# Impacts of Offshore Wind Energy Construction Sounds on Behavior of Longfin Squid


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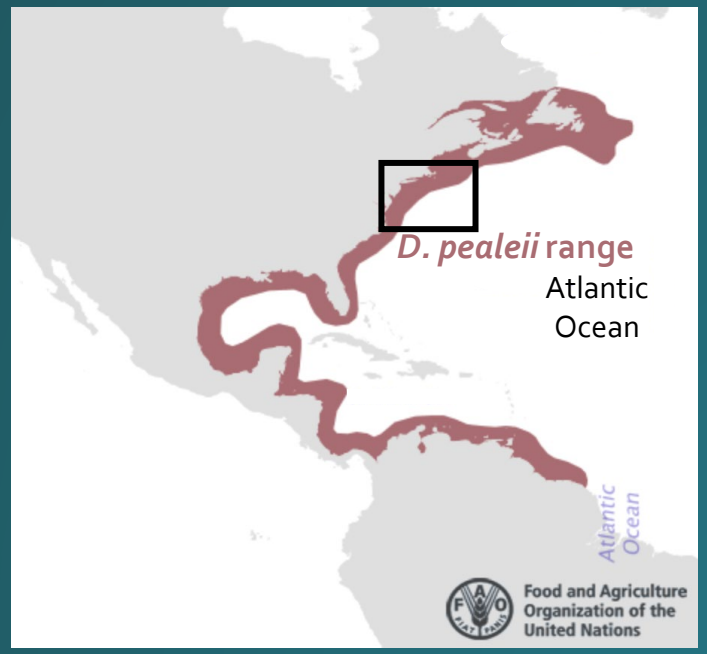
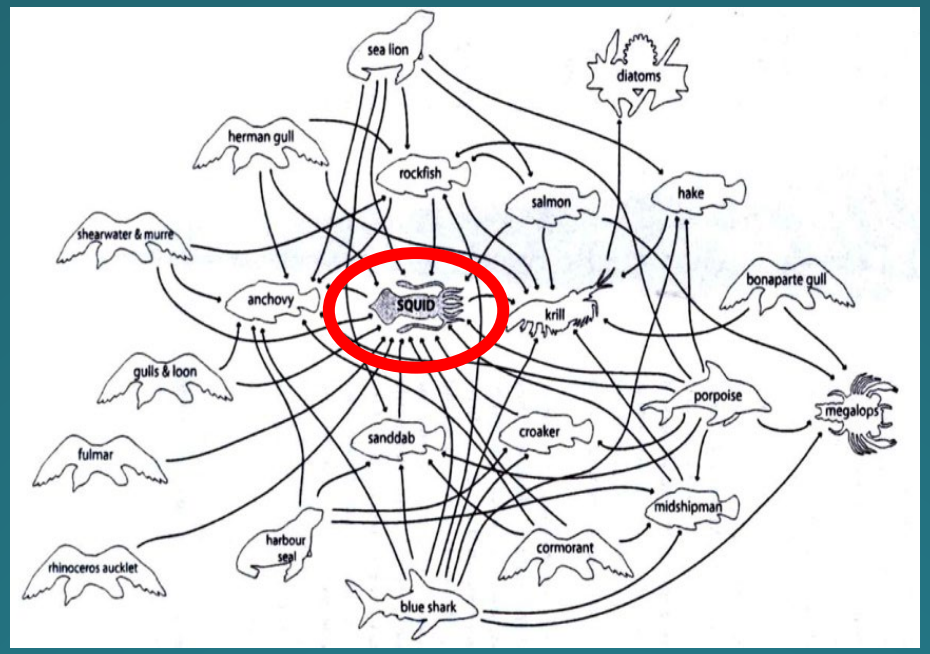
# Longfin squid (*Doryteuthis pealeii*)

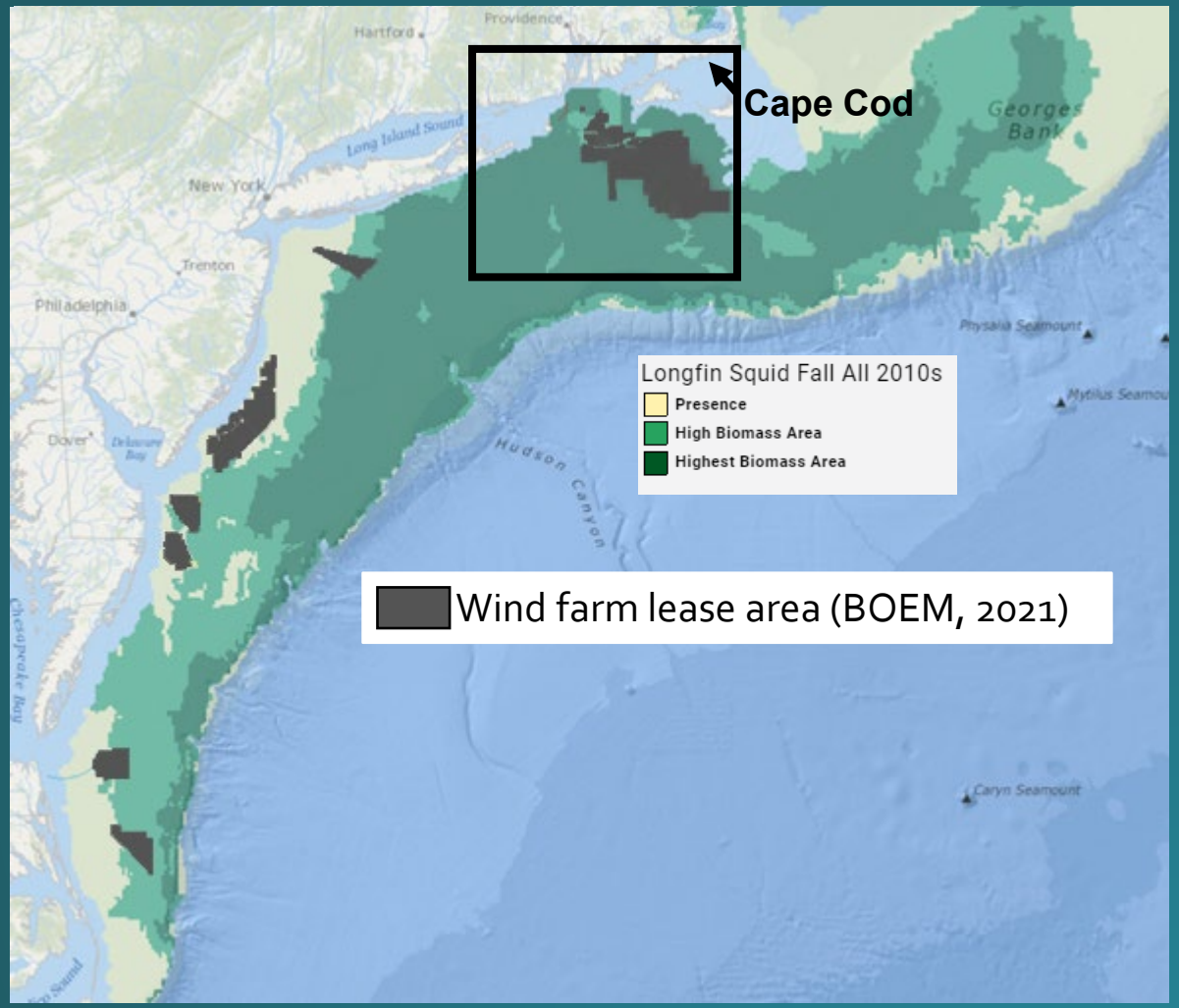



Boyle and Rodhouse, 2005

- Habitat: Continental shelf from Venezuela to Newfoundland
- Central position in marine food webs
- High commercial importance **(ca. $$50M USD/yr)**
- Detect low frequency sounds up to ~1000 Hz (Mooney *et al*. 2010, 2016)

