

Variation of Size at Maturity of Female Hawksbill Turtles (*Eretmochelys imbricata*), with Speculations on Life-History Tactics Relative to Proper Stock Management

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ABSTRACT: The mean nesting sizes, and subsequent reproductive rates, of Arabian Peninsula hawksbill turtles (*Eretmochelys imbricata*) are significantly smaller than other hawksbill populations. These differences can not presently be explained due to the lack of basic life history information and, consequently, resource managers are unable to realistically manage any hawksbill population. Research, although costly and time consuming, must be initiated to obtain the demographic data needed: age at maturity, sex ratios, mortality, recruitment, migratory patterns, nesting intervals, philopatry, and whether hatchlings return as adults to reproduce on their natal beaches.

INTRODUCTION

The reproductive strategies of sea turtles are poorly understood because their oceanic habitat makes turtles difficult to study. Many life history parameters, such as age at maturity, sex ratios, mortality, recruitment, migratory patterns, nesting intervals, philopatry, and whether hatchlings return as adults to reproduce on their natal beaches, are unknown. To understand the complex ecology and adaptive significance of various sea turtle life history parameters, biologists must provide comprehensive reproductive data from all nesting populations. Additionally, they must also develop methodologies to collect unknown life history parameters and ecological relationships of these turtles over their entire life span. Only when these parameters are known can these endangered turtle populations be properly managed (Bustard et al.). Qualitative biologists still sit on beaches counting eggs and quantitative biologists doggedly sit at computer terminals analyzing these data. Research, although costly, must be innovative and tenaciously pursued to obtain the demographic data needed for realistic sea turtle management.

The hawksbill turtle (*Eretmochelys imbricata*) is an interesting example of poorly directed research. The hawksbill, valued commercially for its meat and tortoise shell, is perhaps the least understood of all sea turtles. Variations in mean sizes at

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maturity occurs in different nesting populations, with subsequent differences in reproductive rates, suggesting that there is selection of optimal reproductive sizes in response to varying biological, behavioral, or environmental factors.

Table 1. Straight-line carapace lengths and clutch sizes of seven hawksbill nesting populations.*

Location	Carapace Length (cm)	Number of Eggs per Nest	Source
ATLANTIC OCEAN			
<i>Costa Rica</i>			
Mean	83.1	361.1	Carr et al. (1966)
Range	74.9-91.4	53-206	
Sample	62	57	
<i>Guaymas</i>			
Mean	83.8	158.1	Prichard (1959)
Range	80.0-88.9	138-176	
Sample	23	7	
PACIFIC OCEAN			
<i>Solomon Islands</i>			
Mean	80.5	137.5	McKenna (1977)
Range	68.0-93.0	75-250	
Sample	85	175	
<i>Australia</i>			
Mean	78.4	111.7	Limpas (1960)
Range	71.6-82.7	62-142	
Sample	10	20	
INDIAN OCEAN			
<i>Oman</i>			
Mean	73.3	97.2	Ross (1961)
Range	60.0-83.0	75-118	
Sample	48	9	
<i>South Yemen</i>			
Mean	69.4	81.2	Birth & Carr (1970)
Range	63.5-72.4	66-99	
Sample	15	5	
PACIFIC OCEAN			
<i>Sudan</i>			
Mean	66.0	73.2	Birth & Laif (1960)
Range	53.3-73.7	52-117	
Sample	42	26	

* Data are from populations with 10 or more turtles with straight-line carapace measurements.

MATURE SIZE AND REPRODUCTIVE RATE

The mean sizes of nesting hawksbill turtles are often different between populations (Table 1). These differences reflect different sizes at maturity providing hawksbills essentially stop growing when maturity is reached as occurs in the green turtle (*Chelonia mydas*) (Carr and Goodman, 1970; Bjørndal, 1980; Wood and Wood, 1980). The hawksbill nests in many locations around the world, but reproductive data are scarce (Witzell, 1983). The data presented here represent the seven most complete studies. Mean sizes of nesting hawksbill populations (Table 1) vary from 66.0 cm (Sudan) to 83.1 cm (Costa Rica). The importance of mean nesting size is apparent when assessing the reproductive rate, because the reproductive rate is positively correlated to the mean size of nesting females (Fig. 1). The number of eggs per clutch produced by hawksbills in Costa Rica, Guyana, Australia, and the Solomon Islands are considerably greater than the number produced by the turtle populations in the Arabian Peninsula, and since egg sizes are similar (3.8–4.0 cm) the differences in the number of eggs laid per clutch between hawksbill populations are actual differences in reproductive output. Also, there is no indication that the populations

of smaller turtles lay as many eggs per season as those populations of larger turtles because the estimated number of nests per turtle per season is two for most populations studied, including Costa Rica, Solomon Islands, and Oman. Unfortunately, there are no comparative multi-year nesting data available for these nesting populations.

