

Panama as a Paleo-Nursery Area for Giant Shark Babies

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Nursery Areas

Sharks, especially large species, are very mobile organisms with complex life histories and wide distributions. During their lifetime they utilize 3 types of areas : adult feeding, reproduction and nursery areas. Studies have shown that females of some species travel to discrete geographic areas to give birth or lay their eggs. These nursery areas are usually highly productive, shallow coastal environments where young sharks spend their first weeks, months or years. In these zones juveniles can find abundant food and protection from large predators including other sharks. Nursery areas are characterized by the presence of both gravid females and free swimming neonates and are essential habitats for the sharks' survival.



Late Miocene Gatun Fm.

The Gatun Formation and its faunas were located in the shallow marine seaway that connected the Caribbean Sea and the Pacific Ocean during the late Miocene, ~10 million years ago. It is a highly fossiliferous formation that presents a diverse molluscan assemblage. Studies of the different taxa (foraminifera and fish otoliths) found in the Gatun Fm. have shown that it was a productive, warm, shallow-water marine environment, probably a basin, with a typical Caribbean sequence of mangrove, thalassia grass and coral reefs.

Oxygen isotope studies of mollusk shells indicate that salinity, annual temperature variations, relative seasonality and productivity were more pronounced during the late Miocene relative to those of the modern day in this region.

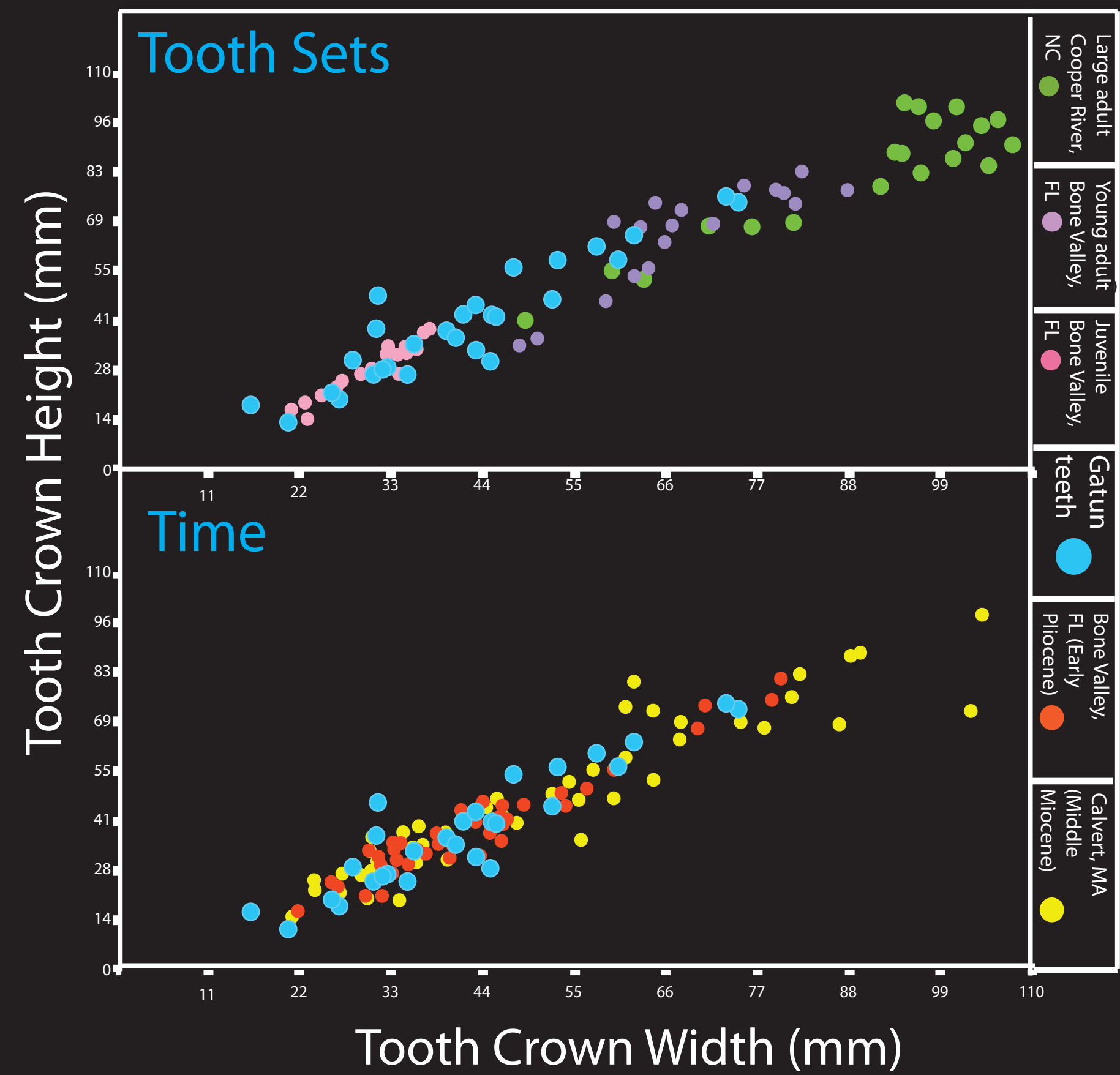
Although sharks are apex predators in the oceans, juveniles are susceptible to being preyed upon by larger individuals. Females give birth in shallow environments called nursery areas to protect their offspring from predators. The extinct shark (*Carcharocles megalodon*), is the biggest shark that ever lived. Fossil teeth *C. megalodon* are found in the Late Miocene Gatun Formation of Panama, where we have collected and measured a number of teeth. Surprisingly, no large teeth are present. We have compared these specimens with different teeth from analogous localities. In addition we have calculated the total length of the individuals found. These comparisons and estimations suggest that *C. megalodon* sharks from the Gatun Fm. were mostly juveniles. During the Late Miocene the Gatun was a productive, warm shallow-water marine environment. We propose that the Gatun Formations represents a nursery area during this period of time and that *C. megalodon* spent their juvenile stages in this area that provided them protection.

