

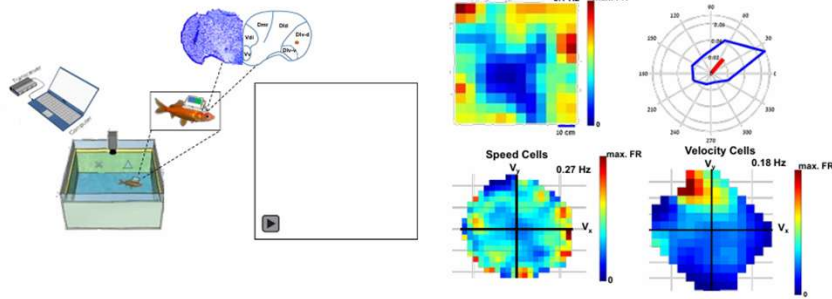


The Sensory Information that Leads to Hydrostatic Depth Perception in Fish

Fish exhibit remarkable depth perception in aquatic environments. Understanding how they sense and interpret hydrostatic pressure is crucial for comprehending their navigation and survival strategies. This presentation explores the complex interplay of sensory systems that contribute to hydrostatic depth perception in fish.

by Anton Pasternak

We found four cell types in a shallow environment



Vinepinsky et al. ,2020, Scientific Reports

Open questions

- Are there pure “pressure cells” in the telencephalon of fish?
- Can we find the neural pathway of pressure sensing in the fish?

Conclusions

- We showed that goldfish can learn both to operate a vehicle and navigate on land
- We found indication for encoding of space in the goldfish brain
- Hydrostatic pressure modulates firing rate of cells in the goldfish telencephalon
- More evidence is needed to establish the existence of “pressure cells”
- Future work- finding the neural pathway of pressure sensing in fish

Depth Perception - Equal Integration of Multiple Sensory Inputs or Single Sense Domination?

Multi-sensory Integration

All fish rely on the same complex combination of sensory systems to perceive depth, including visual cues, the lateral line system, the swim bladder, and nociceptors, all equally important to every fish.

OR

Dominant Sensory System

Depending on the species and environmental conditions, one sensory system might play a more dominant role in depth perception than others. The fish relies heavily on this sense and is lost without it.



Influences of Visual Input on Depth Perception - the Diel Vertical Migration

1

Daytime

During the day, fish often occupy deeper waters, minimizing their exposure to predators and maximizing their access to food.

2

Twilight

As light levels diminish, fish begin to ascend towards shallower waters, taking advantage of the increased availability of plankton and other prey.

