Supplemental Research

Text S1: Watercraft-related wound characterization

Watercraft-related trauma is a common cause of death and injury in the Florida manatee (*Trichechus manatus latirostris*) (Beck et al. 1982, Wright et al. 1995, O'Shea et al. 2001, Lightsey et al. 2006, Rommel et al. 2007). Manatees injured and scarred by collisions with watercraft can be identified from recognizable, distinct, and persistent scars and these marks are used for long-term photo-identification studies (Langtimm et al 2004, FWC 2007). Lightsey et al. (2006) described how watercraft trauma could lead to mortality, and Rommel et al. (2007) reported that wound patterns (e.g. multiple individual wounds from one strike event) generated by collisions with watercraft were diagnostic. Rommel et al. (2007) examined manatee carcasses for healing and fresh wounds for five years (2000–2004) and determined that 35% of the wounds had been caused by propellers only, 27% were from nonpropeller components only, and 22% had been caused by a combination of propeller and nonpropeller components. In the remaining 16%, propeller and nonpropeller damage could not be differentiated. For this evaluation, we assessed fresh external wound patterns associated with acute watercraft-related mortalities to refine the categorization of watercraft-related wound pattern types, which aids in characterizing a more complete range of scar pattern types once fresh sublethal wounds have healed.

Free-ranging manatees have been observed to survive both blunt and sharp trauma to all aspects of the body, except for wounds that penetrate the body cavity. We expect the patterns of both lethal and sublethal injuries to have similarities because they are caused by similar structures. Therefore, the percentage of fresh lethal wound pattern types should be consistent with and reasonably comparable to well-healed sublethal scar pattern types. We defined six categories of external watercraft-related wound patterns based on examination of 384 necropsy records (2000–2009) of manatees that likely died within 48 hours of a vessel strike (i.e., acute mortality) (FWC unpublished data, Figure S1). The six categories were then applied in the assessment of sublethal watercraft scar patterns using necropsy records (n = 3,786) from 2007–2016.

Acute watercraft-related wound types (Figure S1)

Type A wounds were defined as a series of repeating parallel wounds consistent with propeller trauma. A Type B wound was defined as a single linear wound consistent with a hit by a skeg, rudder, hull, or single propeller. A Type C wound was defined as consistent with a combination of a series of propeller wounds roughly perpendicular to a wound from a hull, skeg, rudder, or other projection on the hull or propulsion system. A Type D wound refers to two fresh wounds received simultaneously from a single collision (i.e., one wound associated with a propeller and an associated perpendicular wound from a hull, skeg, or rudder) or received from two separate strike events happening within a short time. In the cases of acute watercraft-related mortality, a Type D wound was conservatively treated as a single watercraft collision in the necropsy report. A Type E wound was defined as having multiple patterns consistent with multiengine vessels or multiple strikes at similar angles within a short time. Conservatively, in assessing cases of acute watercraft-related mortality, Type E wounds were treated as one-vessel interactions. Type F wounds were a more complex and variable array of patterns and were not common. Type F wounds can be nonlinear and irregular or a collection of poorly organized linear wounds. In addition, some carcasses were too badly decomposed to evaluate, and some carcasses that were in good condition had internal watercraft trauma yet no grossly visible external wounds.

Excluding decomposed carcasses and those that had no grossly visible external wounds (n = 33), we found that of the remaining 351 carcasses, 37% of wounds were type A, 29% were type B, 23% were type C, and the remainder were a collection of other wound types (types D, 2%; type E, 4%; type F, 5%). The percentages match closely what Rommel et al. (2007) described. There were 99 acute watercraft cases evaluated by both Rommel et al. (2007) and this evaluation.

