Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia

Holding and Headstarting Sea Turtle Hatchlings

Growing concerns about hatchery practices, including the holding of sea turtle hatchlings before release, and the emergence (or re-emergence) of headstarting programs throughout countries in the Indian Ocean and South-East Asia region were expressed at the 2nd and 4th Meetings of the Northern Indian Ocean Marine Turtle Task Force (NIO-MTTF). As a response, an Advisor to the NIO MTTF, Dr. Andrea D. Phillott, FLAME University, India, was asked to review the best practices for sea turtle hatcheries and the implications of holding or headstarting for hatchling behaviour, health, and survival. The Advisory Committee reviewed and approved this document.

The intention of this document is to inform Signatory States, so that evidence-based decisions about sea turtle management and conservation can be made. Best practices for sea turtle hatcheries were presented at the 8th Meeting of the Signatory States to the IOSEA Marine Turtle MOU and published in the Indian Ocean Turtle Newsletter[1]. This paper presents an overview of the practices and concerns about holding and headstarting programs with reference to relevant sea turtle hatchling biology. Where possible, examples are drawn from research and conservation conducted in Signatory States to the IOSEA Marine Turtle MOU.

Executive Summary

- Human interventions in the natural life history of sea turtles can significantly impact their survival.
- For this reason, it has been previously recommended that hatcheries use evidence-based practices for egg collection, transport and incubation that consider the vulnerability and required environment of the embryo inside the egg. The care and release of hatchlings after emergence from the nest should also be based on their biology and behaviour.
- Hatchlings should be released as soon as possible after their emergence from the nest. Holding (or keeping) hatchlings before they are released is not recommended. It will use energy reserves that hatchlings need to crawl across the beach and swim quickly through inshore waters to avoid predators and reach their first feeding habitat and increase hatchling mortality.
- Headstarting programmes do not address direct threats to sea turtles such as bycatch, illegal take, loss of habitat etc. Protecting sea turtles in the first year of their life through headstarting is unlikely to increase population numbers unless sub-adults and adults are also protected.
- Headstarting programmes should be considered an ongoing experiment and must have a plan that ensures and assesses the health and well-being of captive turtles and measures the survival and normal biology of headstarted turtles after their release into the wild.

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Definitions of holding and headstarting

This overview regards holding and headstarting of hatchlings as distinct practices. There is no single, generally accepted definition of either term, so each is distinguished from the other based on length of time and purpose of the practice. Holding and headstarting facilities are usually associated with a turtle **hatchery**, a protected place to where threatened eggs can be moved and safely incubated in conditions similar to that on the natural nesting beach[1].

Holding is the practice of keeping or retaining hatchlings after their emergence from the nest, for a period of time that may range from hours to days, or longer. The purpose of holding hatchlings is to release them at a convenient time for hatchery personnel and/or display and release of hatchlings for the benefit of the hatchery and observers, e.g. for ecotourism or environmental education purposes. Hatchlings may be retained in conditions ranging from a dry bucket or damp sack to a bucket or tank of water, depending on the length of time for which hatchings are held.

Headstarting is the practice of raising hatchlings in captivity to a larger size, before their release to the wild. Protecting hatchlings from predation is believed to increase the likelihood of their survival, a priority for conservation of the population or species[2].

(Note that holding and headstarting of hatchlings differ from each other. Holding and headstarting are also different to farming, ranching, and/or captive breeding sea turtles for commercial purposes, such as the harvest of meat, shell, leather and other commodities that derive from sea turtles (e.g., blood, oil, fat, bones), and/or conservation[3]. This overview considers holding and headstarting only.)

Holding and headstarting are among the conservation/management actions that have been described as “halfway technology”[4]. While usually practiced with good intentions, holding and headstarting alone do not directly address or reduce direct threats to sea turtle populations- including interactions with fisheries, illegal take, and loss of habitat- and can interfere with hatchling biology and behaviour, reducing their chances of survival.

