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

ANDREA D PHILLOTT[1#], SANTHUSHYA HEWAPATHIRANAGE[2] & RUPIKA S. RAJAKARUNA[2]

[1]FLAME University, Pune, Maharashtra, India

[2]University of Peradeniya, Peradeniya, Sri Lanka

[#]andrea.phillott@flame.edu.in

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).

As a conservation measure to mitigate the impact of the sea turtle meat and egg exploitation in Sri Lanka, the first hatchery was established in 1956 and the second in 1969 (de Silva, 2006). Despite the 1972 ban on collection of sea turtle eggs, existing hatcheries continued operations and new hatcheries were opened without formal permission or approval. The number of hatcheries in south-west Sri Lanka fluctuated over time, reported as 16 hatcheries in 1994, 7 in 1995, 9 in 2000, 7 in 2012, and 15 in 2015 (see de Silva, 1996; Richardson, 1996; Amarasooriya, 2004; Tisdell & Wilson, 2005; Rajakaruna *et al.*, 2013; Jayathalika *et al.*, 2017) with hatcheries opening and closing (see Amarasooriya, 2004) for undescribed reasons. The number of eggs transferred to hatcheries annually appeared to increase dramatically with the rising number of hatcheries (Tisdell & Wilson, 2005), from ~49,000 eggs among three hatcheries in 1981/82 (Wickramsinghe, 1982) to ~300,000 eggs among nine hatcheries in 2000 (Amarasooriya, 2004). Amarasooriya (2004) indicated that the eggs reburied in hatcheries represented about a third of the annual mean egg production in their districts; Tisdell & Wilson (2005) assumed that the remaining two-thirds were consumed. Egg consumption may be ongoing, although among a lower proportion of the population and less frequently than before (Rajakaruna *et al.*, 2009).

The reported hatching success of nests transferred to hatcheries ranged from 0-80% (e.g. Wickramsinghe, 1982; Wickremasinghe, 1983; Dayaratne & Amarasooriya, 1995; Amarasooriya, 2004). Early concerns were raised about hatchery procedures, including the collection and transport of eggs and holding of hatchlings (Fernando, 1977; Dayaratne & Amarasooriya, 1995; Hewavisenthi & Kotagama, 1990; Hewavisenthi & Kotagama, 1991)

