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THE INCIDENCE OF SPINAL DEFORMITIES IN MARINE TURTLES, WITH NOTES ON THE PREVALENCE OF KYPHOSIS IN INDONESIAN *CHELONIA MYDAS*

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SUMMARY

Previously over-looked literature on spinal deformities in marine turtles is reviewed and analysed for data on incidence of kyphosis, lordosis and scoliosis. Field observations on the incidence of spinal deformities in *Lepidochelys olivacea* and *Chelonia mydas* are presented. The overall incidence of spinal deformities in the 11 726 marine turtles examined or reviewed is 0.11%, representing 0.08% kyphosis and 0.03% lordosis and scoliosis. Indonesian *Chelonia mydas* appear to have an unusually high prevalence of kyphosis (1.0%). Hypotheses regarding the etiologies of the various spinal deformities are discussed.

INTRODUCTION

The occurrence of spinal deformities in turtles has received little attention in the literature, and most articles have only documented the occurrence of kyphosis in one or a few specimens of a given species. Though many authors have dealt with the incidence of scute abnormalities in turtle populations, none have investigated the incidence of kyphosis and other spinal deformities. In addition, many literature citations on spinal deformities are buried in longer papers on chelonian natural history and morphometric investigations, and are easily overlooked. For example, the two most recent major papers on the occurrence of kyphosis in turtles (Plymale, Jackson & Collier, 1978; Wilhoft, 1980) are notably deficient in their analysis of previous literature. Plymale *et al.* (1978) in their "survey of all published accounts of chelonian kyphosis" provide only one citation for the occurrence of spinal deformities in marine turtles. They cite Coker (1910) as allegedly describing the occurrence of kyphosis in the loggerhead turtle, *Caretta caretta*. Our reading of that paper indicates no such description. On the other hand, one specimen described by Coker has a definite scoliosis and as such, does represent a case of spinal deformity in a marine turtle.

In order to remedy these shortcomings in the literature, we have initiated an investigation of kyphosis and other spinal deformities in turtles.

The three types of spinal deformity most common among turtles are kyphosis, lordosis and scoliosis. Kyphosis is commonly known as "hump-back" and is defined as a dorsally convex deformity of the spine in the sagittal plane of the animal (whether a turtle or other vertebrate, such as man). Lordosis is also known as "sway-back" and is defined as a ventrally concave deformity of the spine in the sagittal plane. Scoliosis is a lateral curvature of the spine in either direction within the frontal plane of the animal. In turtles this is normally a single curve, in humans usually a double S-curve. In addition, features of two or more of these deformities can be present in a single animal. Kyphoscoliosis, for example, is a complex deformity including deviation into both the sagittal and frontal planes.

METHODS

We performed an extensive literature review to identify as many previously overlooked citations as possible concerning spinal deformities in marine turtles. We also reviewed articles where the authors clearly paid specific attention to the possibility of the presence of skeletal abnormalities in marine turtles, yet where no cases of spinal deformity were noted. In all these reviewed literature citations, we have attempted to calculate the incidence of spinal deformities and kyphosis based on the population data presented, or the maximal possible incidence in those populations where no deformed individuals were noted. In addition, we have made preliminary field observations on the occurrence and incidence of kyphosis and other spinal deformities in marine turtles. This paper and Table I summarize our findings. The incidence of deformities has not been calculated for populations of less than 100 animals: for populations of 100 to 1000 animals the results have been calculated to the nearest one tenth percent, for those above 1000 to the nearest one hundredth percent.

RESULTS

Six previous articles have documented the presence of spinal deformities in marine turtles.