Sea turtle hatchling biology

Depending on species and incubation conditions in the nest, sea turtle embryos have a 6-13 week incubation period[5]. Once hatchlings have escaped the eggshell, internalised (absorbed) any remaining egg yolk and straightened their body which is slightly curled after being inside the egg, hatchlings dig to the top of the nest in a cooperative manner with their siblings[6] and wait below the surface of the sand. *En masse* hatchling emergence from the nest onto the beach is stimulated by a decrease in sand temperature and, therefore, usually occurs at night[7].

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[1] Phillott & Shanker. 2018. Indian Ocean Turtle Newsletter 27:31-34.
[2] Mrosovsky. 1980. Marine Turtle Newsletter 15:1.
[3] Ross. 1999. In: Eckert et al. (eds). Research and Management Techniques for the Conservation of Sea Turtles. Pp. 197-201.
[4] Frazer. 1992. Conservation Biology 6:179-184.
[5] Miller. 1996. In: Lutz & Musick (eds). The Biology of Sea Turtles Volume I. Pp. 52-81.
[6] Carr & Hirth. 1961. Animal Behaviour 9:68-70.
[7] Miller et al. 2003. In: Bolten & Witherington (eds). Loggerhead Sea Turtles. Pp. 125-143.

Survival of hatchlings depends greatly on their ability to emerge from the nest, run down the beach, swim out through nearshore waters, and reach offshore waters as quickly as possible. In the minutes spent crossing the beach, hatchlings use cues such as illumination and beach slope to orient towards the sea[8]. Crawling across the beach is believed to be crucial for hatchlings as it allows them to imprint on the natal beach and return to the area when they are ready to reproduce, known as nesting beach fidelity[9].

Once in the water, hatchlings enter a period of hyperactivity[10], known as the swimming "frenzy", during which they swim continuously for about 24hr. The swim frenzy allows them to minimise the time spent in coastal waters where predators are more abundant[11,12,13]. A combination of cues from wave direction and the light horizon helps hatchlings to orient offshore[14,15]. After the initial frenzy, hatchlings use currents and periodic, active swimming to find suitable habitats[8,16,17,18,19,20] Feeding does not start until they reach foraging habitat, about 1 week after emerging from the nest. Energy used for all hatchling activities, from when they hatch from the egg to when they first begin to feed, is derived from the residual yolk left from the time of hatching[21].

Once out of the nest and on the beach, hatchlings face threats such as predators, physical obstacles, and light pollution, as well as high sand temperatures which can cause burns or over-heating and mortality if they emerge during the daytime. After entering the sea, hatchling numbers are reduced. It is hard to study hatchling mortality at this time, but limited studies indicate that hatchling number can be reduced by an average of ~20% within the first 30 min[22] and 40-60% (and potentially up to 80%) within the first 2 hr[23] of entering the sea. Hatchlings eaten by terrestrial and marine predators play an important role in coastal food chains and nutrient cycles[24,25,26] so hatchling predation should only be controlled if it has the potential to reach unsustainable levels[27].

Best practices for releasing sea turtle hatchlings

Nest management before hatchling release

Nests in a hatchery should be individually enclosed with a basket or non-metallic cage (see Figure 1) before the predicted emergence date to prevent hatchlings from crawling throughout