Megalodon in The Gatun Fm.

Fossil teeth of *C. megalodon* can be found in coastal habitats worldwide, including the Late Miocene Gatun Formation of Panama. Between 2006 and 2009 we collected and measured around 30 *C. megalodon* teeth by surface prospecting. Surprisingly, large teeth are uncommon with crown heights ranging between 16 to 74 mm. In order to know whether if the small size observed is because they were juveniles, or to their position within the jaw; we compared Gatun's tooth size with tooth sets from a juvenile, a small adult and a large adult. In addition, we compared these sizes with those found in older and younger formations to know if the small size observed is a special feature of this species during the late Miocene.



Comparisons

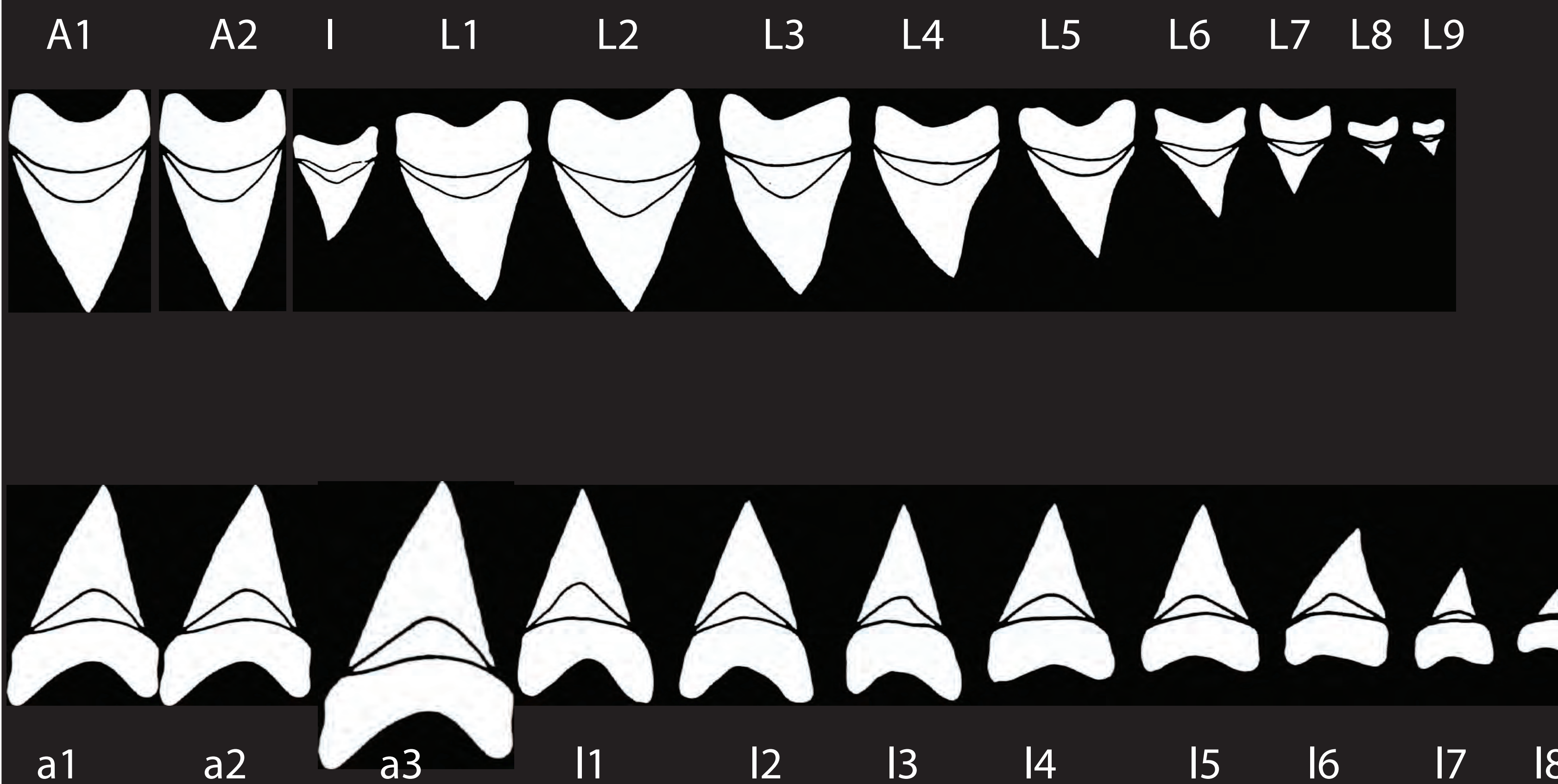


Comparisons with different tooth sets suggest that even when *C. megalodon* tooth size varies within the jaw; the Gatun Fm. teeth are mostly distributed in the same range as juvenile dentition, however a few are larger and fall within the adult size class.

Even though the Gatun teeth are very small when compared with other assemblages; tooth sizes from Gatun are no different from the sizes found in younger and older formations.

How to estimate Megalodon total length?

