \text{number of sampling periods}\times \\ \text{sum of lengths of all transects (m)}\times \\ \text{average duration of oviposition (min.)}\end{array}}$$

The analysis was checked for internal consistency by systematically removing half the sampling sessions (thereby converting the hourly dataset into 2 h sampling intervals) as well as by randomly removing sampling sessions (a jackknife approach). Regressions and non-parametric Kruskal–Wallis tests were carried out using SPSS (ver. 8.0).

Population trends were assessed from the consensus data in Table 3. We adjusted values for 1989–1998 using a simple correction factor, derived by scaling our quantitative estimate for 1999 (180,000) with other estimates (300,000) because the earlier method (counting all emerging turtles, not merely ovipositing turtles) was likely to have resulted in overestimates (see section 4.1 for a detailed discussion). Years with no arribadas were excluded from the trend analysis, since a failure of mass nesting may not truly reflect declines in the population. In Orissa, mortality data indicate that large offshore aggregations of turtles still occurred in the years that the arribada failed (Mrosovsky, 2001). In any case, the inclusion of these years in the analysis did not change the patterns, but merely increased the residual variances and rendered the regressions insignificant.

Table 1
Publications that contain data on arribadas in Gahirmatha, Orissa

Citation	Affiliation of principal author	Source of data
Bustard, 1976	FAO–UNDP	Orissa Forest Department
Kar, 1980	Orissa Forest Department	Orissa Forest Department
Kar and Bhaskar, 1982	Orissa Forest Department	Orissa Forest Department
Moll et al., 1983	Madras Crocodile Bank Trust	Orissa Forest Department
Silas et al., 1983	CMFRI	CMFRI
Whitaker and Kar, 1984	Madras Crocodile Bank Trust	Orissa Forest Department
Whitaker, 1984	Madras Crocodile Bank Trust	Unknown
Silas et al., 1984	CMFRI	CMFRI
Silas et al., 1985	CMFRI	CMFRI
Mishra and Kar, 1986	Orissa Forest Department	Orissa Forest Department
Mohanty-Hejmadi, 1987	Utkal University, Orissa	Orissa Forest Department
James et al., 1989	CMFRI	CMFRI/Orissa FD
Dash and Kar, 1990	Sambalpur University, Orissa	Orissa Forest Department
James et al., 1991	CMFRI	CMFRI
Naik, 1993	Orissa Forest Department	Orissa Forest Department
Mohanty-Hejmadi and Sahoo, 1994	Utkal University, Orissa	Orissa Forest Department
Mohanty-Hejmadi, 1999	Utkal University, Orissa	Orissa Forest Department
Chadha and Kar, 1999	Orissa Forest Department	Orissa Forest Department
Yadava, 2000	Fisheries Department, Government of India	CMFRI/Orissa FD
Patnaik and Kar, 2000	Orissa Forest Department	Orissa Forest Department
Mohanty-Hejmadi, 2001	Utkal University, Orissa	Orissa Forest Department
Patnaik et al., 2001	Orissa Forest Department	Orissa Forest Department

The principal sources were the Orissa Forest Department and the Central Marine Fisheries Research Institute (CMFRI). Data in Mohanty-Hejmadi (2001) is identical to Mohanty-Hejmadi (1999), but includes data from 1999–2001 from Patnaik et al., (2001). Patnaik and Kar (2000) is identical to Patnaik et al., (2001), barring data for 2000–2001.

Table 2
Mass nesting estimates for Gahirmatha quoted by different authors from 1976[a]

	KAR 1980	K&B 1982	W&K 1984	SIL.. 1985	JMS.. 1989		D&K 1990		NAIK 1993	M&S 1994	MH 1999	C&K 1999	YAD 2000	PAT.. 2001
1975–1976	150,000	150,000		150,000									150,000	
1976–1977		150,000		150,000			150,000						150,000	
1977–1978	200,000	200,000		200,000			150,000	*120,000*	230,000		230,000		200,000	
1978–1979	133,000	130,000		130,000			130,000		130,000		130,000		130,000	
1979–1980							183,000	*218,000*	200,000		200,000		200,000	
1980–1981							191,000	*191,000*	200,000		200,000		200,000	
1981–1982							0		0		17600		0	
1982–1983			200,000	200,000			600,000		220,000		619,300		200,000	
1983–1984			300,000		300,000	*200,000*	467,400	*461*	400,000	400,000	468,400		500,000	
1984–1985				279,600	287,000		283,000		286,000	286,000	291,800	29,2000	287,000	292000
1985–1986					48,000		50,000		80,000	50,000	50,000	50,000	48,000	50,000
1986–1987					200,000	*400,000*	250,000	*386,000*	600,000	600,000	636,000	636,000	602,000	636,000
1987–1988									0	0	1000		0	
1988–1989									380,000	318,000	315,000	318,000	325,600	318,000
1989–1990									258,000	200,000	207,000	207,000	258,000	207,000
1990–1991									610,000	610,000	659,000	659,000	610,000	659,000
1991–1992									321,700	805,000	384,000	384,000	321,700	384,000
1992–1993										665,000	687,400		350,000	672,000
1993–1994										451,000	694,500	695,000	200,000	695,000
1994–1995											339,500	339,500	600,000	339,500
1995–1996											290,000	290,000	200,000	290,000
1996–1997											111		0	0
1997–1998											64		0	0
1998–1999													340,000	298,000
1999–2000														711,000
2000–2001														741,000