[8] Salmon et al. 1992. Behaviour 122:1-2.
[9] see Lohmann et al. 2013. In: Wyneken et al. (eds). The Biology of Sea Turtles Volume III. Pp. 59-77.
[10] Carr. 1963. In: Slater (ed). Bio-Telemetry. Pp. 179-192.
[11] Wyneken & Salmon. 1992. Copeia 1992:478-484.
[12] Gyuris. 1994. Coral Reefs 13:137-144.
[13] Wyneken et al. 2008. Marine Biology 156:171-178.
[14] Goff et al. 1998. Animal Behavior 55:69-77.
[15] Pilcher et al. 2000. In: Pilcher & Ismail (eds). Sea Turtles of the Indo-Pacific: Research, Management, and Conservation. Pp. 151-166.
[16] Mansfield et al. 2014. Proceedings of the Royal Society B: Biological Sciences 281:20133039.
[17] Putman & Mansfield. 2015. Current Biology 25:1221-1227.
[18] Briscoe et al. 2016. Proceedings of the Royal Society B: Biological Sciences 283:20160690.
[19] Gaspar & Lalire. 2017. PLoS One 12:e0181595.
[20] Gatto & Reina. 2020. Biological Journal of the Linnean Society 131:172-182.
[21] Kraemer & Bennett. 1981. Copeia 1981:406-411.
[22] Oñate-Casado et al. 2021. Ichthyology & Herpetology 109:180-187.
[23] Pilcher et al. 2000. In Pilcher & Ismail (eds). Sea Turtles of the Indo-Pacific: Research, Management, and Conservation. Pp. 151-166.
[24] Bouchard & Bjorndal. 2000. Ecology 81:2305-2313.
[25] Madden et al. 2008. Biotropica 40:758-765.
[26] Heithaus. 2013. In Wyneken et al. (eds). The Biology of Sea Turtles Volume III. Pp. 249-284.
[27] Phillott. 2020. Indian Ocean Turtle Newsletter 32:31-40.

the hatchery and intermixing with hatchlings from different clutches. The predicted emergence date is usually about 45-55 days after oviposition. About 2-3 days before hatchling emergence from the nest, hatchling personnel may observe the sand surface immediately above the nest collapsing or caving inwards as the volume of the nest contents decrease due to hatchlings emerging from the eggs.

Figure 1: Woven basket (left), plastic mesh cages (centre), and wood and mesh cages (right) that enclose individual nests and prevent emerged hatchlings from crawling throughout the hatchery

(Photos: A.D. Phillott, A.D. Phillott, N. Kale)

Individual nest enclosures should be checked every 30-60 mins from afternoon to dawn and at other times when hatchlings may emerge (e.g., on overcast days and/or after rain) during the predicted emergence dates. Individual nest enclosures should be removed when hatchery personnel are not available to monitor the nests, so that hatchlings do not become exhausted or overheated. The fence or enclosure surrounding the hatchery should protect eggs and hatchlings from threats such as depredation and illegal take, but also be designed to allow the exit of hatchlings from the hatchery if they emerge when personnel are not present[28].

When to release hatchlings

The best practice for hatcheries is to release hatchlings as soon as possible after their emergence from the nest. This prevents hatchling exhaustion, dehydration, overheating, depletion of the energy reserves in the yolk which is needed for movement from the beach to offshore, injury, and even death. Hatchlings that emerge in the heat of day or at a time when immediate release is not possible can be housed in a soft, damp cloth or sack (made of tightly woven material so hatchling claws do not become entangled) in a cool, dark place until release[28].

Where to release hatchlings

Hatchlings should be released in groups to improve the likelihood of survival. However, early emergers from a nest should <u>not</u> be held until more hatchlings emerge as this practice can result in loss of energy (through consumption of the stored yolk). Terrestrial and aquatic predators will congregate at locations which are regularly used for hatchling releases, so release sites should be random and hundreds of metres apart. Hatchlings should be released so they crawl across the beach and enter the ocean to allow imprinting on their natal beach,

[28] see Phillott & Shanker. 2018. Indian Ocean Turtle Newsletter 27:31-34.

as this is believed to facilitate return of sea turtles to breed in the same region where they originally hatched[29].