Acute watercraft-related wounds in regions of the body (Figure S2)

Rommel et al. (2007) reported that watercraft wounds could be complex depending on the impact circumstances. For example, a vessel striking a manatee might change direction and speed, such as the front edge of the hull striking and turning the vessel before the propeller impacts. A manatee might also react by changing direction or flexing its body or fluke, and manatees can be hit from any angle and at any location on the body or fluke (Wright et al. 1995). A manatee's body posture at the time of the strike may also determine the appearance of a wound pattern. Because of these multiple factors, individual propeller wounds within a pattern can develop a nonparallel orientation to one another. We placed wound patterns into four categories after examining the body region and orientation of fresh lethal wounds of all types (n = 277) to determine how individual wounds within a pattern might change orientation to each other as the pattern transitions across different body regions (Figure S2). Region Type 1 includes wounds in a distinctive pattern on the main body (head, torso, or peduncle). Region Type 2 includes wounds in a distinctive pattern across the main body and fluke. Region Type 3 includes wounds in a distinctive pattern across the fluke only. Region Type 4 includes wounds in a distinctive pattern across the body but became an indistinct pattern on the fluke. Large transecting wounds that resulted in loss of the entire fluke were excluded from this evaluation, because they prevent us from evaluating the fluke for additional, pre-existing scar patterns. This evaluation determined that 86% of lethal wound patterns were of Region Type 1, 8% were of Region Type 2, 1% were of Region Type 3, and 5% were of Region Type 4.

Text S2. Comparison of acute wound pattern types and sublethal scar pattern types

Wound pattern Types A, B, and C accounted for the majority (89%) of lethal wounds, and only these three wound types were used to assess sublethal scars. We reduced the number of sublethal categories because individual scar relationships found in Types D–F could become obscured over time from wound healing or from accumulation of newer wound patterns atop or near the earlier wounds. Linear components were instead evaluated as Type A, B, or C. In comparing the relative proportions of Type A–C patterns between wound types and scar types, we found them to be generally consistent: Type A wounds (37%) versus Type A scars (42%), Type B wounds (29%) versus Type B scars (29%), Type C wounds (23%) versus Type C scars (29%), noting that the acute wound percentages were calculated with Type categories D–F included (11%). Of acute mortality cases, 3% of carcasses had no visible wounds and so were a source of undercounting of scar patterns in the sublethal scar assessment.

Watercraft-related scars in regions of the body

When comparing the proportions of Region Types 1–3 between acute wound mortality cases and sublethal scar cases, we found them to be generally consistent: Region Type 1 wounds (86%) versus Region Type 1 scars (79%); Region Type 2 wounds (8%) versus Region Type 2 scars (4%); Region Type 3 wounds (1%) versus Region Type 3 scars (17%), noting that wound type percentages were calculated including Region Type 4 wounds (5%) while scar type percentages were not. Region Type 2 patterns (8% wounds versus 4% scars) differed possibly because components of the patterns across the fluke could become obscured during wound healing or by the accumulation of new wounds. Linear components not clearly part of a larger pattern (i.e., the fluke portion of Type 4 patterns) could have been evaluated as Pattern Types A, B, or C instead but could also become obscured from wound healing or accumulation of additional patterns. In the cases that involved the fluke only (Region Type 3, 1% wounds versus 17% scars), the higher percentage of sublethal fluke-only scars could be explained if watercraft wounds only across the fluke are less likely to be lethal than wounds across the body (except for transecting wounds that sever the fluke).

Text S3: Non watercraft-related lesions and scars

We reviewed 3,786 necropsy records (2007–2016), including photographs, for the presence of fresh and healing skin lesions. Fresh and healing lesions were assumed not to be watercraft-related when they were found on the ventral aspect of the carcass because living manatees are normally oriented ventrum-down in the water, limiting exposure of that aspect of the body to watercraft impacts. Non watercraft-related lesions were also most often thin (a few millimeters wide), relatively short (often <10 cm long), or curved or irregularly shaped. Lesions of these types are most likely the result of rubbing on rocks, barnacles, oysters, docks, or any of a variety of debris items and were generally oriented along the length of the body and concentrated at the shoulder region. Most lesions were superficial and did not damage the dermis. A small percentage of lesions observed on carcasses had turned necrotic and penetrated deep into the dermis, which likely would have caused dermal scarring had the manatee survived. These lesions, however, did not resemble known watercraft wound types in that they were irregularly shaped, and multiple lesions were not evenly spaced and were often not parallel. Manatees can also acquire patches of dermal scar tissue from lesions resulting from severe cold stress (Bossart et al. 2002, Barlas et al. 2011). Such patches, however, are irregularly shaped and do not resemble known watercraft wound patterns (Figure S3).

