Impact of different protection cages on the nesting temperature of *Caretta caretta* nests in Fethiye, Turkey

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ABSTRACT

The use of cages to protect *Caretta caretta* nests from predation and anthropogenic impacts has long been an important part of the field work at Calis and Yaniklar beaches. Many different types of cages – all made of metal – have been produced and used. Metal cages may be easy and cheap in production, but have disadvantages because they corrode and are heavy and unhandy to carry, which should not be underestimated considering most of the field work is done by foot. Therefore, a prototype of a foldable novel wooden cage model was constructed. For a period of 14 days, from 18 to 31 August, the influence of the new wooden and traditional metal cage model on the temperature in the sand was tested by burying two electronic temperature dataloggers (Tinytalks) 20 cm and 40 cm in the sand under each cage. Temperatures were measured every 72 minutes and later read out at the University of Vienna.

The data showed slightly higher temperatures in the sand under the metal cage (in average 1.0°C higher 20 cm in the sand and 1.1 °C higher 40 cm in the sand). Importantly, however, temperatures remained unchanged under the location of the wooden cage after the cage was removed for two days, suggesting that the temperature difference was based on sedimentological factors rather than caused by the wooden cage itself. The Tinytalks under the metal cage recorded overall stronger fluctuations in temperature, whereas under the wooden cage temperatures were more homogeneous.

The wooden represents an overall handy alternative to the metal cage. Crucial for the decision whether the metal or the wooden cage is preferable for the field work is the temperature: if it influences the temperature, then the embryonic development could be impacted. In the future such wooden cage models could be reduced in size and the slats made thinner, but even in its current form the wooden cage would probably not negatively influence nest hatchings and would ease the transportation of protective cages. Importantly, it would also eliminate impact of metal cages on the electromagnetic environment around incubating sea turtle clutches.

KURZFASSUNG

Die Verwendung von Schutzkäfigen, um *Caretta caretta* Nester vor Prädation und anthropogenen Einflüssen zu schützen ist schon lange ein fixer Bestandteil der Feldarbeit an den Niststränden Calis und Yaniklar. Viele verschiedene Käfige – alle aus Metall – wurden in der Vergangenheit aus diesem Grund hergestellt und verwendet. Metallkäfige sind einfach und günstig zu produzieren, haben aber den Nachteil zu rosten sowie unhandlich und schwer zu sein, Eigenschaften die nicht unterschätzt werden sollten, wenn man bedenk, dass die meiste Feldarbeit zu Fuß erledigt wird. Daher wurde ein Prototyp eines faltbaren Holzkäfigs erstellt. Über einen Zeitraum von 14 Tagen, von 18. bis 31. August, wurden vier elektronische Datenlogger (Tinytalks) in einer Tiefe von 20 cm und 40 cm im Sand vergraben und mit je einem Metal- und Holzkäfig bedeckt, um deren Einfluss auf die Temperatur im Sand zu messen. Temperaturen wurden alle 72 Minuten gemessen und später an der Universität in Wien ausgelesen.

Die erhaltenen Daten zeigen gering höhere Temperaturen im Sand unter dem Metallkäfig (durchschnittlich 1.0 °C höher in 20 cm Tiefe und 1.1 °C höher in 40 cm Tiefe), die Temperatur näherte sich jedoch auch nach dem Entfernen des Holzkäfigs nicht der Temperatur unter dem Metallkäfig an, was bedeuten könnte, dass die gemessenen Temperaturunterschiede womöglich sedimentologischen Unterschieden zugrunde liegen, und nicht unbedingt auf die Eigenschaften der Käfige zurückzuführen sind. Die Temperatur unter dem Holzkäfig ist über den gesamten Zeitraum betrachtet homogener als jene unter dem Metallkäfig, welche stärkeren Fluktuationen unterworfen ist.

Der Holzkäfig ist eine handlichere Alternative zum Metallkäfig. Wichtig für die Entscheidung ob in Zukunft ein Metall- oder Holzkäfig verwendet werden soll ist die Einschätzung, inwiefern der Einfluss der Käfige auf die Temperaturfaktoren, besonders die Temperaturfluktuation, eine Rolle in der Embryonalentwicklung spielt. Verbesserte Holzmodelle könnten durch eine Verringerung der Größe und Lattenbreite noch einfacher zu transportieren und tragen werden und könnten schon bald eine wichtige Rolle im erfolgreichen Schutz der Nester spielen.

INTRODUCTION

An important part of the field work concerning the monitoring of *Caretta caretta* nest hatching on the beach is the protection of the nests from predation. Stray dogs as well as other wild animals can take advantage of unprotected clutches and dig out and predate nests. The use of protective cages helps to increase the number of a successful hatching not only by thwarting predators but also by preventing beachgoers from covering the nest with beach towels or sunbeds. Additionally, if designed correctly, the protection cage can also help stop new born hatchlings from going any direction but to the sea when mis- or irritated by artificial light sources. Despite all the good a protective cage can do, consideration must also be given to the potential impact its shadow may have on the temperature inside the nest. To get more insight on protective cage induced temperature changes in nests, Tinytalks were buried into the sand in different depths and covered with two different cage models. Temperature data acquired by the Tinytalks was later read out and interpreted.

MATERIAL AND METHODS

Four Tinytalks were buried in two different locations 20 cm and 40 cm in the sand 2 m apart from each other on 18 August 2016 (table 1). The depths accord to the upper and lower third of average nesting depths of *Caretta caretta (*Demetropoulos and Hadjichristophorou, 1995). to The distance to the sea was 12.8 m. Tinytalks # 2 (20 cm) and #3 (40 cm) were covered by a wooden cage (designed in summer 2015 and built over winter, fig. 1), Tinytalks # 4 (20 cm) and # 6 (40 cm) were covered by a metal cage (provided by the Pamukkale University and used for nest protection in Calis and Yaniklar, fig. 8).

Table 1. Tinytalk locations
Tabelle 1: Tinytalk Platzierungen

	Wooden cage		Metal cage	
Tiny Talk #	2	3	4	6
Tiny Talk model	Tinytalk II TK-4023	Tinytalk II TK-4023	Tinytalk II TK-4014	Tinytalk II TK-4014
Buried depth	20cm	40cm	20cm	40cm

The metal cage features a pyramid shape with a square base (Fig 1a), the wooden cage features a square shape and was later replaced by a model where the slats had been slimmed. Both wooden cages featured adjustable elements; the top of the cages could be flipped back and the bottom front lid could be lifted up (Fig 1b).