[a] Kar, 1980; Kar and Bhaskar, 1982; Whitaker and Kar, 1984; Silas et al., 1985; James et al., 1989; Dash and Kar, 1990; Naik 1993; Mohanty-Hejmadi and Sahoo, 1994; Mohanty-Hejmadi, 1999; Chadha and Kar, 1999; Yadava, 2000; Patnaik et al., 2001. Sources which provide data for multiple years are quoted here; sources that provide data for a single year are cited only in text. (second arribada, if enumerated is in italics).

Table 3
Consensus estimates for nesting population size in Gahirmatha derived from multiple sources; the estimate refers to the largest arribada during a season, usually the first

YEAR	Consensus estimate	Date of arribada			
		Gahirmatha	2nd Arribada	Devi	Rushikulya
1975–1976	**158,000**	?		No data	No data
1976–1977	150,000	?		No data	No data
1977–1978	150,000	28 Dec–2 Jan		No data	No data
1978–1979	133,000	3–9 Feb		No data	No data
1979–1980	218,000	9–11 Feb		No data	No data
1980–1981	191,000	12–19 Jan		Date unknown	No data
1981–1982	0	No arribada		No data	No data
1982–1983	200,000	3–6 Feb	4–9 Apr	No data	No data
1983–1984	300,000	25 Jan–5 Feb	25–19 Mar	No data	No data
1984–1985	**280,000**	14–30 Jan	16–19 Mar	26–19 May	No data
1985–1986	50,000	31 Mar–6 Apr		No data	No data
1986–1987	386,000	5–14 Jan	8–14 Mar	No data	No data
1987–1988	0	No arribada		No data	No data
1988–1989	300,000	25 Jan		No data	No data
1989–1990	200,000	4–14 Mar		No data	No data
1990–1991	350,000	6–14 Mar	28 Apr	No data	No data
1991–1992	320,000	23 Jan–1 Feb	21 Mar	No data	No data
1992–1993	350,000	?		No data	No data
1993–1994	350,000	2–13 Feb	14–22 Mar	No arribada	1–8 Mar
1994–1995	340,000	?		No arribada	14–16 Mar
1995–1996	200,000	1–16 Jan		No arribada	6–8 Mar
1996–1997	0	No arribada		14–17 Mar	31 Jan–3 Feb
1997–1998	0	No arribada		No arribada	20–23 Mar
1998–1999	**180,000**	26–30 Mar		22-23 Feb	No arribada
1999–2000	?	13–19 Mar		No arribada	No arribada
2000–2001	?	2–? Feb		No arribada	26 Feb–4 Mar
2001–2002	0	No arribada		No arribada	No arribada

Dates of mass nesting at the three rookeries in Orissa (Dash and Kar, 1990; Naik, 1993; Pandav, personal observation). No estimates are available for arribadas at Devi river mouth and Rushikulya. The estimates marked in bold are considered as particularly reliable (see Sections 3.1 and 3.2).

3. Results

3.1. Review of nesting at Gahirmatha

Gahirmatha hosted at least one major arribada (>100,000 turtles) during most years from 1974 to 2001. Numerous small arribadas (eight arribadas of <1000 turtles, 4 arribadas of 1000—10,000 turtles) were reported in Gahirmatha from 1976 to 1985 (Dash and Kar, 1990). Data on small arribadas were unavailable for subsequent years.

The data in published literature (Table 2) enabled a consensus estimate for each year between 1976 and 1999 (Table 3; see Appendix for a justification of the estimate for each year). The 1976 estimate of ~150,000 turtles (Bustard, 1976) is considered fairly reliable, since field sampling was carried out rigorously (B.C. Choudhury, personal observation). Two independent organisations (Orissa Forest Department and Central Marine Fisheries Research Institute) conducted censuses in 1985 (Silas et al., 1985; Mishra and Kar, 1986) and 1987 (Mohanty-Hejmadi, 1987; James et al., 1989). Of these, the 1985 estimate is considered particularly reliable since both accounts provide day-wise details of nesting and the Forest Department report (Mishra and Kar, 1986) provides details of the sampling method and calculations. Further, both estimates match closely. The data for the 1990s is fairly poor and estimates from various accounts differ. There is clear consensus that no arribadas occurred in 1982, 1988, 1997, 1998 and 2002.