Providing for observers during hatchling release

To ensure hatchling safety while allowing observers the opportunity to watch hatchlings as they run to the sea, the following steps are recommended[30,31]:

- Create a safe hatching release and crawling area by drawing parallel lines in the sand, about 10m apart and perpendicular to the ocean. Fill any holes and smoothen the sand in the safe hatchling area between the hatchling release point and the sea and remove marine debris and other obstacles.
- Ensure that observers remain outside the lines that mark the safe hatchling area so hatchlings are not accidentally trampled.
- Release hatchlings into the area between the lines to ensure their safety and allow observers to have an unobstructed view of the hatchlings as they crawl down to the sea.
- Place a dim torch or flashlight on the sand as close as possible to the sea, with the light directed landward during night-time releases. This light will help to guide hatchlings so they remain within the safe area and allow observers to see them at night. The torch/flashlight should be switched off when the majority of hatchlings enter the sea so they are not attracted back on to the beach.
- Do not permit camera flashes to be used while filming/photographing hatchlings during night-time releases as the artificial light will cause disorientation.
- Warn observers close to the water not to jump or step to avoid waves as they might step on hatchlings when they are close to or entering the sea.
- Hatchlings that are taking longer than their siblings to cross the beach and enter the sea can be carried to the water and released once the majority of hatchlings have departed.

Concerns about holding sea turtle hatchlings

Holding hatchlings for any time period will result in them unnecessarily using energy reserves that are needed to crawl across the beach and swim quickly through inshore waters to avoid predators and reach their first feeding habitat. Multiple studies have shown that hatchlings that are held before release will crawl and swim at slower speeds and swim with less powerful strokes (Table 1). Hatchlings that are slow and less powerful swimmers will take longer to reach offshore habitats, and will be at greater risk of predation. Hatchlings that do not reach their foraging grounds before their energy reserves are depleted are at greater risk of death[32].

For these reasons, hatchlings should be released as soon as possible after emergence from the nest and not held within the hatchery fence or nest enclosure, or in a bucket, sack, pond or tank etc., for reasons of convenience, scheduled public releases, or unjustified concerns about their health[33,34]; see also Examples 1- 3.

[29] Phillott. 2020. Indian Ocean Turtle Newsletter 32:31-40.
[30] Mortimer. 1999. In: Eckert et al. (eds). Research and Management Techniques for the Conservation of Sea Turtles. Pp. 174-178.
[31] Shanker et al. 2003. Sea Turtle Conservation: Beach Management and Hatchery Programmes.
[32] Mansfield et al. 2014. Proceedings of the Royal Society B: Biological Sciences 281:20133039.
[33] Phillott *et al*. 2018. Indian Ocean Turtle Newsletter 27:8-17.
[34] Phillott *et al*. 2021. Herpetological Conservation and Biology 16:652-670.

Table 1. Research conducted in various Signatory States of the IOSEA Marine Turtle MOU that assessed crawl and/or swim performance in hatchlings which were held before release

Country	Sea Turtle	Holding Time and Conditions	Findings
Malaysia	Green	Held for 0-6 hrs in tanks of seawater	Swim speed reduced significantly with holding time, and swim strokes were also less powerful[35]
	Green	Held for 0-6 hrs in dry conditions	Crawl speed decreased significantly with holding time[36]
Sri Lanka	Green, Hawksbill, Olive Ridley	Held for 0-7 days in tanks of seawater	Distance moved by hatchlings in 30 sec decreased significantly with holding time[37]
	Green, Hawksbill, Leatherback, Loggerhead, Olive Ridley	Held for 1-5 days in tanks of seawater	Number of swimming strokes per minute significantly reduced with holding time[38]
	Green	Held for 0-48 hrs in tanks of seawater	Crawl speed and swim stroke rate decreased significantly with holding time[39]

Example 1: Holding conditions put hatchlings at risk of injury and/or death

Some hatcheries bury a bucket to sand level (see red arrow) to collect hatchlings at night, attracting hatchlings using a torch inside the bucket. When nests are not enclosed or monitored overnight, the bucket saves the hatchery personnel time and effort in gathering all the hatchlings when they arrive in the morning. Hatchlings held in this way can be injured, crushed, and potentially die if many hatchlings emerge overnight and accumulate in the bucket. This practice must not be used.