The wooden caging situation was altered throughout the testing period (table 2). Tinytalks # 2 and #3 were first covered with the wooden cage with closed top which was later flipped up, then with a modified wooden cage with closed and later flipped top, followed by a testing period with no cage at all.

All Tinytalks were removed on 31 August 2016, at 09:00 and placed in a fridge. They were read out in Vienna using the software *Tinytag Explorer Software*.

Table 2. Tinytalks - experimental protocol
Tabelle 2. Tinytalks – experimentales Protokoll

Date	time	Event	
		Tinytalks #2 and 3	*Tinytalks # 4 and 6*
18.Aug.16	07:30	Tiny Talks and Cages placed	Tiny Talks and Cages placed
20.Aug.16	n.a.	Cage displaced (maybe by tourists) and placed in order again	-
23.Aug.16	09:00	Top of wooden cage flipped back	-
24.Aug.16	09:00	wooden cage exchanged with modified wooden cage	-
26.Aug.16	09:00	Top of modified Cage flipped back	-
28.Aug.16	09:00	modified wooden cage removed	-
31.Aug.16	09:00	Tinytalks removed and placed in fridge	Tinytalks removed and placed in fridge

Figure 1. Wooden protection cage top view (left) and front view (right), used for experiment for potential future *Caretta caretta* nest protection at Calis Beach (photo: M. Lambropoulos)
Abbildung 1. Holzkäfig Ansicht von oben (links) und von vorne (rechts), verwendet für den Experiment für den zukünftigen Schutz von *Caretta caretta* Nestern in Calis Beach

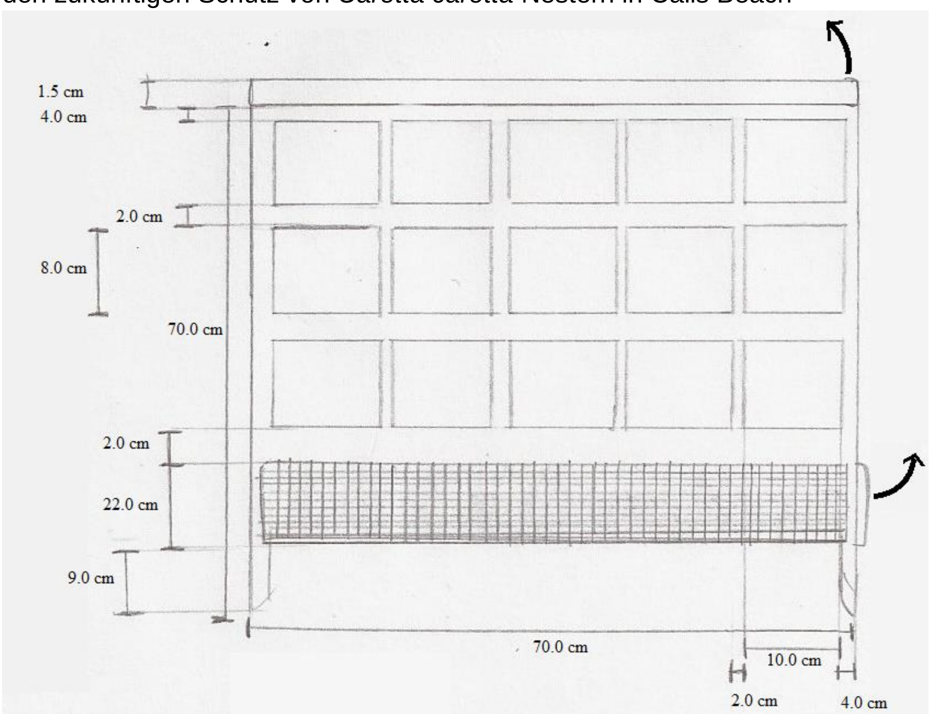

Figure 2. Sketch of wooden wooden cage, side view. Arrows indicate adjustable elements (sketch: Paul Kreiner)
Abbildung 2. Skizze des Holzkäfigs, Seitenansich. Die Pfeile zeigen die verstellbaren Elemente an (Skizze: Paul Kreiner)

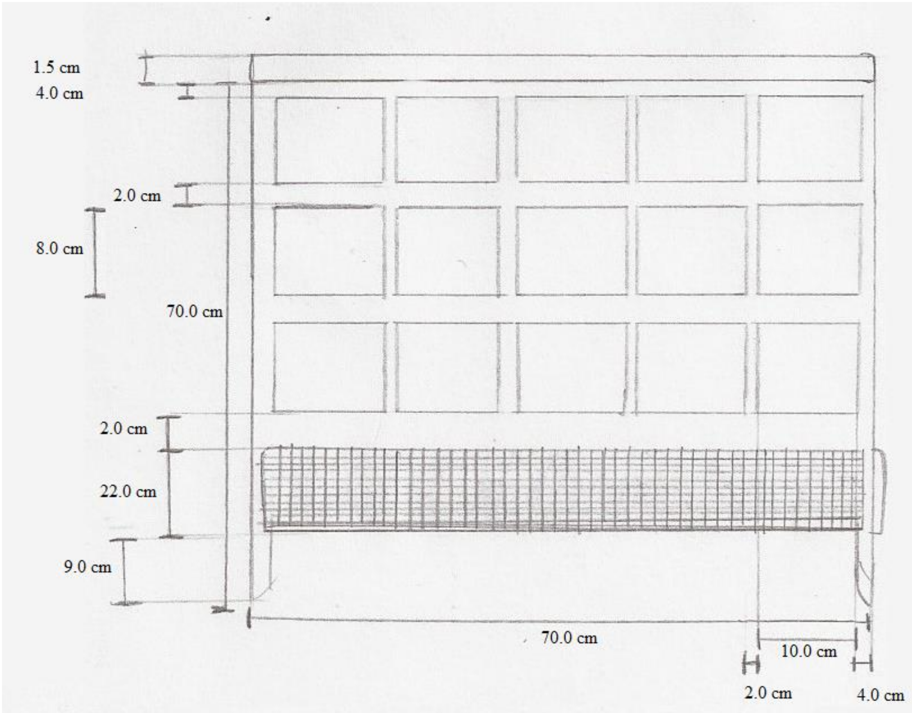

Figure 3. Sketch of wooden cage, front view (sketch: Paul Kreiner)
Abbildung 3. Skizze des Holzkäfigs, Vorderansicht (Skizze: Paul Kreiner)

