**Title**

# Developing New Management Techniques for Sharks in the Drift Gillnet Fishery of the Southern California Bight



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## Background and objectives:

The Southern California Bight (SCB) is a contiguous geographical region that extends from Point Conception, California to northern Baja California and west into the California Current. This region's productive ecosystem supports various recreational and commercial fisheries, some of which target pelagic sharks. For example, the common thresher shark (*Alopias vulpinus*) comprises the largest commercial shark fishery in California waters (the California drift gillnet fishery, or CA-DGF). Mako sharks (*Isurus oxyrinchus*) are also taken in large numbers.

The biology and status of pelagic sharks within the SCB have implications for California's marine resource sustainability. In addition, the SCB is known to be an important nursery area for these and other pelagic shark species. It is thus important to learn what defines mako and thresher shark essential habitat (i.e., the specific areas important for the growth and survival of these species). The objectives for this grant were to learn more about the fine-scale movement patterns and depth distributions of SCB mako and threshers in order to understand ways to reduce their potential vulnerability to the CA-DGF. We accomplished this goal using acoustic telemetry (juvenile makos and threshers) and archival tagging (threshers) technology. This work supported three Scripps Institution of Oceanography (SIO) graduate students as Sea Grant trainees (C. Sepulveda, N. Wegner, D. Cartamil), and provided material for three SIO doctoral thesis chapters (one for trainee Sepulveda, two for trainee Cartamil).

### *Common thresher shark acoustic tracking:*

The objective of this study was to utilize acoustic tracking technology to describe the fine-scale movement patterns and habitat preferences of the common thresher shark in the SCB. Direct observation of shark movement patterns is often impossible due to their offshore, cryptic habitat. However, this problem can be overcome through the use of acoustic telemetry. This involves tagging a shark with an acoustic transmitter which emits an ultrasonic pulse that is detected through the use of a hydrophone mounted on a tracking vessel. Encoded within the ultrasonic pulse are depth and temperature data that are decoded and stored using an onboard receiver unit. A bathythermograph unit is deployed at 2-h intervals during tracks in order to characterize the thermal structure of the water column.

An important goal was to relate the movement patterns of threshers to the timing and placement of drift gillnet gear. This study addressed the question: Can knowledge of thresher shark nocturnal vertical distribution be used to propose alternative methods of drift gillnet deployment in order to reduce catch rates of common threshers in the CA-DGF? We focused our efforts on subadult (i.e., 101 cm < FL < 166 cm) and adult thresher sharks (FL > 166 cm), which are the predominant size classes captured in the CA-DGF.

Eight subadult and adult thresher sharks (FL: 122 to 203 cm) were tracked between April and July, 2005. Our results indicate that:

- Threshers preferentially utilized areas offshore of the continental shelf (Fig. 1).
- All sharks displayed highly directed movements, although there was no consistent direction of travel among the tracked sharks.
- Mean rate of movement (ROM, ± SD) was 2.15 ± 0.46 km $h^{-1}$. ROM showed a strong diurnal pattern, peaking at dawn and decreasing until sunset, while nocturnal ROM exhibited little variability.
- Diurnal vertical movements of thresher sharks were characterized by either prolonged vertical excursions below the thermocline, or a preference for the upper thermocline. Nocturnally, all sharks remained within the mixed layer with little variability in depth (Fig. 2). These results suggest that thresher sharks are primarily diurnal predators.

***Common thresher shark archival tagging:***

While acoustic tracking studies deliver high-resolution, real-time movement pattern data, the duration of the track is limited by the endurance of the tracking crew, weather conditions, fuel supplies, and other logistical considerations. Additional studies are necessary to provide insight into patterns of behavior that can only be observed over longer time scales. To this end, electronic data-logging archival tags were used to examine the movement patterns of thresher sharks in the SCB.