(Photo: A.D. Phillott)

[35] Pilcher & Enderby. 2001. Journal of Herpetology 35:633-638.
[36] van der Merwe et al. 2013. Animal Conservation 16:316-323.
[37] Hewavisenthi & Kotagama. 1990. Proceedings of the Sri Lanka Association for the Advancement of Science 46:92.
[38] Amarasooriya. 2004. In Coyne & Clark (comps). Proceedings of the Twenty-First Annual Symposium on Sea Turtle Biology and Conservation. Pp. 92-93.
[39] Balsalobre & Bride. 2016. Marine Turtle Newsletter 151:16-21.

Example 2: Holding conditions use hatchling's energy reserves before release

A report[40] described a hatchery practice of digging a bowl of seawater into the beach surface so that hatchlings emerging during the night, when nests are not monitored, would not get dehydrated. Holding hatchlings in conditions where they are crawling and/or swimming for extended periods depletes the valuable energy reserves needed to cross the beach and swim quickly through coastal waters to reach offshore feeding habitats and is not a best practice for hatcheries. Hatchlings do become dehydrated between hatching from the egg and emergence from the nest due to the energy required to escape the nest[41]. However, exposure to humid air after emergence does not result in greater dehydration[42]. Further, hatchlings held in dry conditions have a stronger swim stroke than hatchlings held in seawater[38], so providing hatchlings with water to swim in before release reduces their fitness. Hatchery design should allow hatchlings that emerge at night to escape the hatchery without intervention if nests cannot be monitored.

Example 3: Holding hatchlings for unjustified health reasons

Hatcheries that hold hatchlings for several days have justified this practice as protecting hatchlings against attack from marine leeches[43] or predatory fish[44] at the site where the yolk is absorbed. However, there is no evidence that leeches or fish attack hatchlings at this site. This unjustified concern is perceived as an excuse for holding hatchlings that will attract tourists to hatcheries that are also operating as business ventures[44]. This practice should be discontinued immediately[45].

Recommendations for holding hatchlings

The majority of hatchlings should not be held before release unless they emerge in bright daylight hours. Hatchlings crossing the beach in the daytime will experience more predation[46], and be at risk of overheating, dehydration, and death. If a public hatchling release is assessed as having high promotional, educational, or economic value for important or special guests, students, and tourists, then <10% of hatchlings from a clutch, and including hatchlings that remain in the nest after the majority of the clutch emerges, can be held for this purpose. The hatchling release should occur in the early morning (before ~7am) or late afternoon (after ~5pm). Observers of the hatchling release should be made aware of why there are limited numbers of hatchlings to observe and understand that holding healthy hatchlings for scheduled release reduces their chance of survival.

If hatcheries do not have enough personnel, including volunteers, to monitor nests around the predicted emergence date and immediately release hatchlings, then hatchlings should not be retained until it is convenient to release them. Instead, nest enclosures should be removed when personnel are not present and the hatchery fence material should allow hatchlings to

[40] Sundaram et al. 2019. International Journal of Life Sciences7:83-91.
[41] Bennet et al. 1986. Comparative Biochemistry and Physiology 83A:507-513.
[42] Fujimoto et al. 2020. Herpetological Conservation and Biology 15:579-587.
[43] Hewavisenthi & Kotagama. 1990. Proceedings of the Sri Lanka Association for the Advancement of Science 46:92.
[44] see Richardson. 1996. The Marine Turtle Hatcheries of Sri Lanka. Turtle Conservation Project Report.
[45] Phillott et al. 2018. Indian Ocean Turtle Newsletter 27:8-17.
[46] Pilcher & Enderby. 2001. Journal of Herpetology 35:633-638.

escape the hatchery and crawl to the sea without human assistance[47]. Obstacles between a hatchery and the ocean and light sources around and inland of a hatchery should be minimised, so hatchlings are not disoriented away from the sea, and do not unnecessarily exert additional energy trying to escape or avoid obstacles and/or reorient trying to find the most direct route to the sea.

