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Development and Testing of a Sub-Carangiform Biomechanical Fish to Mimic Thresher Shark (*Alopias sp.*) Locomotion

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Goals

- **To design and synthesize a biomechanical fish tail towards the realization of a robotic thresher shark**
  - Fish tail will vibrate at 1 Hertz
  - System is controlled with pulse width modulation (PWM)
  - Fish tail motion which mimics Thresher Shark's tail
- **To validate the design using image analysis**
  - ProAnalyst software for motion tracking
  - Fourier analysis

Outline

- System design
  - SolidWorks CAD & CAM
  - CNC mold creation
  - Mold fabrication
  - Mechanical assembly

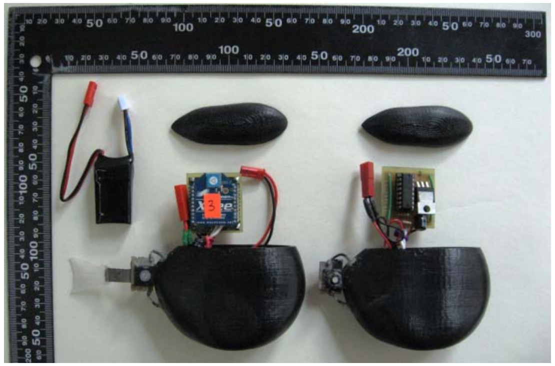
- Experiments
  - Image Analysis

- Conclusions

- Future work
  - Remotely operated mechanical fish
  - Energy scavenging

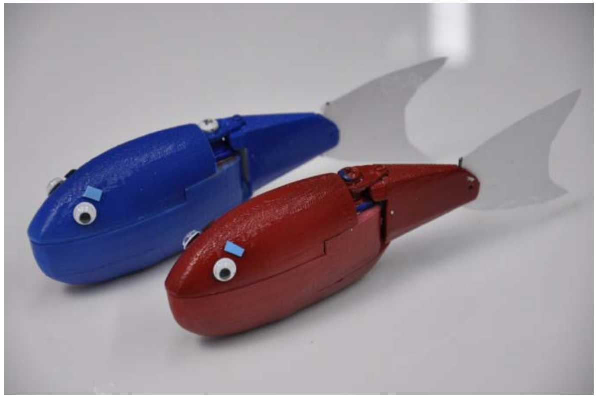
Background (1)

Underwater robotics, Dynamical Systems Laboratory, NYU-Poly



Miniature biommetic vehicles propelled by Ionic Polymer Metal Composites (IPMCs)

Miniature biommetic vehicles propelled by watertight miniature servomotors and passive tail elements



Background (2)

Underwater robotics,

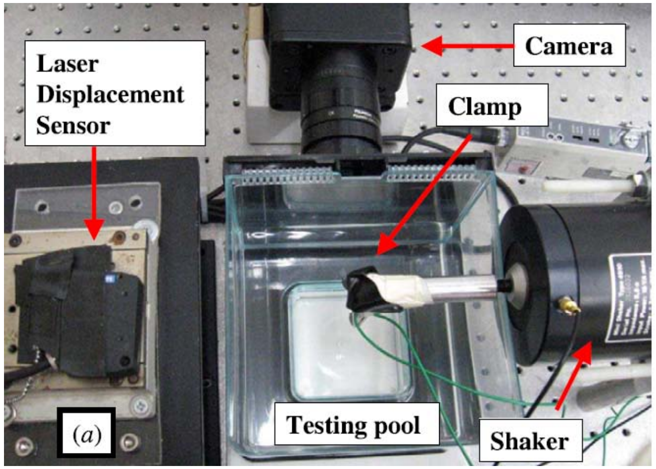
Dynamical Systems Laboratory,

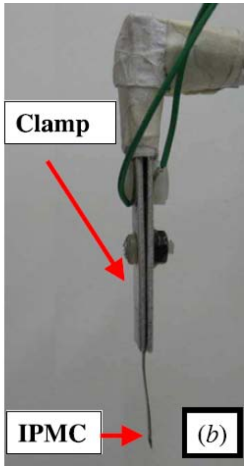
NYU-Poly

Ph.D. students interacting with elementary students at New York Aquarium, raising interest in STEM topics and awareness in different fields of engineering

Motivation

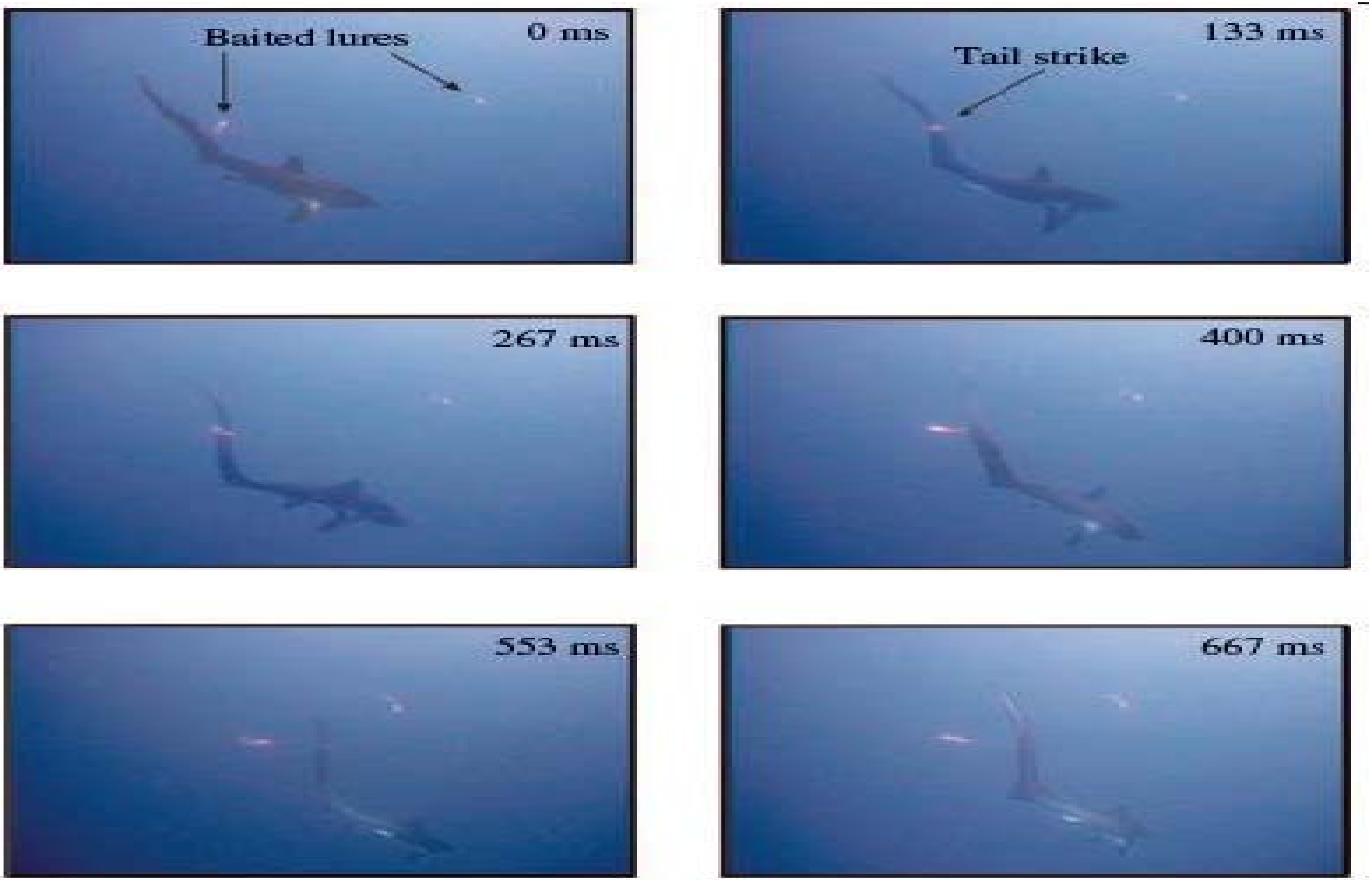
- Understanding the fluid dynamics of aquatic animals has resulted in the design and realization of bio-inspired vehicles
- Creating biomimetic underwater vehicles with multiple applications
- Decreasing ecological impact
- Interacting with organisms to help carry out ecological rescue operations and reduce environmental contamination
- IPMC's as an energy harvesting device