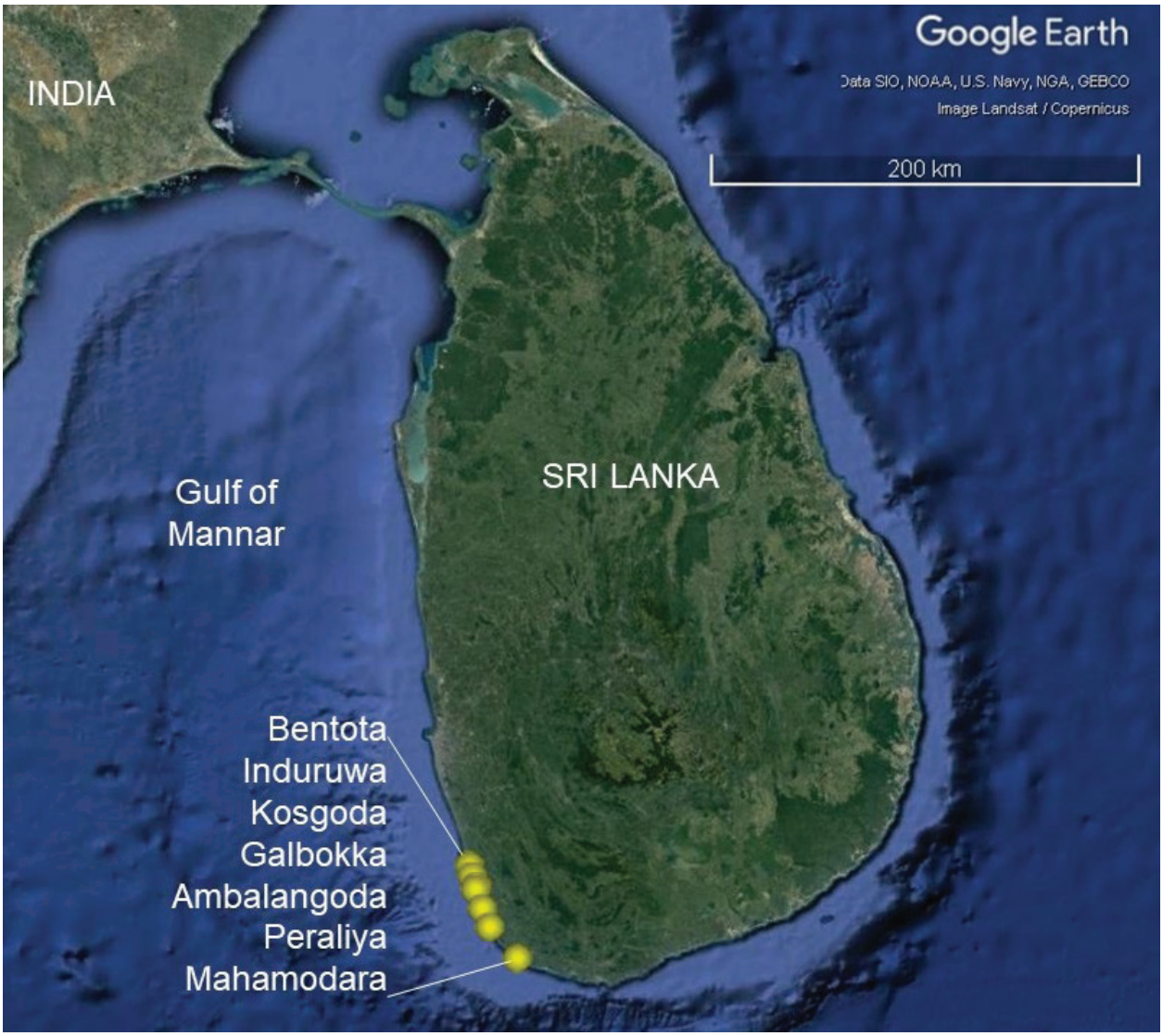

Figure 1. Location of sea turtle hatcheries in Sri Lanka, 2015/16.

and the hatcheries themselves were described as a major threat to nesting sea turtle populations in Sri Lanka (see Amarasooriya & Dayartne, 1997 in Amarasooriya, 2000). This was accompanied by criticism that the hatcheries main objective had shifted from conservation to tourism (Dayaratne & Amarasooriya, 1995), with the implication that less attention was paid to maintaining effective hatchery management practices. Many authors called for national guidelines and regulations for sea turtle hatcheries in Sri Lanka and identified a need for licenses and inspections (Dayaratne & Amarasooriya, 1995; de Silva, 1996; Richardson, 1996; Hewavisenthi, 2001; Amarasooriya, 2004), and Richardson (1996) even outlined hatchery management guidelines to initiate discussion in the country.

The 2004 Indian Ocean tsunami severely damaged or destroyed most hatcheries in Sri Lanka at the time and was identified as an opportune time for the Department of Wildlife Conservation to introduce regulations for the previously illegal operations (Kapurusinghe, 2006). However, hatcheries recommenced egg collection within 2 months of the disaster (Brodie *et al*., 2008) and some hatcheries were rebuilt on a larger scale than before (Kapurusinghe, 2006). Both concern for the effect of hatchery practices on hatchling production, survival, and fitness (Rajakaruna *et al*., 2013; Balsalobre & Bride, 2016) and calls for national regulation (Rajakaruna *et al*., 2013) are ongoing. The current study builds on the most recent description of hatchery infrastructure and practices in Sri Lanka (Rajakaruna *et al*., 2013) so we can better understand the potential impact of hatcheries as an *ex situ* conservation strategy on nesting sea turtle populations in the northern Indian Ocean.