Concerns about headstarting sea turtle hatchlings

Early concerns about headstarting included questions about whether sea turtles could imprint on their natal beach, survive in the wild, complete a successful breeding migration, be tagged for later identification, what proportion of eggs should be incubated in headstarting programmes, how the success of such programmes could be assessed, and if protection of other life stages would be a better option than headstarting[4849,50,51,52,53,54]. Some of these questions have been answered by long-term studies of a number of projects, including the Cayman Turtle Farm (see Example 4), and the Kemp's Ridley Sea Turtle Restoration and Enhancement Program (see Example 5).

Example 4: Cayman Island Turtle Farm

Sea turtle nesting populations at Grand Cayman Island were decimated by a fishery operating from mid-1600's to late-1700's, and less intensively after that time. Local nesting populations were believed to have become extinct and foraging populations to be very small in the 1900's[55,56]. In 1968, the Cayman Turtle Farm was established to restore local green turtle populations and provide an alternative source of turtle meat to reduce harvest of wild turtles. Adult turtles and/or eggs were imported from Ascension Island, Costa Rica, Guyana, Mexico, Nicaragua, and Suriname to establish a captive breeding population at the farm. Offspring of different captive bred generations were raised for 4–6 years and then released into the wild, kept as breeding stock, or slaughtered for meat production[56]. Wild nesting populations have increased in the Cayman Islands, with about 430 green turtle nests, about 240 loggerhead turtle nests, and 4 hawksbill turtle nests recorded in 2019[57]. Recovery of the green and loggerhead (but not hawksbill) turtle nesting populations is due to a combination of various conservation actions, including release of about 16,500 captive bred hatchling and about 14,500 yearling green turtles from the Cayman Turtle Farm between 1980 and 2001[58], protection of in situ nests[57], legislation that prohibits possession of eggs and interference with nesting turtles[59], changes to turtle fishery regulations to stop the take of adult turtles and extend seasonal closures[60], and the end of legal take of sea turtles in

47 see Phillott & Shanker. 2018. Indian Ocean Turtle Newsletter 27:31-34.
48 Pritchard. 1979. International Zoo Yearbook 19:38-42.
49 Mrosovsky. 1980. Marine Turtle Newsletter 15:1.
50 Pritchard. 1980. American Zoologist 20:609-617.
51 Allen. 1981. Marine Turtle Newsletter 19:2.
52 Buitrago. 1981. Marine Turtle Newsletter 19:3.
53 Pritchard. 1981. Marine Turtle Newsletter 19:3-4.
54 Goodwin. 1981. Marine Turtle Newsletter 19:4-5.
55 see Aiken et al. 2001. Oryx 35:145-151.
56 see Barbanti et al. 2019. Molecular Ecology 28:1637-1651.
57 see Blumenthal et al 2021. Frontiers in Marine Science 8:663856.
58 Bell et al. 2005. Oryx 39:137–148.
59 Bell et al. 2006. Endangered Species Research 2:63–69.
60 Blumenthal et al. 2010. Aquatic Biology 9:113–121.

2008[61]. Criticisms of the Turtle Farm included stress, injury, and disease due to sea turtles being kept in captivity[62], and international trade infractions[63].