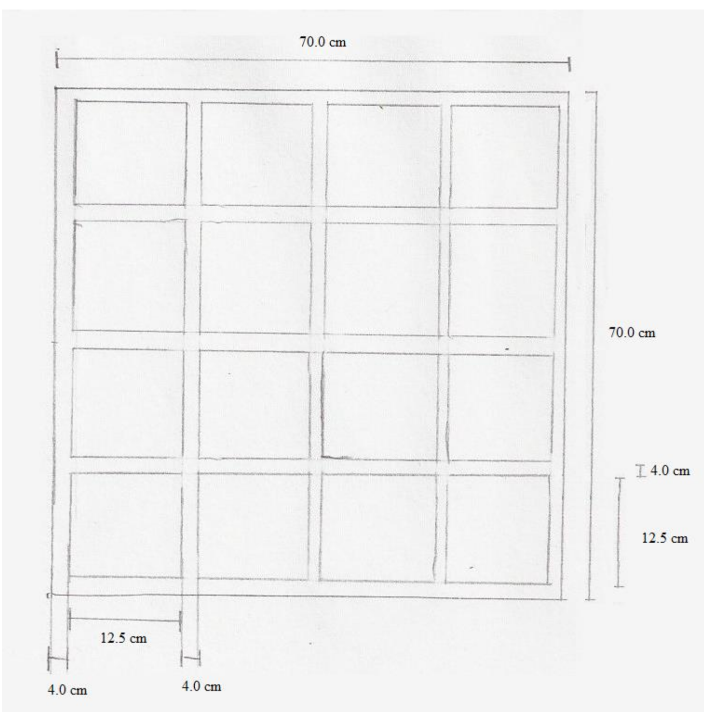

Figure 4. Sketch of wooden cage, top view (sketch: Paul Kreiner)
Abbildung 4. Skizze des Holzkäfigs, Aufsicht (Skizze: Paul Kreiner)

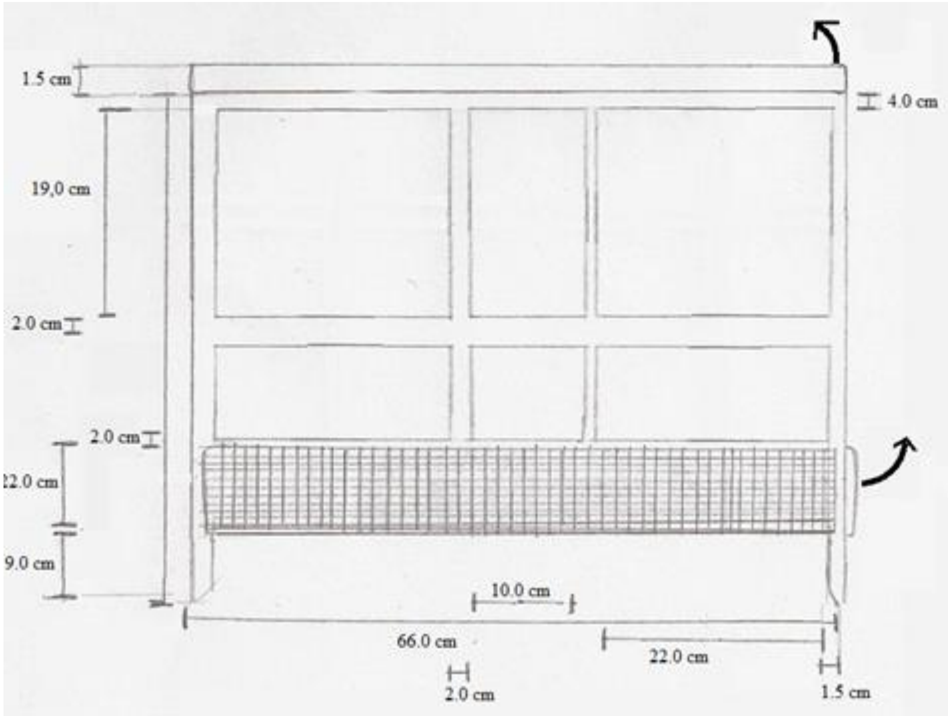

Figure 5. Sketch of slim wooden cage, side view. Arrows indicate adjustable elements (sketch:Paul Kreiner)
Abbildung 5. Skizze des modifizierten Holzkäfigs, Seitenansich. Pfeile deuten verstellbare Elemente an (Skizze: Paul Kreiner)

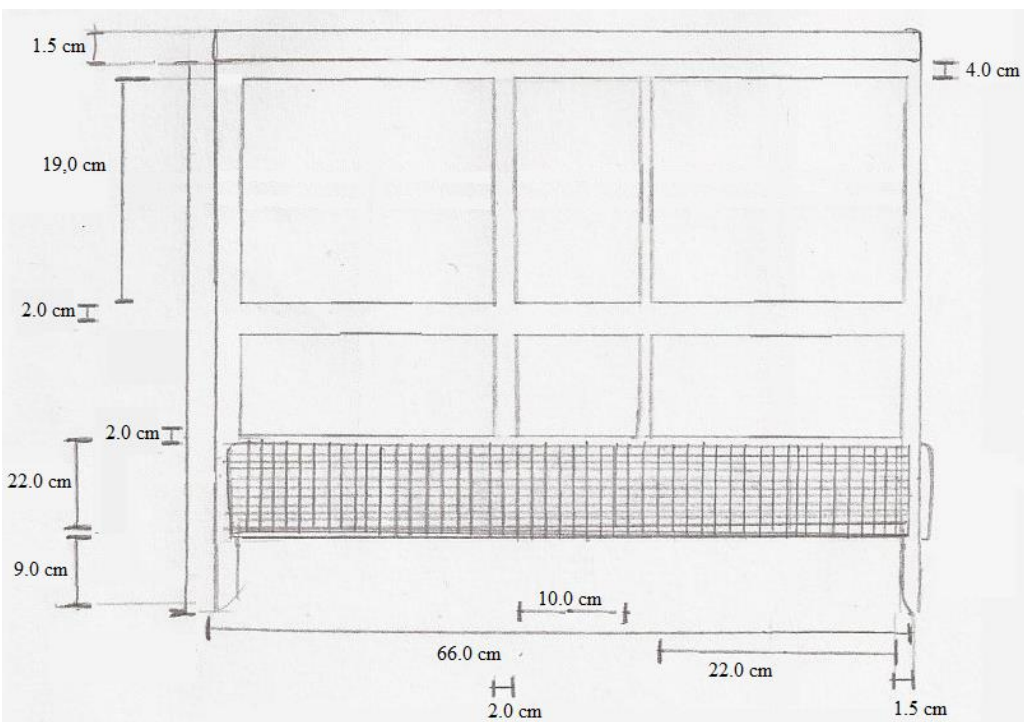

Figure 6. Sketch of slim wooden cage, front view (sketch: Paul Kreiner)
Abbildung 6. Skizze des modifizierten Holzkäfigs, Vorderansicht (Skizze: Paul Kreiner)