TABLE I. Incidence of spinal deformities and kyphosis in marine turtle populations

Genus and species	Locality	*N*	Spinal deformities No.	Spinal deformities %	Kyphosis No.	Kyphosis %	Source
Chelonia							
C. agassizi	Baja California	2600	0	<0.04	0	<0.04	Caldwell 1962
C. mydas	Australia	984	1	0.1	0	<0.1	Moorhouse 1933
C. mydas	Indonesia	409	5	1.2	4	1.0	Present Study
C. mydas	Sri Lanka	214	0	<0.5	0	<0.5	Deraniyagala 1939
	Worldwide totals	4207	6	0.14	4	0.10	Above 4 Refs.
Lepidochelys							
L. olivacea	Sri Lanka	378	1	0.3	0	<0.3	Deraniyagala 1939
L. olivacea	Mexico	300	1	0.3	1	0.3	Present Study
L. olivacea	Guyana	241	0	<0.4	0	<0.4	Pritchard 1969
	Worldwide totals	919	2	0.2	1	0.1	Above 3 Refs.
Caretta							
C. caretta	South Carolina	398	0	<0.3	0	<0.3	Baldwin and Lofton 1959
C. caretta	North Carolina	208	1	0.5	0	<0.5	Coker 1910
	Worldwide totals	689	1	0.2	0	<0.2	Above 2 Refs. and Moorhouse 1933
Dermochelys							
D. coriacea	Guyana	5878	4	0.07	4	0.07	Fretey 1978
	Worldwide totals	5911	4	0.07	4	0.07	Above Ref. and Present Study
	Overall totals	11726	13	0.11	9	0.08	

Coker (1910), as mentioned above, described a case of scoliosis in a hatchling loggerhead (*Caretta caretta*) from North Carolina. He examined 208 specimens, thereby giving an incidence of 0.5% spinal deformities in the population, and <0.5% kyphosis.

Moorhouse (1933) examined 984 specimens of hatchling green turtles (*Chelonia mydas*) from Heron Island, Queensland, Australia and found one specimen with a mild spinal deformity causing depigmentation and tail loss. This represents an incidence of 0.1% spinal deformities in the population, and <0.1% kyphosis.

Deraniyagala (1939) examined 378 specimens of olive ridleys (*Lepidochelys olivacea*) from Sri Lanka and found one hatchling with lordosis. This represents an incidence of 0.3% spinal deformities in the population, and <0.3% kyphosis.

Villiers (1958) illustrated a single adult green turtle (*Chelonia mydas*) from West Africa with pronounced kyphosis. He made no mention of the population sample examined, but stated that shell deformities are apparently relatively common among sea turtles.

Witham and Futch (1977) illustrated and described the development of lordosis in captive-raised *Chelonia mydas* from Hutchinson Island, Florida. They indicated that at least 10 animals out of about 2500 developed lordosis, for an incidence of at least 0.4% spinal deformities. Since no deformities were noted at hatching and the lordosis developed during growth in captivity, this deformity may have represented a nutritional osteodystrophy secondary to a dietary calcium/phosphorous imbalance or other disorder of calcium metabolism. Because this population is a captive-raised one, the figures on incidence of spinal deformities are not included in Table I or in the analysis of the data.

Fretey (1978) examined 5878 mature female leatherback turtles (*Dermochelys coriacea*) nesting in Guyana and found 4 with "kyphotic" shells. He does not elaborate on this description other than stating that one of the specimens had a foreshortened carapace as a result. Whether his specimens represent true kyphosis or kyphoscoliosis remains unclear. The 4 specimens