Archival tagging is similar to acoustic tracking in that a depth and temperature-sensing tag is placed upon the shark's body. Rather than continuously transmitting data back to a trailing research vessel, however, archival tags log data at preprogrammed intervals. The shark must be re-captured by a fisherman and the tag returned (all tags carried reward information) in order to access the stored data. Although archival tags do not provide precise geopositional information (as can be obtained through acoustic tracking), they are able to collect and store large data sets - up to twelve weeks, at 2 min resolution. These data can be considered complimentary to the acoustic telemetry data, and also serve to 'ground truth' findings from the tracking study.

Results: Fifty-seven common threshers were captured and released with data-logging archival tags between March 2004 and July 2005. Three tags have thus far been returned by commercial and recreational fishers, yielding approximately 36 weeks of movement data. Preliminary analyses of archival data show:

- Threshers undergo different daytime depth 'modes' (i.e., deep or shallow) for weeks at a time, which may be related to feeding activity (Fig. 3).
- Peak diving periods appear to consistently occur at crepuscular periods.
- Dive descent rates (22.7 ± 12.9 m $min^{-1}$; $\overline{X} \pm$ SD) were significantly higher than ascent rates (12.0 ± 6.4 m $min^{-1}$).
- Dive descent time and duration appear to be correlated to the length of the post-dive surface interval (the amount of time spent at the surface between dives).

***Mako shark acoustic tracking:***

Acoustic telemetry was used to track the vertical and horizontal movement patterns of seven juvenile (80–145 cm fork length) shortfin mako sharks in the SCB. Makos were attracted to the tracking vessel using fish chum and subsequently fed a mackerel containing an acoustic transmitter. Feeding the transmitter to the shark, rather than attaching it externally, allowed not only the monitoring of stomach temperatures of the tracked sharks, but also ensured that there was no stress associated with the tagging procedure.

We tracked makos for up to 45.4 h. Our results show that:

- The mean horizontal swimming speed was 2.3 km $h^{-1}$.
- For the six tracks that lasted over 21 h, there was a positive correlation between body size and maximum depth attained by the shark.
- Mean stomach temperature was 3.8±1.5 °C above ambient, and body size was positively correlated with both maximum and average stomach temperature. Stomach content analyses of four makos captured at the end of tracking verified the occurrence of feeding events as indicated by changes in stomach temperature (Fig. 4).
- Makos used more of the water column during daylight hours. Collectively, the mako sharks spent 80% of the track record at 0–12 m, 15% at 12–24 m, and 5% at depths >24 m (Figure 5).

***Implications for the CA-DGF:***

Drift gillnets in the CA-DGF are set at night at depths of 11 to 50 m. Therefore, the nocturnal vertical distribution of thresher and juvenile mako sharks directly affects their susceptibility to this fishery. Threshers studied with acoustic tracking and archival tags spent approximately 40% of their nocturnal vertical distribution within the 'capture zone' of drift gillnets (depths > 11 m), while tracked juvenile makos spent substantially less time (20%) in this area of increased susceptibility to capture. This has important implications for the management of drift gillnet fisheries, as the minimum legally mandated depth at which driftnets can be set is an easily manipulated parameter that can be used to decrease (or potentially increase) the catch rates of various pelagic species impacted by the CA-DGF. However, more research is needed on the habitat preferences of other commercially important species such as swordfish, in order to determine how any proposed changes in set depth would impact catch rates of these target species.

**Publications:**

Sepulveda C.A., S. Kohin, C. Chan, R. Vetter, and J.B. Graham. 2004. Movement patterns, depth preferences, and stomach temperatures of free-swimming juvenile mako

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Cartamil, D., N. Wegner, S. Albers, C. Sepulveda, A. Baquero and J.B. Graham. Diel movement patterns and habitat preferences of subadult and adult common thresher shark, *Alopias vulpinus*, in the southern California Bight, determined through acoustic telemetry. In Preparation.

Cartamil, D., C. Sepulveda, N. Wegner, A. Baquero, S. Albers, and J.B. Graham. Archival tagging of common thresher shark, *Alopias vulpinus*. In Preparation.