3.2. Estimate of the arribada in Gahirmatha, Orissa in March 1999

Mass nesting occurred over 5 days on two islands in Gahirmatha in March, 1999. Nesting occurred over the entire length of the beach on Nasi 2 island (about 2 km) and was localised to 700 m of beach on Nasi 1 island. During 4 days of peak nesting, 116,500–153,500 ridley turtles are estimated to have nested on Nasi 2 island (Table 4). Nesting was extrapolated to the first day (when sampling was not carried out). Based on available information on duration of nesting and area available on Nasi 1 island, nesting was estimated by extrapolating densities of nesting of Nasi 2 island on the same days (Table 5). The total nesting during this event is estimated

Table 4
Estimates of nesting numbers during four days of peak nesting on Nasi 2 in March 1999

Day	Mean (with 95% confidence intervals)	Standard error	Coefficient of variation (%)
1	51,981±7544	3772.21	7.26
2	55,182±6583	3291.46	5.96
3	17,053±1925	962.85	5.65
4	10,850±2578	1289.28	8.87
Combined	135,066±18,630		

Table 5
Extrapolation of total nesting numbers in March 1999 in Gahirmatha (based on length of nesting beach on Nasi 1, which was 1/3 length of Nasi 2, and approximately the same width)

Date	Nasi 1		Nasi 2		
	Day	Night	Day	Night	No.
24–25 March 1999				High sporadic	
25–26 March 1999		Sporadic	Nesting (??)	*17,000*	
26–27 March 1999		Sporadic	Nesting (??)	51,981	1
27–28 March 1999	Mass nesting	*18,394*		55,182	2
28–29 March 2001		*5684*		17,053	3
29–30 March 2001		*3616*		10,850	4
Column total		27,694		152,066	
Estimated total	179,760 nesting turtles				

Extrapolated numbers are in italics.

to be ~180,000 clutches. The jackknife estimates differed from the original estimate by <5%, indicating that the result was robust. The average duration of oviposition used in the calculations was 13.5 min. This is slightly less than the value of 15 min indicated in Valverde and Gates (1999) which would give an estimate of ~160,000 clutches.

3.3. Review of nesting at other arribada beaches

Orissa has two other arribada beaches, at Devi River Mouth (Kar, 1982) and Rushikulya (Pandav et al., 1994; Pandav, 2001b), neither of which has been monitored regularly (Pandav et al., 1998). At Rushikulya, about 200,000 turtles are believed to have nested in 1994 (Pandav et al., 1994) and a 'guesstimate' of 25–50,000 turtles nested annually between 1995 and 1998 (Pandav, 2001b). Two medium arribadas (>10,000 turtles) in 2001 and one minor arribada (<10,000 turtles) in 2002 are documented, but no estimates are available. Arribadas occurred at Pentha at the Barunei River mouth, 30 km south of Gahirmatha, during March and April 1999 (Shanker and Mohanty, 1999; Patnaik et al., 2001). The timing of the arribadas (usually a few weeks after the arribada at Gahirmatha, Table 3) and the fact that arribadas were recorded only at any two sites within the same season suggests that the same turtles nest at all the rookeries.

3.4. Review of mortality

Biswas (1982) reported the shipping of 6000 turtles during 3 months in 1974–1975 and 21,000 turtles during 3 months in 1978–1979 from Orissa and West Bengal. Das (1985) reported that, prior to 1981, 6–7 truckloads of turtles (each with 125–150 turtles) arrived in Calcutta every day. He calculates that this amounts to 80,000 turtles per season. Many accounts report an annual catch of 50,000 turtles from the Orissa and West Bengal coast until 1980 (see Silas et al., 1983). Though it is unclear how long fishing has continued, it is likely to have reached this intensive level by the 1970s with the introduction of mechanisation. After the implementation of the Indian Wildlife (Protection) Act (1972) with respect to the turtle fishery in Orissa in the late 1970s, the exploitation decreased substantially (Kar, 2001). In the 1980s, incidental mortality of a few hundred ridleys per year was reported in Orissa (James et al., 1989). Pandav (2001a) provides a detailed account of mortality along the Orissa coast in the 1990s, with an increase from 5000 per year in 1994 to 13,000 turtles per year in 1999, a total of ~46,000 dead turtles along the Orissa coast in 6 years. Current mortality rates are believed to be ~15,000 turtles per year (B. Mohanty, personal communication). Reports suggest an increase in fishing intensity from <1000 mechanised boats in the late 1980s to >4000 boats by 1996.