Aureli, et al, 2009

Applications



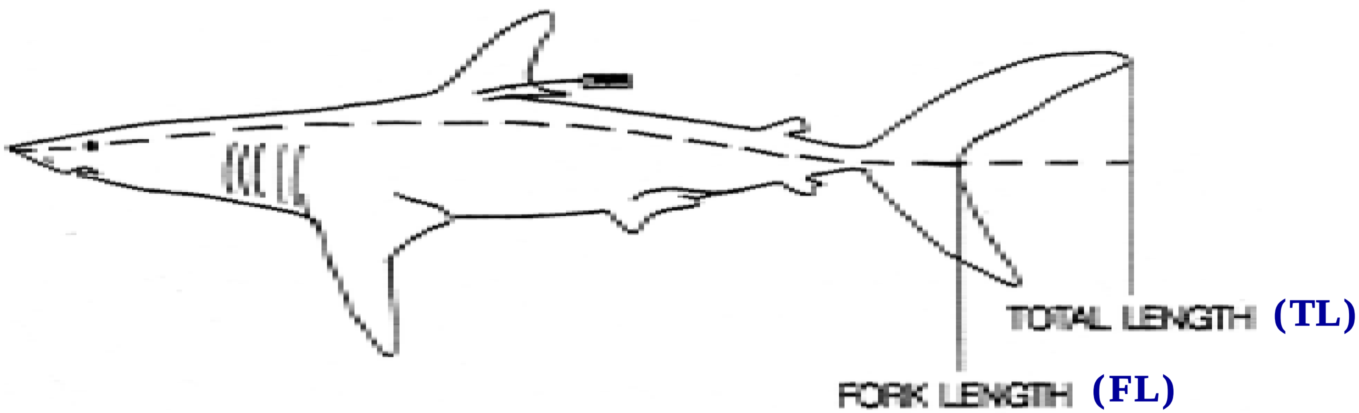
Aalbers et al, 2010.