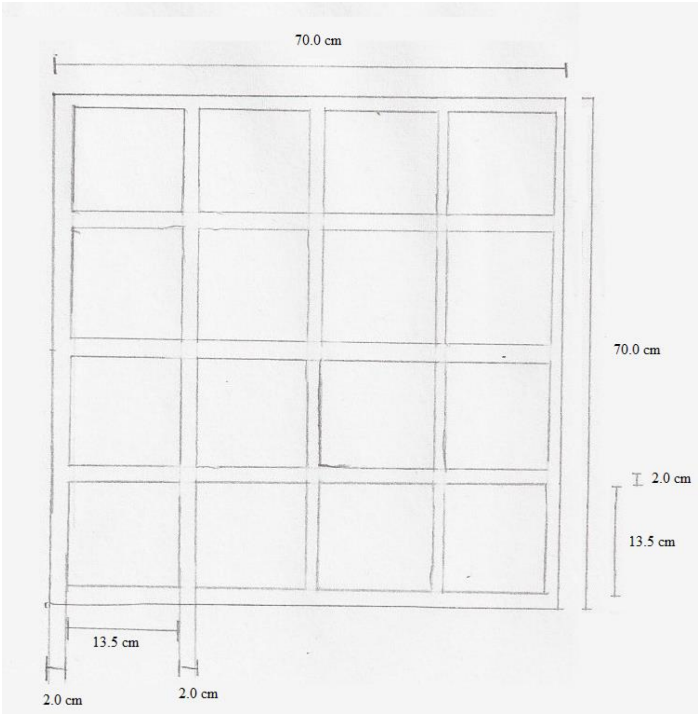

Figure 7. Sketch of slim wooden cage, top view (sketch: Paul Kreiner)
Abbildung 7. Skizze des modifizierten Holzkäfigs, Aufsicht (Skizze: Paul Kreiner)


Figure 8. Metal protection cage provided by Pamukkale University. Side view (left) and front view (right), used for *Caretta caretta* nest protection at Calis Beach, (Photo: Paul Kreiner)
Abbildung 8. Metallkäfig von der Pamukkale Universität, seitliche Ansicht und Frontalansicht (links), verwendet für den Schutz von *Caretta caretta* Nestern in Calis Beach

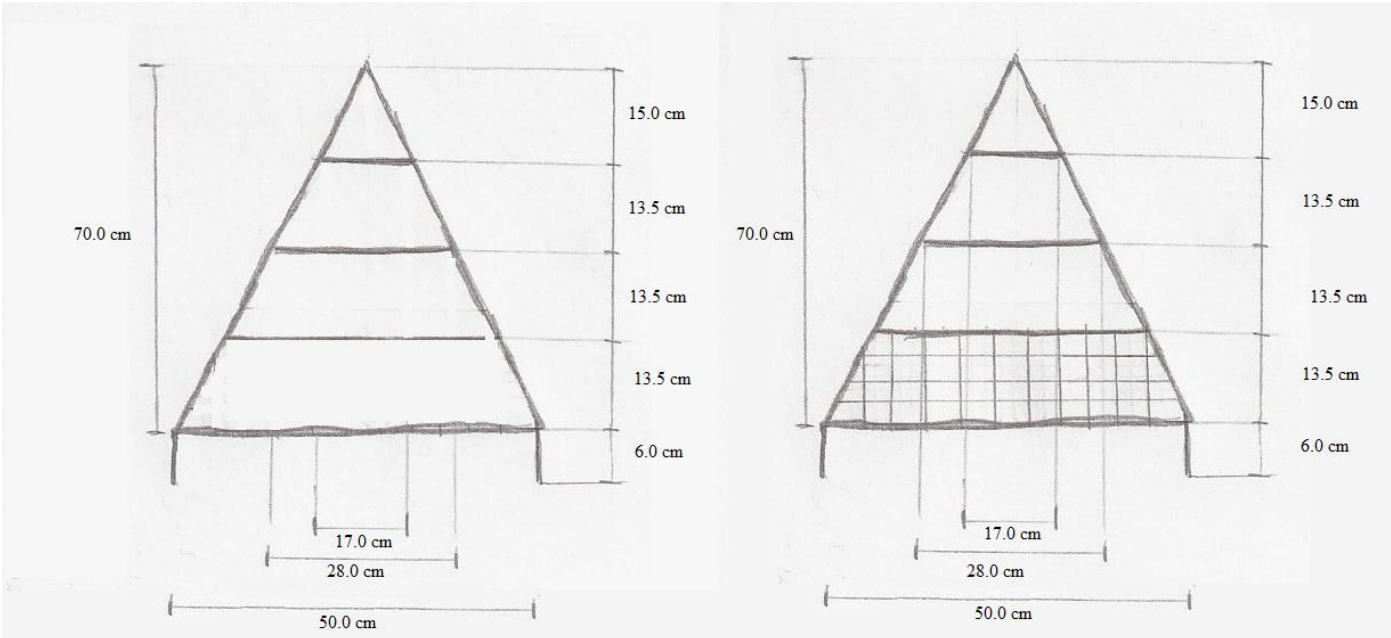

Figure 9. Sketch of the metal cage, side view (left) and front view (right) (sketch: Paul Kreiner)
Abbildung 9. Skizze des Metallkäfigs, Seitenansicht (links) und Vorderansicht (rechts) (Skizze: Paul Kreiner)

RESULTS

The Tinytalks reveal a general temperature shift between day and night, showing highest temperatures at night around 01:00 (CET/MEZ) (Fig. 10 & fig. 13). Standard deviations of recorded temperatures (table 3) as well as temperature graphs (Fig. 10 & 13 and 12 & 14) show stronger temperature fluctuations in 20 cm than in 40 cm depth. The temperatures standard deviation 20 cm under the surface is 0,39°C under the wooden cage (Tinytalk #2) and 0,50°C under the metal cage (Tinytalk #4) whereas in 40 cm depth standard deviations are around 0,15°C under the wooden cage (Tinytalk #3) and 0,19°C under the metal cage (Tinytalk #6).

