ARTICLES

SEA TURTLE HATCHERY PRACTICES AND HATCHLING PRODUCTION IN KARACHI, PAKISTAN, FROM 1979-1997

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INTRODUCTION

Major nesting populations for green (*Chelonia mydas*) sea turtles occur in Pakistan (Figure 1) (Firdous *et al*., 2011). Historically, olive ridley (*Lepidochelys olivacea*) turtles nested at the same locations but have not been observed nesting in Pakistan since 2003 (Hussain, 2009 in Khan *et al*., 2010). Hawksbill (*Eretmochelys imbricata*) turtle tracks have been observed at Cape Monze (Sindh province) and Astola Island (Balochistan province) and leatherback (*Dermochelys coriacea*) tracks at Mubarak Village (Sindh province), and Pishukan and Jiwani (Balochistan province) (see Khan *et al*., 2010) (Figure 1); there are no estimates of the size of these nesting populations. Sea turtles in Pakistan are protected under the Sindh Wildlife Protection Ordinance of 1972 (amended in 1993 to the Sindh Wildlife Protection Act) and Balochistan Wildlife Protection Act (1974). However, protected areas have not encompassed nesting sites (Khan *et al*., 2005 in Khan *et al*., 2010) and nesting females, nests and hatchlings have been, and are still, subject to human (e.g. coastal development, lighting, poaching) and non-human (e.g. wild dogs) threats on nesting beaches.

In response to nest and hatchling mortality on nesting beaches, sea turtle hatcheries at Hawkesbay and Sandspit beaches in Karachi, Sindh province, were established in 1979 (Figure 1). Three (one at Hawkesbay and two at Sandspit beaches) enclosures of 24m × 24m with a concrete footing and ~3m high wire fence were constructed above the high tide line; each hatchery enclosure had the capacity to hold 300 nests, and individual nests were protected with cages (45cm high, 90cm circumference, 2.5cm wire mesh walls and roof) (Firdous, 2001). Hatcheries have remained close to their original location since construction, being moved a few hundred feet if the fence deteriorated beyond repair (Kabraji & Firdous, 1984), and are still in operation to protect eggs against predation by wild dogs and poaching, and hatchlings against predation by wild dogs and disorientation by lighting associated with beach development. Hatcheries are now also a local ecotourist attraction. The current facilities are managed by the Sindh Wildlife Department.

HATCHERY MANAGEMENT PRACTICES, 1979-1997

Only vulnerable nests, those close to villages with associated wild dogs or laid below or close to the high tide line, were transferred to the hatchery (Kabraji & Firdous, 1984). Eggs were originally retrieved from the bottom of the nest as the turtle was laying, but the practice soon changed to catching the eggs in a cloth bag directly below the ovipositor, as recommended by Mortimer (1999), to reduce the coverage of individual eggs with sand (Kabraji & Firdous, 1984). After collection, eggs were then transported by foot in a straw basket (Kabraji & Firdous, 1984) or plastic bucket (Firdous *et al*., 2011) to the closest hatchery enclosure. Relocation of nests most often occurred within 30min of oviposition (Firdous, unpubl.), although the time between oviposition and reburial sometimes reached 6hr (Firdous *et al*., 2011). Within the hatchery, eggs were reburied at a depth of 70cm (Kabraji & Firdous, 1984) at a density of 1 nest/m^2 (Firdous *et al*., 2011).

Previously, hatchlings that emerged at night were immediately released close to the high tide line and guarded from predators until they reached the water; hatchlings that emerged during the day were held until dark before release (Kabraji & Firdous, 1984). Nests were excavated to calculate hatching success and the nest contents (eggshells, unhatched eggs etc) were removed and buried away from the hatchery to minimise the accumulation of organic matter in the