3

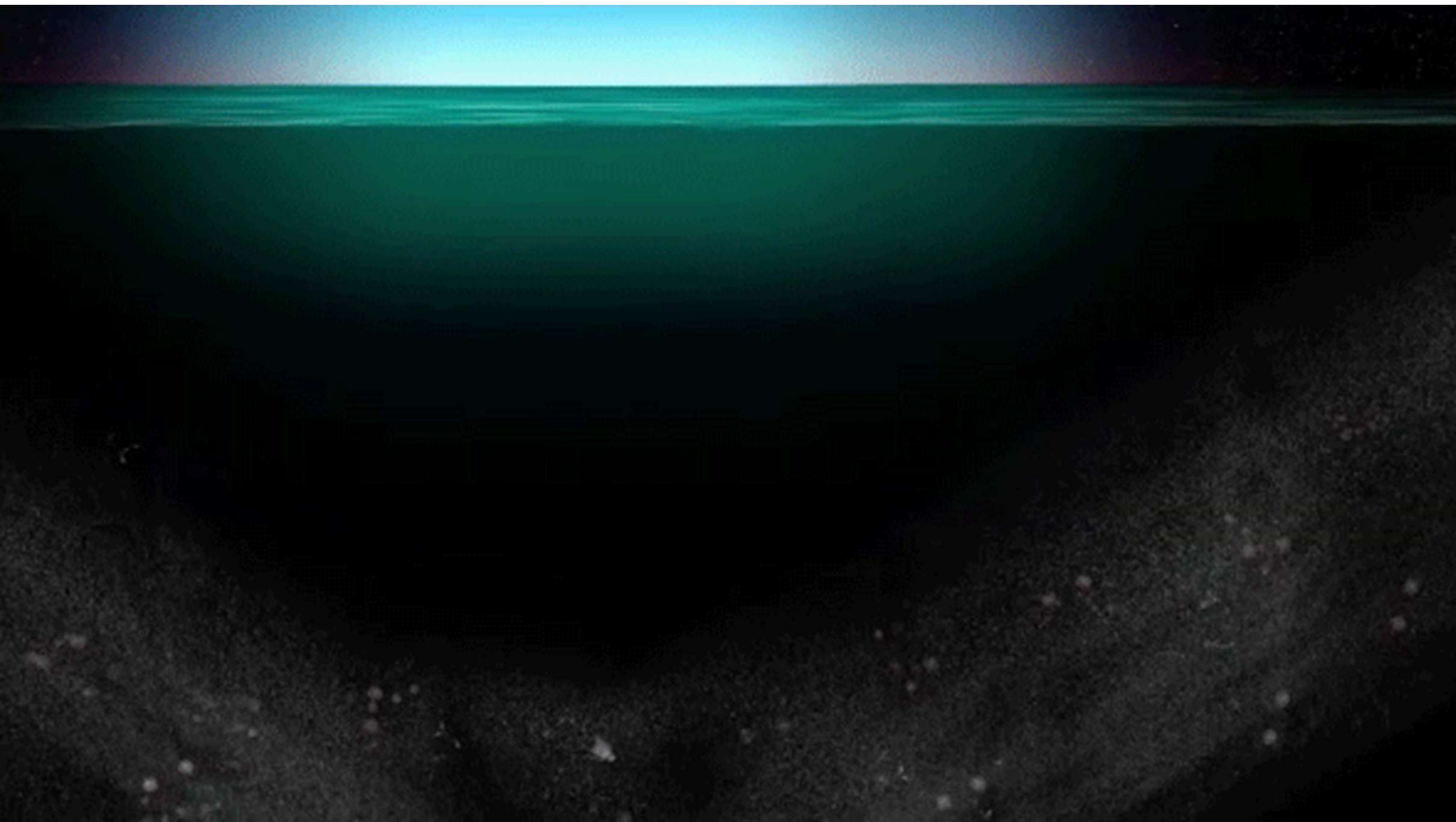
Nighttime

During the night, fish may stay in shallower waters or migrate further upwards to the surface, depending on their feeding habits and the presence of predators.

4

Dawn

As dawn approaches, fish begin to descend back to deeper waters, completing their daily vertical migration cycle.



The Role of the Lateral Line System in Detection of Water Movement, Flow and Depth Perception

1 Hydrodynamic Sensing

The lateral line system is a remarkable sensory organ that detects water movements, vibrations, and