Shark Morphometric Equations

- $FL = a \times TL + b$

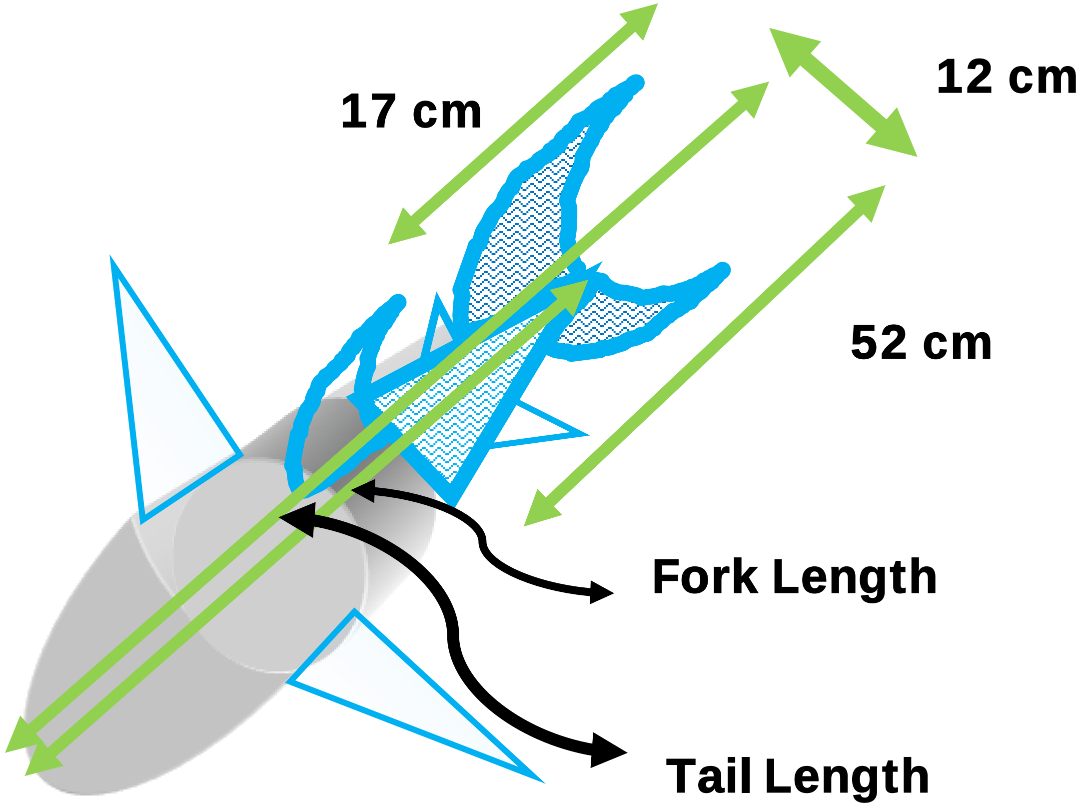
- $Weight = a \times FL + b$

- $TL - FL = \Delta L$

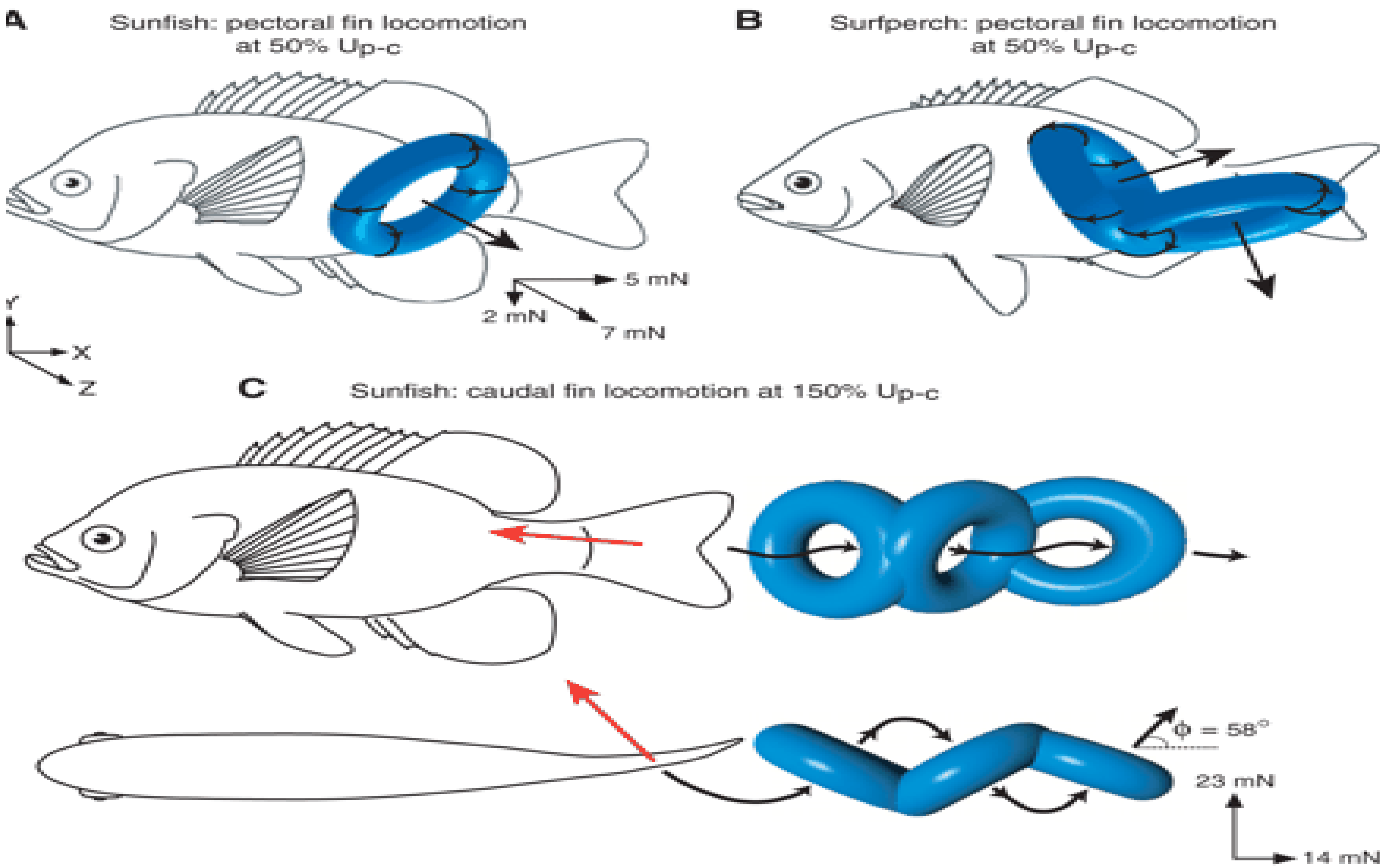


Kohler, et al., 1996

Dimensions of Model



Locomotion Patterns



Lauder, 2000

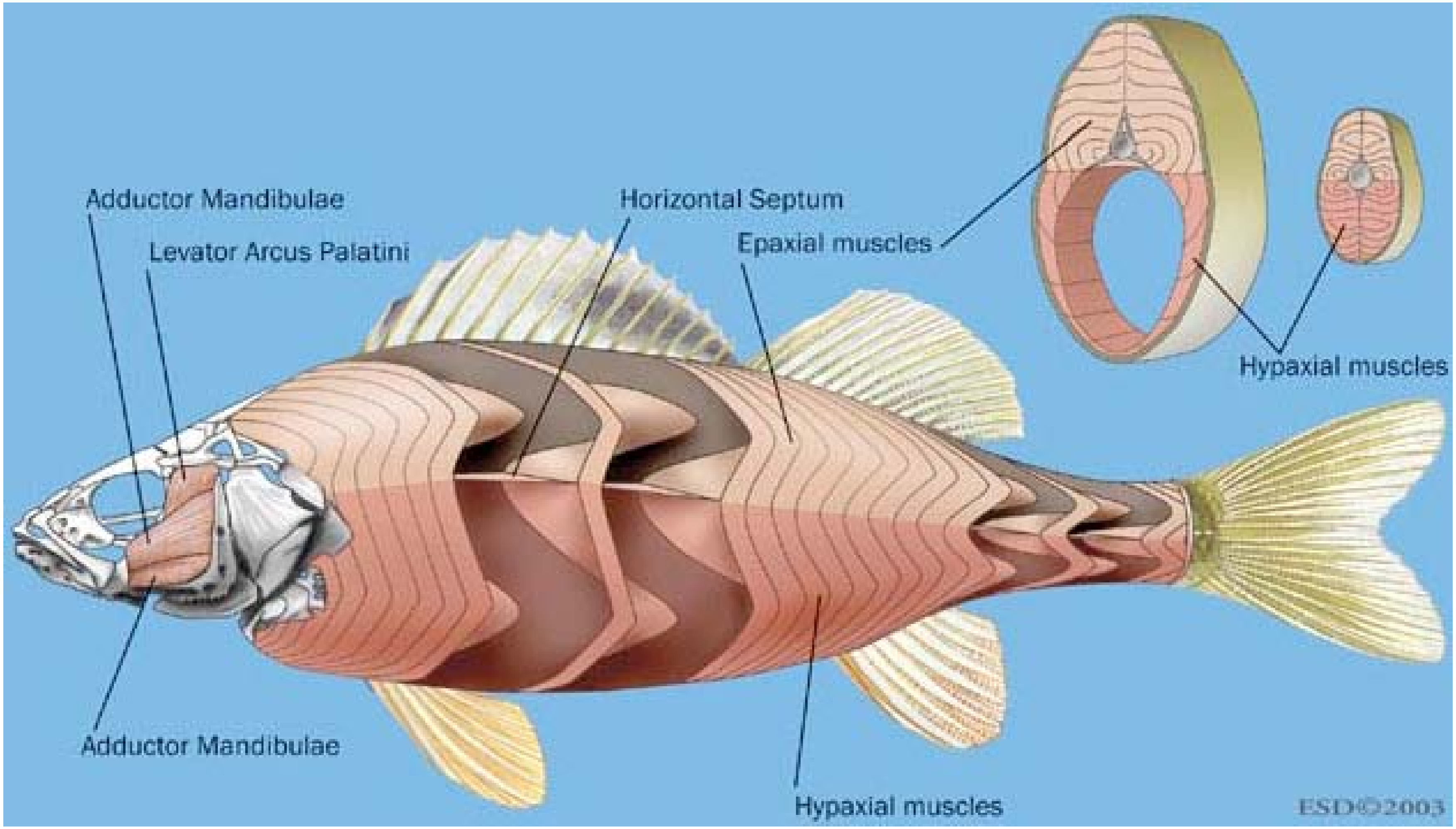
Fish and Slender Beams

Vertebral Column – A slender beam with contracting muscles

Biomimetic shark tail

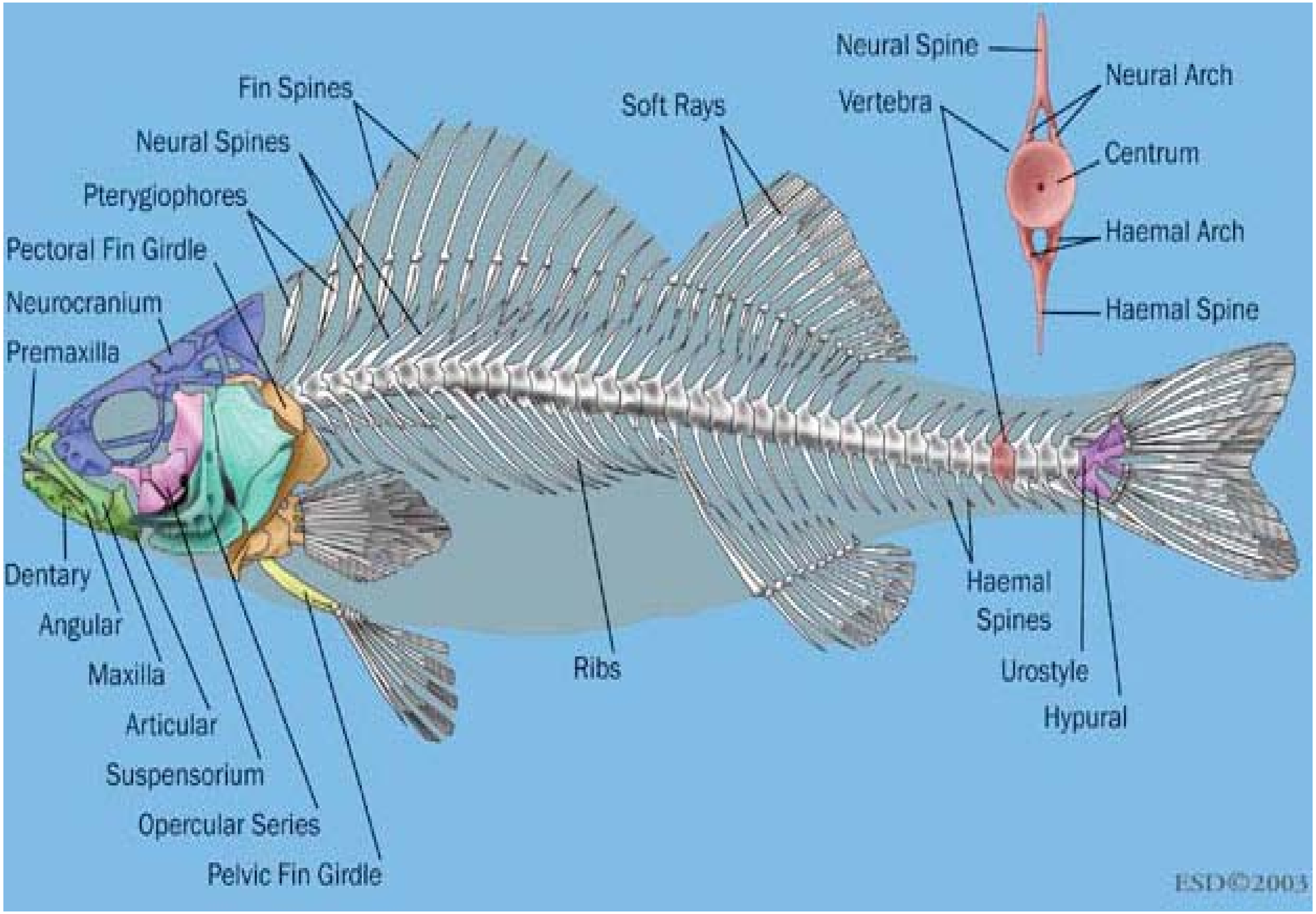
Caudal fin of Thresher Shark