METHODS

To determine management practices and productivity of sea turtle hatcheries in Sri Lanka, we conducted face to face interviews with hatchery owners, managers, or other senior personnel from hatcheries from December 2015 to January 2016. Informed consent was obtained before participants were asked questions about hatchery structure, egg collection and relocation techniques, nest incubation conditions, hatching success, hatchling emergence and release, and record keeping.

RESULTS

Eleven hatcheries operated in south-west Sri Lanka (Figure 1) at the time of this study, and representatives from all 11 contributed to this study. The majority of hatcheries (73%) identified tourism as their primary reason for operating, while the remainder (27%) decribed dual purposes of tourism and conservation. Approximately half of the hatcheries were a long-term (>17yr) operation, while the remainder were relatively new (<10yr). Hatcheries supported an average of 7 employees (range 3-15), which included owner/s, manager/s, worker/s, guard/s and accountant/s (Table 1). Managers and other staff at the majority (64%) of hatcheries had never participated in a workshop relating

Table 1. The name and basic organisation details for 11 hatcheries operating in south-west Sri Lanka in 2015.

Name	Location	# Years Operation	# Employees	Hatchery Purpose
Arun and Amal Turtle Conservation and Research Center	Kosgoda	3	12	Tourism
Bentota Sea Turtle Conservation and Research Project	Bentota	22	7	Tourism and conservation
Induruwa Sea Turtle Conservation	Induruwa	4	10	Tourism
Kosgoda Sea Turtle Conservation Project	Kosgoda	27	4	Tourism
Marine Turtles Protecting Center	Kosgoda	20	7	Tourism
Sea Turtle Hatchery	Ambalangoda	3	4	Tourism
Sea Turtle Hatchery and Rescue Center	Peraliya	9	4	Tourism
Sea Turtle Hatchery Center	Mahamodara	2	4	Tourism and conservation
The Wunderbar Turtle Project	Bentota	17	3	Tourism
Turtle Hatchery Galbokka	Galbokka	2	4	Tourism and conservation
Victor Hasselblad Sea Turtle Conservation and Research Center	Kosgoda	35	15	Tourism

to hatchery management techniques; respondents for the remainder (36%) of the hatcheries reported they were members of the 'Sea Turtle Conservation and Breeding Association of Sri Lanka' in response to the question about training in hatchery management. Of the participants from ten hatcheries that responded to a question about records of their operations, only 50% indicated that they maintain records of the number of eggs or nests collected annually, hatching success, and number of hatchlings released annually. Those records were reported to be shared with the National Aquatic Resources Research and Development Agency (NARA) of Sri Lanka.

All hatcheries had been situated in permanent locations throughout their periods of operations, but sand was replaced annually. The average number of nests incubated at each hatchery was 242.4 (range 80-700), with a total of ~2,560 reported nests incubated all hatcheries. Exact numbers of nests and eggs for each species were not provided but hatcheries each reported nests of 2-3 species of sea turtles; green and olive ridley turtle nests were incubated at all hatcheries, hawksbill nests at 46% of hatcheries, and loggerhead nests at 18% of hatcheries. No leatherback nests were incubated at hatcheries during the study period.

The 11 hatcheries acquired their eggs from a total of 15 beaches (Figure 1; Table 2; average of 2.8 beaches per hatchery, range 1-4) in south-west Sri Lanka, with all but one hatchery acquiring eggs from up to 20 egg collectors (Table 3). Survey participants described nests being transported up to 20km (Table 2) in a bucket, plastic bag, or cardboard box by foot, three-wheeler, bicycle, or bus. Multiple clutches were often mixed during transport (Rajakaruna, unpubl.). Hatcheries purchased all available, unbroken eggs. Egg price was LKR 10-15 (Sri Lankan Rupees) at the peak of the nesting season and LKR 20-25 when nesting numbers decreased (Table 3).