Table 3. standard deviation and variance of temperatures measured between 18 to 31 August indicate more stable temperatures in the sand under the wooden cage.
Tabelle 3. Standardabweichung und Varianz aller Temperaturen gemessen zwischen 18. und 31. August deutet auf weniger Temperaturschwankungen im Sand unter dem Holzkäfig hin

	Tiny Talk #			
	2	3	4	6
standard deviation	0,39 °C	0,15 °C	0,50 °C	0,19 °C
variance	0,15	0,02	0,25	0,04

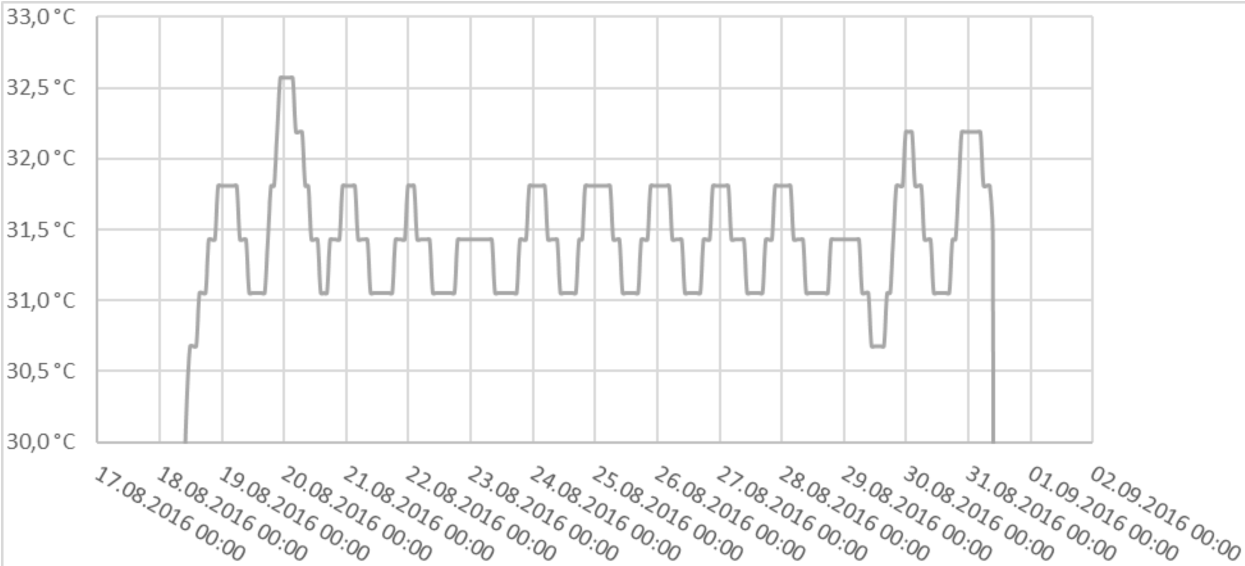

Figure 10.Tinytalk #2 (20 cm depth, wooden cage) temperature graph. Each peak represents one day
Abbildung 10. Temperaturverlaufs gemessen von Tinytalk #2 (20 cm Tiefe, Holzkäfig). Jeder Peak stellt einen Tag dar

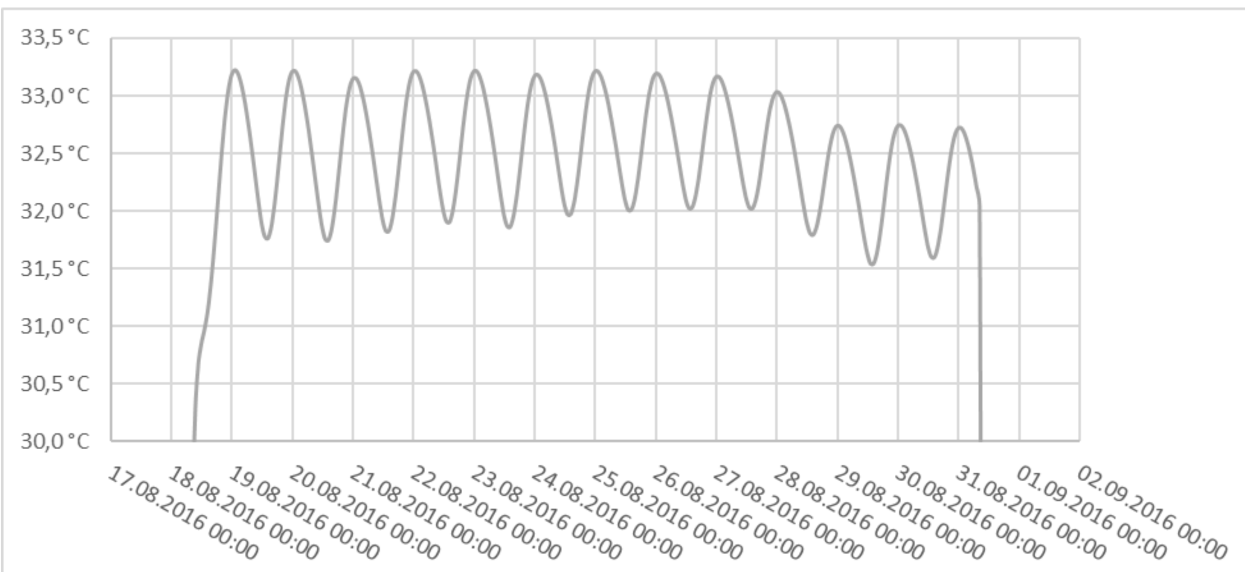

figure 12 Tinytalk #4 temperature graph (20 cm depth, metal cage). Each peak represents one day
Abbildung 12 Temperaturverlaufs gemessen von Tinytalk #4 (20 cm Tiefe, Metallkäfig). Jeder Peak stellt einen Tag dar