Muscular anatomy



McCauley & Heyer, 2007

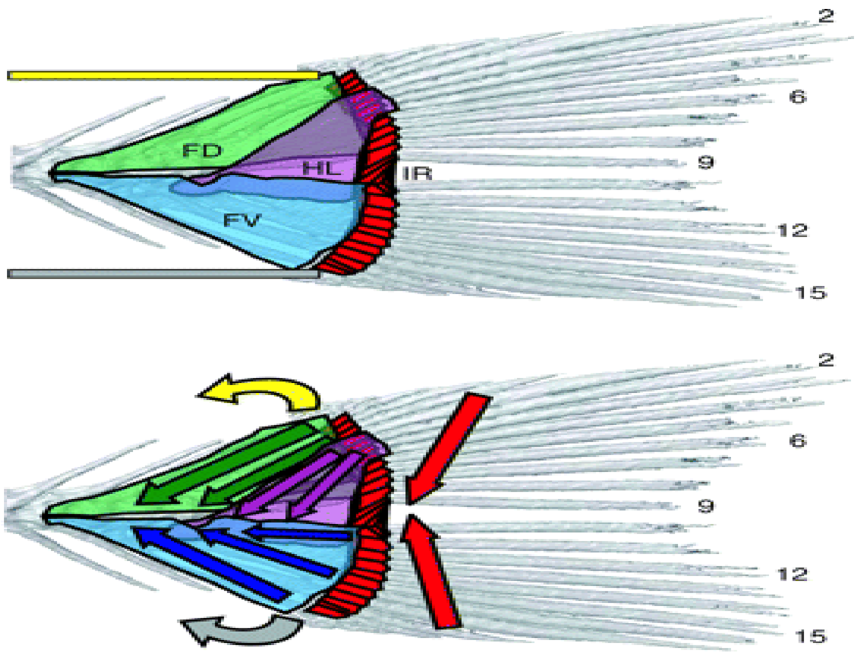
Skeletal anatomy



McCauley & Heyer, 2007

Tail anatomy

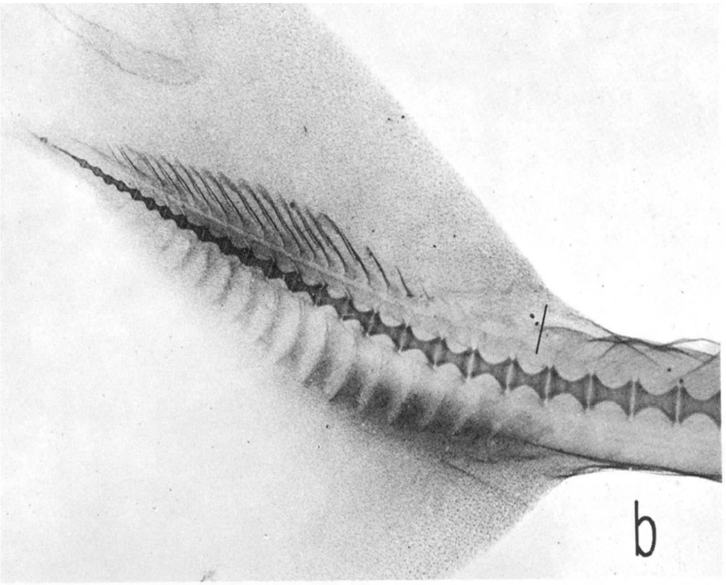
- Anatomy of intrinsic caudal muscles, overlaid on a computer microtomography (μCT) scan of a bluegill sunfish tail.
- Arrows in the bottom diagram indicate the direction of movement of fin components caused by muscle contraction as determined from electrical stimulation experiments.



Flammang and Lauder, 2007