pressure changes. It plays a crucial role in navigating through complex aquatic environments.

2 Depth Perception

By detecting subtle changes in water flow, the lateral line system contributes to depth perception, enabling fish to identify their position relative to the bottom.

3 Predator Detection

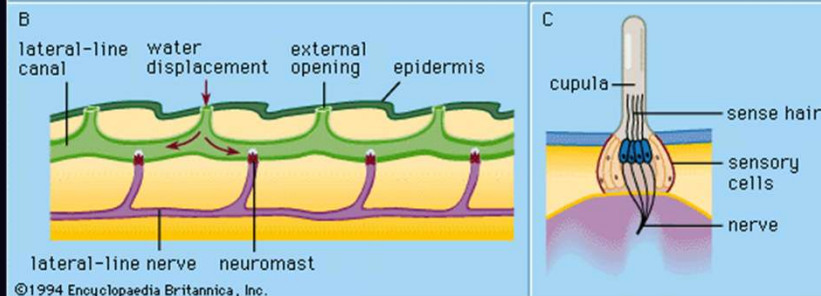
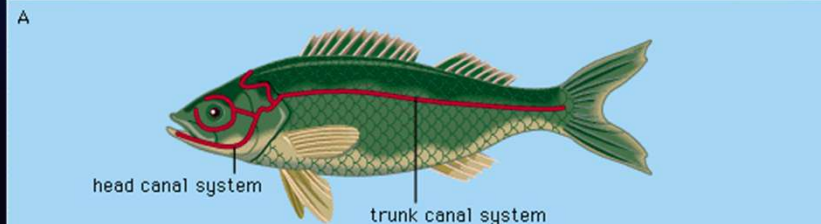
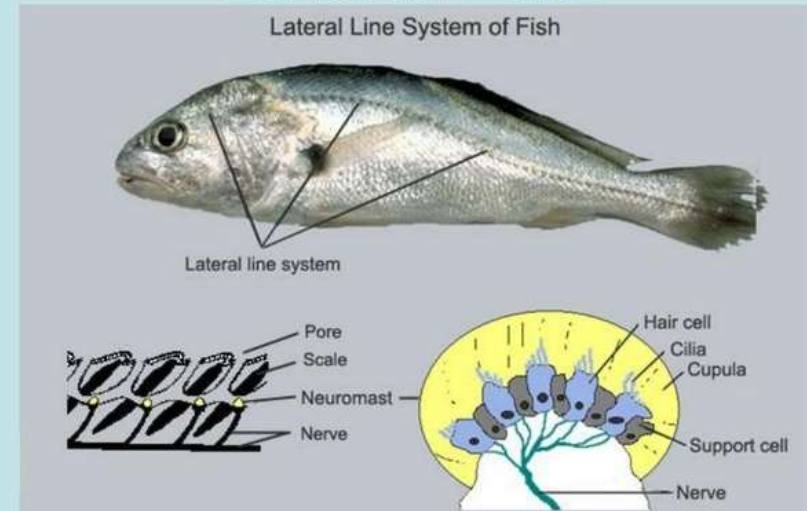
The lateral line system helps fish detect the approach of predators or prey by sensing the disturbances they create in the water.

