Movements of White Marlin, *Kajikia albida*, Tagged off the Yucatan Peninsula

Los Movimientos de la Marlin Blanca, *Kajikia albida*, Marcados en la Península de Yucatán

Mouvements de Makaire Blanc, *Kajikia albida*, Marqués au de la Péninsule du Yucatan

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EXTENDED ABSTRACT

The White Marlin, *Kajikia albida*, is a highly-mobile predatory fish inhabiting the warm waters of the Atlantic Ocean. Despite being of limited commercial importance, White Marlin are caught in multiple fisheries (primarily as bycatch) and the population has decreased dramatically since 1990; as a result of the loss in biomass, the stock is currently considered overfished (ICCAT 2012). Conservation and management plans will benefit from knowledge of White Marlin movements and habitat use, however, limited information on these topics exists and is primarily from individuals tagged on the northern limits of the White Marlin range (e.g., Hoolihan et al. 2015). The goal of this study was to examine the movements and vertical habitat use of White Marlin within the Gulf of Mexico.

Twenty-one White Marlin were captured via rod and reel off the eastern Yucatán Peninsula, Mexico between May 2014 and June 2016 and tagged with pop-up archival satellite transmitting tags (MiniPAT, Wildlife Computers). Tags recorded and archived depth, temperature, and light levels at 15-sec intervals and were programmed to detach from the marlin after 365 days. After detachment, the tags transmitted summaries of the archived data as histograms and temperature -depth profiles via satellite transmission. Tags from 2015 and 2016 that prematurely detached also transmitted a time-series of depth data at 5-min intervals.

Daily geolocation estimates were calculated from archived light data and filtered to determine a most probable track for each marlin using a Kalman filter state-space model incorporating sea surface temperature and bathymetry filter with the 'TrackIt' and 'analyzepsat' packages (Lam et al. 2010, Galuardi 2012) in R.

Because marlin were tagged at different times and occupied different locations during their tracks, environmental conditions experienced by the marlin varied between and within tracks. Cluster analysis was performed on the temperature-depth profiles to group temperature-depth profiles into thermal habitats (Vaudo et al. 2016). Prior to cluster analysis, temperature-depth profiles were interpolated to 1-m resolution. Divisive hierarchical cluster analysis was performed on the matrix of Euclidean distances using the 'cluster' package in R (Maechler et al. 2015).

After all the daily temperature-depth profiles had been classified into thermal habitats, attributes associated with marlin dive behaviors (i.e., maximum daily depth, number of dives, dive length, and dive depth) were examined using linear mixed models. Linear mixed models were fit in R using the 'lme4' package (Bates et al. 2014). Random intercept and random slope models were examined and all models included individual marlin as a random effect. Best fit models were selected using AIC. Pairwise comparisons (Tukey contrasts) for fixed effects were performed using the 'multcomp' package (Hothorn et al. 2008) in R.

Data were received from 18 of the 21 tags. Marlin tracks ranged from 11 to 329 days (mean: 73 days), yielding data across a total of 1,307 days. Marlin traveled approximate distances ranging from 891 to 10,570 km (mean: 3978 km). Ten individuals remained in the Gulf of Mexico and northwestern Caribbean Sea, while eight individuals entered the Atlantic Ocean in the late spring or summer via the Florida Strait and followed the Gulf Stream as far north as 42.3° N. In the warmest water columns, marlin spent 18% of the time at depths > 100 m compared to < 1% in the coldest water columns. Clear differences in day and night depth distributions were observed in all thermal habitats, with more time spent near the surface during the night. Mean daily maximum dive depth (range: 83.2 - 151.7 m; overall maximum depth: 456 m). Dives below 50 m were, in general, more frequent during the day (6.9 - 13.4 dives per 12 hour) than at night (1.3 - 7.1 dives per 12 hour), although the disparity between the number of day and night dives decreased as water warmed. Night dives were also more common in warmer waters. Mean dive duration varied considerably across habitats during the day (range: 3.7 - 54.9 min) and was longest in the warmest habitat. Mean night dive durations were fairly consistent across habitats (range: 10.9 - 20.2 min). Mean dive depth (56.3 - 97.4 m) increased as water columns warmed, but did not differ between day and night. Overall, White Marlin experienced temperatures between 10.0 and 33.6° C, and regardless of thermal habitat, White Marlin spent the majority of their time in waters > 24° C.

The results of this study demonstrate the importance of temperature in driving the behavior of pelagic fish. Thermal structure of the water column contributed greatly to differences in the dive behaviors of White Marlin both between and within individuals. Even within waters that are traditionally thought to be environmentally stable (e.g., subtropical and tropical waters), considerable thermal variability exists within the water column that could alter the vertical distribution of large pelagic predators, such as White Marlin.

KEYWORDS: Billfish, depth distribution, dive behavior, PSAT, satellite telemetry

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