Sea Turtles and Marine Energy: Linking Shell Mechanics to Impact

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Material testing suggests sea turtle shells are highly compliant but tough. An understanding of shell mechanics is important for simulating turbine strikes for risk assessment.

Background

- Sea turtles use waters along the coast of Florida as feeding grounds, sheltering areas, and migratory routes.
- These waters likely overlap with marine current energy testing and deployment sites (i.e., the Florida current, inlets, and passes).
- Sea turtles do not avoid other in-water structures or moving objects; for example, they are often struck by marine vessels when at or near the surface.
- Blunt force trauma to the shell can result in serious injury or death.
- Field studies on blade collision with other marine animals (seal carcasses) report severe trauma from turbine collisions (Onoufriou et al., 2019).
- Since strike risk in sea turtles is unknown, it is important to understand how sea turtle shells respond to impact forces.

The study aim is to quantify the biomechanical properties of sea turtle shells of coastal life stages to understand how the shell responds to loads. These data are crucial for predicting strike risk from marine renewable energy technologies.

Methods: Shells & Compression Testing

Shells were collected from carcasses of green (*Chelonia mydas*), Kemp's ridley (*Lepidochelys kempii*) and loggerhead (*Caretta caretta*) turtles across a wide range of body sizes. 5-10 samples per shell were tested in compression (Fig. 1) and through pendulum impact tests (Fig. 3, 4). ANSYS was used to model the impact test on a boney sandwich structure.

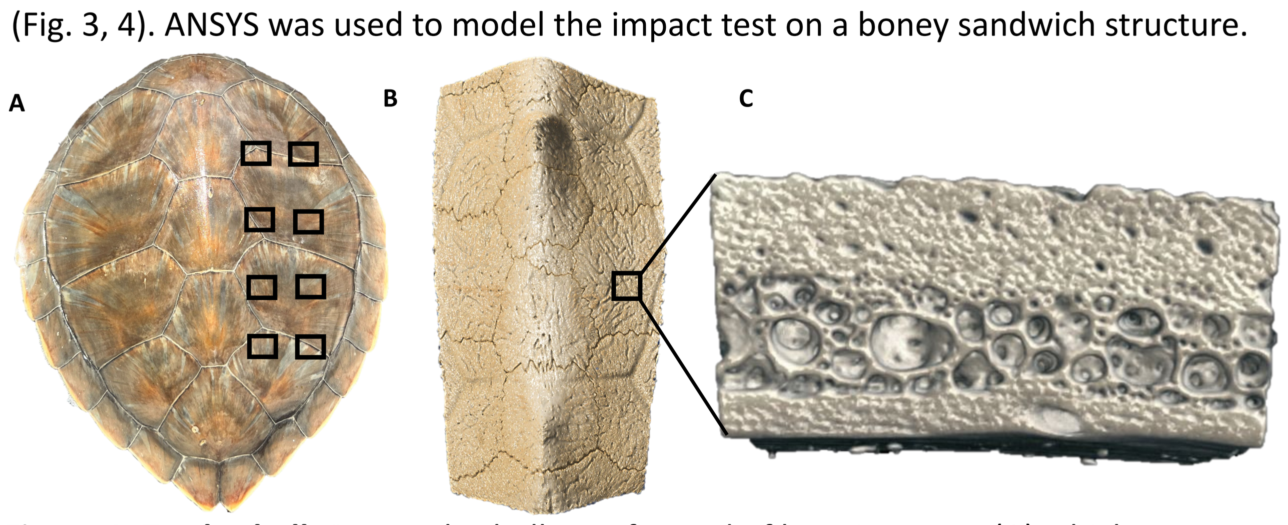

Figure 1. Turtle shell. Sea turtle shells are formed of keratin scutes (A) which cover underlying bone. Samples, black squares, are cut from the carapace (B) which is formed from a modified ribcage and vertebral column. The "ribs" are made of bone organized in a sandwich composite (C).

Methods: Impact Testing

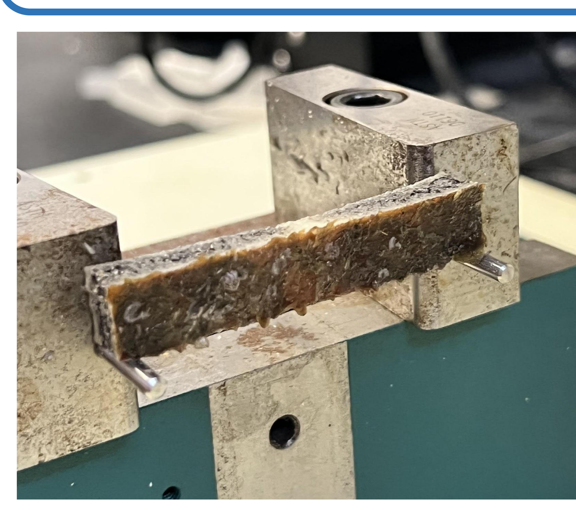

Figure 2. Turtle shell sample on the impact testing device. Samples include all bone layers and keratin; Potential energy is for all tests was 2.77 J while hammer speed was ~3.6 m/s.

