Comments

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Tiger sharks eat songbirds: reply

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In response to our recent paper (Drymon et al. 2019), Yosef (2019) questions the mechanism proposed to explain interactions between tiger sharks (*Galeocerdo cuvier*) and migratory songbirds, while offering an alternative mechanism based on a single observation. We appreciate the comments from Yosef and the opportunity to respond.

Yosef (2019) questions two aspects of the mechanism we suggested. First, he states that "*the frequency and scale of inclement weather in fall is not consistent or regular between years.*" To this first point, we disagree. For small migratory birds, inclement weather events include cold fronts, rain, mist, or adverse winds (Newton 2007), which are sufficiently common in the northern Gulf of Mexico during the fall. Moreover, we found that tiger shark/bird interactions were common from year to year, occurring in every year (nine total) we examined tiger shark stomach contents. We also found that the interaction was not strictly limited to a few individuals; nearly 40% of the tiger sharks we examined had avian remains in their stomachs.

Second, Yosef (2019) states that "*although a relatively large portion of the avian migrants do not complete their migration, it usually does not occur immediately after leaving landfall.*" To this second point, we disagree. Although it was initially surprising that these interactions were more common in the fall compared to spring (and thus taking place closer to the migratory departure location rather than the migratory destination), we are confident that the mechanism we have proposed (adverse weather in the fall) is sufficient rationale. During fall migration, young-of-the-year birds are traveling south on their first migration and are likely to overshoot into the Gulf of Mexico at night, before correcting and trying to return to land. If they do not realize they have overshot soon enough, or they experience adverse weather when they do turn around, they would be highly likely to either exhaust themselves, fall into the water and die of exposure, or exhaust themselves and die before reaching the water.

Yosef (2019) goes on to suggest behavioral thermoregulation may explain the interaction between tiger sharks and terrestrial birds, and suggests we try and "*correlate (our) data with species abundance but also with inclement weather, especially heat waves.*" The account of behavioral thermoregulation in European Bee-eaters (*Merops apiaster*, Yosef 2010) is interesting and may provide an explanation for the occurrence of a Bee-eater from a single tiger shark stomach (Yosef et al. 2002); however, behavioral thermoregulation is highly unlikely to explain the interactions reported in Drymon et al. (2019), for the following reasons.

First, there are dramatic differences in climate between the two study areas in question: the northern Gulf of Mexico (Drymon et al. 2019) and the northern Red Sea (Eilat, Israel; Yosef et al. 2002). For example, the average fall temperatures in the northern Gulf of Mexico are less than 31°C, compared to 43°C and greater in the northern Red Sea. Perhaps more importantly, the climate in the northern Gulf of Mexico is extremely humid, compared to the khamsins described by Yosef (2010), which are hot, dry winds. Therefore, the evaporative cooling evoked in Yosef (2010) would be impossible in the humid climate of the northern Gulf of Mexico.

Second, we found no evidence in the literature of behavioral thermoregulation for any of the migratory species in our area; we interpret this to mean the behavior described in Yosef (2010) may be unique to European Bee-eaters in Eilat, where small, shallow (i.e., 20 cm), predator-free salt ponds are available, unlike the northern Gulf of Mexico.

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The feeding habits of tiger sharks are truly extraordinary. Over half a century ago, a single yellow-billed cuckoo (*Coccyzus americanus*) was found in the stomach of a tiger shark (Saunders and Clark 1962). The authors suggested the bird was a fallen migrant, a mechanism echoed by Dodrill and Gilmore (1977). Since then, inclement weather (Carlson et al. 2002, Gallagher et al. 2011) and behavioral thermoregulation (Yosef 2010) has also been advanced to explain the presence of terrestrial birds in the stomachs of tiger sharks. Intuitively, the ways in which tiger sharks encounter terrestrial birds are likely context dependent. However, based on the preponderance of tiger shark stomachs containing bird remains (41 of 105 examined) collected over a 9-yr period, we maintain that the most parsimonious explanation for the prevalence of migratory birds in the diets of tiger sharks in the northern Gulf of Mexico is the mechanism proposed in Drymon et al. (2019).

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