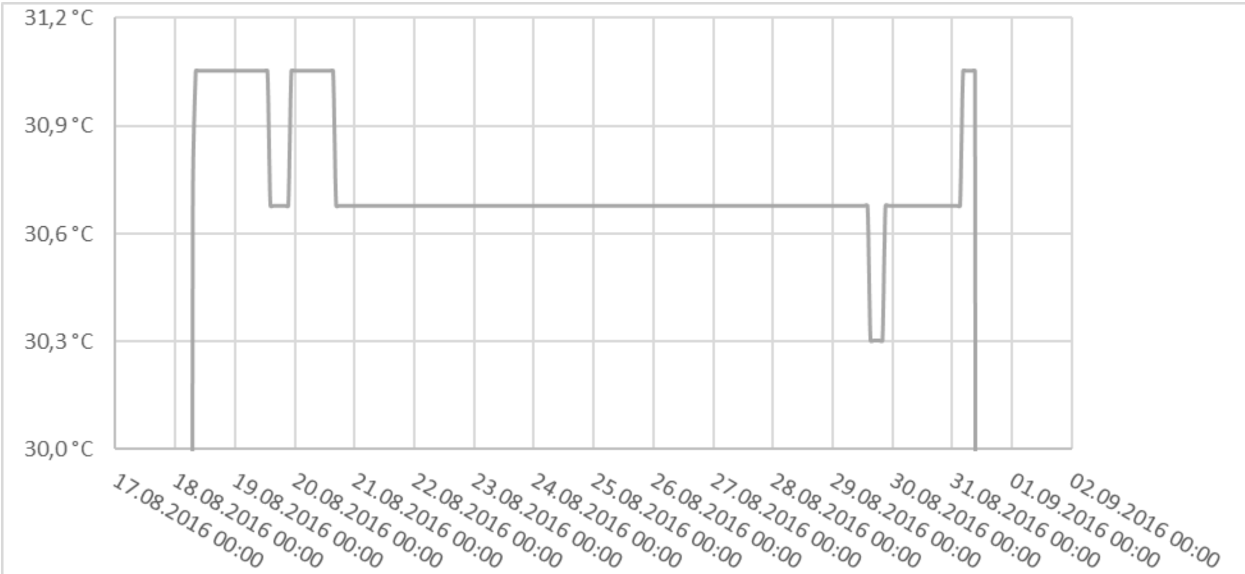

figure 13: Tiny Talk #3 temperature graph (40 cm depth, wooden cage). Each peak represents one day. Note lack of clear fluctuations at this depth
Abbildung 13. Temperaturverlaufs gemessen von Tinytalk #3 (40 cm Tiefe, Holzkäfig). Jeder Peak stellt einen Tag dar. Zu beachten ist das Fehlen eindeutiger Fluktuationen in dieser Tiefe.

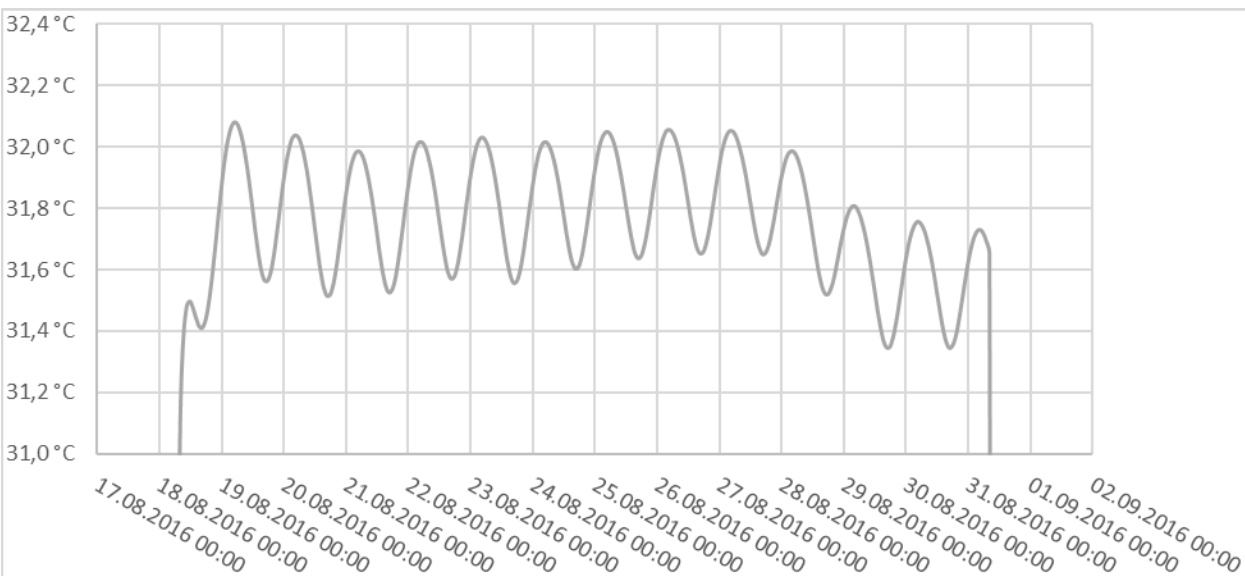

figure 11: Tinytalk #6 temperature graph (40 cm depth, metal cage). Each peak represents one day.
Abbildung 14. Temperaturverlaufs gemessen von Tinytalk #6 (40 cm Tiefe, Metallkäfig). Jeder Peak stellt einen Tag dar.

Table 4 and 5 show that the average temperature measured every day at 13:00 from 18 to 31 August is shifting around 0.9°C between day and night under the wooden cage in 20cm depth and 0,1°C in 40cm depth. The metal cage shows temperature differences of 1.2°C between day and night in 20cm depth (Tinytalk #4) and 0.2°C in 40cm depth.

Table 4. Temperatures measured at 13:00 (CET/MEZ) indicate higher temperatures under the metal cage
Tabelle 4: Temperaturen gemessen um 13:00 (CET/MEZ) deuten auf höhere Temperaturen unter dem Metallkäfig hin

Date	Temperature			
	#2 (20 cm) Wooden cage/no cage	#3 (40 cm) Wooden cage/no cage	#4 (29 cm) Metal cage	#6 (40 cm) Metal cage
18.08.2016	30.7 °C	31.1 °C	31.0 °C	31.5 °C
19.08.2016	31.1 °C	31.1 °C	31.8 °C	31.7 °C
20.08.2016	31.4 °C	31.1 °C	31.8 °C	31.7 °C
21.08.2016	31.1 °C	30.7 °C	31.8 °C	31.7 °C
22.08.2016	31.1 °C	30.7 °C	31.9 °C	31.7 °C
23.08.2016	31.1 °C	30.7 °C	31.9 °C	31.7 °C
24.08.2016	31.1 °C	30.7 °C	32.0 °C	31.7 °C
25.08.2016	31.1 °C	30.7 °C	32.0 °C	31.8 °C
26.08.2016	31.1 °C	30.7 °C	32.0 °C	31.8 °C
27.08.2016	31.1 °C	30.7 °C	32.0 °C	31.8 °C
28.08.2016	31.1 °C	30.7 °C	31.8 °C	31.7 °C
29.08.2016	30.7 °C	30.7 °C	31.5 °C	31.5 °C
30.08.2016	31.1 °C	30.7 °C	31.6 °C	31.5 °C
Average	31.0 °C	30.8 °C	31.8 °C	31.7 °C