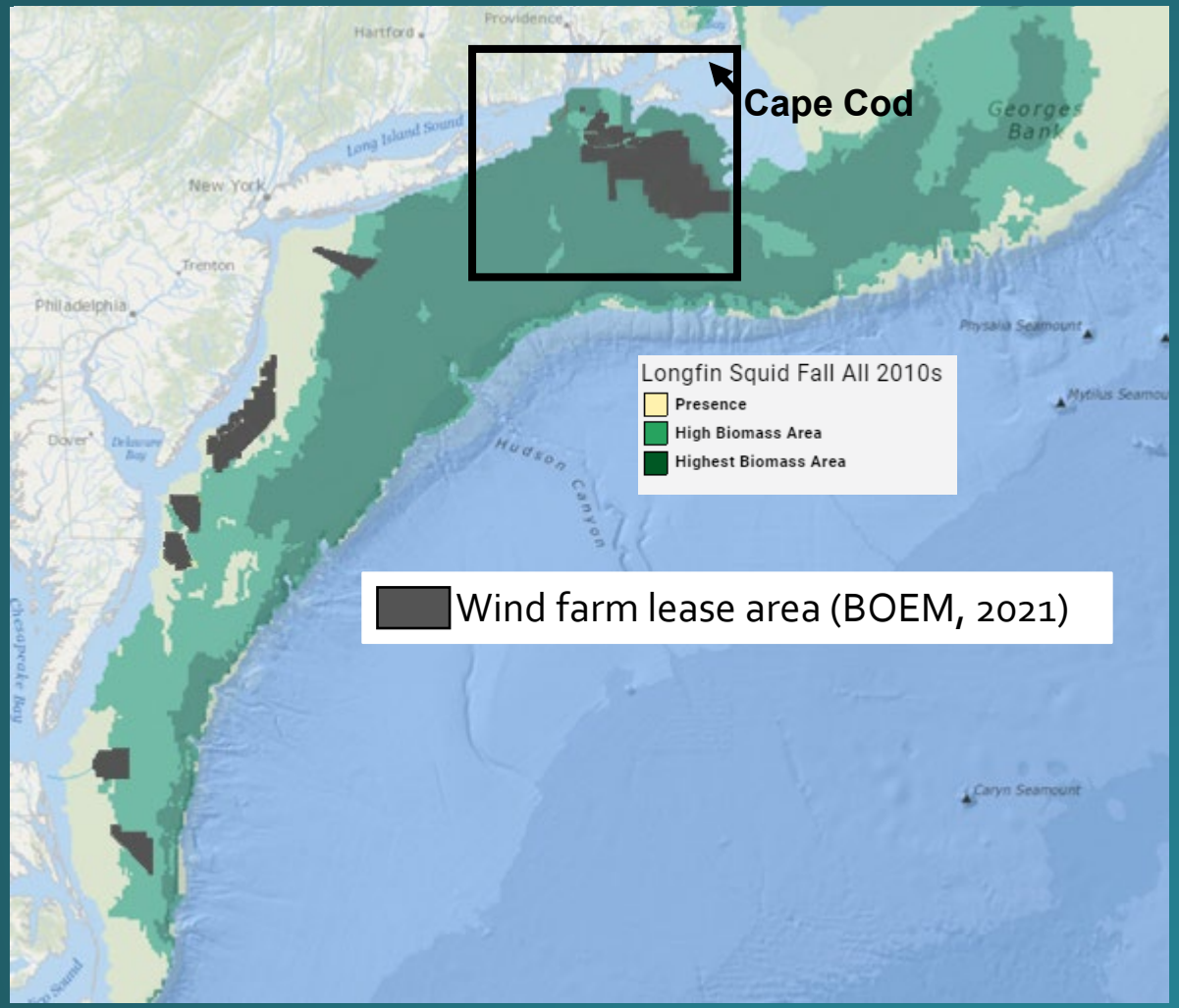
# Wind farm construction in *D. pealeii* habitat and fishing grounds