Example 5: The Kemp's Ridley Sea Turtle Restoration and Enhancement Program

*The nesting population of Kemp's ridley turtles at Rancho Nuevo, Mexico, declined from an estimated 40,000-42,000 nesters in a single "*arribada*" (mass nesting event) to about 700 nests in a season from 1947 to 1985 due to fisheries bycatch and illegal take of eggs. The Mexican Government started protection of eggs and females at Rancho Nuevo in 1966, and efforts to establish a secondary nesting colony at South Padre Island in Texas commenced in 1977, as a safeguard against the species' extinction. The island is within the historical nesting range of the species. Eggs were transferred from Rancho Nuevo to South Padre Island and exposed to sand from the island to imprint embryos/hatchlings to this location. Hatchlings from Padre Island, Rancho Nuevo and Cayman Turtle Farm, were also exposed to the sea at Padre Island to facilitate imprinting and then headstarted in a lab for 7-15 months before release with a tag to allow them to be later identified. Close to 13,500 headstarted hatchlings imprinted to South Padre Island were released from 1978-2000. The first imprinted, headstarted turtle was found nesting at Padre Island in 1996. A peak of 210 Kemp's ridley nests were recorded on the south Texas coast in 2012. The age, size, feeding, behaviour and reproductive biology of headstarted turtles is similar to that of wild Kemp's ridleys[64, 65, 66, 67, 68]. Protection of turtles and eggs at the nesting beach and the introduction of compulsory turtle excluder devices (TEDs) on US trawlers are likely to have contributed to increasing numbers[69].*

Both projects show indications of success: captive-bred green turtles from the Cayman Turtle Farm are nesting in the Cayman Islands, and imprinted, headstarted Kemp's ridley turtles are nesting on the Texas coast[70]. Headstarting has contributed greatly to the recovery of green turtle populations in the Cayman Islands[71]; other conservation actions, including protection of *in situ* nests[72], legislation against possession of eggs and interference with nesting turtles[73], changes to turtle fishery regulations[74], and the end of legal take of sea turtles[75], also contributed to increasing green (and loggerhead, but not hawksbill) turtle populations in the area. Similarly, the protection of *in situ* nests and nesting turtles, reduction in US trawlers and seasonal closures in Mexico waters, and requirement for US trawlers to use turtle excluder devices (TEDs) assisted with increased numbers of Kemps ridley turtles[76]. It should be noted that the number of nesting Kemp's ridley turtles to date represents only a small fraction of the

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[61] Nuno et al. 2018. Conservation Biology 32:390-400.
[62] Arena et al. 2014. Journal of Agricultural and Environmental Ethics 27:309-330.
[63] Donnelly. 1992. Marine Turtle Newsletter 58:12-14.
[64] Manzella et al. 1988. Marine Fisheries Review 50:24-32.
[65] Shaver. 1991. Journal of Herpetology 25:327-334.
[66] Taubes. 1992. Science 256:614-616.
[67] Zug et al. 1997. Biological Conservation 80:261-268.
[68] Shaver & Wibbels. 2007. In: Plotkin (ed). Biology and Conservation of Ridley Sea Turtles. Pp. 297-323.
[69] see Lamont et al. 2021. Aquatic Conservation: Marine and Freshwater Ecosystems 31:3003-3010.
[70] see Shaver & Caillouet Jr. 2015. Herpetological Conservation and Biology 10(Symposium):378-435.
[71] see Barbanti et al. 2019. Molecular Ecology. 28:1637-1651.
[72] see Blumenthal et al. 2021. Frontiers in Marine Science 8:663856.
[73] see Bell et al. 2006. Endangered Species Research 2: 63–69.
[74] see Blumenthal et al. 2010. Aquatic Biology 9:113–121.
[75] Nuno et al. 2018. Conservation Biology 32:390-400.
[76] see Caillouet Jr. 2019. Marine Turtle Newsletter 158:1-9.

total number of headstarted hatchlings, and early estimates of survivorship to maturity was estimated to be ten times higher in wild Kemp's ridleys at Nuevo Rancho than for headstarted turtles from Padre Island[77]. A longer study is needed to estimate if this trend in Kemp's ridley continues or improves, and forthcoming publications should compare the survivorship between wild and headstarted turtles in the Cayman Islands.