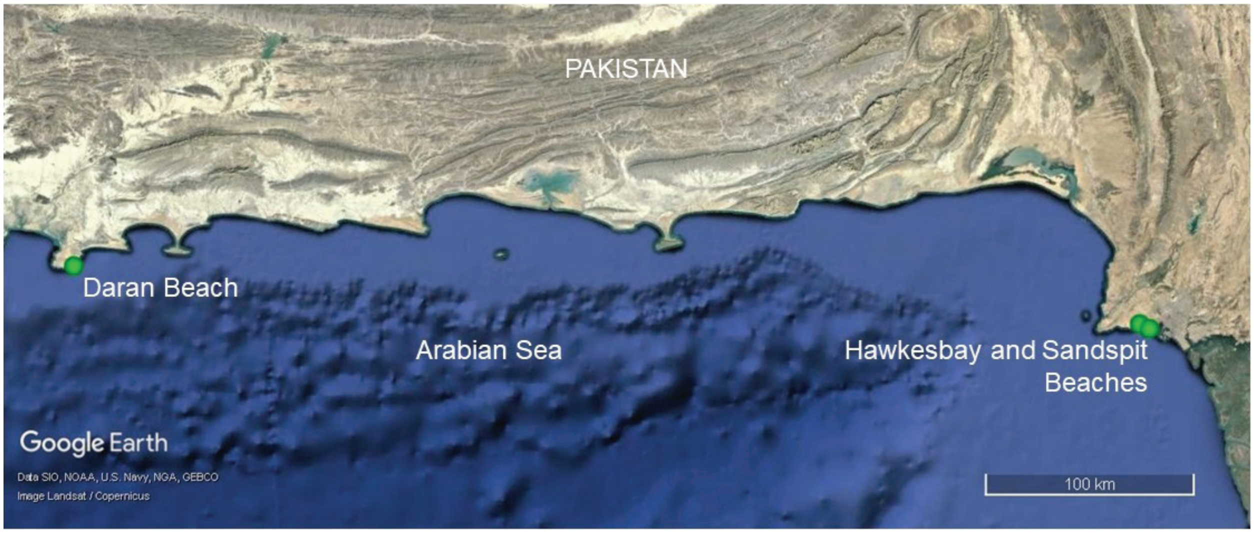

Figure 1. Green sea turtle nesting areas in Pakistan. Hatcheries exist at Hawkesbay and Sandspit Beaches, Karachi, whereas *in situ* nest protection occurs at Daran Beach, Jawani.

enclosure (Firdous, unpubl.). The nest chamber was exposed for at least 2-3 days, to minimise microbial growth, before re-use (Kabraji & Firdous, 1984).

LOW HATCHING SUCCESS IN HATCHERIES AND POTENTIAL CONTRIBUTING FACTORS

Between 1979 and 1997, 17,048 green turtle nests were relocated to the hatcheries by the Sindh Wildlife Department (Firdous, 2001; Firdous *et al*., 2011); 654 olive ridley turtle nests were relocated to the same hatcheries between 1980 and 1997. The reported hatching success for nests of both species was relatively low; green turtle hatching success on average was 25.5% (range 11-43%) and average hatching success of olive ridley nests was 27.1% (range 6-74%) (Firdous *et al*., 2011).

Acknowledging that the overall hatching success was low, Kabraji & Firdous (1984) described four potential contributing factors related to hatchery management practices: during collection, eggs became covered in sand that reduced the exchange of respiratory gases during incubation (as per Mortimer, 1999); high microbial load in the hatchery substrate; dry nest substrate after 2-3 days of exposure post-emergence before the same nest chamber was utilised for another clutch; and, underestimation of hatchlings due to escape from the nest enclosure. Some of these factors were unlikely to have resulted in long-term low hatching success. For example, their methods of egg collection changed from removing eggs from the bottom of the nest during oviposition to collecting them directly from the ovipositor to reduce the likelihood of eggs becoming covered in sand and an implicating factor in embryo mortality (Kabraji & Firdous, 1984). The escape of hatchlings from nest enclosures should not have affected the determination of hatching success, unless the number of emerged hatchlings per nest was used instead of the number of hatched eggs in the calculation. (Hatching Success = (number of hatched eggs/total number of eggs) x 100%; Miller, 1999).

