

Soft Robotics in Underwater Environments

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Introduction

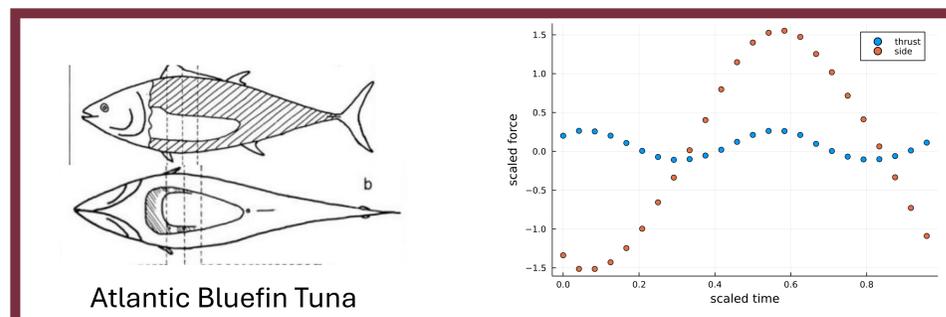
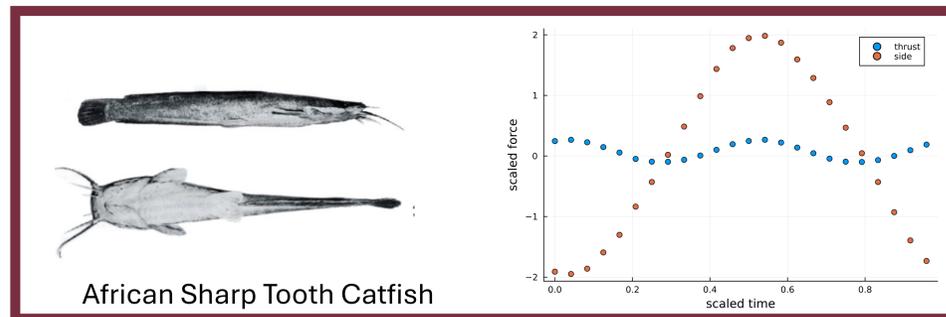
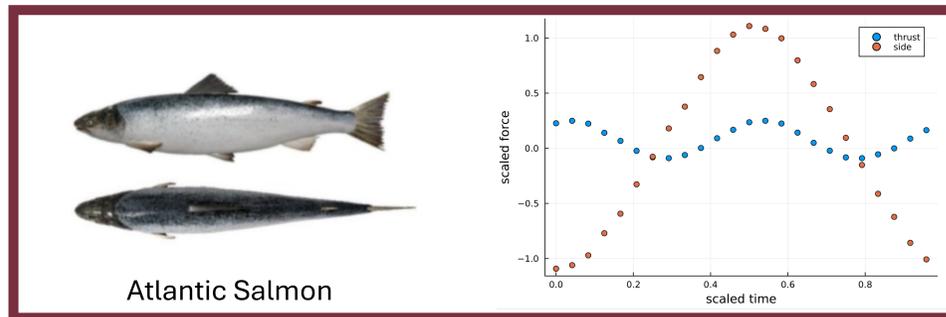
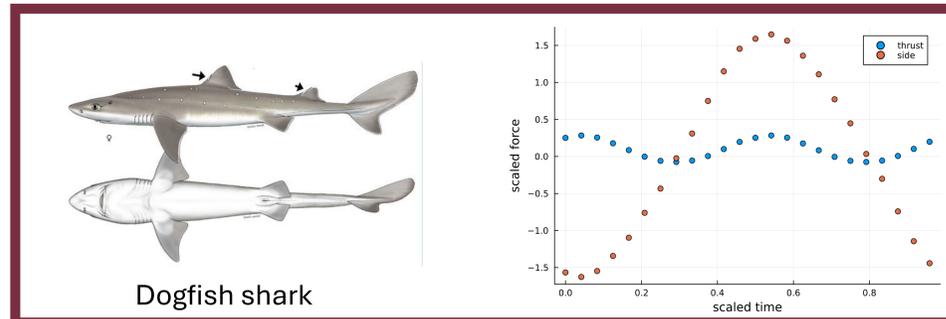
Soft robotics is revolutionizing underwater exploration by using flexible, adaptive materials to create efficient aquatic robots. Biomimetic designs mimic fish locomotion, with research showing that tuna shaped fish swim most efficiently and fast, while elongated fish move slower. Sinusoidal motion algorithms replicate these movements, and reinforcement learning enables real-time adaptation. However, challenges remain in optimizing locomotion for unpredictable conditions. Most studies focus on controlled environments, leaving gaps in understanding how different swimming strategies perform in varying aquatic settings. The integration of reinforcement learning with biomimetic designs also needs further exploration. This study develops soft robotic fish to test efficient swimming strategies in uncertain underwater conditions. By combining sinusoidal algorithms and reinforcement learning, these robots will adapt movements for maximum efficiency. These findings can advance and enhance the performance of marine research, exploration, underwater search-and-rescue, autonomous underwater vehicles, and much more.

Methodology

The experimental setup consists of these steps:

1. Fish Shape and Swimming Pattern Design: In the simulation (simulation software- *Julia*) and physical tests, data such as size, shape, and thickness must be measured and implemented into the code.
2. Motion Programming: Sinusoidal algorithms in the simulation and physical testing's programming control undulatory propulsion patterns, while reinforcement learning algorithms enable real-time adaptation to environmental conditions.
3. Performance Testing: The robots are tested in various water conditions to assess speed, energy efficiency, and adaptability. Metrics such as propulsion efficiency, velocity, and maneuverability are recorded.
4. Comparison with Biological Models: Findings are then validated using existing data on natural undulatory swimmers to identify the most effective locomotion strategies.

Results



Observations

Dogfish Shark

Forward Thrust: 0.284

Sideways Force: 1.68

Atlantic Salmon

Forward Thrust: 0.259

Sideways Force: 1.11

African Sharp Tooth Catfish

Forward Thrust: 0.247

Sideways Force: 1.98

Atlantic Bluefin Tuna

Forward Thrust: 0.263

Sideways Force: 1.2

Key Takeaways:

- Dogfish Shark demonstrated the greatest thrust
- African Sharp Tooth Catfish demonstrated the greatest Side force.

Conclusions

According to what we have observed with the data from the simulation, it is safe to say that our results are concurrent with the latest research. Our results demonstrated that longer and slimmer fish such as the dogfish shark and the African catfish create greater sideways fluid forces as they swim; a direct indication of less efficiency when propelling forwards. The Atlantic Bluefin Tuna and Atlantic Salmon both have a shorter more rounded shape, causing greater forward thrust and less side forces; a better ratio of energy dispersion that indicates better overall efficiency. These differences in efficiency are due to shape and patterns of movement that these fish demonstrate. Fish such as tuna have an oscillating movement closer to the tail end, while fish like the catfish oscillate a much greater length of their bodies to push themselves through the water. While the full body movement seen in longer fish reduces efficiency, it can help with things like maneuverability in tight spaces. Fish like Tuna need speed and efficiency when swimming through the open sea, for both hunting and escaping from predators. Catfish and eels live in much smaller areas and crevices, where being maneuverable is crucial for survival.

References

<https://doi.org/10.1017/jfm.2012.561>
<https://www.irphe.fr/~eloy/assets/pdf/JFM2013a.pdf>

