Tooth Loss Rate from Two Captive Sandtiger Sharks (*Carcharias taurus*)

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For 6 months, two sandtiger sharks (*Carcharias taurus*) were held captive together in a small enclosure at the Lisbon Zoo. During that period, the gravel was monitored daily for teeth shed by the animals. At the end of their stay, the number of teeth divided by the number of days yielded a tooth loss rate of 1.06 teeth per day per shark. The plotting of mean monthly values for tooth loss rate against mean monthly temperatures showed that these two variables increased with time, suggesting that the animals' metabolism was influenced by the increase in water temperature. Zoo Biol 18:313–317, 1999.

Key words: elasmobranch; metabolism; temperature; tooth shedding

INTRODUCTION

Unlike bony fishes, cartilaginous fishes replace their teeth continuously, as described for several species by Strasburg [1963]. The subject of shark tooth replacement has received attention from many authors such as Ifft and Zinn [1948], Moss [1972], Gomes and Reis [1990], and Luer et al. [1990].

In 1991, Overstrom presented a short note on this subject using data derived from two captive sandtiger sharks (*Carcharias taurus*; Rafinesque, 1810) and estimated this value at 0.48 teeth/shark/day. Overstrom suggested that shark metabolic rate may be affected by water temperature [Love, 1970; Dodd, 1983 cited in Overstrom, 1991] and stated that it would be of great interest to examine tooth replacement under varying environmental conditions, particularly water temperature. Such conditions were present at the Lisbon Zoo, where two large sharks of this species were held captive in a relatively small tank with no water chilling system. At 40°00 N, Portugal is considered a typical temperate climate, with temperatures dropping as low as 0 to 5°C in winter and rising to 35–40°C in summer. The sharks arrived in winter and left in summer, which created an opportunity for assessing tooth loss rates and correlate them with water temperature changes.

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MATERIALS AND METHODS

On 9 February 1995, one 200-cm male and one 204-cm female sandtiger shark arrived at the Lisbon Zoo and were held captive for 163 days (left on 21 July). The sharks were kept together in an octagonal tank 13 m long × 3 m wide × 1.5 m deep, with no water chilling system.

The tank had a 15-cm thick gravel bed, collected at a beach near Lisbon. Sea water was trucked directly from the Atlantic Ocean during the first month to allow 100% weekly water changes. This was necessary in the beginning because the biological filtration was not as yet mature at the time the sharks arrived. Afterward, any water lost through evaporation was replenished by addition of city freshwater (approximately 5% per week). Salinity was tested daily and corrected to 35 ppt using commercial sea salt.

The tank was equipped with a filtration system consisting of 1) one high-rate sand filter, 2) one high-rate activated carbon filter, 3) one external biological filter, 4) one foam fractionator, and 5) one ultraviolet sterilizer. The suction for the filtration circuit consisted of four PVC drilled plates placed on the bottom of the tank above the gravel bed. There was therefore no water circulation through the gravel bed. The circulated water was returned both at the surface and bottom.

A water-heating system was used during the first month to maintain the water temperature at a constant 21°C, which was the temperature in Struisbai, South Africa, where the sharks were caught. Temperature was measured three times daily (8:00, 12:00, and 16:00) directly in the tank near the surface using a standard thermometer. An average of these three values was recorded daily. Mean monthly temperature values were calculated at the end of each month.

A few weeks after the animals arrived, particularly during May 1995, atmospheric temperature increased gradually, thus having a direct effect on the water temperature, since a water-cooling device was not available. This scenario created a perfect opportunity for assessing tooth loss rate (TLR) with temperature changes over time.

Starting 1 March, the whole gravel surface was examined carefully for teeth at the end of each day. These teeth were retrieved and counted. The gravel-bed surface area was small enough (13 × 3 m) that it could be easily examined for teeth. The contrast between white teeth and brown gravel facilitated this process.

The time spent each day monitoring the gravel ranged from 15 min to 1 hr. The gravel was monitored visually through direct observation starting in one end of the tank while moving to the opposite end. It is unlikely that every single tooth shed each particular day was retrieved. It was assumed, however, that the cumulative number of teeth collected since day 1 reflected the total number of teeth shed since day 1.

The height of every tooth retrieved (longest length from the base to the tip) was measured to the nearest millimeter. The relative frequency of all tooth heights was calculated to assess whether the retrieving process was size biased.

TLR was calculated monthly by dividing the number of teeth retrieved that month by the number of days in such month. This figure was then divided by two since there were two animals in the tank and it was assumed that both had equal TLR. A monthly TLR of 1.0 therefore means that each shark shed, on average, one tooth per day during that month.