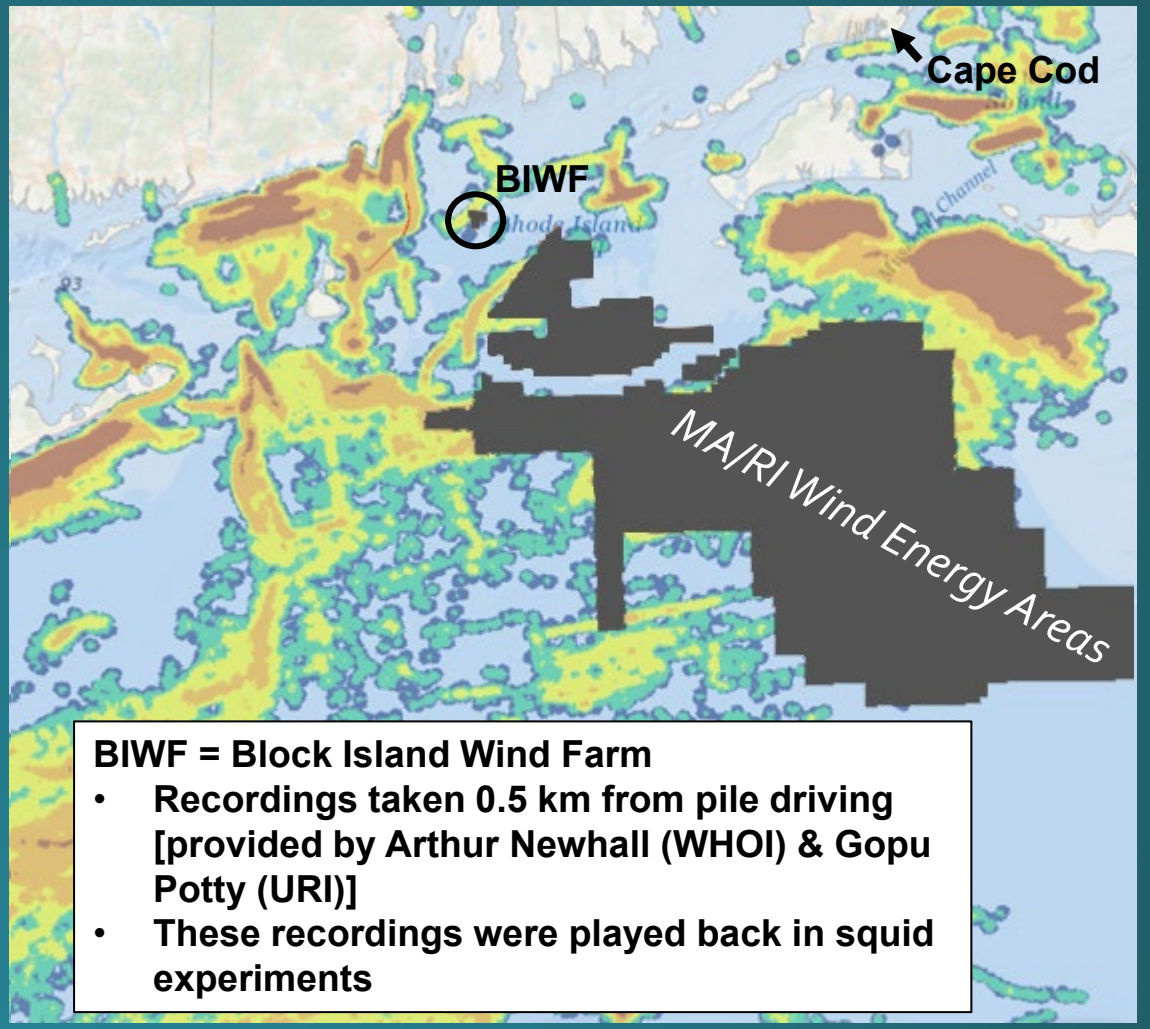

2010-2020 autumn *D. pealeii* biomass

Data from: https://portal.midatlanticocean.org/

# Wind farm construction in *D. pealeii* habitat and fishing grounds




2010-2020 autumn *D. pealeii* biomass




*D. pealeii* fishing vessel activity

Data from: https://portal.midatlanticocean.org/

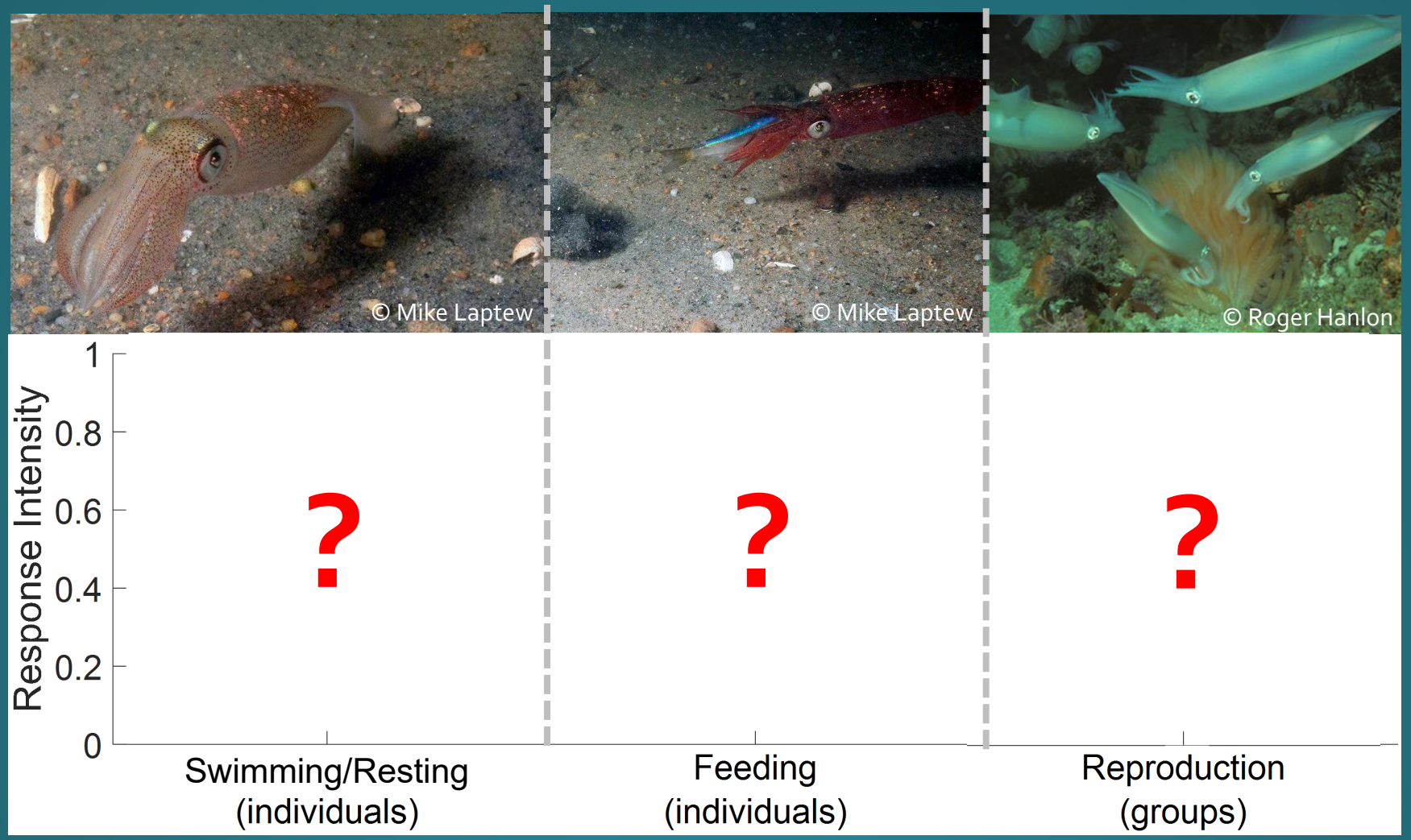
# Pile driving noise

- Pile driving: construction of docks, oil rigs, wind turbines, etc.)
- This noise is:
  - High intensity
  - Detectable over long distances
  - *Impulsive*
- Adverse effects of pile driving noise (on fish and marine mammals) can be:
  - Physical (Halvorsen et al. 2011)
  - Physiological (Kastelein et al. 2016)
  - Behavioral (Herbert-Read et al. 2017)


Block Island Wind Farm (BIWF)

Steamship Authority

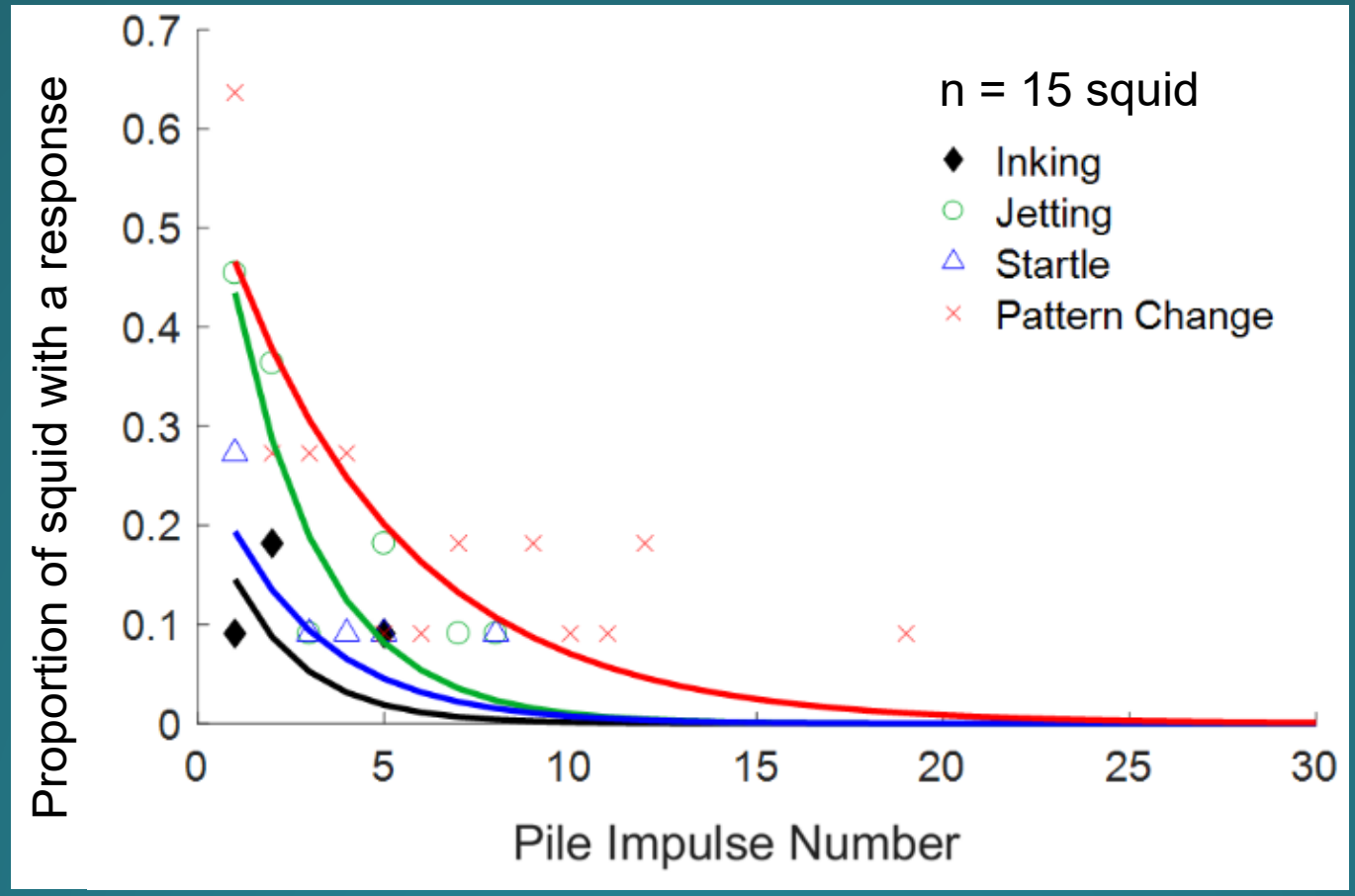
# Goal: assess squid's response intensity to pile driving noise in multiple behavioral contexts