Figure 3. Fractured shell sample after impact testing. Note that the keratin layer remains intact while the bone breaks upon impact. Bone fracture through all layers has been seen in 100% of samples tested to date

Compression Testing Results

Table 1. Compression testing of marine turtle shells (Lezcano et al., 2025). Each value is the average and standard deviation of all shells in a particular size class (juvenile or subadult/adult). N = number of samples per species and size class. Note that green turtles had the stiffest, strongest shells; loggerheads differed little in stiffness and strength with size compared to the other species and were the least stiff as adults. Kemp's ridley shells were intermediate.

Species	Life stage	Stiffness (MPa)	Yield Strength (MPa)
Green turtle	Juvenile	83.64 ± 35.62, N=12	9.64 ± 3.95, N=9
Chelonia mydas	Subadult/Adult	194.79 ± 42.80, N=5	13.8 ± 6.11, N=4
Kemp's ridley	Juvenile	28.30 ± 16.04, N=9	3.56 ± 1.66, N=9
Lepidochelys kempii	Subadult/Adult	89.13 ± 4.36, N=4	6.89 ± 3.09, N=3
Loggerhead	Juvenile	55.21 ± 7.59, N=5	3.91 ± 0.56, N=5
Caretta caretta	Subadult/Adult	58.04±14.65, N=5	3.40 ± 1.41, N=5

Impact Testing Results

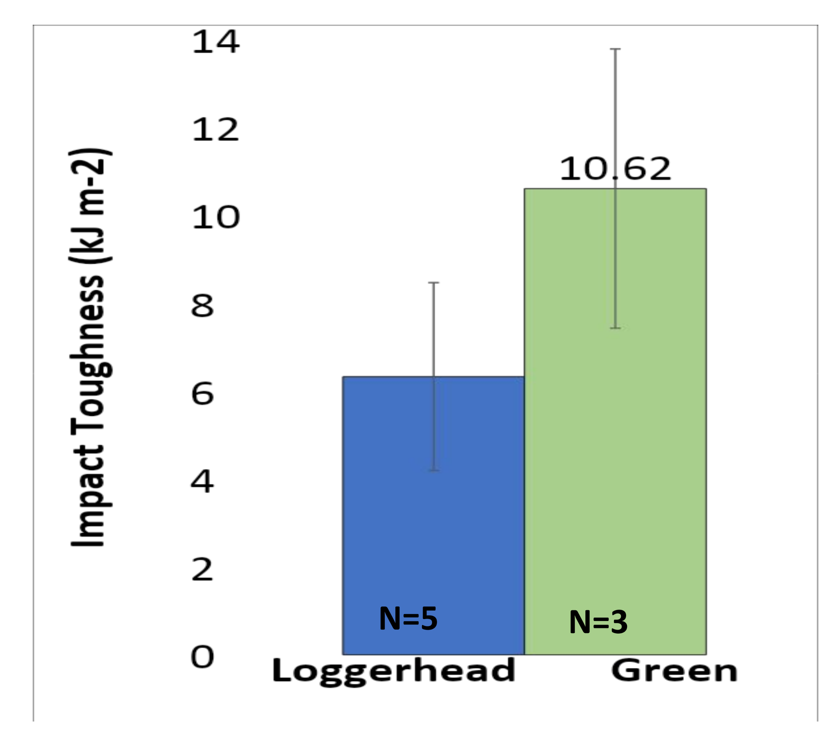

Figure 4. Impact testing of two marine turtle species' shells. Bars represents the means & whiskers are the standard error. N=sample size. Subadult and adult loggerhead and green turtles have been tested due to availability. Note that green turtles are tougher to impact than loggerheads.