3.5. Population trends at Gahirmatha

The unadjusted dataset showed a marginal linear increase over 25 years (Fig. 2a), though the adjusted values did not show this increase (Fig. 2b). However, non-linear quadratic fits showed an increase through the 1980s, followed by a decline in the 1990s (Fig. 2). This is consistent with known patterns of exploitation. Linear regressions were carried out separately for the late 70s (with intentional take), 1980–1993 (low mortality) and 1994–present (high incidental mortality). Here, the trends show stability or increase in the 80s and sharp decline in the 1990s (Fig. 3). However, the decline in the 1990s is not statistically significant since it is represented by fewer data points.

Measurements were taken from nesting females, mating pairs, and dead stranded individuals (Table 6). Overall, curved carapace lengths ranged from 51.0 to 82.0 cm, curved carapace widths from 47.0 to 78.0 cm, straight carapace lengths from 49.0 to 75.0 cm and straight carapace widths from 48.5 to 72.0. Compar-

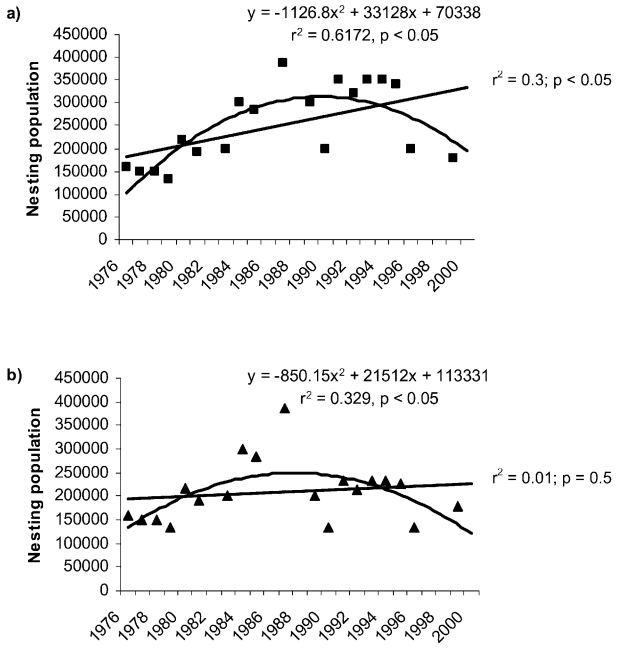

Fig. 2. Linear and non-linear (quadratic) fits for nesting trends in Gahirmatha over the last 25 years using (a) consensus data from Table 3 (b) adjusted data for 1989–1998, based on a correction factor which was derived by scaling the quantitative estimates for 1999 with estimates from other sources. Equations are provided for the non-linear functions, whereas only r^2 and P values are provided for the linear functions.

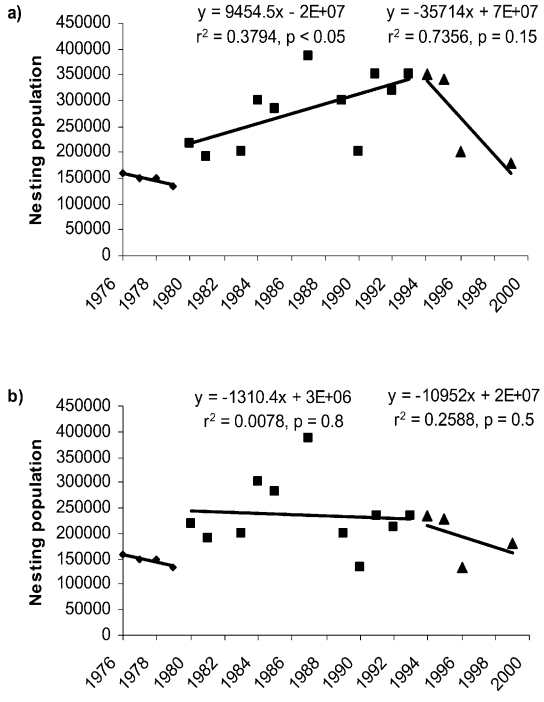

Fig. 3. Nesting trends in Gahirmatha over the last 25 years after dividing the data into three time zones: pre 1979, high intentional take; 1980–1993, relatively low mortality; post 1994, when incidental mortality has been increasing. (a) consensus data from Table 3 (b) adjusted data for 1989–1998, based on a correction factor which was derived by scaling the quantitative estimates for 1999 with estimates from other sources. Equations, r^2 values, and P values are given for the second and third time zones for each figure.