4 Schooling Behavior

Fish use the lateral line system to maintain their position within a school, coordinating their movements with other individuals.

Lateral Line

Lateral Line System of Fish



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The Role of the Swimming Bladder In Depth Perception

1

Buoyancy Control

The swim bladder is a gas-filled sac that helps fish control their buoyancy, allowing them to maintain their position in the water column without expending excessive energy.

2

Sound Transmission

The swim bladder acts as a **sound receptor**, amplifying sound waves and transmitting them to the inner ear. This **auditory** function enhances depth perception.

3

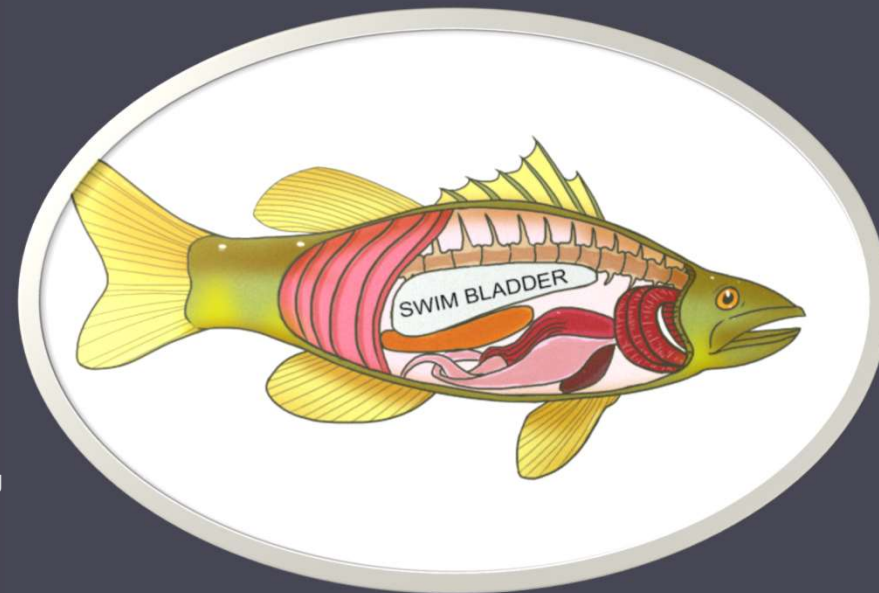
Pressure Sensing

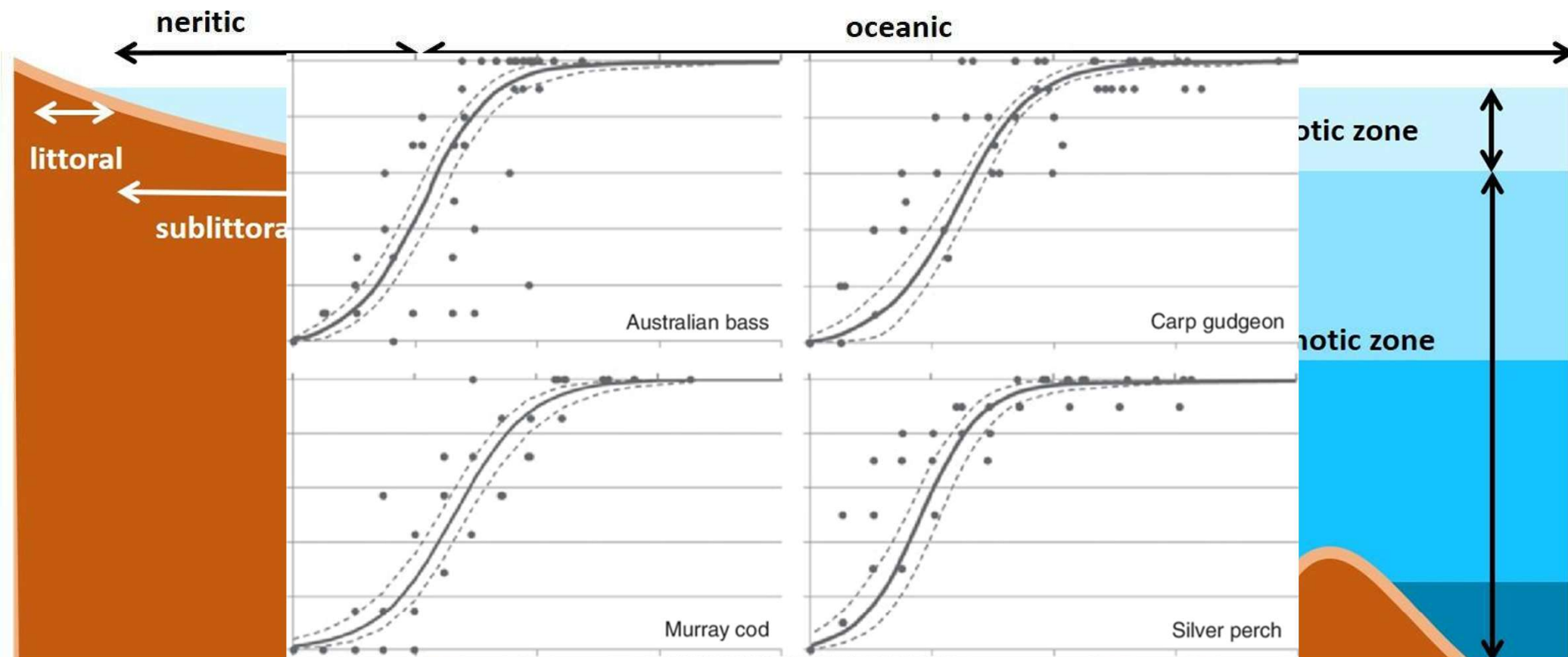
Changes in hydrostatic pressure affect the gas content of the swim bladder, providing fish with information about their depth.

4

Depth Perception

By monitoring the pressure changes in the swim bladder, fish can perceive their depth relative to the surface or the bottom.





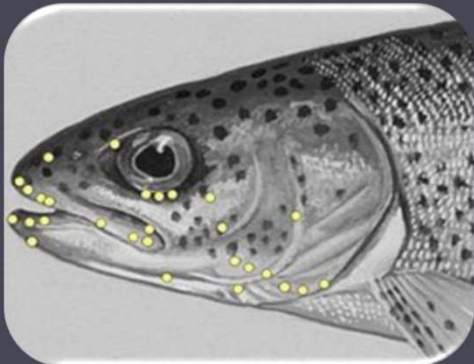
The probability of injury increased as the natural log of ratio pressure change ($\ln(RPC)$) increased for Australian bass, carp gudgeon, Murray cod and silver perch. Solid lines represent Eqn 1 calculated with coefficients for each individual species (Table 4). Dotted lines are 95% confidence limits, which were limited to the range of tested $\ln(RPC)$ to ensure accuracy, and dots are individual results for each trial where the number of fish observed with an injury was divided by the number of fish in the trial.

In natural habitat
3,000+ feet below sea-level

After extreme tissue damage from
being pulled up rapidly by fishers



Photichthys argenteus AMZ 142771-001



The Contribution of Nociceptors for Pressure Sensing and Depth Perception

Pain Receptors

Nociceptors are sensory receptors responsible for detecting pain and noxious stimuli, such as extreme temperatures or pressure.