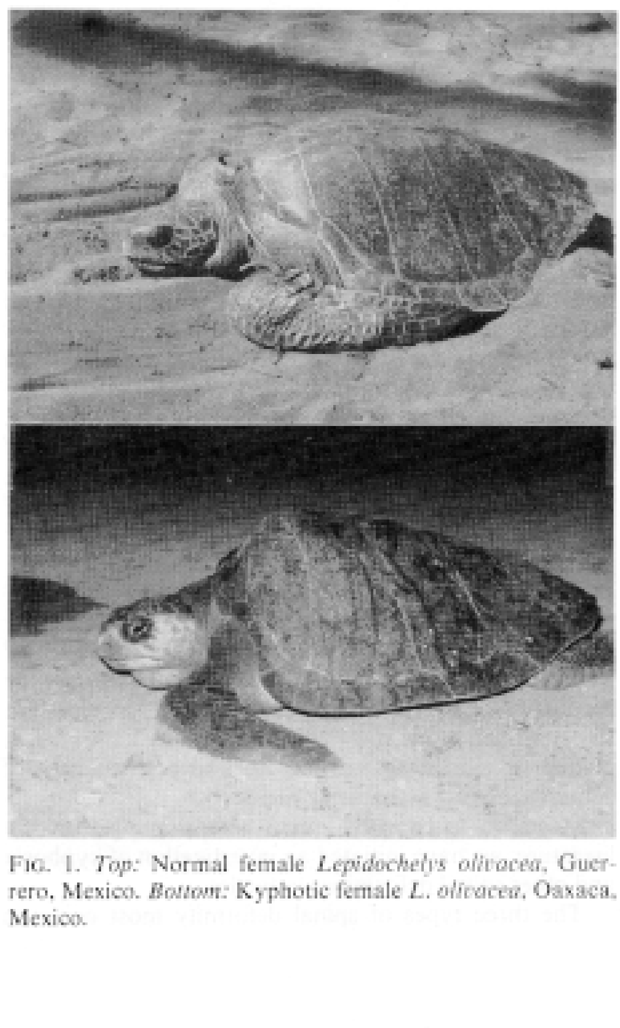

FIG. 1. *Top:* Normal female *Lepidochelys olivacea*, Guerrero, Mexico. *Bottom:* Kyphotic female *L. olivacea*, Oaxaca, Mexico.

represent an incidence of 0.07% spinal deformities in the population, and probably 0.07% kyphosis.

Five previous studies have addressed the question of occurrence of skeletal deformities in marine turtle populations without apparently discovering any cases of spinal deformity. Because a maximum possible incidence of spinal deformities in the population can be calculated from the number of animals studied, these citations are included for comparative purposes. Caldwell (1962) examined ca. 2600 *Chelonia agassizi* from the Gulf of California without noting any cases of spinal deformity, yielding an incidence of <0.04% spinal deformities. Deraniyagala (1939) found none among 214 *Chelonia mydas* from Sri Lanka for an incidence of <0.5%. Pritchard (1969) found none among 241 *Lepidochelys olivacea* from Guyana for an incidence of <0.4%. Baldwin & Lofton (1959) found none among 398 *Caretta caretta* from South Carolina for an incidence of <0.3%. Moorhouse (1933) found none among 83 *Caretta caretta* from Australia.

In addition to the above literature citations, we have made a few preliminary field observations on the occurrence and incidence of spinal deformities in marine turtles.

During a field survey of marine turtles in Oaxaca and Guerrero, Mexico in January, 1982, we (AGJR and PCHP) were able to examine ca. 300 olive ridleys (*Lepidochelys olivacea*) obtained from the slaughterhouse in Puerto Angel. We found one adult female with a kyphotic spinal deformity (Fig. 1), representing an incidence of 0.3% spinal deformities in the population, and 0.3% kyphosis. At the same time we examined 11 adult leatherbacks (*Dermochelys coriacea*), none with spinal deformities. In addition, AGJR has examined 15 adult *D. coriacea* from U.S. waters, and RAM 7 from Surinam, also all without spinal deformities. These 33 specimens have been added to Fretey's (1978) much larger sample for analysis of incidence of spinal deformities in *D. coriacea*.

During a visit to Bali, Indonesia in October, 1982, we (AGJR and RAM) surveyed the commercial sea turtle pens at Serangan and Benoa one day and examined 409 adult green turtles (*Chelonia mydas*). We found 5 animals with spinal deformities, of which 4 represented true kyphosis (Fig. 2) and one a case of lordosis (Fig. 3). This represents a total incidence of 1.2% spinal deformities in the sample, with 1.0% kyphosis and 0.2% lordosis. The turtle sample represented in these commercial pens probably does not constitute a single natural population, as the turtle fishery industry based on Bali encompasses a broad area within Indonesia, including Bali, Sumbawa, Flores, Timor, southern Sulawesi, and southeastern Kalimantan (Polunin & Sumertha Nuitja, 1982; Sumertha Nuitja & Akhmad, 1982). The turtles caught within this broad geographic region can well have originated from any one of several Indonesian green turtle nesting grounds. The most likely of these would be Ai-Ketapang on Sumbawa, Sukamade on Java, or Berau on East Kalimantan (see Polunin & Sumertha Nuitja, 1982).