isons among years within female turtles revealed significant differences in curved carapace lengths (KW = 491.3, $P < 0.001$), curved carapace widths (KW = 479.9, $P < 0.001$), straight carapace lengths (KW = 488.5, $P < 0.001$), and straight carapace widths (KW = 231.6, $P < 0.001$) with a decrease in all measurements from 1996–1997 to 2001–2002. Comparisons among years within male turtles also revealed differences in curved carapace lengths (KW = 154.6, $P < 0.001$), curved carapace widths (KW = 118.2, $P < 0.001$), straight carapace lengths (KW = 277.7, $P < 0.001$), and straight carapace widths (KW = 151.8, $P < 0.001$) with a decrease in all measurements from 1996–1997 to 2001–2002. Average curved carapace lengths and widths for adult males and females from 1978 to 1985 (from Dash and Kar, 1990) were larger than those measured from 1996 to 2002 (Table 6).

4. Discussion

4.1. On the arribadas at Gahirmatha

Arribadas have been documented in Orissa since 1974. Apart from 1999, standardised methods have not been used to estimate these arribadas. The published reviews of nesting in Orissa (Dash and Kar, 1990; Mohanty-Hejmadi and Sahoo, 1994; Chadha and Kar, 1999; Mohanty-Hejmadi, 1999, 2001; Patnaik and Kar, 2000; Patnaik et al., 2001) do not discuss the methods used in counting turtles or in estimation. None of these papers appear in refereed literature, and estimates from books and reports by different authors disagree (even when the data are ostensibly from the same source) or omit an estimate of variance. The inconsistency of these accounts has hindered the assessments of trends in population size and dynamics.

The estimates of the Orissa Forest Department were derived by marking and counting all emerging turtles in demarcated strips or plots (Mishra and Kar, 1986). The total count of turtles stranding within the sectors was then extrapolated to the entire beach (Mishra and Kar, 1986). The proportion of emergences that resulted in oviposition was not determined (B. Pandav, personal observation). As many turtles are likely to emerge repeatedly before nesting successfully, turtle surveys during arribadas are indexed to only the ovipositing turtles (Gates et al., 1996). In Gahirmatha, the fragmentation of the nesting beaches and tidal inundation of the rookery led to multiple emergences before nesting (B. Pandav, personal observation). In fact, arribadas may have failed during 1997 and 1998 due to inundation of the nesting beaches (Prusty et al., 2000). Hence the figures reported for Orissa would overestimate the number of turtles to an unknown degree, especially since the fragmentation of the beaches in 1989.

Table 6
Mean carapace measurements for male and female olive ridley turtles in Orissa, based on primary data from 1996–1999 and 2001–2002

Year	Curved carapace length	Curved carapace width	Straight carapace length	Straight carapace width
Overall	70.0 (2.9; 3864)	68.2 (2.7; 3864)	65.9 (2.7; 3636)	57.8 (2.5; 3636)
Males				
1978–1985*	72.9 (2.2; 176)	72.1 (2.6; 176)		
1996–1997	71.4 (2.4; 228)	69.1 (2.4; 228)	67.4 (2.6; 170)	58.9 (2.3; 170)
1997–1998	70.3 (2.7; 352)	67.9 (2.5; 352)	67.1 (2.7; 497)	58.4 (2.2; 497)
1998–1999	69.2 (3.1; 873)	67.7 (2.8; 873)	65.2 (2.9; 663)	57.5 (2.4; 663)
2001–2002	68.8 (2.3; 196)	66.5 (2.3; 196)	64.2 (2.2; 196)	56.7 (2.2; 196)
Females				
1978–1985*	72.6 (2.2; 277)	71.6 (2.3; 277)		
1996–1997	72.1 (2.2; 231)	69.9 (2.5; 231)	67.1 (2.5; 172)	58.5 (2.4; 172)
1997–1998	71.3 (2.3; 323)	69.0 (2.6; 323)	67.1 (2.1; 464)	58.5 (2.4; 464)
1998–1999	71.1 (2.6; 845)	69.3 (2.5; 845)	66.4 (2.4; 658)	58.1 (2.3; 658)
2001–2002	68.6 (2.5; 816)	66.6 (3.1; 816)	64.3 (2.3; 816)	56.8 (2.7; 816)

Males and females were both captured while mating. Female nesting turtles were also measured. Dead stranded turtles were sexed and measured. Standard deviations and sample sizes are given in parenthesis. *Data is also provided for 1978–1985 from Dash and Kar (1990).