A major concern of the Kemp's Ridley Sea Turtle Restoration and Enhancement Program was the unintentional production of predominantly male hatchlings in the early years of artificial incubation of eggs, before it was known that incubation temperature determined the sex of the hatchlings. This was corrected later in the project by the deliberate manipulation of incubation temperature to produce predominantly females[78]. The risk of interfering with as-yet unknown, or incompletely understood, aspects of sea turtle biology are still a risk for current and future headstarting projects. For example, the large number of small sea turtles entering the population from the Kemp's Ridley Sea Turtle Restoration and Enhancement Program, without the natural predation of eggs and hatchlings, may actually be limiting population recovery through competition for food and other resources[79], and a reduction in production of hatchlings may be required[80]. Headstarting also carries risks of stress, injury, disease and parasite outbreak[81,82,83], and turtles could need exercise[84] and to be familiarised with wild conditions and habitats to increase chances of survival[85]. The location and season (temperature) at which headstarted turtles are released can also be important for offshore migration[86].

Recommendations for headstarting hatchlings

The Cayman Island Turtle Farm and the Kemp's Ridley Sea Turtle Restoration and Enhancement Program were responses to populations in crises due to overexploitation of turtles and eggs and/or high bycatch rates and mortality in fisheries. Population models show that protecting sea turtles in the first year of their life is unlikely to be effective unless sub-adult and adult survival is also maximised, and conservation efforts should protect older life stages by reducing fisheries bycatch rather than just hatchlings through headstarting[87],[88].

Facilities that house and display sea turtles can present opportunities for education and raising awareness among students of different ages, other community members, government officials, tourists, as well as a source of community livelihoods. However, vigorous hatchlings which emerge from the nest without assistance should not be headstarted for this purpose. Instead, hatchlings which remain in the nest after the majority (about 80%) have emerged, and turtles that require treatment or rehabilitation such as those that have stranded or been recovered from fishing gear, including ghost gear, can be used for display and potential release. Personnel at such facilities should consult up to date research and guidelines to be informed about the best understanding of suitable conditions for sea turtle housing, feeding, health

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77 Heppell & Crowder. 1998. Bulletin of Marine Science 62:495–507.
78 see Bowen et al. 1994. Conservation Biology 8:853-856.
79 Caillouet Jr. 2019. Marine Turtle Newsletter 158:1-9.
80 Caillouet Jr. 2021. Marine Turtle Newsletter 163:1-7.
81 Arena et al. 2014. Journal of Agricultural and Environmental Ethics 27:309-330.
82 Crespo-Picazo et al. 2017. BMC Veterinary Research 13:154.
83 Oros et al. 2020. Journal of Comparative Pathology 174:73e80.
84 Stabenau et al. 1992. Journal of Experimental Marine Biology and Ecology 161:213-222.
85 Okuyama et al. 2010. Endangered Species Research 10:181-190.
86 Mansfield et al. 2009. Marine Biology 156:2555-2570.
87 Heppell et al. 1996. Ecological Applications 6:556-565.
88 Heppell et al. 1999. American Fisheries Society Symposium 23:137-148.

monitoring etc[89,90,91,92,93]. Educational materials at the facility can educate visitors about the natural biology of sea turtles, threats to local and global populations, local conservation efforts (and why holding and headstarting healthy hatchlings are not one of them), and actions that visitors to the facility can take to help conserve sea turtles.

Final Summary

Sea turtle eggs, hatchlings and post-hatchlings are vulnerable life stages, but they also have important roles in coastal ecosystems, where, among other things, they serve as a valuable nutrient source[94]. Holding or headstarting hatchlings removes them from their natural role as prey for terrestrial and marine predators, interrupts their biology, may have limited benefits at the population level, and can reduce the health, fitness, and survivorship of individuals. Holding and headstarting also fail to address the cause of declines in sea turtle populations. Vulnerable sea turtle populations in the IOSEA region would benefit the most from reduced anthropogenic threats, including mortality after interaction with fisheries[95] and illegal take for trade[96,97].

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