One of the potential factors described by Kabraji & Firdous (1984)- high substrate microbial load- may have contributed to low hatching success. There were no descriptions of sand within the enclosures being replaced or overturned, but nest chambers remained exposed to sunlight after excavation before re-use. After hatchling emergence, nests were excavated and eggshells, unhatched eggs, and other organic matter were removed from the hatchery. However, these practices may not have been sufficient to minimise the accumulation of organic matter and, potentially, a high microbial load which can invade eggs (e.g. Phillott, 2004; Phillott *et al*., 2004) or alter respiratory gas availability (Bézy *et al*., 2014, 2015) and result in embryo mortality.

The practice of exposing empty nest chambers for several days before re-use may have resulted in dry nest substrate, and low moisture availability is known to have a negative impact on embryonic development (reviewed by Miller *et al*., 2003). However, hatching success at Sandspit and Hawkesbay hatcheries was low year -round, (see Table 1 in Firdous, 2001), including during periods of rainfall, so low substrate water potential would only be expected to limit embryonic development and hatching success in dry seasons.

Other hatchery practices are unlikely to have contributed to low hatching success. Nest density (1/ m^2) was as recommended for sea turtle hatcheries in the region (Shenoy *et al*., 2011). Nest depth (~70cm; Kabraji & Firdous 1984) in the hatcheries was within the range of reported nest depths for green turtles elsewhere in the northern Indian Ocean, however, exceeds that of olive ridley nests (Table 1).

The time between oviposition and reburial of eggs was usually less than 30min (Firdous, unpubl.), within the recommended range of less than 2hr (Mortimer, 1999; Shenoy *et al*., 2011). However, those nests that were not moved until up to 6hr after oviposition (Firdous *et al*., 2011) may have experienced movement-induced embryo mortality (Limpus *et al*., 1979; Parmenter, 1980). Firdous *et al*. (2011) indicates that the number of nests in the latter category were few; if so, it seems unlikely that movement-induced embryo mortality would be a major contributing factor to long-term low hatching success.

The effect of environmental conditions on hatching success were later considered when analysing data sets for Sandspit and Hawkesbay hatcheries. Firdous *et al*. (2011) predicted that the monsoonal rain in June and July could reduce hatching during these months. However, while heavy rainfall may reduce hatching success through nest flooding and reduced respiratory gas exchange (Kraemer & Bell, 1980; Miller *et al*., 2003), figures in Firdous *et al*. (2011) indicate comparatively low numbers of nesting turtles in the months prior to and during the monsoon so rainfall is unlikely to have affected many nests and meaningfully decreased the overall hatching success. The limited nest temperature data available (range 16.06-29.03°C, n=1 in Firdous *et al*., 2011; average 25-26°C, range 22.5-31.1°C, n=4 in Shahid *et al*., 2015) indicated thermal conditions are below the upper thermal limit for sea turtle embryos (see Howard *et al*., 2014) so there is no current evidence for concluding that heat-induced mortality is a contributing factor to low hatching success.

It is interesting to note that the incubation duration recorded for green (average 62 days, range 22-160 days) and olive ridley nests (average 49 days, range 42-69 days) (Kabraji & Firdous, 1984) in the hatcheries at Sandspit and Hawkesbay beaches are longer than those for the same species in the northern Indian Ocean (Table 2). It should be noted that the average incubation duration for green turtle nests was likely to be an underestimate as the minimum was reported as 20-30 days for several years, and development from gastrula to hatchling would be unlikely to occur in that time, regardless of incubation temperature (see Miller, 1985). Long incubation periods may result from slow embryonic development in environmental conditions such as low nest temperatures and/or low moisture availability (reviewed by Miller, 1985; Miller *et al*., 2003), which may also contribute to embryonic mortality and low hatching success.