The time between collection of eggs and reburial in the hatchery was more than 2hr at 73% of hatcheries (Table 2). Nests were incubated at a density of 1-3/m^2 and depth of 45-70cm (Table 4). The reported average hatching success of nests for all species was 82% (range 65-99%) (Table 4); average hatching success by species across all hatcheries was 84% (range 65-99%) for green turtles, 81% for olive ridley turtles (range 65-95%), 77% for hawksbill turtles (range 65-90%) and 85% for loggerhead turtles (range 80-90%). Once emerged, many hatchlings were held for a short period (1-3d) or longer (2wk) before release, while some were held for 3-4yr for display purposes (Table 5). Animals held at the hatcheries were housed in permanent, salt-water concrete tanks.

DISCUSSION

A comparison of the 11 hatcheries operating in 2015 (this study) with the seven recorded in the same area in 2010 (Rajakaruna *et al*. 2013) demonstrated the variability of hatchery operations in Sri Lanka; five new hatcheries have opened since 2010, two appear to have closed at least temporarily, and four have continued their operations. This reflects the observation by Amarasooriya (2004) that hatcheries in this country may open and close at various intervals. Based on the responses of survey participants, this study estimated ~2,560 nests were collected annually among the 11 hatcheries identified during our study, suggesting a comparable number of eggs transferred to hatcheries in 2015 as the most recently estimated 300,000 eggs among nine hatcheries in 2000 (Amarasooriya, 2004).

From the self-reported descriptions of egg collection and handling, nest incubation, and hatchling emergence and holding procedures of these 11 hatcheries in southwestern Sri Lanka in 2015, three practices were identified as potentially limiting hatching success and hatchling fitness. The first is the time between collection of nests from the nesting beach and reburial in the hatchery. Eight of the 11 hatcheries reported that several hours may pass between the time the eggs are collected and when they arrive at the hatchery. The reported time does not include the interval between oviposition and collection of the eggs, as 10 of the 11 hatcheries source their eggs from collectors at dawn (Rajakaruna, unpubl.). It follows that eggs moved to hatcheries in south-west Sri Lanka may be several hours or several days old (Hewavisenthi & Kotagama, 1991; this study) and transported in a bucket, bag or box by bicycle or bus etc where movement of the eggs is likely to occur (this study). This is longer than the recommended time between oviposition and reburial when nests are moved (2hr by Parmenter, 1980; 3hr by Harry & Limpus, 1989) and likely to result in increased rates of embryo mortality and decreased hatching success (Limpus *et al*., 1979; Parmenter, 1980.

Given the extended time between nests being laid and reburied, the rates of hatching success (see Phillott *et al*., 2018) reported by hatcheries participating in this study is surprising. Few hatcheries maintain records (Rajakaruna *et al*., 2013; this study) and historical information was lost during the 2004 Indian Ocean tsunami (Rajakaruna *et al*., 2013), so more accurate data to calculate the mean and range of hatching success for nests incubated at hatcheries in Sri Lanka using the reported methods of egg collection and transport are currently unavailable. In addition, most hatcheries estimate hatching success by counting the number of hatchlings emerged from a nest and not by excavating the nest contents, whereas the more accurate

Table 2. Source beaches and handling distances and times for sea turtle nests relocated to hatcheries in southwestern Sri Lanka. Each cell indicates sea turtle species (Cc- loggerhead; Cm- green; Dc- leatherback, Ei- hawksbill, Lo- olive ridley), total # nests collected annually from that beach, maximum transport distance (km) to the hatchery, and maximum time (hr) between egg collection and reburial in the hatchery as reported by survey participants.