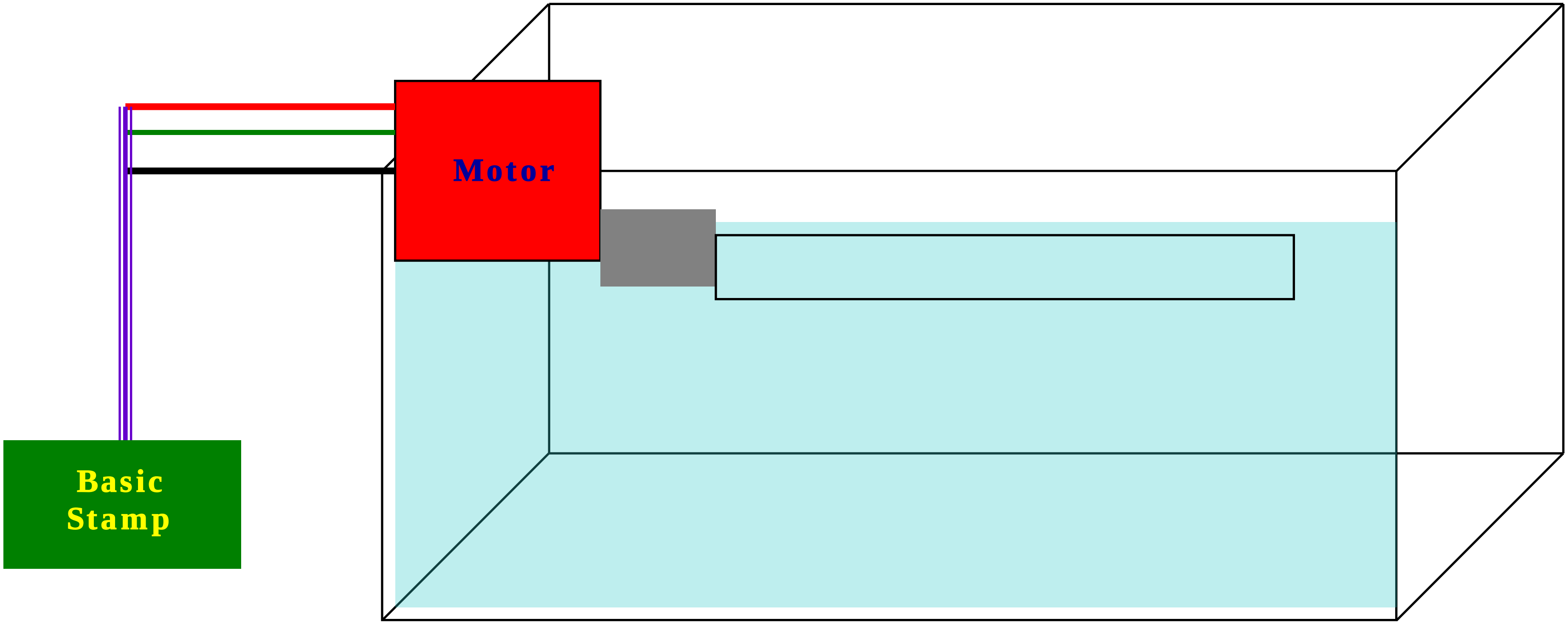
Caudal Fin Radiograph

- Caudal skeleton of ***Isistius brasiliensis*.** Specimen (SIO 52-413-5A), 386 mm long, from equator at 100°00' W. long.
- Caudal vertebrae counted as 22, the last 2 interpreted as much elongated.



BULL. SCRIPPS INST. OCEANOGR. VOL. 10 [HUBBS-IWAI-MATSUBARA] PLATE 6

Experimental Design



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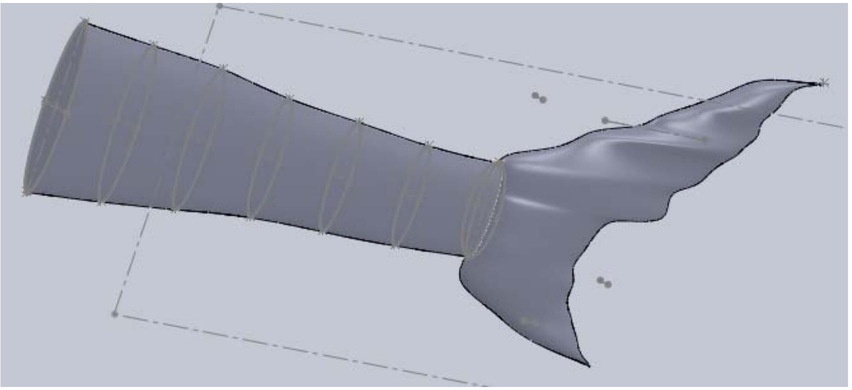
Preliminary Tests on some beams and results