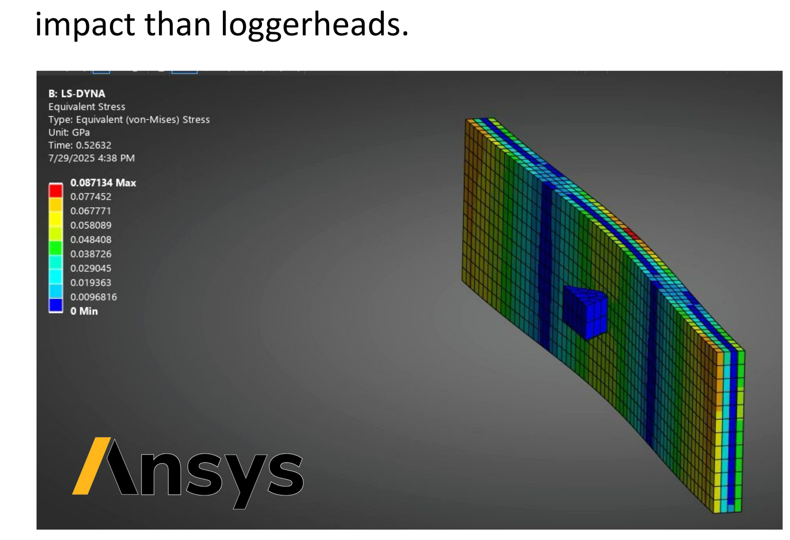

Figure 5. Ansys model of turtle shell impact test. Samples include all 3 bone layers of the composite plus the outer keratin scute. The blue triangle represents the pendulum striking the sample. Note the higher stress areas (warmer colors) opposite the pendulum and at the anchored ends.

An interdisciplinary approach to environmental risk assessment

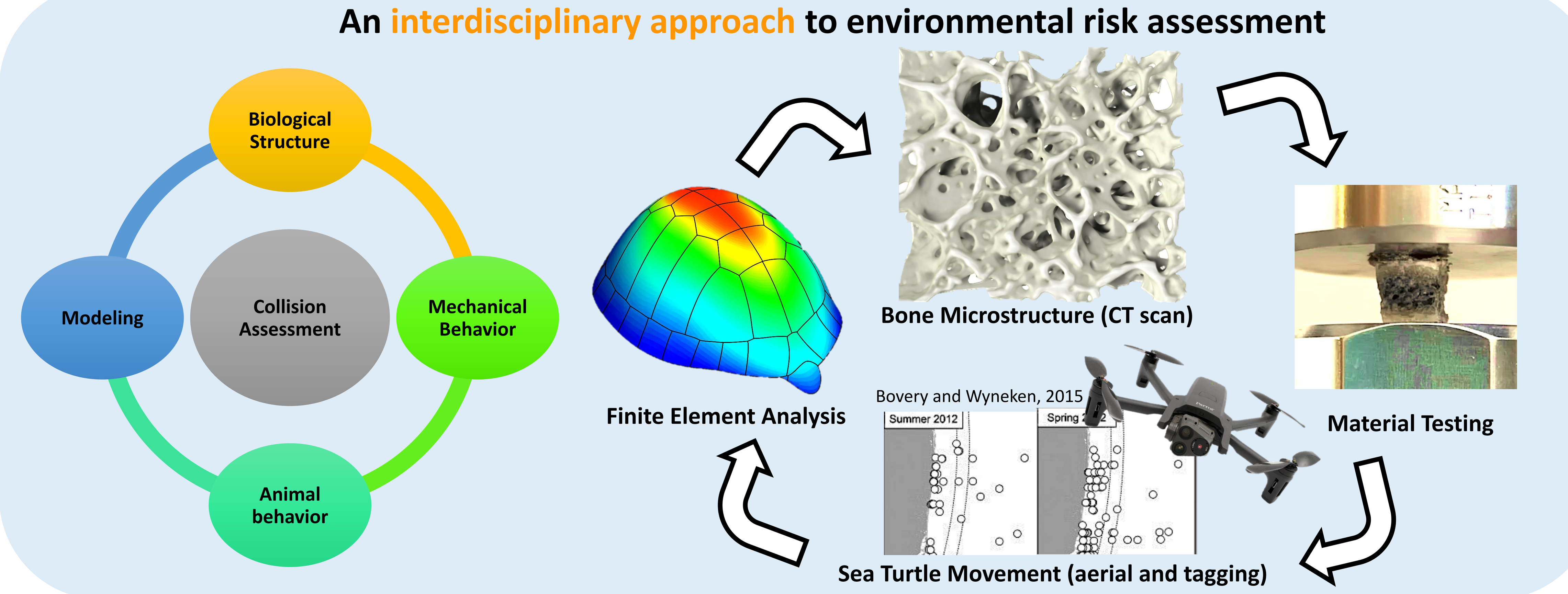

Figure 6. Proposed framework for an interdisciplinary and collaborative approach to environmental risk assessment (collision risk).

Conclusions

- Marine turtle shells are tough and compliant under compression and impact loads (Table 1; Fig. 2).
- Green turtles have the stiffest, strongest and toughest shells, but these values are considered low in relation to non-marine turtles.
- Initial data on impact testing suggests that blunt force impact, expected under turbine collisions, may lead to serious fracture of the carapace's sandwiched bone layers. The outer keratin acts as if it were an "adhesive tape", binding the broken bone (Fig. 3).
- Future testing with finite element modeling will be used to refine our understanding of the likely severity of potential collisions with equipment (Fig 6).
- To make substantial progress in environmental risk assessment, we are pursing an interdisciplinary approach that merges ocean engineering and biomechanics.

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