The extant white shark (*Carcharodon carcharias*), has been used as living model of the extinct *Carcharocles megalodon*. The teeth of *C. carcharias* can give an estimate of its total length. Based on the work of Shimada (2003), every tooth position in the jaw corresponds to one regression equation that calculates its body size in *C. carcharias*; we have extrapolated *C. megalodon* crown height to estimate its total length

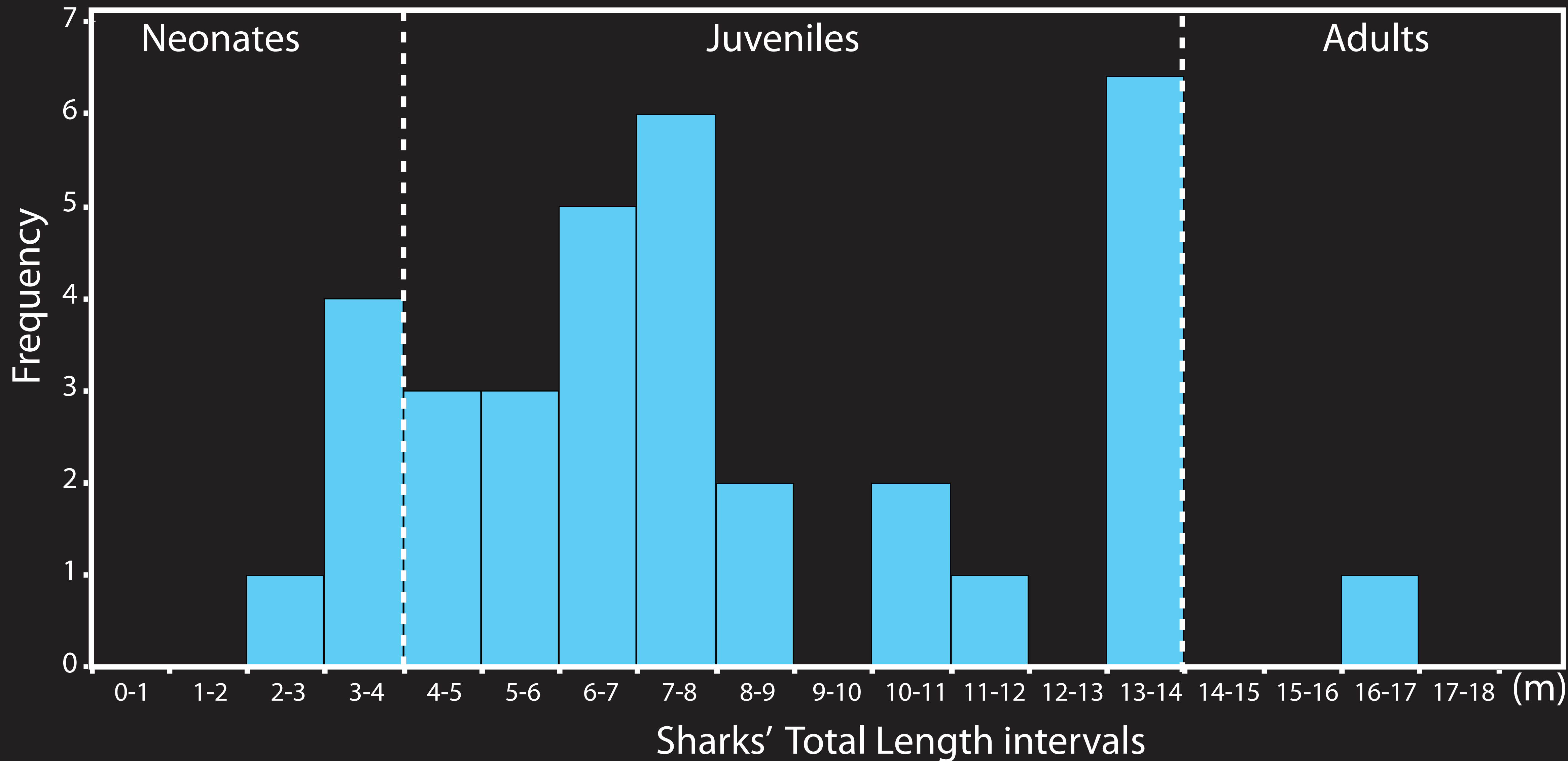


Megalodon Total Length Estimations

Position	Regression Equation (x=CH)	Specimen	CW (mm)	CH (mm)	Position	TL (m)
A1	TL= 5.234+11.522x	UF 237898	53.0	50	A1-A2	5.9
A2	TL= -2.16+12.103x	UF 237914	31.4	46.4	L1-L5	8.0
I	TL= 19.162+15.738x	UF 237949	35.7	32.9	A1-A2	3.9
L1	TL= 5.54+14.197x	UF 237950	47.7	54.2	a1-a2	7.6
L2	TL= 4.911+13.433x	UF 237951	26.8	17.6	L1-L5	3.1
L3	TL= 0.464+14.550x	UF 237952	43.2	31.3	L1-L5	5.4
L4	TL= 5.569+17.658x	UF 237953	30.9	24.5	I1-I5	7.2
L5	TL= -5.778+26.381x	UF 237954	41.7	41.2	A1-A2	4.9
L6	TL= -71.915+50.205x	UF 237955	28.4	28.5	A1-A2	3.4
L7	TL= -8.216+14.895x	UF 237956	44.9	28.1	I4-I6	16.8
L8	TL= -7.643+13.597x	UF 237957	26.7	19.4	L6-L9	4.4
L9	TL= -10.765+17.616x	UF 237959	16.1	16.0	a1-a2	2.2
a1	TL= -8.216+14.895x	UF 242801	31.2	27.5	L1-L5	6.4
a2	TL= -7.643+13.597x	UF 242802	45.1	41.0	L1-L5	7.1
a3	TL= -10.765+17.616x	UF 242803	40.8	34.7	L1-L5	6.0
I1	TL= 9.962+17.437x	UF 242804	32.3	26.5	A1-A2	3.1
I2	TL= 1.131+19.204x	PPP001	60.3	56.4	A1-A2	6.7
I3	TL= -30.947+25.132x	PPP002	57.7	60.1	A1-A2	7.1
I4	TL= -51.765+35.210x	PPP003	43.2	43.8	a1-I2	6.2
I5	TL= -73.120+55.262x	CTPA 3827	20.6	11.2	I5-I7	10.0