Table 5. Temperatures measured at 01:00 (CET/MEZ) also indicate higher temperatures under the metal cage
Tabelle 5: Temperaturen gemessen um 01:00 (CET/MEZ) deuten ebenfalls auf höhere Temperaturen unter dem Metallkäfig hin

Date	Temperature			
	#2 (20 cm) Wooden cage/no cage	#3 (40 cm) Wooden cage/no cage	#4 (29 cm) Metal cage	#6 (40 cm) Metal cage
19.08.2016	31.8 °C	31.1 °C	33.2 °C	31.9 °C
20.08.2016	32.6 °C	31.1 °C	33.2 °C	31.9 °C
21.08.2016	31.8 °C	30.7 °C	33.2 °C	31.9 °C
22.08.2016	31.8 °C	30.7 °C	33.2 °C	31.9 °C
23.08.2016	31.4 °C	30.7 °C	33.2 °C	32.0 °C
24.08.2016	31.8 °C	30.7 °C	33.2 °C	31.9 °C
25.08.2016	31.8 °C	30.7 °C	33.2 °C	32.0 °C
26.08.2016	31.8 °C	30.7 °C	33.2 °C	32.0 °C
27.08.2016	31.8 °C	30.7 °C	33.2 °C	32.0 °C
28.08.2016	31.8 °C	30.7 °C	33.0 °C	31.9 °C
29.08.2016	31.4 °C	30.7 °C	32.7 °C	31.8 °C
30.08.2016	32.2 °C	30.7 °C	32.7 °C	31.7 °C
31.08.2016	32.2 °C	30.7 °C	32.7 °C	31.7 °C
Average	31.9 °C	30.7 °C	33.1 °C	31.9 °C

Table 6 shows the effect of the various cage configurations on the wooden cage on temperature. In average, Tinytalk #2 measured 31.4°C for all different caging situations except the period between 24 and 26 August when an average of 31,5 °C was measured. Tinytalk #3 measured an average temperature of 30.7 °C for all caging situations.

Table 6. Tinytalks #2 and 3, Impact on temperature of wood cage events. There was no significant change in temperature and, most importantly, not even when the cage was removed completely.
Tabelle 6. Tinytalks #2 und 3, Auswirkung der Holzkäfigevents auf die Temperatur.

	Date	Event	average temperature tt2	average temperature tt3
from to	18.Aug.16 23.Aug.16	Tinytalks and cages placed	31.4°C	30.7 °C
from to	23.Aug.16 24.Aug.16	Top of wooden cage flipped	31.4 °C	30.7 °C
from to	24.Aug.16 26.Aug.16	Wooden cage exchanged with modified wooden cage	31.5 °C	30.7 °C
from to	26.Aug.16 28.Aug.16	Top of modified cage flipped	31.4 °C	30.7 °C
from to	28.Aug.16 31.Aug.16	Modified wooden cage removed	31.4 °C	30.7 °C

Figure 15 compares temperature data acquired by the Tinytalks at 13:00 (CET/MEZ) with the outside temperature. An outside temperature drop by 6-7°C on 28 August is follow by a slight temperature drop on 29 of August measured by Tinytalks #4 and #6 of about 0.5°C and a drop of 0.4 °C measured by Tinytalk #2. The temperature of Tinytalk #3 remained unchanged.

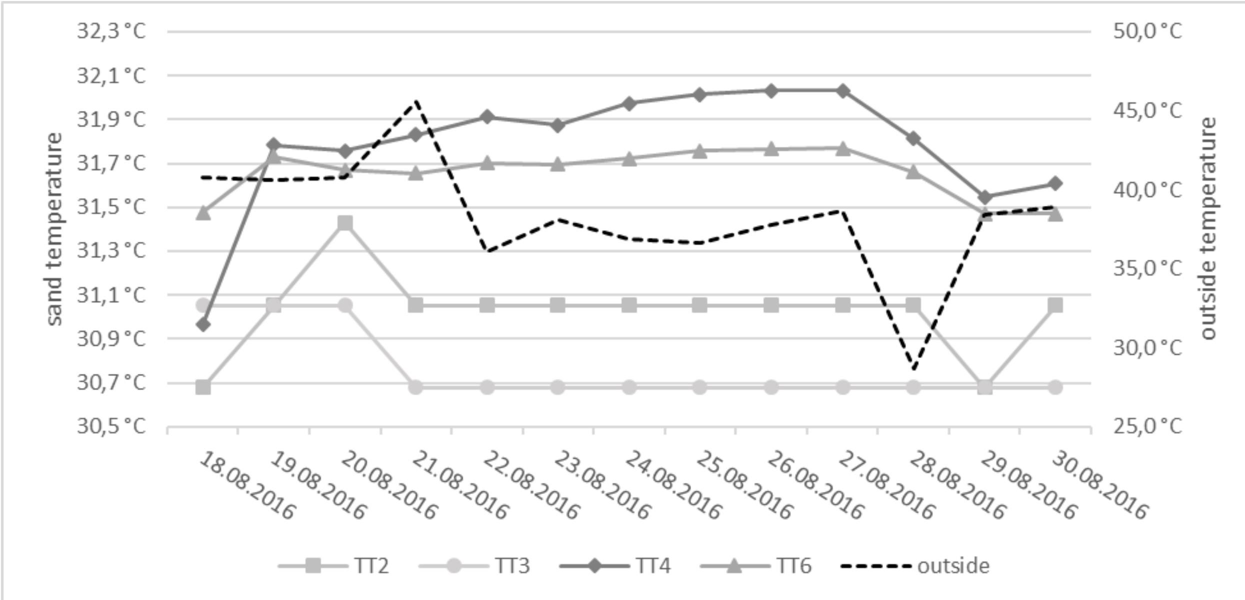

Figure 15. Comparison of temperatures measured by all Tinytalks at 13:00 (CET/MEZ) between 18 and 31 August. The right axis is relevant for outside temperature; the left axis is relevant for temperatures measured by Tinytalks.