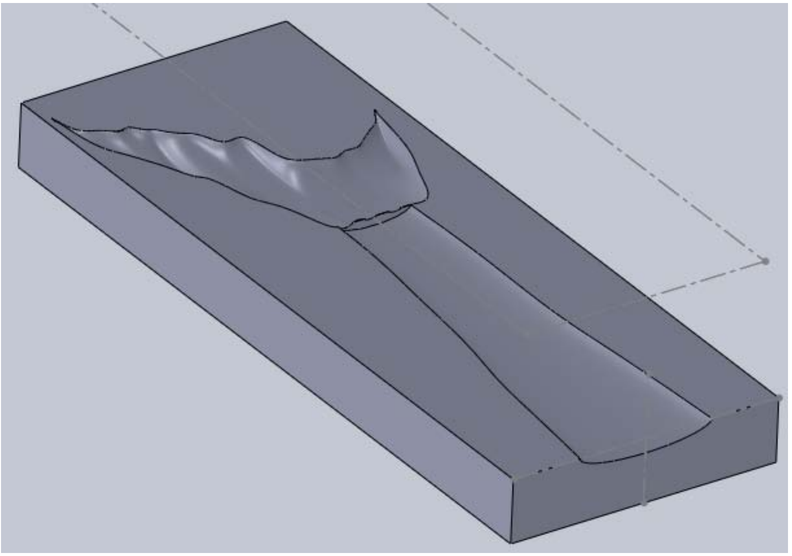
Dynamical systems laboratory

- We tested stainless steel and clear plastic beams in air and water
- Water added mass effect creating dampening force on beams

CAD/CAM

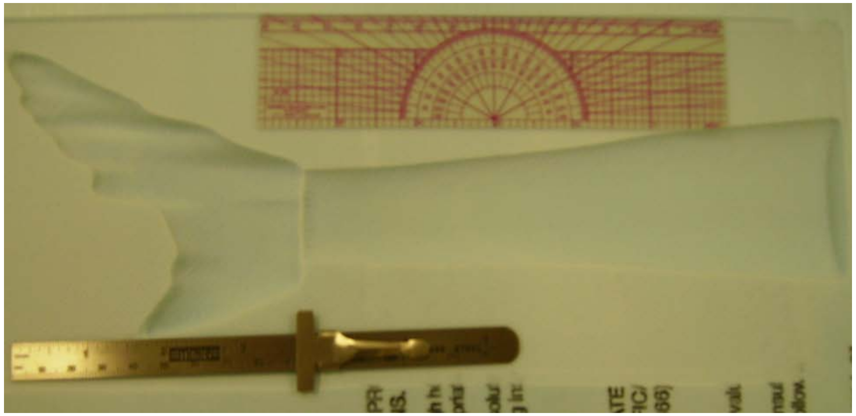


Thresher Shark inspired fish tail realized through Computer Aided Design/Manufacturing (CAD/CAM) software



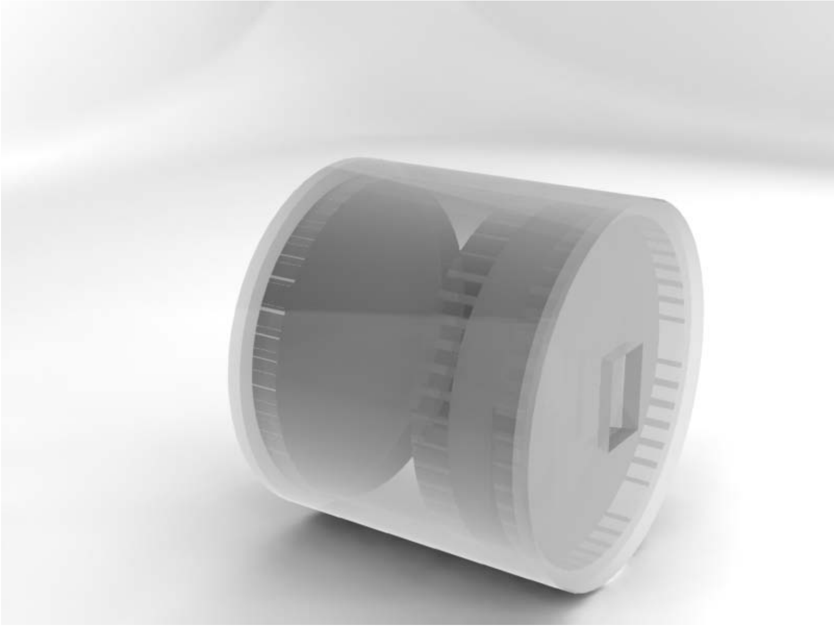
Mold Design

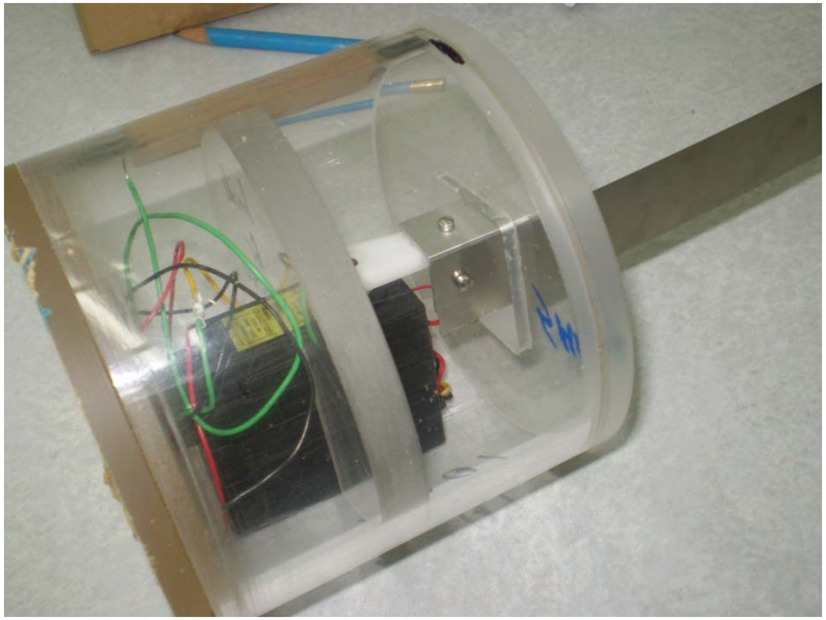
- PartWorks 3D translates SolidWorks files to ShopBot for CNC
- After allowing 2 ½ days for curing we removed silicone from mold and trimmed excess reservoirs



Motor Assembly

- CAD designed motor encasement (left)
- Manufactured motor encasement (right)





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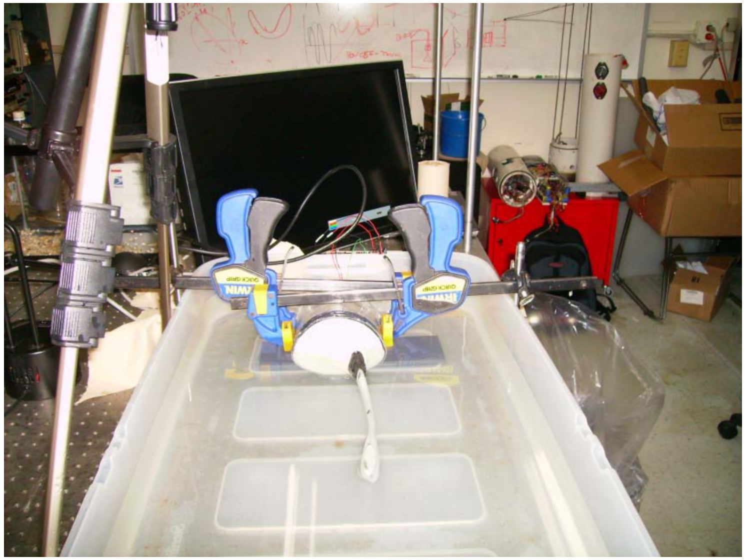
Data Points for Tracking