Despite these shortcomings in the data, we conclude that Gahirmatha has had no drastic decline in the nesting population over the last 25 years, based on a comparison of reliable estimates at the two ends of the spectrum. Both interrupted linear trend analysis and non-linear analysis suggest stability or increase in the size of 1980s arribadas. This may be due to enforcement of legislation in the late 1970s which stopped the heavy directed take of turtles. However, we interpret the 1990s data as suggestive that the population may be declining or on the verge of a decline. This is consistent with the recent increase in fishery related mortality and other threats. Given the inconsistency in the population estimates in the literature, we actually know very little about the Orissa rookeries except that major arribadas ($>100{,}000$ turtles) have occurred during most years since 1974, and that current population sizes are in the range of 150–200,000 nesting females per year.

Studies of arribadas in Mexico suggest that ridley populations that are subjected to a high level of disturbance may become unpredictable in the size and timing of arribadas (Marquez et al., 1996; F.A. Abreu-Grobois, personal communication). No arribadas occurred in Gahirmatha in 1997, 1998 and 2002, which is the highest incidence of failure in the documented history of this rookery. Nesting has also been reported from new sites (Patnaik and Kar, 2000), but this may reflect lack of monitoring in previous years rather than a shift in nesting habitat by the turtles. The unpredictability in the site, size and timing of arribadas in Orissa may reflect a high level of disturbance in the offshore waters.

The measurements of a large number of adult ridleys between 1996 and 2002 suggests a decline in adult sizes, which is even clearer when compared with data from 1978 to 1985. The decrease in sizes may be related to the mortality of breeding adult ridleys as over 90,000 dead turtles have been counted on the Orissa coast since 1994. Many turtle carcasses do not strand on the coast (only 7–14% according to Epperly et al., 1996), so the number of turtles actually killed is likely to be even higher. If a large proportion of the adult population has been killed, and recruits of smaller size classes form a significant part of the population, the average size of the population would decrease. Given our estimate of $<200{,}000$ turtles in 1999, and documented mortality of over 90,000 turtles within the last decade, the Orissa population is clearly of imminent conservation concern.

Limpus (1995) points out that the abundance of olive ridleys at a few rookeries has led to the impression that these turtles may not be endangered. However, arribada rookeries have collapsed in Mexico and Surinam due to exploitation and by-catch (Limpus, 1995), notably the Kemp's ridleys in Mexico which declined to a few hundred in the 1980s (Marquez et al., 1996). Small populations of olive ridleys have declined drastically in Pakistan (Asrar, 1999), Myanmar (Thorbjarnarson et al., 2000), Malaysia, and Thailand (Limpus, 1995). Olive ridley populations may also have declined on the east coast of India south of Orissa (Bhupathy and Saravanan, 2002; Tripathy and Choudhury, in press) and in the Andaman and Nicobar islands (Andrews et al., 2001). Even if the Orissa population has not declined yet, it would be prudent to monitor the population and to take action towards reducing mortality.

4.2. Conservation of olive ridley turtles in Orissa

Incidental catch is a major cause of sea turtle mortality in India (Silas et al., 1983; James et al., 1989; Rajagopalan et al., 2001) and in international waters (Pritchard, 1997). Marine turtles are protected in Orissa

by Orissa Marine Fisheries Act (1982) and Rules (1983) which prohibit all mechanised fishing within 5 km of the coast and within 20 km of the Gahirmatha coast (~35 km). However, despite the efforts of the Orissa Forest Department (Patnaik and Kar, 2000) and non-government organisations (Shanker and Mohanty, 1999), mortality has been increasing. Turtle Excluder Devices are mandatory in Orissa and although some government agencies are promoting them, there is opposition to their use within the trawler community (Shanker and Mohanty, 1999).

Olive ridley turtles use multiple rookeries within Orissa (Pandav, 2000a) and may adopt new rookeries (Patnaik and Kar, 2000). Hence, the size and location of offshore aggregations of mating turtles may vary across years and must be assessed carefully throughout a nesting season. Orissa turtles also suffer mortalities during their inter-nesting migrations through the offshore waters of Andhra Pradesh (Tripathy and Choudhury, in press) and Tamil Nadu (Bhupathy and Saravanan, 2002). Anecdotal accounts establish that large numbers of turtles migrate along the east coast of India before and after the nesting season (Whitaker and Kar, 1984). In recent years, more than 20 breeding turtles tagged in Orissa have been recovered near Sri Lanka (Pandav, 2000a) and satellite telemetry indicates that some turtles remain in Orissa offshore waters, while others migrate to Sri Lanka after nesting (K. Shanker et al., unpublished data; see http://www.wii.gov.in for a map). This population is also subject to terrestrial threats including depredation of nests (Kar, 2001), changes in the beach morphology which may lead to failure in mass nesting (Prusty et al., 2000), and coastal development (Pandav et al., 1998).