	Hatchery										
Beach	**Arun & Amal Turtle Conservation & Research Center, Kosgoda**	**Bentota Sea Turtle Conservation & Research Project, Bentota**	**Induruwa Sea Turtle Conservation, Indurawa**	**Kosgoda Sea Turtle Conservation Project, Kosgoda**	**Marine Turtles Protecting Center, Kosgoda**	**Sea Turtle Hatchery, Ambalangoda**	**Sea Turtle Hatchery & Rescue Center, Peraliya**	**Sea Turtle Hatchery Center, Mahamodara**	**The Wunderbar Turtle Project, Bentota**	**Turtle Hatchery Galbokka, Galbokka**	**Victor Hasselblad Sea Turtle Conservation & Research Center, Kosgoda**
Ahungalla											Cm, Ei, Lo 100 nests 4km, 6hr
Akurala							Cm, Lo 50 nests 4.5km, 4hr				
Balapitiya		Cc, Cm, Dc, Ei, Lo 200 nests 20km, 8hr	Cm, Dc, Ei, Lo 100 nests 15km, 5hr								Cc, Cm, Dc, Ei, Lo 200 nests 10km, 6hr
Bentota									Cm, Lo 50 nests 6km, 6hr		
Dadalla								Cm, Lo 25 nests 3km, 0.5hr			
Galbokka										Cm, Lo 150 nests 6km, 0.5hr	
Induruwa		Cm, Lo 150 nests 5km, 6hr	Cm, Lo 50 nests 1km, 5hr	Cm, Lo 64 nests 8km, 5hr	Cm, Lo 50 nests 8km, 4hr						Cm, Lo 100 nests 6km, 6hr
Kahawa						Cm, Ei, Lo 70 nests 10km, 2hr	Cm, Lo 50 nests 5km, 4hr				
Kaikawala		Cm, Ei, Lo 70 nests 10km, 7hr	Cm, Ei, Lo 30 nests 1km, 5hr								
Kaluwella								Cm, Lo 25 nests 3km, 0.5hr			
Kosgoda	Cm, Lo 150 nests 1km, 0.25hr		Cm, Ei, Lo 70 nests 8km, 5hr	Cm, Ei, Lo 100 nests 1km, 5hr	Cm, Ei, Lo 60 nests 1km, 4hr	Cm, Ei, Lo 50 nests 25km, 3hr			Cm, Ei, Lo 100 nests 10km, 6hr		Cm, Lo, Ei 300 nests 2km, 6hr
Mahamodara								Cm, Lo 30 nests 1km, 0.5hr			
Mudumpe						Cm, Lo 30 nests 1km, 2hr					
Peraliya							Cm, Lo 30 nests 1km, 4hr				

Table 2 cont.

	Hatchery										
Beach	**Arun & Amal Turtle Conservation & Research Center, Kosgoda**	**Bentota Sea Turtle Conservation & Research Project, Bentota**	**Induruwa Sea Turtle Conservation, Indurawa**	**Kosgoda Sea Turtle Conservation Project, Kosgoda**	**Marine Turtles Protecting Center, Kosgoda**	**Sea Turtle Hatchery, Ambalangoda**	**Sea Turtle Hatchery & Rescue Center, Peraliya**	**Sea Turtle Hatchery Center, Mahamodara**	**The Wunderbar Turtle Project, Bentota**	**Turtle Hatchery Galbokka, Galbokka**	**Victor Hasselblad Sea Turtle Conservation & Research Center, Kosgoda**
Seenigama							Cm, Lo 20 nests 2km, 4hr				
Thotawaththa					Cc, Cm, Dc, Ei, Lo 90 nests 4km, 4hr						
# Source Beaches	1	3	4	2	3	3	4	3	2	1	4
Total # Nests	150	420	250	164	200	150	150	80	150	150	700
Range Max. Transport Distance (km)	1	5-20	1-15	1-8	1-8	1-25	1-5	1-3	6-10	6	2-10
Range Max. Transport Time (hr)	0.25	6-8	5	5	4	2-3	4	0.5	6	0.5	6

Table 3. Number of egg collectors supplying hatcheries in southwestern Sri Lanka and purchase price per egg (LKR; Sri Lankan Rupees). A range of prices indicates the cost per egg from the peak of the turtle nesting season to when nesting numbers are low.