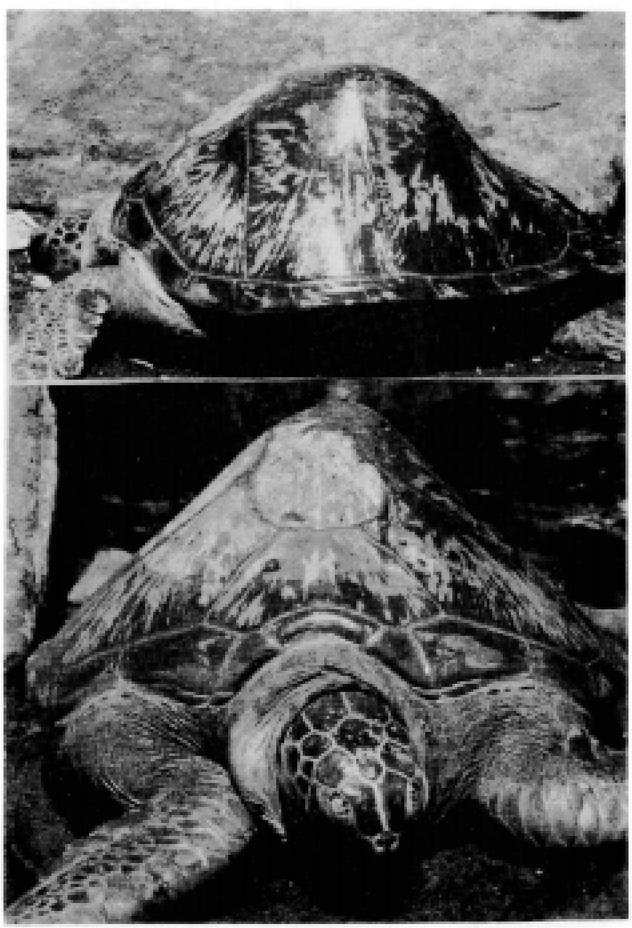

FIG. 2. Lateral and anterior views of kyphotic female *Chelonia mydas*, Bali, Indonesia.

FIG. 3. Dorsal view of lordotic female *Chelonia mydas*, Bali, Indonesia.

DISCUSSION

The overall incidence of spinal deformities in the 11 726 marine turtles reviewed is 0.11%. Of this figure, 0.08% represents the incidence of kyphosis, 0.03% the incidence of other spinal deformities such as lordosis and scoliosis. There is little appreciable difference in the incidence of deformity between the three genera of the family Cheloniidae examined (*Chelonia*, *Lepidochelys*, and *Caretta*). The morphologically divergent *Dermochelys* of the family Dermochelyidae may have a lower incidence of spinal deformities than the hard-shelled Cheloniidae, but, despite hypotheses to the contrary (Nixon and Smith, 1949; Plymale *et al.*, 1978), does indeed develop kyphosis. The overall incidence of spinal deformities in the Cheloniidae is 0.15% based on 5815 specimens. The overall incidence in the Dermochelyidae is 0.07% based on 5911 specimens. For the incidence of kyphosis alone, the figures are nearly identical, with 0.09% in the Cheloniidae, 0.07% in the Dermochelyidae.

The prevalence of kyphosis (1.0%) among Indonesian *Chelonia mydas* is most unusual when comparing it to the data presented above on other marine turtle populations. However, the incidence of lordosis in the population (0.2%) falls within the general range for incidence of spinal deformities among other cheloniid marine turtles reviewed. As such, the incidence of total spinal deformities of 1.2% probably reflects primarily the comparatively high incidence of kyphosis alone.