**Other publications citing Sea Grant support to trainees Sepulveda, Cartamil and Wegner**

Wegner, N.C., Sepulveda, C.A., Graham, J.B. 2006. Gill specializations in high-performance pelagic teleosts, with reference to striped marlin (*Tetrapturus audax*) and wahoo (*Acanthocybium solandri*). Bulletin of Marine Science. 79: 747-760.

Sepulveda, C.A., Wegner, N.C., Bernal, D., Graham, J.B. 2005. The red muscle morphology of the thresher sharks (family Alopiidae). Journal of Experimental Biology. 208: 4255-4261.

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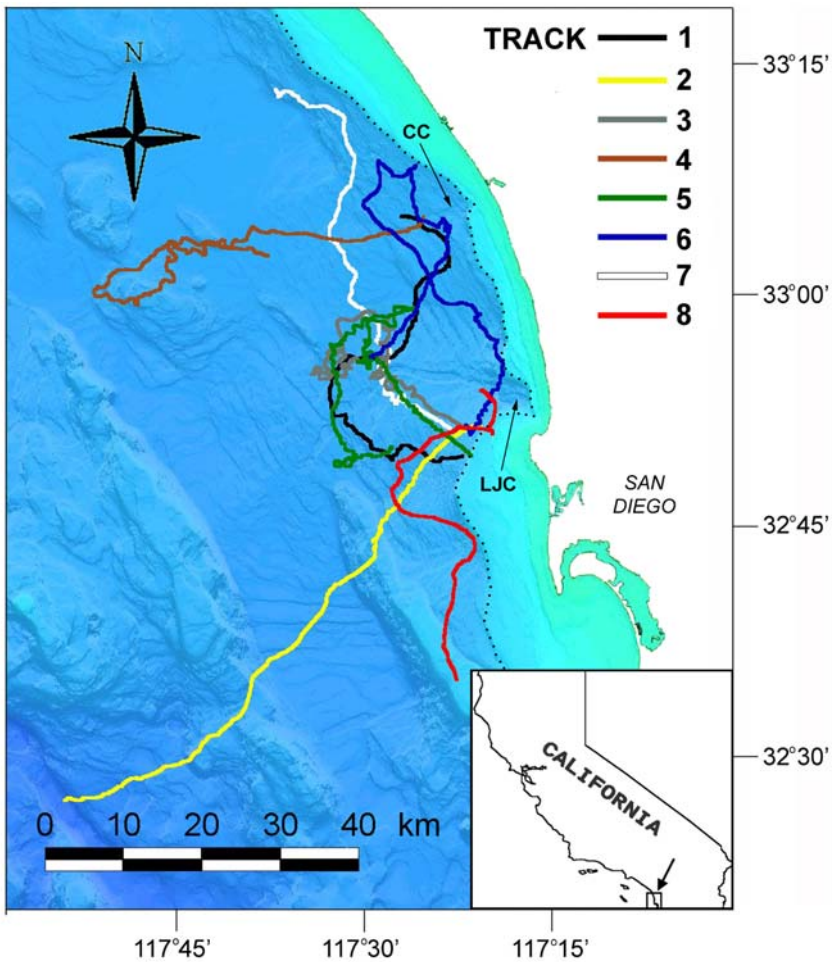


Figure 1. Movements of 8 common thresher sharks tracked by acoustic telemetry off San Diego County, California. Inset shows the general tracking area in relation to California. Darker blue shading indicates deeper water (max depth: ca. 1800 m), dotted line delineates the offshore edge of the continental shelf, colored light blue. LJC = La Jolla Canyon, CC = Carlsbad Canyon.