I6	TL= -117.456+96.971x	CTPA 3835	73.2	70.9	L2-L4	11.6
I7	TL= -64.732+138.350x	CTPA 4347	39.6	36.6	L1-L3	5.2
I8	TL= -137.583+231.411x	CTPA 4825	45.6	40.5	L1-L5	7.0
		CTPA 4850	31.8	25.9	I3-I6	13.1
		CTPA 4856	62.2	63.2	a2-I1	10.2
		CTPA 4857	35.0	24.5	L5-L7	7.2
		CTPA 4858	52.4	45.4	L1-L3	6.4
		CTPA 4934	23.2	19.2	L6-L9	4.8
		CTPA 6671	74.7	72.3	A1-A2	8.6

Megalodon from Gatun were mostly juveniles

We inferred the life stage of every *C. megalodon*, by extrapolating it from the relationship between body size and life stage in *C. carcharias* following Gottfried et al. (1996). This suggest that the *C. megalodon* from the Gatun Fm. were mostly neonates and juveniles; however, it also appears some adults were present.



During the Late Miocene the Gatun Fm. was a productive, warm, shallow-water marine environment that served as a nursery area for *C. megalodon*. Teeth from the Gatun Fm. are relatively small. However, tooth sizes from Gatun are also comparable to other time periods. The individuals that occurred in this ecosystem were mostly neonates and juveniles. Sharks can spend their first days, weeks or years in shallow waters to avoid predators. We propose that during the late Miocene *C. megalodon* spent their juvenile stages in this area that provided them protection.

We would like to thank G. Hubbell, C. Jaramillo, A. Rincon, The Panama Canal Project Field Team in STRI, F. Rodriguez, G. Morgan, The Smithsonian Institution, D. Bohanska, R. Purdy, A. Odea, and J. MacLaughlin. This project has been funded by FLNMH, NSF and Sigma Xi