# Alarm response of resting squid

Jones, I. T., Stanley, J. A., Mooney, T. A. (2020). *Marine Pollution Bulletin*

# Strong alarm responses of resting squid



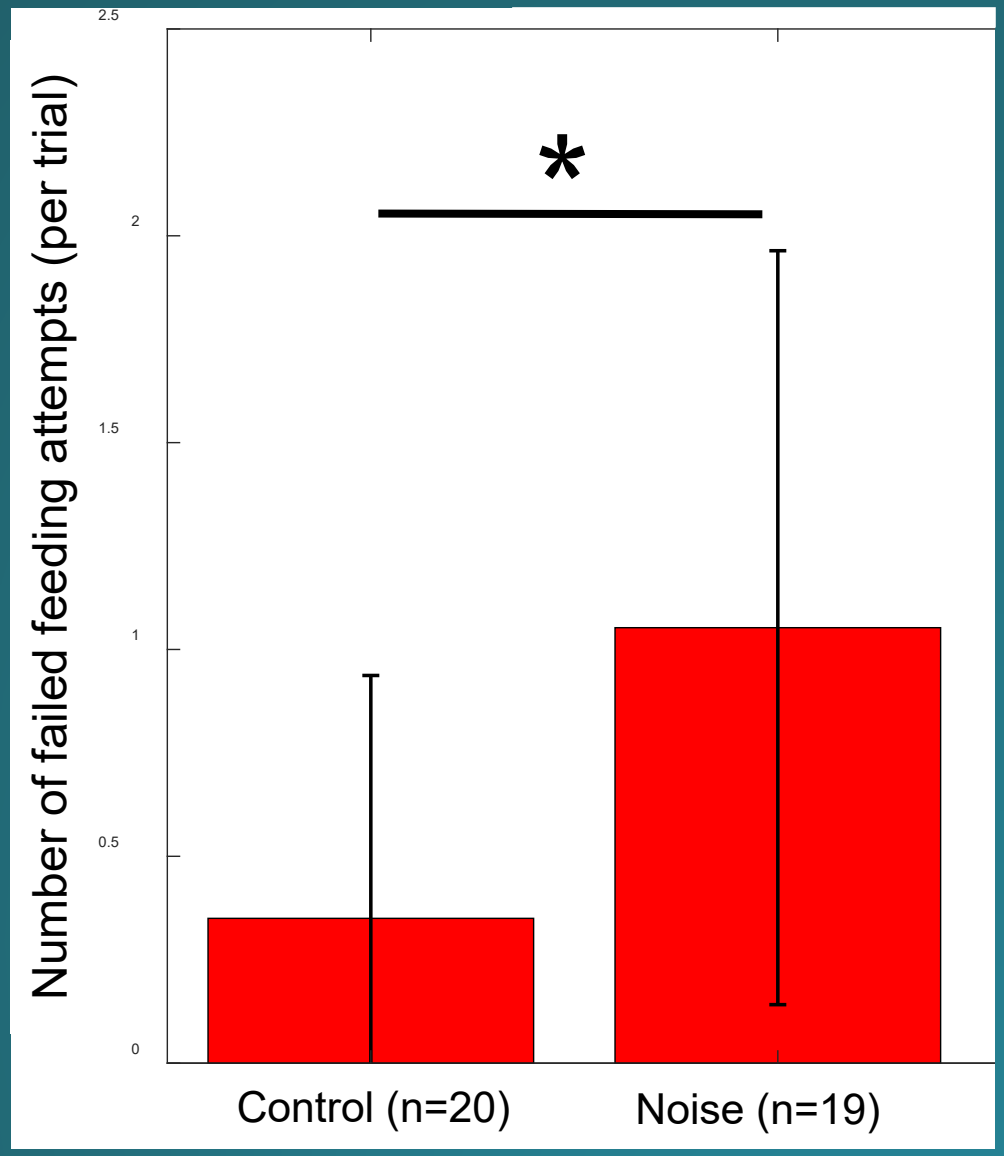

(Fitted curves: Poisson GLMs, $p < 0.05$ for all models)

Jones, I. T., Stanley, J. A., Mooney, T. A. (2020). *Marine Pollution Bulletin*

# Distraction from feeding

Jones, I. T., Peyla, J. F., Clark, H., Song, Z., Stanley, J. A., Mooney, T. A. (2021). *Marine Environmental Research*

# Failed Predation Attempts:




- Increase in number of failed predation attempts if pile driving started during squids' pursuit of prey

Mann-Whitney U test, *$p < 0.01$

Jones, I. T., Peyla, J. F., Clark, H., Song, Z., Stanley, J. A., Mooney, T. A. (2021). *Marine Environmental Research*

# Squid reproductive dynamics

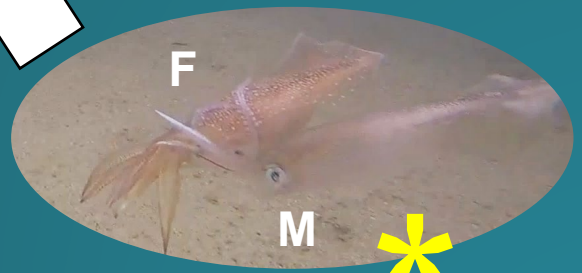

Eggs on substrate


Males attracted to eggs

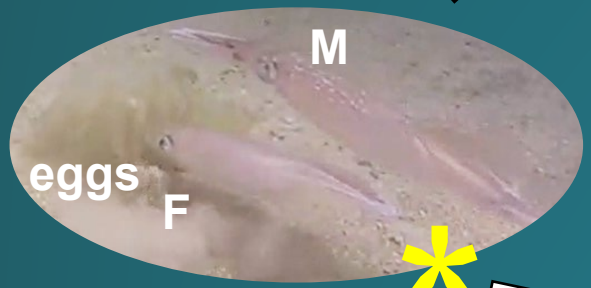
**'Start'**


Fighting behaviors between males (chases, lunges)