Dynamical systems Laboratory

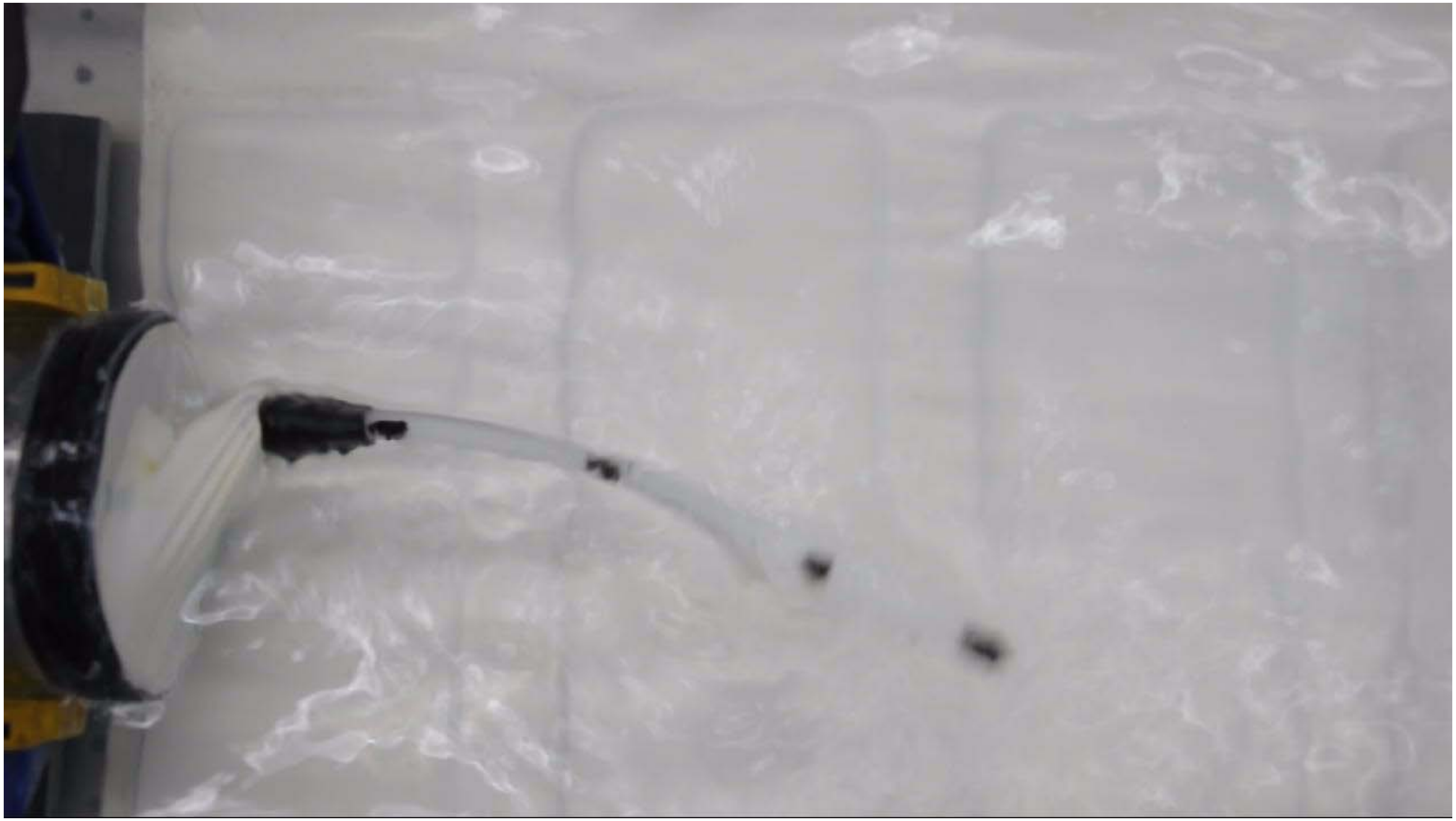
- Points were put on tail at ¼ length, ½ length, ¾ length, and end to be tracked with the image software analyzer ProAnalyst.



- Tail fixed in place over small tank and recorded digitally for analysis.