RESULTS AND DISCUSSION

At the end of the 163-day period, the two sharks had shed 344 teeth yielding a potential final individual TLR of 1.06 teeth/day. This means that, on average, every 23 hr both sharks potentially lost one tooth each. This figure is somewhat surprising, especially since it is more than double the parallel figure given by Overstrom [1991].

There is one fundamental difference between this study and that of Overstrom [1991]. Whereas Overstrom collected teeth from an empty tank after the sharks left, the tank in Lisbon was small enough to allow daily collections. It is doubtful that every tooth shed daily was retrieved the same day. However, one can assume that each day the cumulative number of teeth collected since day 1 roughly equaled the total number of teeth shed since day 1 also.

During the same period of time, the water temperature gradually increased from 22°C to 28°C, which may have influenced the animals' metabolic rate and subsequently may have influenced their tooth shedding rate.

Both TLR and temperature increased with time (Fig. 1) (Table 1). Since no other known or observable factors varied with time (e.g., lighting, food intake, amount of visitors per day), it is possible that the overall increase in TLR was caused by the gradual increase in water temperature and a subsequent increase in the metabolic rate. This phenomenon has been described in other species, such as the nurse shark (*Ginglymostoma cirratum*) by Luer et al. [1990].

Although both temperature and TLR trends show a marked increase with time, this potential correlation should be interpreted cautiously since there is no assurance that the number of teeth retrieved each month corresponded exactly to the number of teeth shed that particular month. Also, the design of the filtration system might have caused loss of some teeth to the sand or filters. Loss of teeth means that the calculated TLR is potentially underestimated.

The relative frequency of tooth heights in retrieved teeth (Fig. 2) suggests a distribution similar to the size distribution described by Compagno [1984] for this

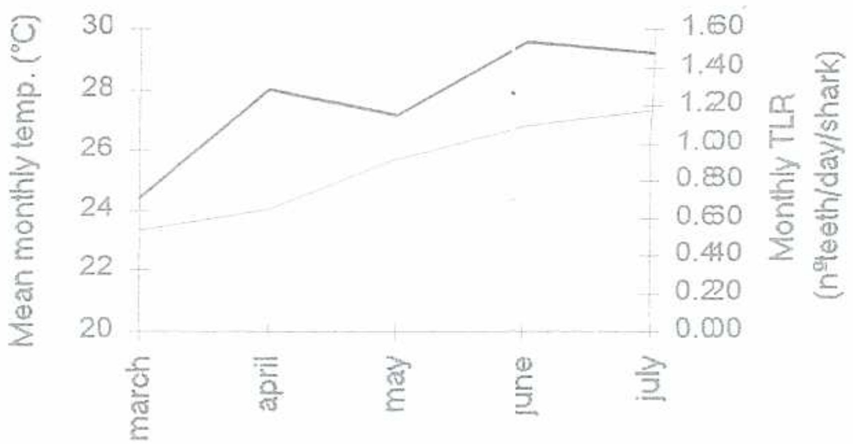

Fig. 1. Observed monthly tooth loss rate (thick line) of two captive sandtiger sharks and mean monthly temperatures (thin line) of water temperature.

TABLE 1. Descriptive statistics of TLR and temperature versus months in two captive sandtiger sharks (*Carcharias taurus*)

Month	No. of days	No. of teeth	Monthly TLR	Avg ± SD temp
February	20	—	—	—
March	31	42	0.68	23.3 ± 1.07
April	30	77	1.28	24.0 ± 1.78
May	31	71	1.15	25.7 ± 0.72
June	30	92	1.53	26.8 ± 0.97
July	21	62	1.48	27.3 ± 0.57
Total	163	344	—	—

Monthly TLR denotes the total of teeth retrieved in that month divided by the number of days per shark (no. teeth/shark/day). Avg temp shows mean temperature during that month (°C).
Avg, average; SD, standard deviation; temp, temperature.

species. The frequency distribution includes teeth with a height as small as 5 mm, which suggests that the monitoring of the gravel was relatively efficient.

There were no obvious changes in the number of teeth in the animals' mouths, which suggests that the amount of teeth retrieved were replaced naturally. However, the number of teeth in the individual mouths was not controlled, hence the use of the term tooth loss rate instead of tooth replacement rate.

In summary, this study depicts a situation in which data were available opportunistically, rather than an experiment designed to answer an hypothesis. Although the lack of experimental design prevents solid conclusions to be drawn, the fact remains that plotting TLR and temperature does show two increasing trends. Also, the overall TLR value calculated after the last day remains as a reference for this species' behavior in captivity.

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Fig. 2. Relative frequencies of tooth heights for 344 teeth that fell from two captive sandtiger sharks between February and July 1995.

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