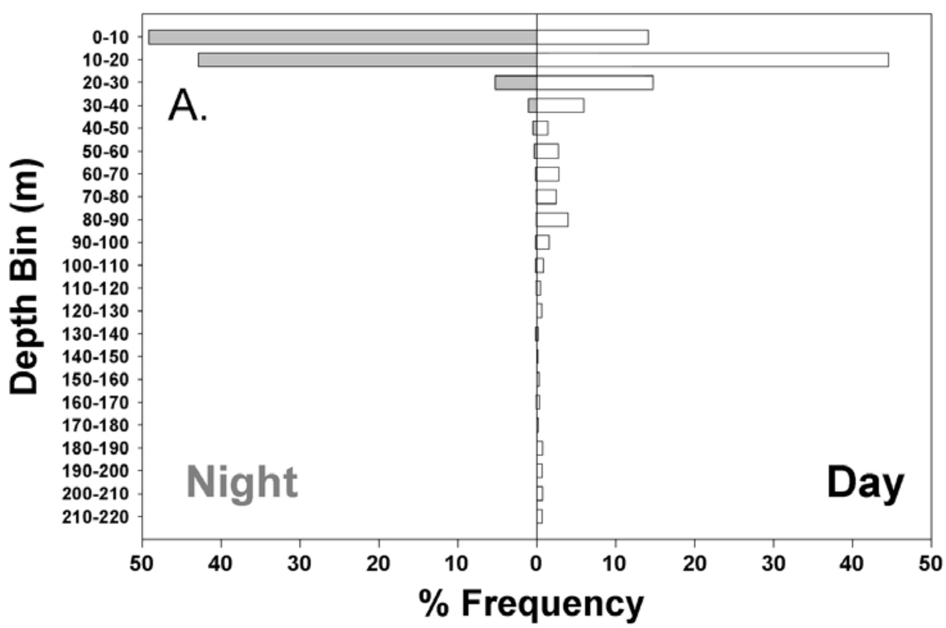


Figure 2. Pooled depth distributions (% frequency) for all acoustically tracked common thresher sharks in 10 m bins, over night (shaded bars) and day (unshaded bars) periods.