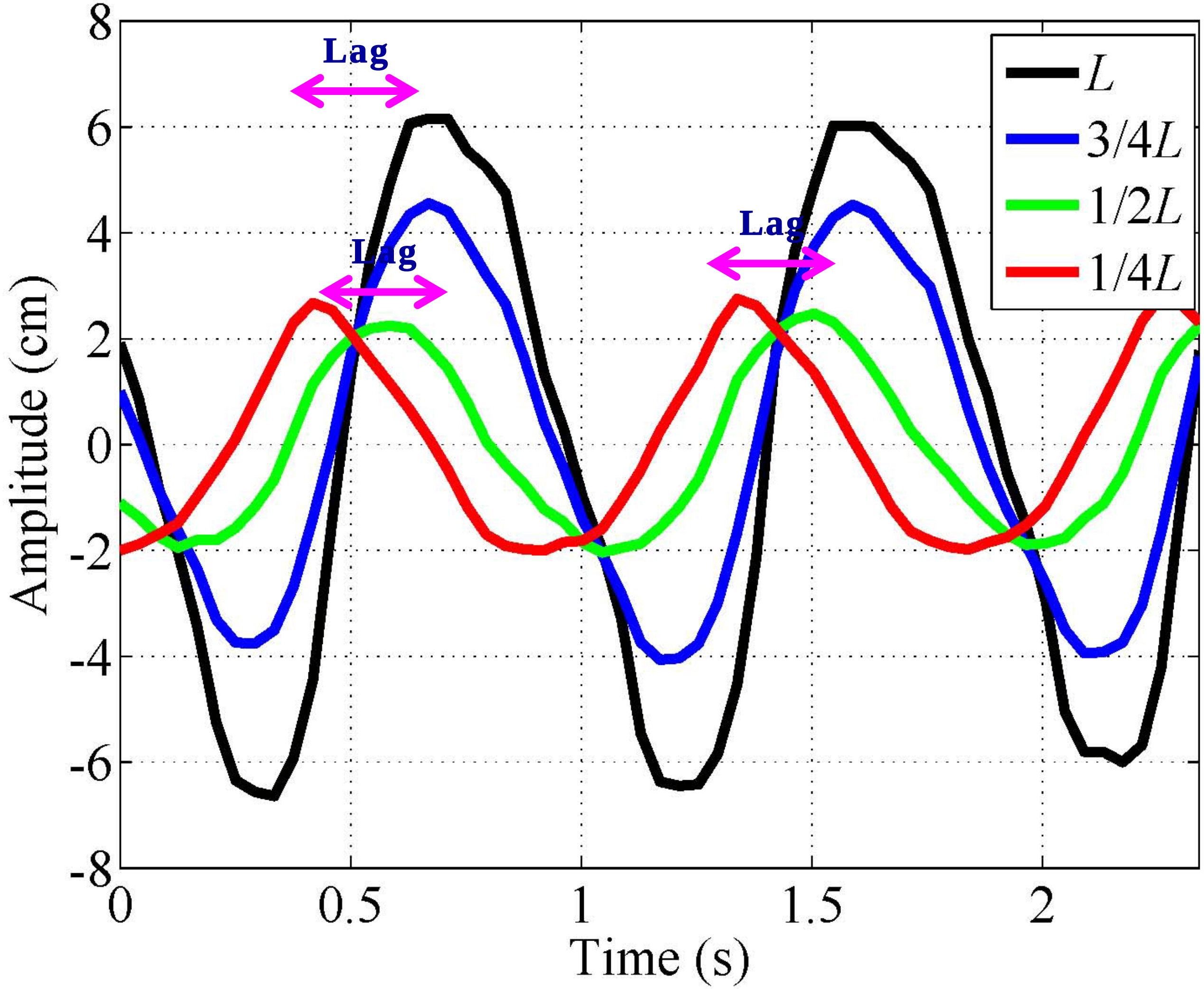
Experimental Footage

- Points placed on tail allow video tracking using ProAnalyst software to graphically represent displacement data



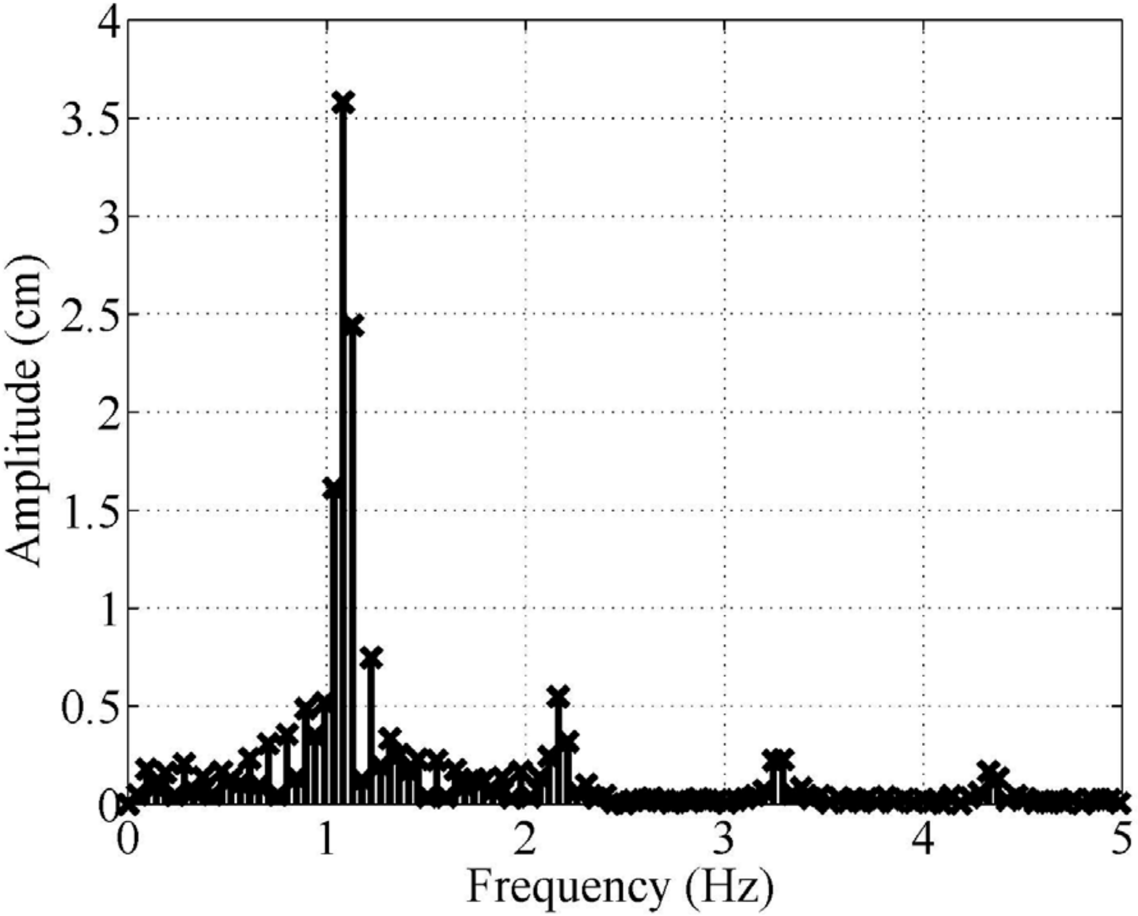
Biomimetic locomotion

- Fish tail movement shown graphically is lagging sinusoidal waveform



Experimental Parameters

- Fourier analysis of amplitude and frequency
- Most prevalent movement achieved 1.05 Hz



Conclusions

- **In this presentation we:**
  - Presented the design and realization of a biomechanical fish tail inspired by the Thresher Shark
  - Experimentally validated the biomechanical fish tail via image analysis
  - Outlined the future implementation of the biomechanical tail as a fully realized remotely operated mechanical fish and energy scavenger

Future Exploration

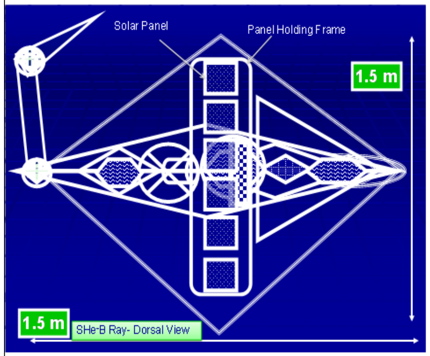
Future Milestones:

- Closely evaluate impact of adjusted PWM
- Flow visualization
- Mimic flow phenomena of Thresher Shark
- Explore attachment of IPMC's for energy harvesting
- Add anterior section of body for buoyancy and onboard electronics

Future Applications:

- Applications in aquatic veterinary medicine – chemical immobilization of fish in streams, lakes, ponds and the seas
- Energy scavenging from environment

Buoyancy Apparatus



Mahmoud (L) and Alvin (R), conducting hydrostatic studies on a modular submersible

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