The differences in reproductive rates between nesting Arabian and non-Arabian hawksbills illustrate the divergence that can occur in a widely distributed species that consists of independently breeding populations. Presuming that all stable animal populations produce the number of eggs that result in the optimal number of young surviving to reproduce and continue the populations (Lock, 1954, 1966), then why are the reproductive strategies of those hawksbill populations surrounding the Arabian Peninsula different from the other hawksbill populations?

The most important factor offsetting the disadvantage of smaller mature size (and fewer eggs per turtle) is early maturity, which maximizes the number of hatchlings at an early age. This increases evolutionary fitness in several species (Cole, 1954; Meats, 1971; Stearns, 1976). Assuming that wild hawksbill growth rates are similar, and they essentially stop growing at maturity, then do the small-sized Arabian Peninsula populations reach maturity at an earlier age than the other hawksbill populations?

Are there advantages to being small and laying smaller clutches? Do smaller hawksbills indeed nest faster, thereby avoiding the desiccation and intense predation pressure (harassment?) that larger turtles must endure? Perhaps smaller clutches incubate faster or have higher hatching rates than larger clutches, as occurs in other sea turtle species (Ackerman, 1980; Balasingam, 1967).

REPRODUCTIVE SELECTION PRESSURES

The frequently hypersaline environment of the Red Sea area probably had an effect on the evolution of Sudan and Yemen hawksbill populations. The Red Sea is unique in that it has a relatively high degree of faunal depauperacy and endemism. This is a result of paleogeographical processes during the Pleistocene when complete isolations of the Red Sea were caused by fluctuations of the sea level, resulting in a high rate of evolutionary changes (Klauewitz, 1972; Johnson and Feltes, 1984).

It has been speculated that short-term upwellings of cold water inhibit turtle growth or regulate the food supply (Ross, 1980), even though the Red Sea turtles do not undergo this phenomenon. Perhaps the Arabian hawksbills are small because they do not migrate long distances, and therefore do not need large bodies necessary to store sufficient energy needed for both migration and egg production, as occurs

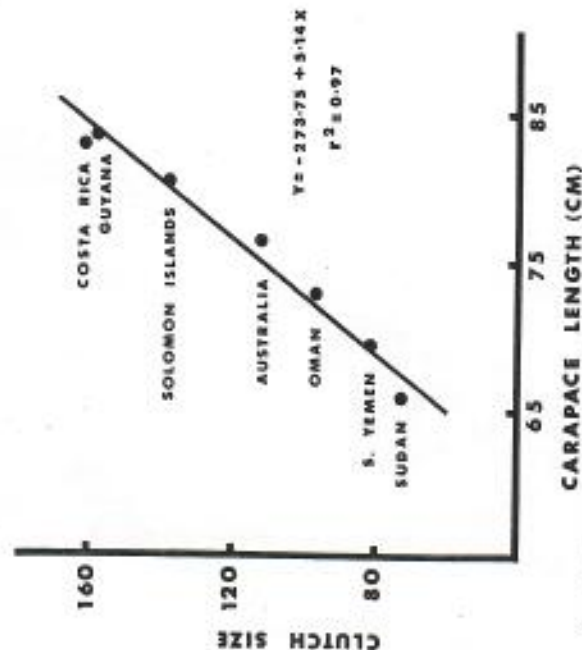


Fig. 1. Linear regression analysis of mean straight-line carapace length and mean clutch size of seven nesting hawksbill sea turtle populations.

in other sea turtles (Carr and Goodman, 1970). Interestingly, some of the clutches in Costa Rica and the Solomon Islands contain variable numbers of small, shelled yolkless lumps but all of the Arabian clutches have large numbers of these lumps. Perhaps these large numbers of lumps laid in each Arabian clutch are, in fact, a vestige of a genetic propensity for traveling long distances and laying larger clutches. Perhaps an extremely high predation rate of subadults and adults in the Arabian area by the numerous sharks (Consteau and Consteau, 1970; Steinitz, 1973; Pillai and Honma, 1978) has helped select for early maturity at a smaller size.

CONCLUSION

Divergent reproductive strategies of independently breeding hawksbill populations are not surprising, considering the flexibility of this species (Witzell 1983). The hawksbill is possibly the most adaptive of all sea turtles, these flexible traits enabling individual populations to evolve diverse life history tactics. These diverse life history tactics ensure species dissemination and survival.

However, it is fairly obvious that sea turtle researchers have not only failed at understanding these tactics and underlying mechanisms, but have failed at even addressing basic life history information. Without parameters such as knowing age at maturity, migratory patterns, nesting intervals, philopatry, and whether hatchlings return as adults to reproduce on their natal beaches, resource managers will never be able to properly manage these important species.

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要 旨

種タイマイの成熟時の大きさの変異

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アフリカ半島のタイマイの産卵個体の平均は他地域の個体群と比べて有意に小さく、繁殖率も同様らしい。この理由は生活史の基礎資料が不足のため、いまのところ説明できない。異質がかかり時間もかかるが、これら生活史の資料を得るための研究が必要である。