At this stage, we can only hypothesize as to the cause of this unusual prevalence of kyphosis. Plymale *et al.* (1978) have listed the various theories already proposed in the literature for the development of kyphosis. Wilhoft (1980) also summarizes some of these. Neither of these authors, nor any previous workers, have differentiated between the various types of spinal deformity when discussing etiology. In fact, within the general field of chelonian teratology, the term "kyphosis" has unfortunately become more or less loosely synonymous with "spinal deformity". For example, Wilhoft (1980) described a purely lordotic snapping turtle (*Chelydra serpentina*) as "kyphotic", and MacCulloch (1981) described scoliotic painted turtles (*Chrysemys picta belli*) as "kyphotic". We believe that such laxity of definition can only lead to confusion and misdirected generalizations in any discussion of spinal deformity. We therefore urge a strict adherance to proper anatomic definitions.

In our opinion, the causes of spinal deformities are multiple. Initially, a distinction must be made between pre- and post-natally acquired deformities. Both kyphosis and lordosis can develop during growth as a result of nutritional osteodystrophy or other developmental factors. The lordotic green turtles discussed by Witham and Futch (1977) and the lordotic snapping turtle described by Wilhoft (1980) are representative of post-natal deformities. In addition, PCHP has observed one kyphotic green turtle (*Chelonia mydas*) raised at the Cayman Turtle Farm which might also fall into this post-natal category.

Pre-natally acquired deformities may be either congenital or secondary to alterations in the internal egg environment. For example, lordosis may well develop as a response to external pressure on the developing embryo, possibly as a result of excessive moisture loss and drying of the incubating egg (see Lynn & Ullrich, 1950, for experimental results on egg dessication). In turtle species with soft, pliable eggshells such as the marine turtles such deformation may occur as a result of collapse of the eggshell itself. In turtle species with hard, brittle eggshells such as the terrestrial tortoises of the family Testudinidae, such deformation can probably occur as the result of increasing size of the internal air bubble, also due to excessive moisture loss and drying of the incubating egg. Kyphosis, on the other hand, is more likely a congenital abnormality reflecting some internal defect. In humans, congenital kyphosis is due either to a partial failure of formation or failure of segmentation of the developing spinal vertebrae. Whether these mechanisms can account for chelonian kyphosis remains to be investigated. In addition, it would appear from preliminary observations on kyphosis in turtles in general, that there may be two different types of kyphosis, which may have different etiologies. Of these, one type is a smoothly high-domed deformity affecting the entire bony carapace which might well be related to post-natal developmental factors such as the yolk-retraction theory of Williams (1957). Kyphotic specimens of soft-shelled turtles (Trionychidae) appear to demonstrate this condition frequently (see Mertens, 1940; and Smith, 1947). The other type of kyphosis is the presence of an asymmetrical angular deformity in a smaller portion of the carapace which is more likely the result of a congenital defect. Most of the marine turtles reported on here, and most other hard-shelled turtles previously indicated in the literature represent this second type of kyphosis.

Further investigations will be required to delineate the causes of chelonian spinal deformities. Special attention should be focused on abnormal situations such as the high prevalence of kyphosis in the Indonesian population of *Chelonia mydas*. As Mitchell & Yntema (1973) have demonstrated, teratogens such as malathion and captan can cause an increased incidence of spinal abnormalities in turtles. Whether some unknown teratogenic effect is at work on the Indonesian green turtle population warrants further analysis.

A final note of caution must, however, be raised concerning any interpretation of the significance of the apparently high incidence of spinal deformities in Indonesian green turtles. These animals play an important role in social and religious contexts in Bali and it is not known whether these social factors influence the rate at which deformed specimens are sold in the market. It is possible that kyphotic or lordotic specimens accumulate in the commercial pens, either because they are highly valued by the seller, or because they are avoided by the buyer. If either case is true, then the actual incidence of these deformities in the natural Indonesian population would be much lower than that seen in the captive population in the commercial pens we examined. Further studies are clearly needed.

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