4.3. The danger of poor data

The variation in inter and intra-annual habitat use and the complex migratory lifecycle of sea turtles necessitate a dynamic strategy for effective conservation, requiring cooperation between many agencies such as the Forest Department, Fisheries Department, Coast Guard, as well as biologists, non-government organisations and local communities. The estimates of large nesting populations in 2000 and 2001 (in Mohanty-Hejmadi, 2001; Patnaik et al., 2001) are routinely quoted in the press and in reports and project a false sense of security that may obscure the actual status of olive ridley turtles in the region, leading government agencies (such as fisheries organisations) to downplay concerns and minimise efforts for their conservation. Some stakeholders, in particular the trawler owners associations, question the endangered status of olive ridleys and the need for stringent conservation measures (Shanker and Mohanty, 1999).

We have established a lack of consistency in the population estimates given in books (Dash and Kar, 1990; Patnaik and Kar, 2000) and symposium proceedings (Mohanty-Hejmadi and Sahoo, 1994; Mohanty-Hejmadi, 1999). Yet other authors use these sources as the basis for establishing trends and for justifying a conservation agenda according to the criteria of the IUCN Red List. Using data from any one of the above sources could clearly lead to erroneous conclusions. The assessment of trends at other olive ridley rookeries is hindered by similar problems (Valverde et al., 1998) and to some extent, all population estimates are subject to errors and bias. Hence it is imperative that conservationists are careful to verify the authenticity of data and evaluate the magnitude of error before using such data to reach important conclusions.

The lack of reliable data also hinders the formulation of appropriate management plans. For example, would some level of utilization be sustainable? Can eggs be harvested? Given the poor economic conditions of the coastal communities, programmes in which local people benefit from the turtles (such as egg harvesting during arribadas) may serve conservation objectives better than total protectionism. Appropriate decisions on these subjects require reliable information, without which a more precautionary principle is adopted for the species.

4.4. Conclusions

Popular accounts state that Orissa ridley rookeries are the 'world's largest' yet also 'highly endangered'. The former claim attracts attention, while the latter helps obtain national and international funding. 'Hype' can have serious negative consequences for long term conservation objectives by undermining the credibility of the process (Mrosovsky, 2002). Objective and scientifically collected data are required to assess population trends for the formulation of an appropriate conservation strategy, perhaps including some level of utilisation or exploitation. That this population is genetically distinct and ancestral to other olive ridley populations highlights its significance. Apart from continuing conservation action, there is an urgent need to train management personnel in population estimation techniques and collection of scientific data in order to evaluate status, threats and trends to manage and conserve olive ridley turtles in Orissa effectively.

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Appendix A. Arribadas in Gahirmatha from 1975–2002. Year by year account of estimates in literature and justification for the consensus estimate for each year

1975–1976—Bustard (1976) reports that 158,171 turtles were enumerated during an arribada in February 1976. There is evidence that the field exercise was carried out rigorously (B.C. Choudhury, personal observation), but details of analysis and estimation are not available.

1976–1977—Kar (1980) provides estimates for 1976, 1978 and 1979, but does not provide an estimate for 1976–1977, except to say that the numbers were larger than in 1976. In Kar and Bhaskar (1982) however, 150,000 turtles are reported to have nested in 1977, which is quoted in subsequent accounts. Dash and Kar (1990) also report that a second arribada occurred but no estimate was made.

1977–1978—Kar (1980) gives a figure of 200,000 which is quoted by most authors subsequently, except a few accounts which mention 230,000. Neither figure matches Dash and Kar (1990) who mention two arribadas of 150,000 turtles and 120,000 turtles. Since it is unclear as to whether values larger than 150,000 were derived by adding estimates from different arribadas, 150,000 is assumed to be the best estimate.

1978–1979—Kar (1980) reports 133,000 turtles. This figure is quoted in all subsequent accounts without major discrepancy.

1979–1980—Dash and Kar (1990) report two arribadas of 183,000 and 218,000, but all subsequent references give a figure of 200,000.

1980–1981—Dash and Kar (1990) report two arribadas of 191,000 each, and all subsequent references give a figure of 200,000

1981–1982—There is consensus that no arribada took place during this year.

1982–1983—Moll et al. (1983) report that 160–175,000 turtles were estimated to have nested on 2 days on 3 and February 1983, a week before their arrival in Gahirmatha. Silas et al. (1983) also report 200,000 turtles nesting during 3–9 February 1983. Both figures are attributed to the Orissa Forest Department. Though Dash and Kar (1990) report the nesting of 600,000 turtles during this arribada, ~200,000 turtles appears to have been the original estimate.