Mating guarding



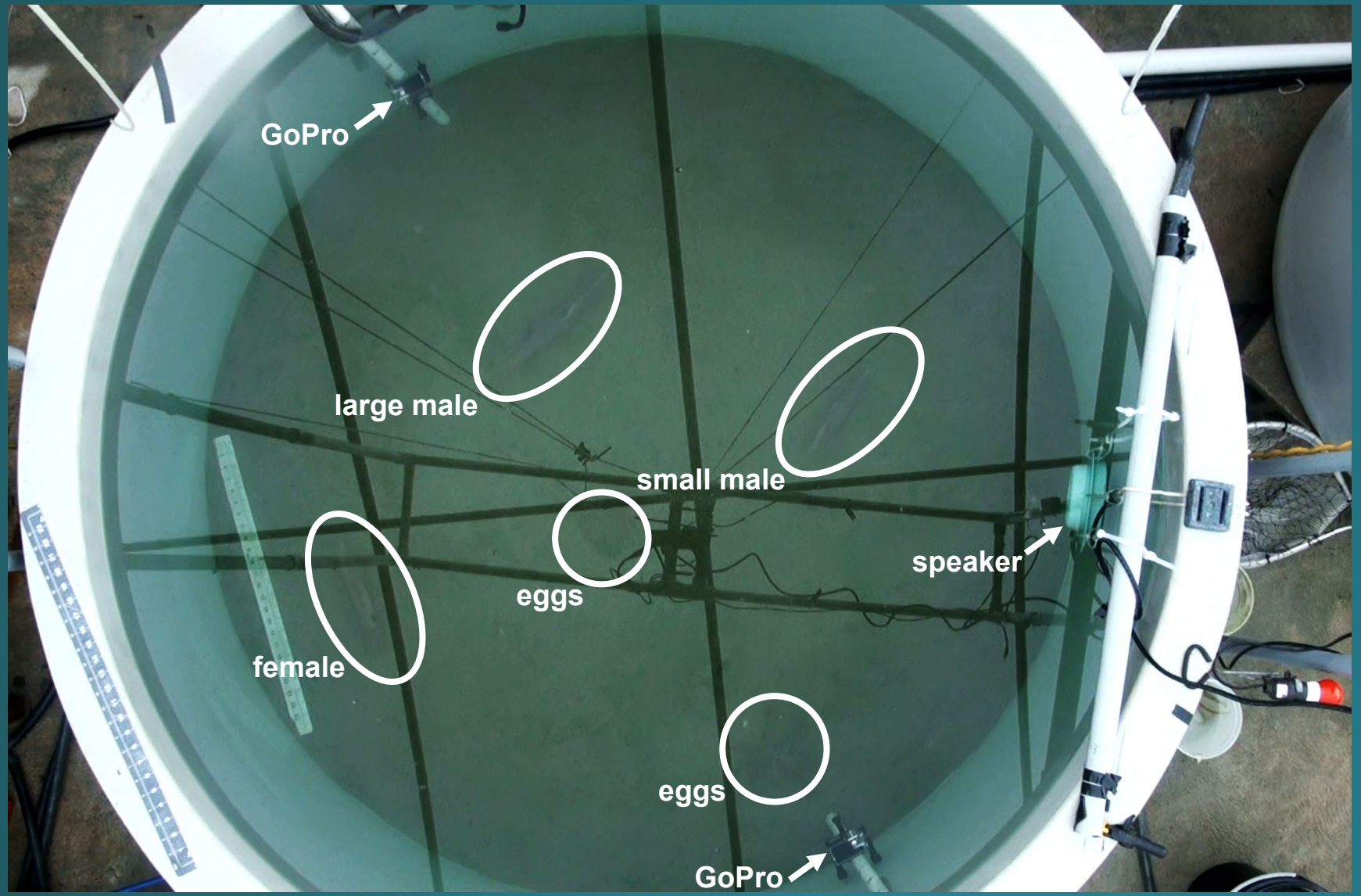

Mating




Egg laying after mating

*quantified behaviors

# Experimental Setup




Cameras:

- Top-down
- Underwater

Speaker played either:

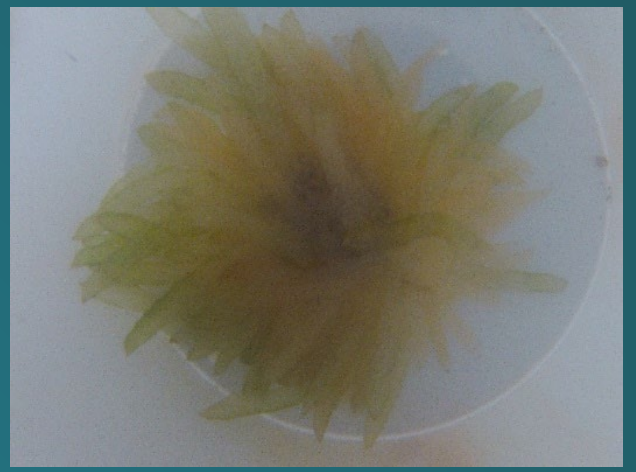
- Pile driving noise
  - (recording from Block Island Wind Farm)
- "Silent" control file

Jones, I. T., Schumm, M., Stanley, J. A., Hanlon, R.T., Mooney, T. A.. ICES J of Marine Sciencedoi: 10.1093/icesjms/fsad117

# Squid Reproductive Behaviors: Methods

- 30 trials analyzed:
  - 15 noise, 15 control
- **5-min** long audio playback periods
- → **10 min silence**
- **3 playback** periods per trial
- Playback in tank simulated **particle acceleration** amplitudes recorded in field 0.5 km from pile driving

Madison Schumm (SSF)



Squid egg cluster

**1st** audio playback, (5 min duration) → ≥ 10 min quiet → **2nd** audio playback, (5 min duration) → ≥ 10 min quiet → **3rd** audio playback, (5 min duration)

Mate guarding

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# Sustained mating during noise