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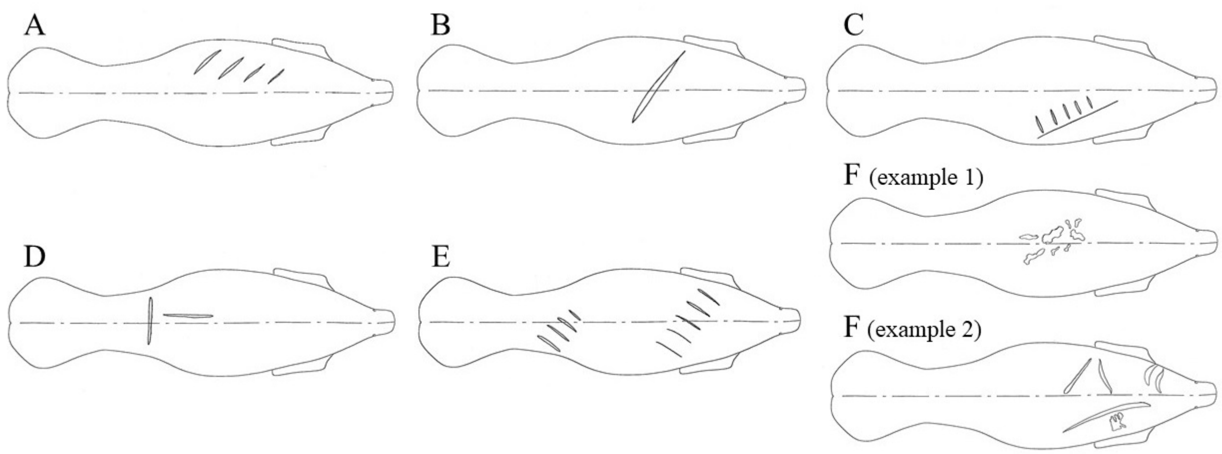

Fig. S1. Representative examples of watercraft-related wound types for each category. A) Parallel wounds: 33%, n = 129. B) Single linear wound: 27%, n = 103. C) Parallel wounds with one perpendicular wound: 21%, n = 80. D) Two perpendicular wounds: 1%, n = 6. E) Two wound patterns: 4%, n = 14. F) Irregular wounds: 5%, n = 19. Six percent of carcasses were too badly decomposed to evaluate, n = 22. Three percent of carcasses with watercraft-related mortality had no grossly visible wounds, n = 11

