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BAYESIAN HAZARD REGRESSION MODELLING OF FACTORS AFFECTING POST-RELEASE MORTALITY OF LOGGERHEADS CAUGHT IN PELAGIC LONGLINE FISHERIES

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Bayesian hazard regression modelling of factors affecting post-release mortality of loggerheads caught in pelagic longline fisheries

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The threatened loggerhead sea turtle is exposed to major anthropogenic hazards such as pelagic fisheries, coastal net fisheries, and alteration of nesting beaches. Many turtles caught in pelagic longline fisheries are alive when released from the gear (Witzell 1999) but might die soon after because of hook-induced injuries. There are few robust estimates of post-release mortality for sea turtles despite being essential for risk assessment and hazard mitigation (Chaloupka et al. 2004).

We used pop-up satellite archival tag (PSAT) telemetry deployed by 2 different observer programs to estimate post-release mortality of 29 loggerheads caught in US-based North Pacific pelagic longline fisheries between 2002 and 2006. The Pacific longline fisheries out of California and Hawaii were both previously found to cause jeopardy to the continued existence to leatherback and loggerhead sea turtle populations under the U.S. Endangered Species Act (ESA) and the fisheries were temporarily closed. In an effort to provide reliable estimates of survivorship of sea turtles after longline-fisheries encounters, we trained at-sea fisheries observers in the attachment of PSATs on the carapace of hard-shelled sea turtles that were subsequently released from fishing gear. PSAT technology is considered more useful for estimating sea turtle post-release mortality than the more commonly used platform terminal transmitter (PTT) telemetry (Swimmer et al., 2006). PSATs provide auxillary information that is needed to distinguish between transmitter equipment failures and a mortality event, which cannot be done reliably using PTTs (Chaloupka et al. 2004,). Originally designed to track the

movements and survival of large pelagic fishes, PSATs record dive depths and ambient water temperatures and provide a daily estimate of geolocation (Arnold and Dewar 2001, Graves et al. 2002).

We programmed all the PSATs to release and transmit data after a maximum of 243 days at liberty. Tracking a sea turtle for longer will confound natural mortality with post-release mortality (Chaloupka et al. 2004). All PSATs except one reported before the scheduled release date. If a loggerhead died at sea then the PSAT was programmed to release when the sinking turtle reached 1200 m, which is a depth well beyond the recorded swimming limits of loggerheads. The PSATs were also programmed to release and transmit data if no significant pressure change was recorded over four consecutive days, which reflects either a dead loggerhead floating at the surface or one that had sunk to the seabed at a depth < 1200m. The application of PSAT technology for tracking sea turtles has been described in detail in Swimmer et al. (2006). A PSAT that reports prior to its scheduled report date is considered indicative of an apparent mortality, although other explanations also exist, which we examine in this study.

We modeled time-to-report for each PSAT using an extended Cox-type semiparametric hazard rate model to identify informative covariates affecting apparent post-release mortality. Covariates included specific observer program, date and geo-location of PSAT deployment or retrieval, turtle size, hooking severity (shallow, deep) and whether the hook was removed before release. Nonlinear and time-varying covariate effects were modelled using Bayesian penalized splines and varying-coefficient techniques. Spatial effects were treated as correlated random effects estimated using a 2-dimensional P-spline surface smoother. Individual heterogeneity associated with each PSAT (or turtle) was treated as an unstructured random effect. The time-to-report data were also subject to censoring mechanisms including right censoring (because PSAT still functioning at release data), left censoring (failed before first possible satellite upload) and left truncation (staggered entry design) that were accounted for in this Bayesian modelling framework. Our analysis found: 1) a monotone increasing baseline hazard (PSAT “aging” effect) reflecting high and increasing probability of apparent post-release mortality; (2) a

declining hazard rate over the 5-year study period (perhaps reflecting improving PSAT technology or turtle handling procedures): and (3) that the hazard rate was not a function of hooking severity but was spatially-dependent reflecting a westward movement of the longer surviving loggerheads. We reviewed time-depth profiles recovered from the PSATs that reported prematurely (apparent mortality) to determine if those turtles actually died or if we could identify other factors that could contribute to the acquired depth data and concluded that only 2 turtles possibly died following release from the longline gear. This significant discrepancy between apparent mortality (early reporting) and depth profiles indicative of death (sinking) reflects PSAT equipment and/or attachment failures.

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