Abbildung 15. Vergleich der Temperaturen gemessen von allen Tinytalks um 13:00 (CET/MEZ) zwischen 18. Und 31. August. Die rechte Achse bezieht sich auf die Außentemperatur, die linke Achse bezieht sich auf die gemessenen Temperaturen der Tinytalks.

Figure 16 shows the same comparison but for temperatures collected at 01:00 (CET/MEZ). A temperature increase of 2-3°C in the night of the 24^{th} of August shows no significant impact on temperatures in 20 cm and 40 cm depth, but again a decrease in temperature of Tinytalk #4 and 5 is evident on 29 August.

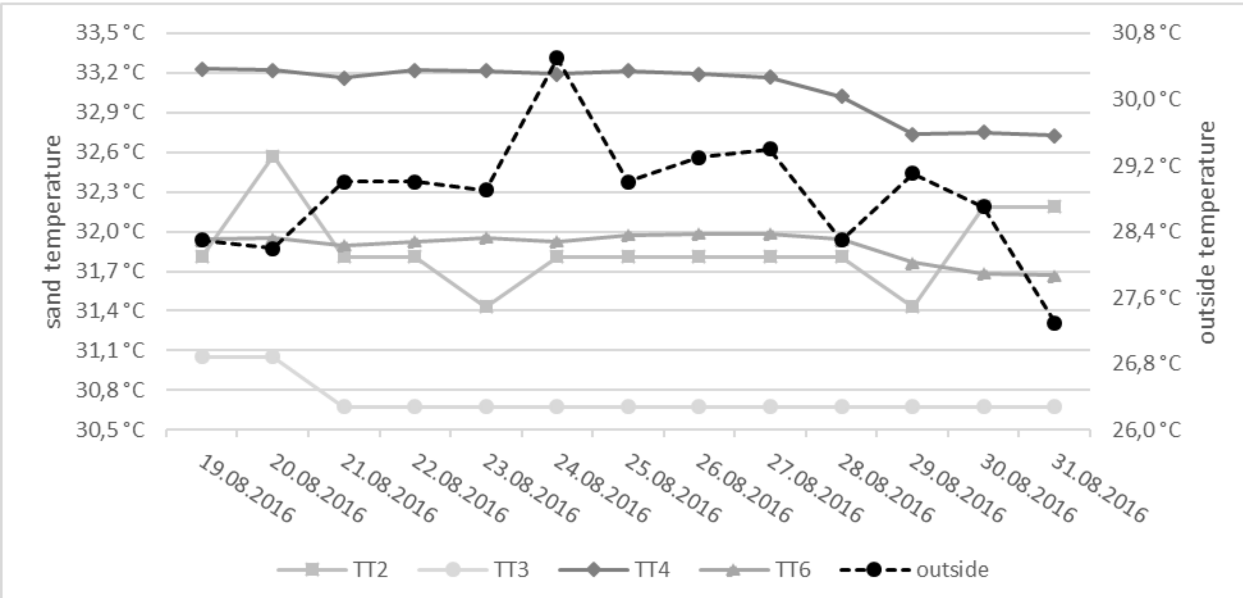

Figure 16. Comparison of temperatures measured by all Tinytalks at 01:00 (CET/MEZ) between 19 and 31 August. The right axis is relevant for outside temperature; the left axis is relevant for temperatures measured by Tinytalks.

Abbildung 16. Vergleich der Temperaturen gemessen von allen Tinytalks um 13:00 (CET/MEZ) zwischen 19. Und 31. August. Die rechte Achse bezieht sich auf die Außentemperatur, die linke Achse bezieht sich auf die gemessenen Temperaturen der Tinytalks.

DISCUSSION:

Regarding the data recorded by the Tinytalks, slightly lower temperatures (~1°C) were measured in the sand under the wooden cage compared with the metal cage. Nonetheless, there was no significant change in temperature (Table 6) and, most importantly, not even when the cage was removed completely. This suggests a low (or minimal) impact of the new cages shadow on the temperature in the sand. Temperature differences between the locations protected by the wooden and metal cage therefore may arise from different sedimentological conditions (even though the cages were only a few meters apart) or from influences by the metal cage, for example its metallic nature. We also observed more stable temperatures in the sand under the wooden cage, temperature fluctuations are higher under the metal cage protected spot. Regarding these fluctuations, it remains to be determined which situation reflects an uninfluenced sea turtle nest.

Advantages of the wooden cage over the metal cage, apart from temperature consideration, lie in its material. Metal cages tend to corrode quickly in the salty environment. While the degradation of the wood under same conditions remains to be evaluated, the rust problem and the repeated painting required for metal can be avoided. The wooden cage may also be potentially re-designed to make it less heavy; the present model is bigger than necessary. The modifications could involve making it smaller and reducing the number and diameters of the slats. This would further simplify the transportation of the foldable cages.

Finally, and perhaps most important, metal cages – as a Faraday cage – can influence the underlying electromagnetic field. Metal cages can therefore potentially impact sea turtle hatchlings regarding imprinting and orientation (Irwin et al. 2004). This would not be the case with the new wooden cages.

It remains to be determined whether the metal cage or the environmental conditions surrounding the Tinytalks caused the higher temperatures in the sand under the metal cage. Overall the wooden cage model shows few disadvantages over a metal cage model and clearly has several advantages. One potential disadvantage is that the aesthetically more pleasing wooden models might be more susceptible to theft. Smaller wooden cage models in the future will most likely represent a superior protection over metal models.

A new test series with an additional control Tinytalk location (without cage) alongside other tested cage models, for a longer time period of 60 to 90 days and accompanying air temperatures is suggested to see which cage affects the natural temperature regime less.

Examples of how other protective cages may be designed are shown in the images below.

Figure 17. Different models of cages used for nest protection; Calis, Turkey (top left); Anamur, Turkey (top right and bottom left); Crete (bottom right) (Photos: M. Stachowitsch and, bottom right, A. Beer)
Abbildung 17. Unterschiedliche Käfigmodelle, die für den Nestschutz eingesetzt werden; Calis, Türkei (oben links), Anamur, Türkei (Oben rechts, unten links), Kreta (unten rechts).

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Irwin, W. P., Horner, A. J. & Lohmann, K. J. Magnetic field distortions produced by protective cages around sea turtle nests : unintended consequences for orientation and navigation ? **118,** 117–120 (2004).