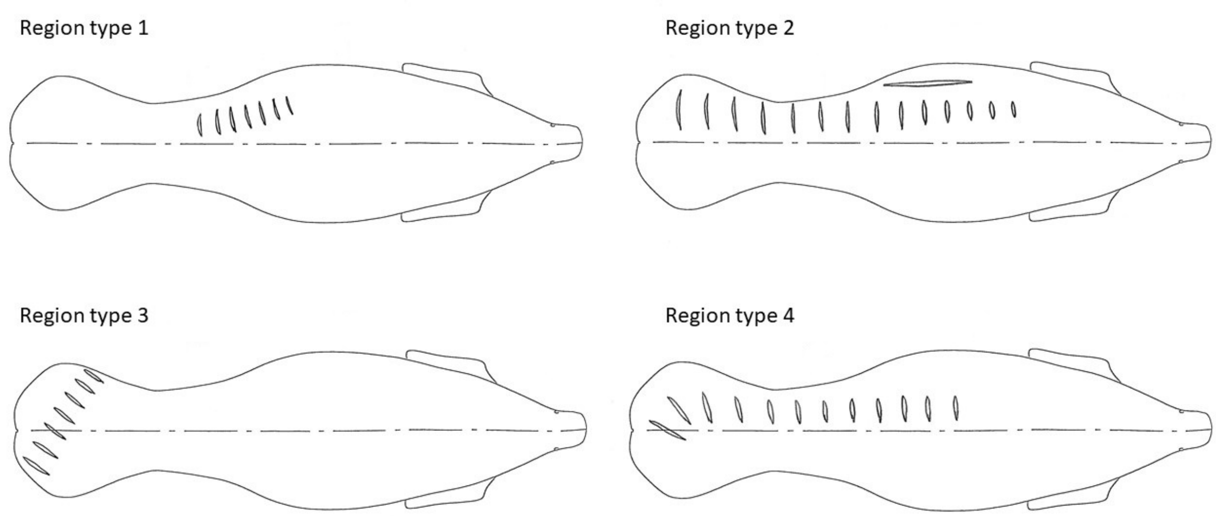

Fig. S2. Acute wound placement by body region type. 1) Pattern across main body only (head, torso, or peduncle): 86%, n = 239. 2) Distinctive pattern across main body and fluke: 8%, n = 23. 3) Distinctive pattern across fluke only: 1%, n = 2. 4) Distinctive pattern across main body but developed into irregular pattern on fluke: 5%, n = 13