Pressure Sensitivity

In addition to pain, nociceptors can also detect changes in pressure, contributing to depth perception in fish.

Depth Regulation

By sensing pressure changes in the environment, nociceptors provide feedback to the fish's brain, allowing it to adjust its position and maintain the appropriate depth.

Survival Mechanism

The nociceptors' ability to sense pressure changes plays a vital role in the fish's survival, enabling them to avoid obstacles and navigate effectively in the water.

Suggestions for the Experimental Stage

Experimental Setup

Design controlled environments that allow for manipulating hydrostatic pressure and visual cues.

Sensory Deprivation

Employ methods to selectively eliminate different sensory systems (e.g., no visual stimuli, blocking the lateral line, morphine injection) to isolate the contributions of individual senses.

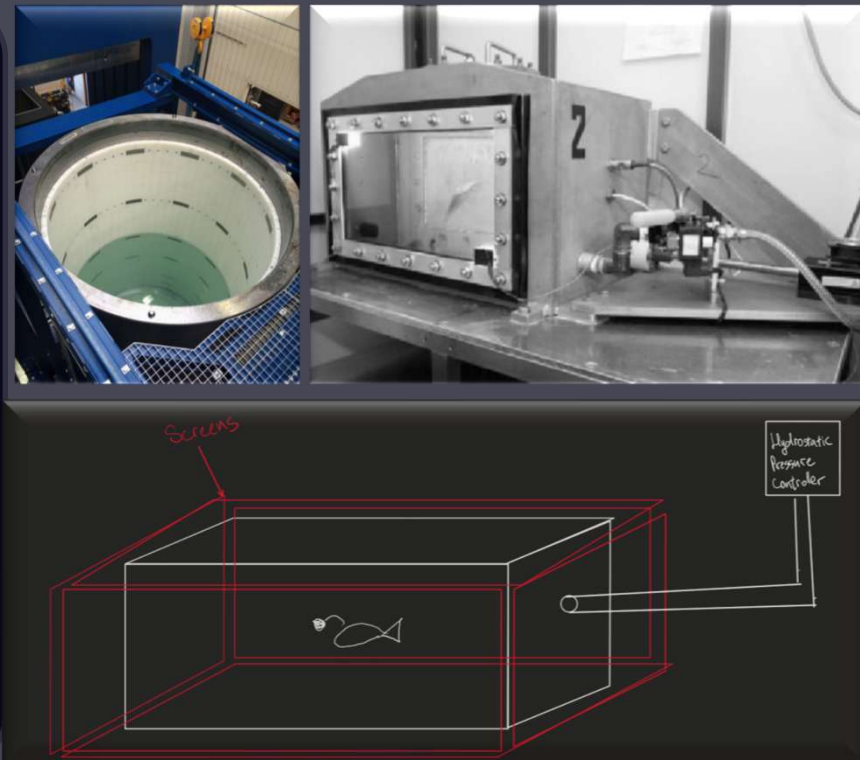
Behavioral Observations

Record and analyze the fish's behavioral responses to changes in depth cues, including their swimming patterns, orientation, and "escape" strategies.

Data Analysis

Utilize statistical analysis to determine the significance of the observed behavioral changes and identify the relationships between sensory input and depth perception for numerous fishes.

And finally showing the explained variance of each biological sensor.



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OR

Dominant Sensory System

Depending on the species and environmental conditions, one sensory system might play a more dominant role in depth perception than others. The fish relies heavily on this sense and is lost without it. (For example, for fish that live in murky water, the lateral line system may be the dominant one)

My Main Hypothesis: The Dominant Sensory System

Different fish species, adapted to diverse environmental conditions, may exhibit varying degrees of reliance on specific sensory systems for depth perception. One sensory modality often predominates, serving as the primary cue for depth estimation. To investigate this further, we propose analyzing the contribution of each biological sensor to depth perception by treating them as principal components. . The provided graph visually represents this hypothetical distribution of variance explained by different sensory components in depth perception in two different kinds of fish. However, this hierarchy may vary across fish species based on their ecological niches and behavioral adaptations. It's plausible that additional, yet unidentified, sensory data contribute to depth perception in certain fish.