There are only two small data-sets for *in situ* nests at Sandspit and Hawkesbay beaches against which to compare the hatchling production from hatchery nests. Kabraji & Firdous (1984) reported an average hatching success of 60% (range 4-98%; n=6) and Shahid *et al*. (2015) an average hatching success of 49% (range 40-66%; n=4). A low hatching success was also reported for caged *in situ* nests at Daran Beach (Figure 1) in Jiwani, Balochistan province; between 1999 and 2008, 2,751 caged nests demonstrated a hatching success of 32%. Cages were placed over the nests without disturbing the eggs or requiring nest relocation. The only potential factor identified by (Waqas *et al*., 2011) as contributing to low hatching success at Daran Beach was heavy rainfall and erosion of an undescribed number of nests in 2006-2007. The low sample sizes of *in situ* nests at Sandspit and Hawkesbay beaches, and spatial and temporal differences to nest data at Daran Beach, does not allow a rigorous comparison of hatching success. Conditions on sea turtle nesting beaches in Pakistan may potentially contribute to a lower hatching success than that recorded for green and olive ridley turtles elsewhere in the region (Table 3).

Table 1. The depth of *in situ* green and olive ridley sea turtle nests in the northern Indian Ocean.

Sea Turtle	Location	Mean Nest Depth±S.D. (Range) (cm)	# Nests	Source
Green	St. Martin's Is., Bangladesh	100±11 (85-104)	4	Rashid & Islam, 2006
	Saurashtra Coast, Gujarat, India	83 (62-122)	35	Venkatesan *et al*., 2004
	Kosgoda, Sri Lanka	73±12 (30-114)	482	Ekanayake *et al*., 2016
Olive ridley	St. Martin's Is., Bangladesh	41±7 (33-50)	21	Rashid & Islam, 2006

Table 2. The incubation duration of *in situ* green and olive ridley sea turtle nests in the northern Indian Ocean.

Sea Turtle	Location	Mean Incubation Duration±S.D. (Range) (Days)	# Nests	Source
Green	St. Martin's Is., Bangladesh	62±3* (-)	-	Hossain *et al*., 2004
	Qaruh & Umm Al-Maradim Is., Kuwait	- (53-57)	73	Al-Mohanna *et al*., 2014
	Daran Beach, Pakistan	- (55-104)	-	Waqas *et al*., 2011
	Ras Baridi, Saudi Arabia	60±3 S.D. (50-82)	39	Pilcher & Al-Merghani, 2000
	Kosgoda, Sri Lanka	51±4 S.D. (43-68)	-	Ekanayake *et al*., 2016
	Rekawa, Sri Lanka	53±4 S.D. (43-68)	-	Ekanayake, 2003 in Ekanayake *et al*., 2016
Olive ridley	St. Martin's Is., Bangladesh	64±4* (-)	-	Hossain *et al*., 2004

- Not reported
* S.D. or S.E. not specified

THE FUTURE OF HATCHERIES IN PAKISTAN

With low hatching success from nests in hatcheries at Sandspit and Hawkesbay beaches but ongoing threats to nests and hatchlings from wild dogs, Kabraji & Firdous (1984) suggested that only the most vulnerable nests be relocated to the nest enclosures and the hatching success of *in situ* nests be monitored for comparison. As the threats have not abated (and poaching of eggs and hatchlings may be increasing; Shahid pers.obs.) and successful management strategies for canines are limited, their recommendation remains as the most practical for conservation of sea turtle nests at this location. However, current hatchery management practices can be complemented with additional measures and research to maximise hatchling production. One of the possible contributing factors to low hatching success in hatcheries is accumulation of organic material in the hatchery substrate and subsequent high microbial load. It is recommended that sand be replaced (from a low-density nesting area or adjacent beach) or turned over annually, and potentially treated with a fresh- or saltwater wash (for example see Bézy *et al*., 2015) if the hatchery itself cannot be constructed in a new place each year with comparatively clean substrate. Treatment of hatchery substrate, further research into environmental conditions within the nest (e.g. temperature and moisture availability) and other potential causes of low hatching success, and monitoring of hatching success and environmental conditions of *in situ* nests, could give greater insight and enable higher hatchling production in the declining population of green turtles in Sindh province (as described by Firdous *et al*., 2011).