		Price Per Egg (Sri Lankan Rs)			
Hatchery	**# Egg Collectors**	**Green**	**Olive Ridley**	**Hawksbill**	**Loggerhead**
Arun and Amal Turtle Conservation and Research Center	8	20	20	-	-
Bentota Sea Turtle Conservation and Research Project	7	20	18	-	20
Induruwa Sea Turtle Conservation	10	15-20	15-20	15-20	-
Kosgoda Sea Turtle Conservation Project	10	12	12	12	-
Marine Turtles Protecting Center	15	10-25	10-25	-	10-25
Sea Turtle Hatchery	20	10-20	10-20	10-20	-
Sea Turtle Hatchery and Rescue Center	20	20	20	-	-
Sea Turtle Hatchery Center	3	15	15	15	-
The Wunderbar Turtle Project	6	-	8-20	-	-
Turtle Hatchery Galbokka	20	15-20	15-20	15-20	-

- No information provided

Table 4. Incubation conditions and hatching success at sea turtle hatcheries in southwestern Sri Lanka.

Hatchery	Green Turtle Nests			Olive Ridley Turtle Nests			Hawksbill Turtle Nests			Loggerhead Turtle Nests		
	Nest Density (/m²)	Nest Depth (cm)	Hatching Success (%)	Nest Density (/m²)	Nest Depth (cm)	Hatching Success (%)	Nest Density (/m²)	Nest Depth (cm)	Hatching Success (%)	Nest Density (/m²)	Nest Depth (cm)	Hatching Success (%)
Arun & Amal Turtle Conservation & Research Center	1	60	75	-	-	75	-	-	-	-	-	-
Bentota Sea Turtle Conservation & Research Project	2	60	97	2	45	90	-	-	-	2	60	90
Induruwa Sea Turtle Conservation	3	70	99	3	45	95	3	60	90	-	-	-
Kosgoda Sea Turtle Conservation Project	2	60	70	2	45	70	2	60	70	-	-	-
Marine Turtles Protecting Center	2	60	80	2	45	80	-	-	-	2	60	80
Sea Turtle Hatchery	3	45	90	3	45	90	3	45	90	-	-	-
Sea Turtle Hatchery & Rescue Center	2	60	90	2	45	90	-	-	-	-	-	-
Sea Turtle Hatchery Center	2	70	85	2	45	80	-	-	-	-	-	-
The Wunderbar Turtle Project	2	60	80	2	45	70	2	60	70			
Turtle Hatchery Galbokka	2	60	90	2	45	90	-	-	-	-	-	-
Victor Hasselblad Sea Turtle Conservation & Research Center	2	45	65	2	45	65	2	45	65	-	-	-

- No information provided

Table 5. Hatchling release and holding conditions at sea turtle hatcheries in southwestern Sri Lanka.

Hatchery	Time Between Hatchling Emergence and Release	Hatchling Release Time	Tourist/Local Observers
Arun and Amal Turtle Conservation and Research Center	100 %- 2wk	> 5.30pm	Yes
Bentota Sea Turtle Conservation and Research Project	100%- 1-2d	> 6.00pm	Yes
Induruwa Sea turtle Conservation	80%- day of emergence 20%- 3-4d	> 5.30pm	Yes
Kosgoda Sea Turtle Conservation Project	95%- day of emergence 5%- kept for display	> 6.30pm	Yes
Marine Turtles Protecting Center	2-3 hatchlings- 3-4yr 10-15 hatchlings- 2-4d Remainder- day of emergence	> 5.30pm	Yes
Sea turtle Hatchery	100%- 2-3d	> 6.00pm	Yes
Sea Turtle Hatchery and Rescue Center	100%- day of emergence	> 6.30pm	Yes
Sea Turtle Hatchery Center	100%- day of emergence	> 10.00pm	No
The Wunderbar Turtle Project	100%- 2-3d	>8.30pm	Yes
Turtle Hatchery Galbokka	10-15 hatchlings- 2-3d Remainder- day of emergence	> 5.30pm	Rarely
Victor Hasselblad Sea Turtle Conservation and Research Center	90%- day of emergence 10%- 2-4d	6.00-10.00pm	Yes

estimation is using that described by Miller (1999). Such uncertainty in the self-reported hatching success makes it difficult to assess the hatchery management practices and their impact on hatchling production.