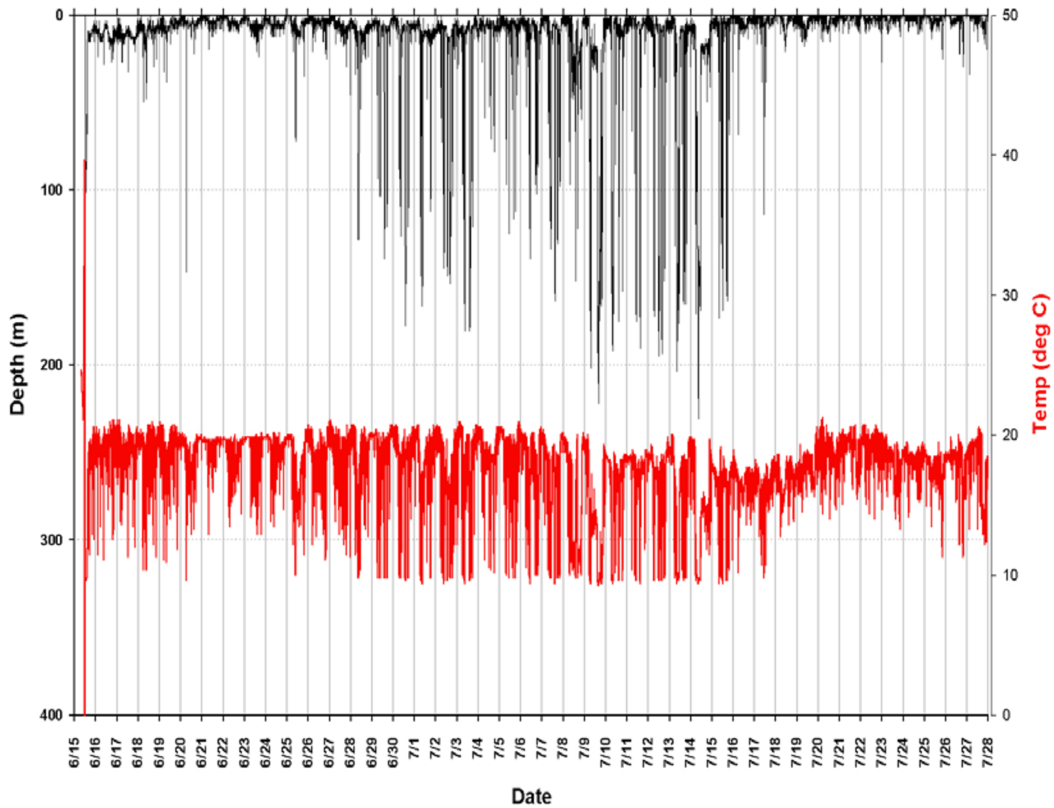


Figure 3. Profile of vertical movements and corresponding temperature fluctuations for thresher shark 8322, downloaded from an archival tag that had been attached to the animal over 500 days.

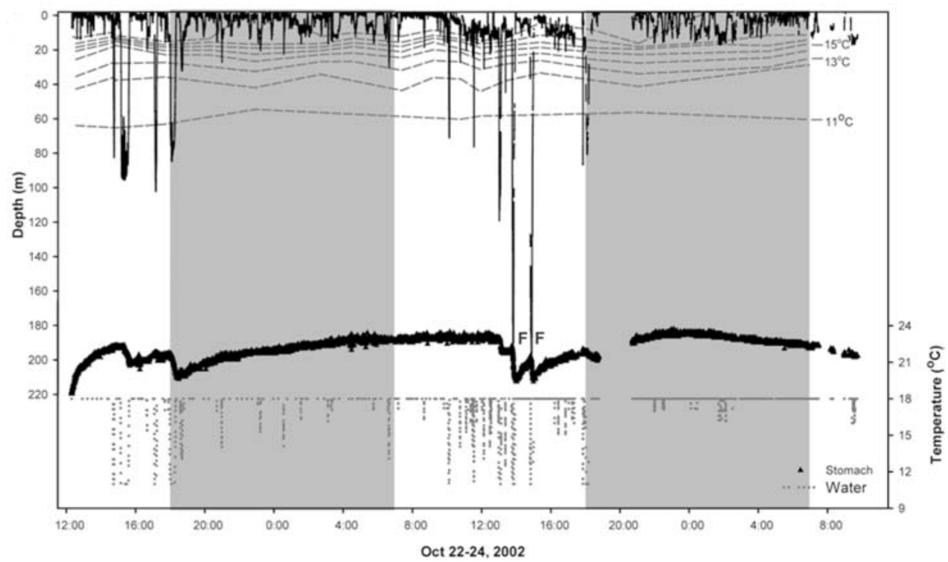


Fig. 4. Vertical movements and stomach temperatures of a juvenile mako shark tracked in the Southern California Bight. Top to bottom: swimming depth (solid line), ambient isotherms (dashed lines), stomach temperature (triangles) and corresponding water temperature (dotted lines) plotted over time. Shaded areas indicate hours between sunset and sunrise. Suspected feeding events (F).

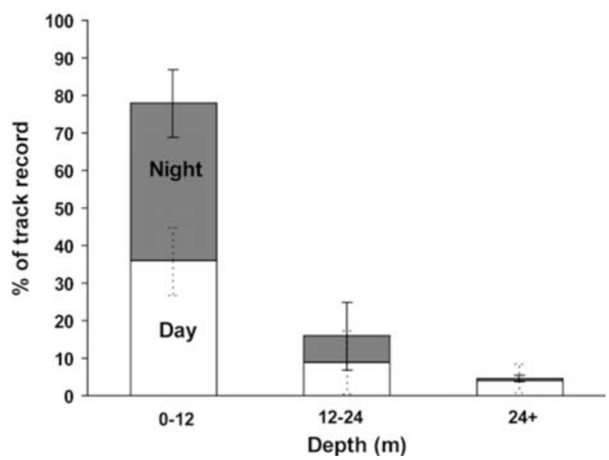


Fig 5. Combined depth distribution data (presented as percentage of track record) for six makos. Day (white) and night (shaded) hours indicated for three depth categories: surface to 12 m, 12-24 m, and > 24 m. (from Sepulveda *et al.*, 2004).