People associated with hatcheries in Pakistan have expressed concern about the potential contribution of high nest temperatures to embryo and hatchling mortality in Sandspit and Hawkesbay hatcheries (Phillott, unpubl.). However, nest temperatures exceeding the thermal maximum for sea turtle embryos have not yet been recorded and hatcheries and individual nests are currently unshaded. Various studies have assessed potential mitigation strategies for the effects of climate change on sea turtle nest temperatures (for examples see Jourdan & Fuentes, 2015) but it is not recommended that these be implemented in Pakistan without first measuring the range of nest temperatures over time in the hatcheries, and relating nest temperatures to the thermal tolerance of sea turtle embryos, natural sex ratios from *in situ* nests, and incubation temperature for these populations of green and olive ridley sea turtles at which 100% female hatchlings are produced. If nests are shaded or watered to decrease nest temperatures unnecessarily, the sex ratio of hatchlings produced by hatcheries in Pakistan could be

Table 3. The hatching success of green and olive ridley sea turtle nests in the northern Indian Ocean*.

Sea Turtle	Geographic Location	Nest Location	Mean Hatching Success±S.D. (Range) (%)	# Nests	Source
Green	Sandspit and Hawkesbay beaches, Pakistan	Hatchery	26 (11-43)	17,048	Firdous, 2001; Firdous *et al*., 2011
	Madhavpur, Gujarat, India	Hatchery	83 (-)	146	Venkatesan *et al*., 2004
	Kosgoda, Sri Lanka	*In situ*	77±22 (66-81)	526	Ekanayake *et al*., 2016
	St. Martin's Is., Bangladesh	Hatchery	80 (-)	10	Hossain *et al*., 2004
	Ras Baridi Coast, Saudi Arabia	*In situ*	80±16 (32-99)	28	Pilcher & Al-Merghani, 2000
	Qaruh & Umm Al-Maradim, Is., Kuwait	*In situ*	75 (-)	73	Al-Mohanna *et al*., 2014
Olive ridley	Sandspit and Hawkesbay beaches, Pakistan	Hatchery	27 (6-74)	654	Firdous, 2001; Firdous *et al*., 2011
	Adyar River, Madras, India	Hatchery	66 (-)	504	Shanker, 1994
	Kasargod District, Kerala, India	Hatchery	66±23 (35-90)	104	Kumar, 2002
	Vishakapatnam, Gangavaram and Pudimaka coast, Andhra Pradesh	*In situ*	70 (-)	389	Nath, 2000
	Rushikulya rookery, Odisha, India	*In situ*	83 (66-93)	5,362	Chandarana *et al*., 2017
	Ramayapatana, Odisha, India	Hatchery	95±2 (87-100)	195	Behera & Kar, 2013
	Sonadia Island, Bangladesh	Hatchery	92±5 (-)	43	Islam *et al*., 2011
	Cox's Bazaar, Bangladesh	Hatchery	88 (74-98)	260	Islam & Mollah, 2015
	St. Martin's Is., Bangladesh	Hatchery	81 (-)	10	Hossain *et al*., 2004

*A detailed account of hatching success in hatcheries in India is given in Phillott & Kale, 2018

\- Not reported

mistakenly skewed towards a higher proportion of males.

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UNREGULATED NUMBERS AND MANAGEMENT PRACTICES OF SEA TURTLE HATCHERIES AN ONGOING CONCERN IN SRI LANKA

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INTRODUCTION

Green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*), and olive ridley (*Lepidochelys olivacea*) turtles nest in Sri Lanka. In response to the country's historically over-exploited sea turtle fishery, legal protection of sea turtles and their eggs was first introduced by an amendment in 1972 to the Fauna and Flora Protection Ordinance of 1937 (Hewavisenthi, 1990). Nevertheless, consumption of eggs continued despite the legislation, with an estimated take of 20,000 eggs annually (Hoffman, 1975 in Hewavisenthi, 1990). In subsequent decades, close to 100% of eggs were harvested for sale or local consumption at Rekawa (Cooray, 1988; Ekanayake *et al*., 2002), Mirissa (Dattatri & Samarajiva, 1982), and other locations (see de Silva, 2006) resulting in no hatchling production from these nesting beaches (Cooray, 1988). Egg exploitation has been regarded as a major threat to nesting sea turtle populations in Sri Lanka (see de Silva, 1996; Amarasooriya & Dayartne,1997 in Amarasooriya, 2000).