The second hatchery management practice of concern is the reported nest density up to 3 per square metre. Only one hatchery in our study maintained the suggested distance of 1m between adjacent nests (Mortimer, 1999). Higher nest densities in experimental settings result in higher nest temperature and CO_2 concentration and reduced O_2 concentration, which may cause embryo mortality (see Honarvar *et al.*, 2008). The reported nest depth in the hatcheries is unlikely to reduce hatching success, and the piling of sand over nest (as frequently observed during this study and reported previously by Rajakaruna *et al.*, 2013) is less likely to effect embryonic survival than the interval between oviposition and reburial of eggs and nest density.

The holding of hatchlings after emergence is the third management practice of concern in Sri Lankan hatcheries. Hatchlings are often held for several days, with explanations such as reducing the likelihood of marine leeches (Hewavisenthi & Kotagama, 1990) or predatory fish (Perera, 1986 in Richardson, 1996) attacking the hatchling at the abdominal scale where the yolk was absorbed. However, there has been no documented observation of this event occurring in the wild or captivity and it is, therefore, an inadequate and unvalidated reason for holding hatchlings before release. Richardson (1996) suggests the primary objective for the practice is to attract tourists. However, holding hatchlings for several days after emergence at hatcheries in Sri Lanka has been demonstrated to significantly reduce both crawl speed (Hewavisenthi & Kotagama, 1990; Balsalobre & Bride, 2016) and swimming stroke rate (Amarasooriya, 2004; Balsalobre & Bride, 2016) over time. These findings are similar to studies on hatchery management practices conducted in Malaysia (Pilcher & Enderby, 2001; van der Merwe *et al.*, 2013) and Japan (Okuyama *et al.*, 2006). Therefore, the practice is likely to reduce hatchling fitness and survival at sea and should be discontinued immediately.

Our concerns are similar to those already expressed about the time interval between eggs being laid and relocated to hatcheries (Hewavisenthi & Kotagama, 1991) and the holding of hatchlings (Hewavisenthi & Kotagama, 1990; Amarasooriya, 2004; Rajakaruna *et al*., 2013; Balsalobre & Bride, 2016) at hatcheries in Sri Lanka and we, too, call for centrally licensed, regulated and monitored hatcheries to ensure egg collection and movement and nest incubation practices minimise the risk of early embryonic death and result in high hatching success. As hatcheries in Sri Lanka may play an important role in making visitors aware of the threats to sea turtles, we suggest that predominantly deformed hatchlings or injured turtles (such as those rescued from fishing gear) be kept for display and a minimal number of hatchlings be held for this purpose. Hatchlings emerging from nests in Sri Lankan hatcheries at night should be released immediately; hatchlings emerging during daylight hours when there is additional threat of dehydration, heat stress or predation should be kept in dark, dry conditions such as those suggested by Mortimer (1999) and SToI (2011) before release at dusk.

We also recommend that nest protection strategies on the nesting beach be further considered. For example, Ellepola *et al*. (2014) report the successful use of wire cages to protect *in situ* sea turtle nests from predators at Panama on the east coast of Sri Lanka, and Turtle Conservation Project successfully engaged prior egg collectors as nest protectors at Rekawa (e.g. Richardson, 1994) and Kosgoda (e.g. Kapurusinghe *et al*., 2008) to deter poachers. Revenue from sea-turtle related tourism could be used to support such conservation initiatives (for example see Rathnayake, 2016).

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