1983–1984—Dash and Kar (1990) record 467,000 turtles during the first arribada. However, Silas et al. (1984) estimated 300,000 turtles during this arribada. Silas et al. (1984) also report that 200,000 turtles nested during a second arribada in end March. Strangely, Dash and Kar (1990) only report 461 turtles during this arribada. Even more strangely, Whitaker (1984) quotes unknown sources to suggest that 800,000 turtles nested during this arribada. This particular figure has been quoted in non peer-reviewed and peer-reviewed literature as a possible high value for arribadas in Orissa, but no other sources appear to validate it. The figure of 300,000 is assumed to be most reliable since it is quoted in a contemporary paper (Silas et al., 1984) based on primary data.

1984–1985—The arribada occurred between 14–30 January 1985. Mishra and Kar (1986) estimated 283,671 turtles to have nested. Silas et al. (1985) estimated 279,600 turtles to have nested. Both authors provide day-wise breakup of nesting and Mishra and Kar (1986) provide a detailed account of the method. This is considered to be one of the most reliable estimates available from literature as field methods and primary data are reported (Mishra and Kar, 1986) and estimates from two sources (Silas et al., 1985; Mishra and Kar, 1986) match closely.

1985–1986—Dash and Kar (1990) say that an arribada did take place this season, during November–December 1987. Otherwise, there is general consensus that only 50,000 turtles nested. While Dash and Kar (1990) state that the arribada occurred in the first week of April, James et al. (1989) quote the Forest Department to state that the arribada occurred between 1–10 March.

1986–1987—Mohanty-Hejmadi (1987), James et al., (1989, 1991) and Dash and Kar (1990) clearly describe two arribadas of 200–250,000 turtles and ~386-400,000 turtles. Later figures of >600,000 turtles are clearly additions of these estimates

1987–1988—There is consensus that there was no arribada during this year.

1988–1989—There is consensus on a figure of 300,000.

1989–1990—There is consensus on a figure of 200,000

1990–1991—A figure of >600,000 is provided in all the literature. However, all previous estimates of arribadas of this size are generally the sum of multiple arribadas, and Mohanty-Hejmadi and Sahoo (1994) indicate that two arribadas occurred during this year. From other estimates of this size, a conservative value of 350,000 is estimated for a single arribada in this year.

1991–1992—Naik (1993) and Yadava (2000) agree on a figure of 321,700, but figures deriving from the Orissa Forest Department (Chadha and Kar, 1999; Mohanty-Hejmadi, 1999) give estimates of 370–384,000. Mohanty-Hejmadi and Sahoo (1994) give a figure of 805,000. Larger estimates may be additive, so the value of 320,000 is used for this year

1992–1993—Figures deriving from the Orissa Forest Department (Mohanty-Hejmadi and Sahoo, 1994;

Chadha and Kar, 1999; Mohanty-Hejmadi, 1999) give estimates of >600,000, but Mohanty-Hejmadi and Sahoo (1994) indicate that there were two arribadas. Yadava (2000) gives a figure of 350,000, which may indicate the nesting during one of the arribadas.

1993–1994—Chadha and Kar (1999) and Mohanty-Hejmadi (1999) give estimates of >600,000 turtles, but Mohanty-Hejmadi and Sahoo (1994) report 451,000 turtles for the first arribada, while Yadava (2000) reports an estimate of 200,000. From other estimates of this size, a conservative value of 350,000 is assumed for a single arribada in this year.

1994–1995—Here, Chadha and Kar (1999) and Mohanty-Hejmadi (1999) give estimates of 339,000 turtles, but Yadava (2000) reports an estimate of 600,000.

1995–1996—Chadha and Kar (1999) and Mohanty-Hejmadi (1999) give estimates of 270–290,000 turtles, but Yadava (2000) gives an estimate of 200,000. Again, assuming that the Orissa Forest Department estimates may be sums, the value of 200,000 is assumed for analysis.

1996–1997 and 1997–1998—There was no arribada during these years.

1998–1999—Nesting was estimated to be ~180,000 turtles during an arribada in March (see section 3.2). Yadava (2000) and Patnaik et al., (2001) give higher estimates.

1999–2000 and 2000-2001—There are reports of >700,000 turtles in single arribadas (Patnaik et al., 2001). These estimates are considered unlikely since the beaches are too fragmented to support nesting of such a large number of turtles, and there is no logical premise for the sudden increase in the size of nesting populations. These years are not included in the analysis.

2001–2002—No arribada occurred during 2002 (B. Mohanty, personal communication).

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