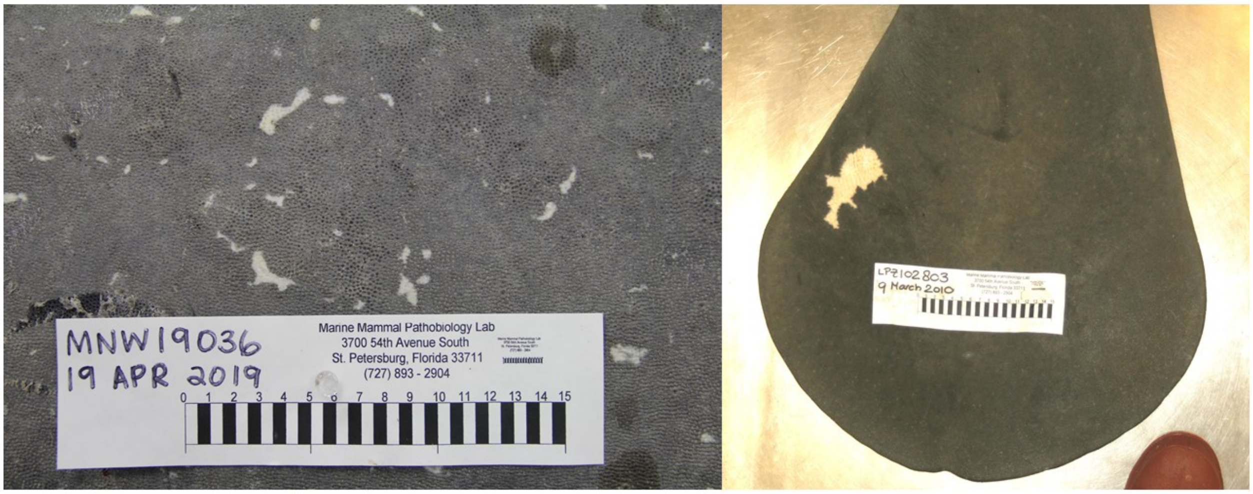

Fig. S3. Examples of non watercraft-related skin scarring in the Florida manatee

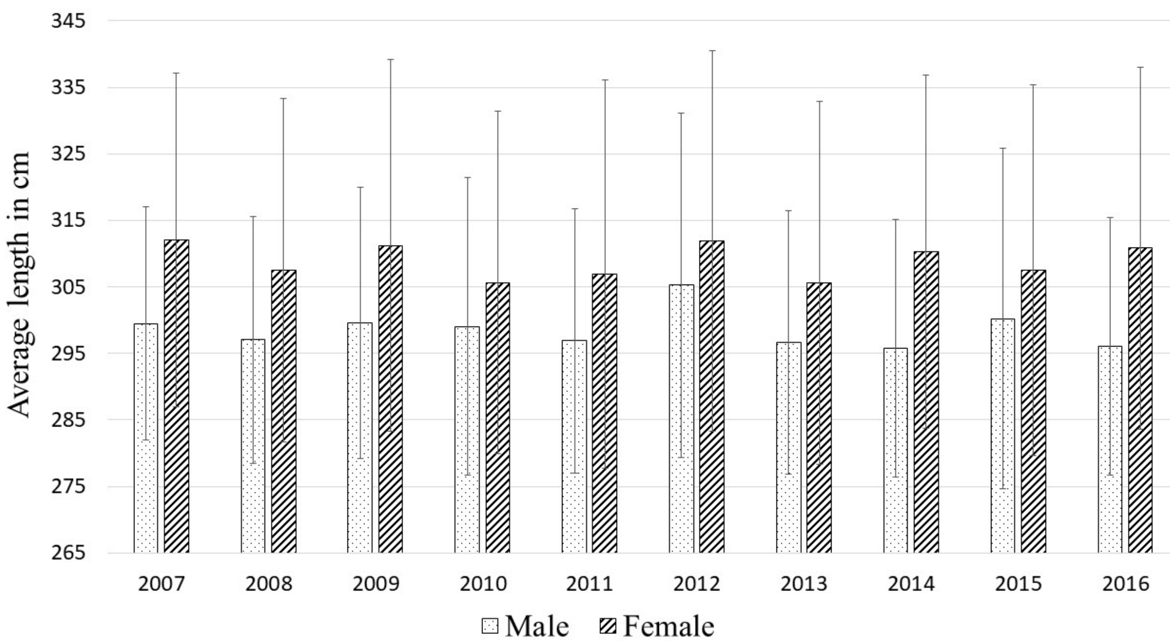

Fig. S4. Average length (± SD) of adult Florida manatee carcasses by sex and year, 2007–2016

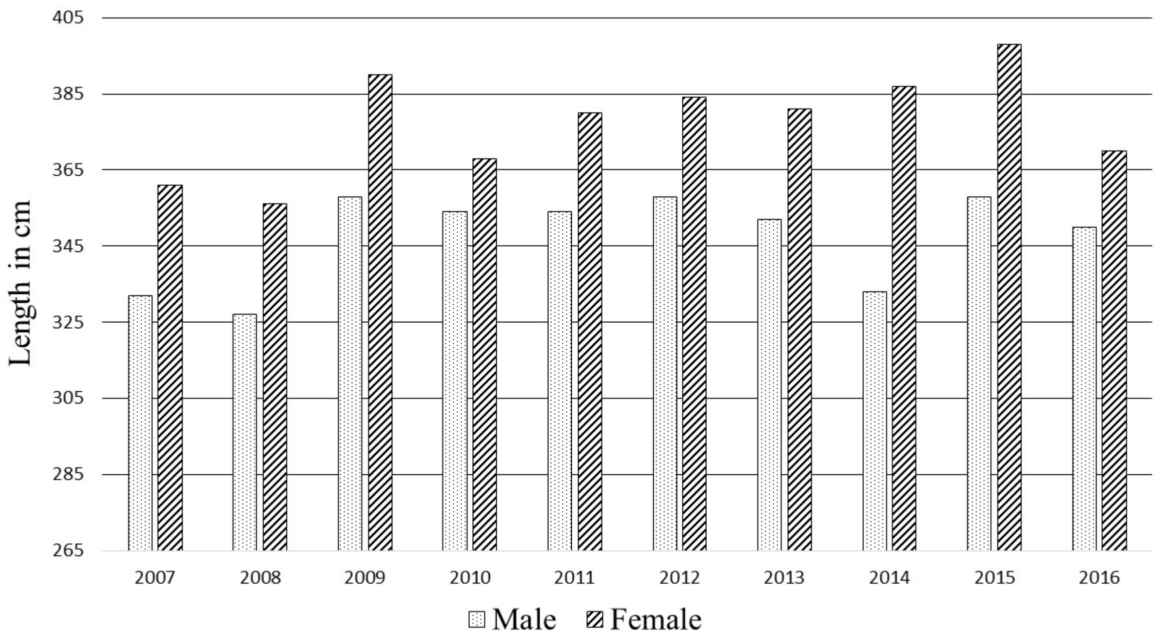

Fig. S5. Maximum length of adult Florida manatee carcasses by sex and year, 2007–2016