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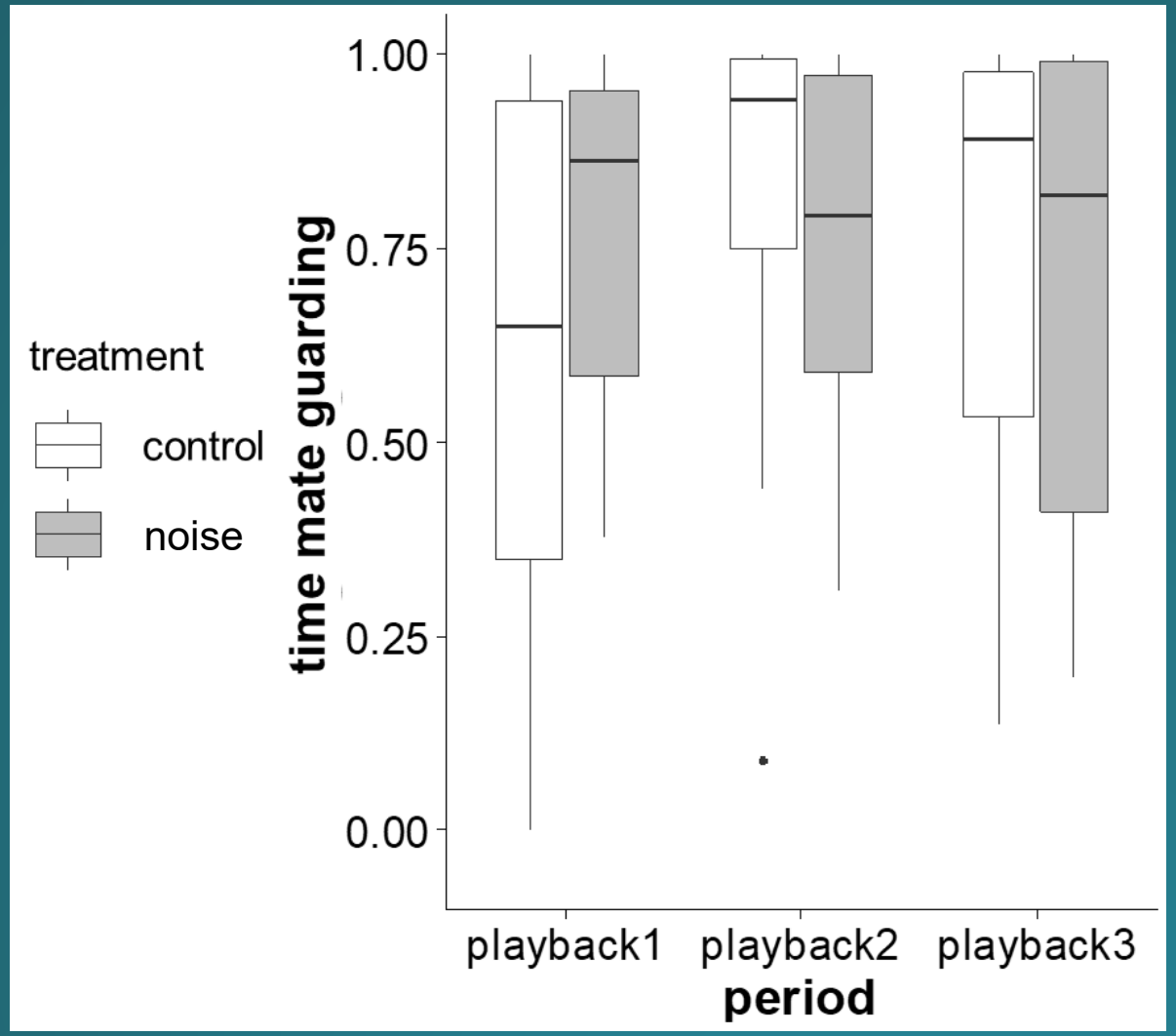
# Resilience of mate guarding to noise




- No significant effect of noise

Beta GLMM (Large Males only):
treatment: p = 0.35

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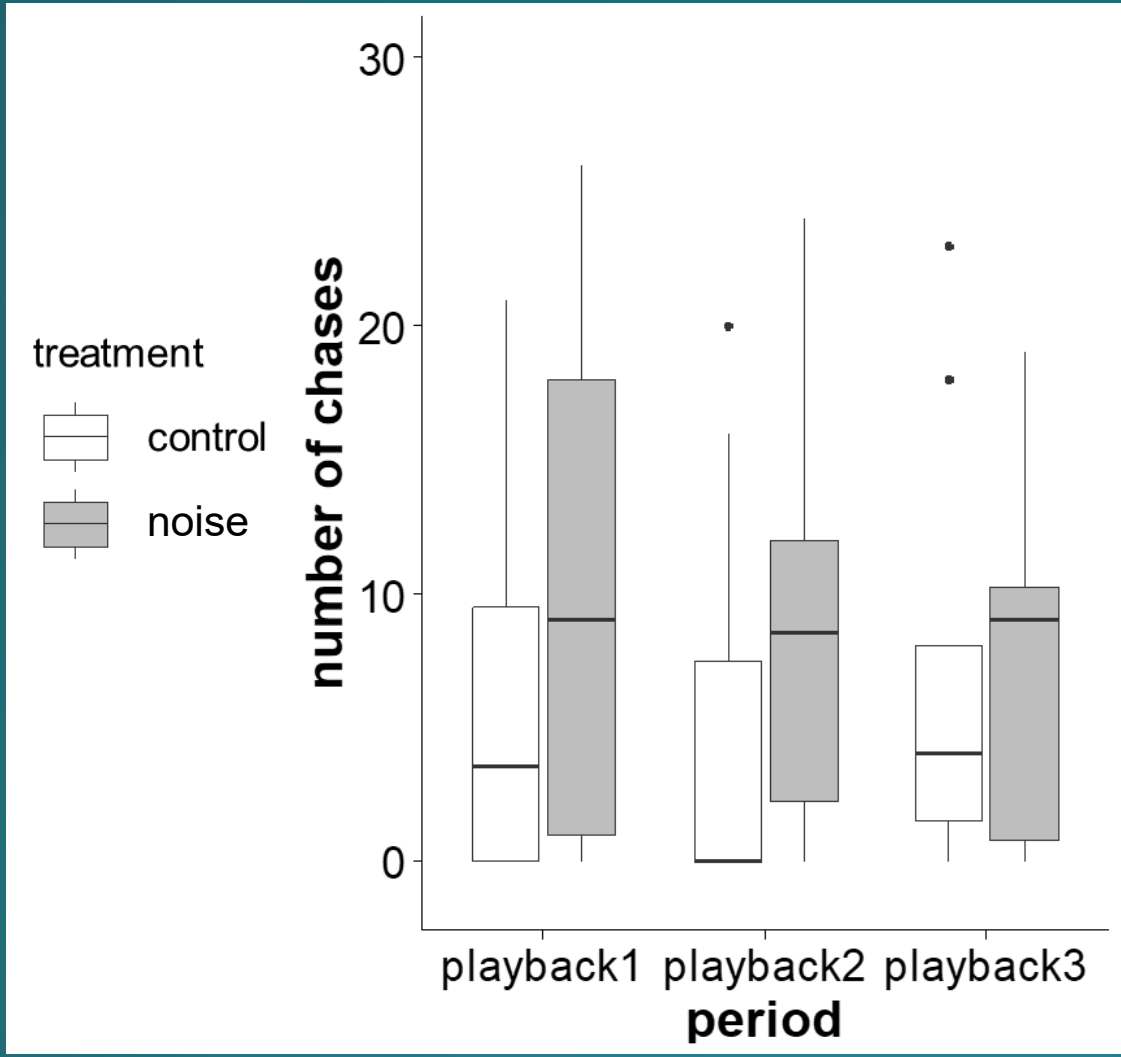
# Resilience of fighting behaviors to noise:




- No significant effect of noise

Negative binomial GLMMs:
treatment: p= 0.17

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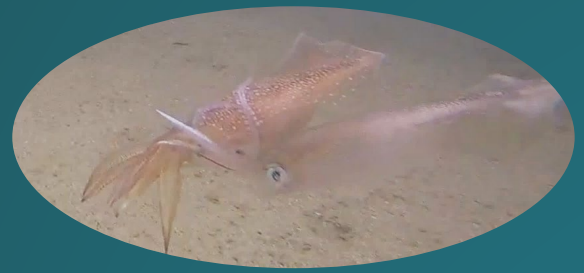
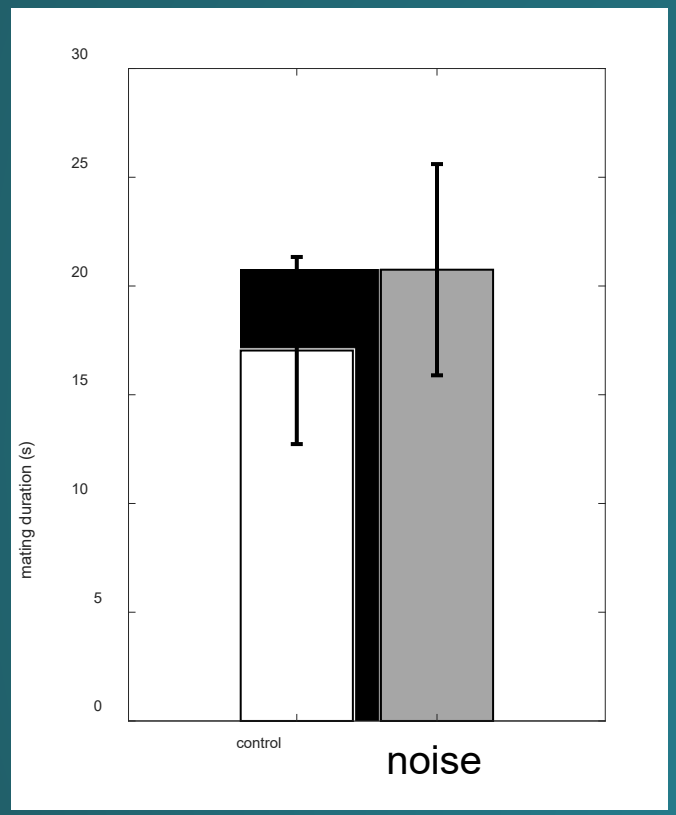
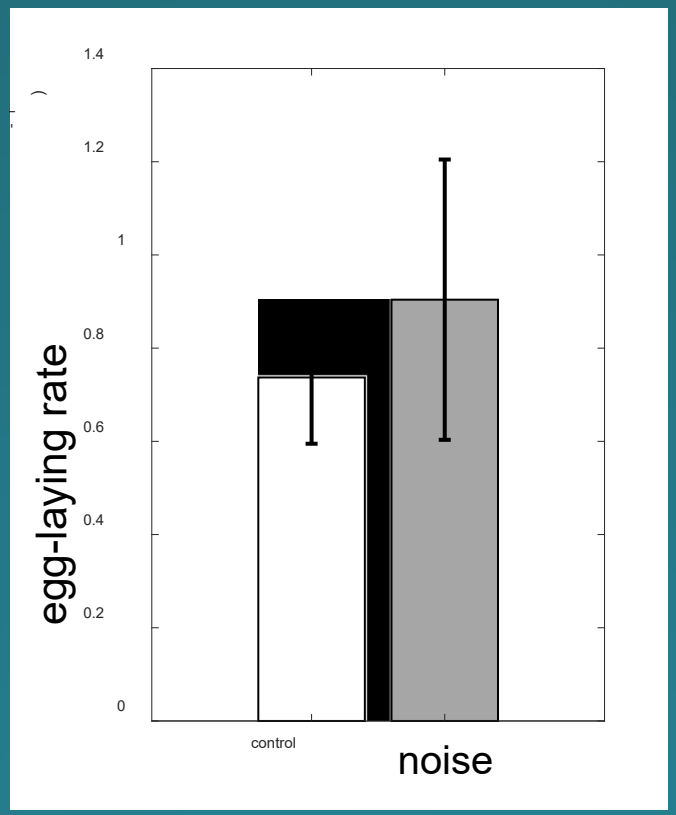
# Persistence of mating and egg laying






- Mating observed in 30% of trials (5 control, 4 noise)
- No significant differences between noise and controls trials of:
  - Duration of mating events
    - (p = 0.10, MWU)
  - Frequency of egg laying
    - (p = 0.41, MWU)

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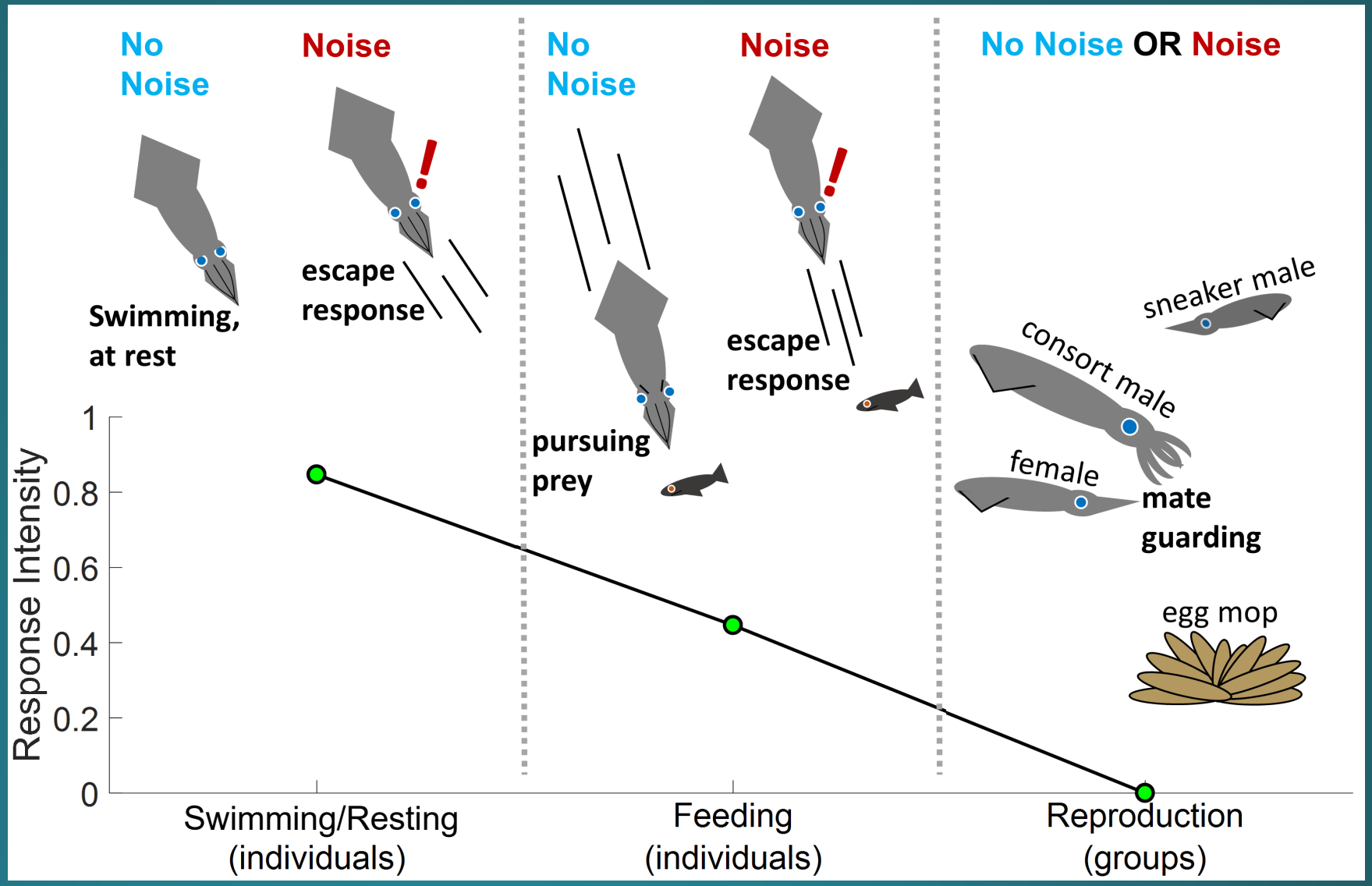
# Response intensity to noise is context-dependent

Significant response behaviors:

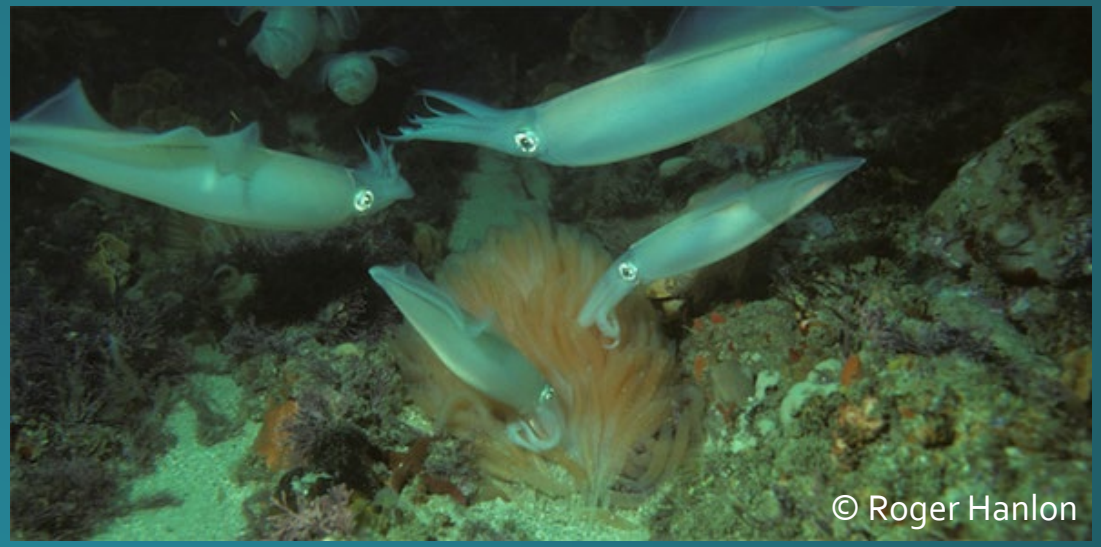
- **Resting: alarm behaviors**
- **Feeding: failed predation attempts**
- Reproduction: none

Pile driving schedules and regulations can mitigate noise effects on invertebrates by considering behavioral context

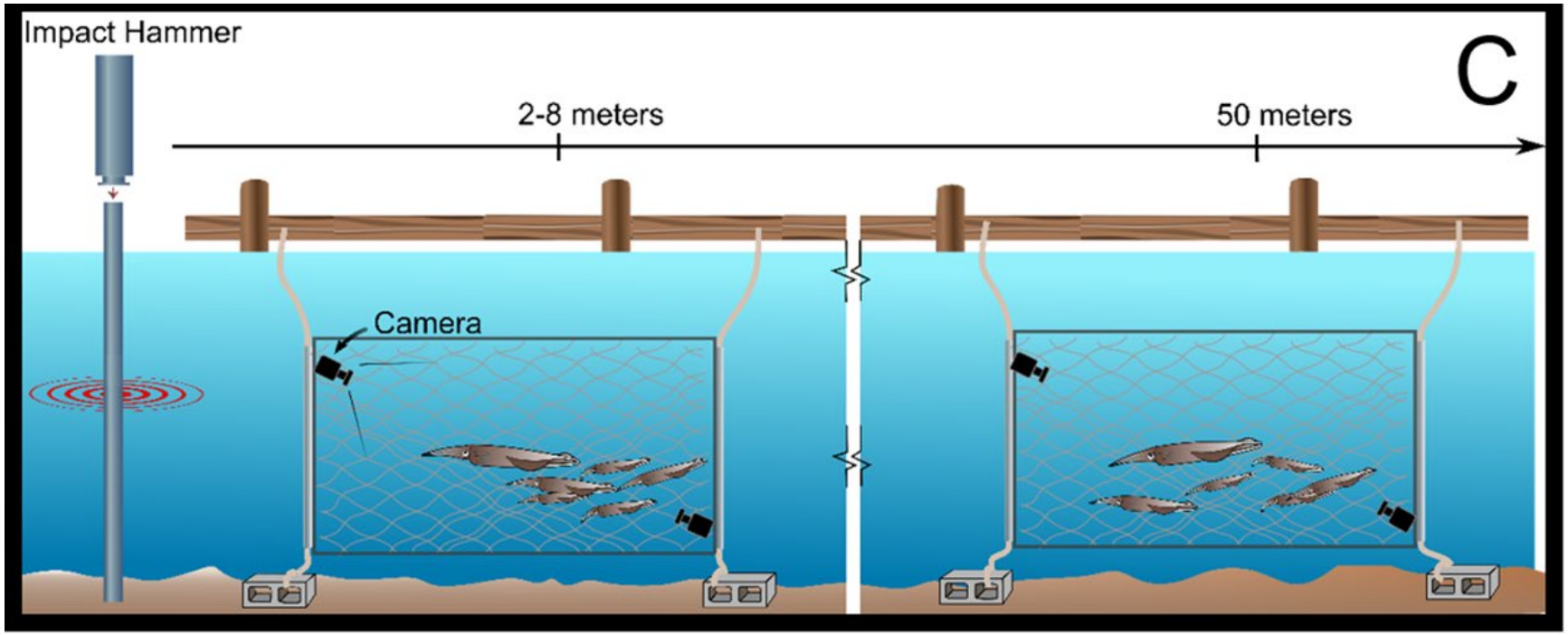


# Why are squid reproductive behaviors resilient to noise?

- *D. pealeii* have short lifespan (< 1 yr) & are semelparous, having limited opportunity to reproduce.
  - High motivation to reproduce even during environmental stressors



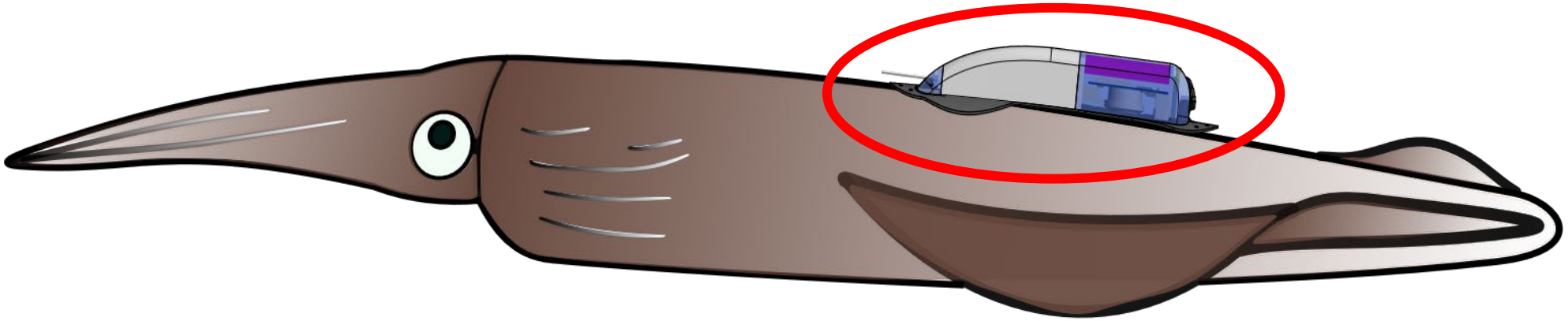
# What about to actual pile driving?




Questions:

1) **Are responses the same in this field-setting?**
2) **Are responses energetically costly?**
3) **Does pile driving disrupt schooling?**
4) Does the loud noise induce hearing loss?

# Individual squid behavior via a biologging tag

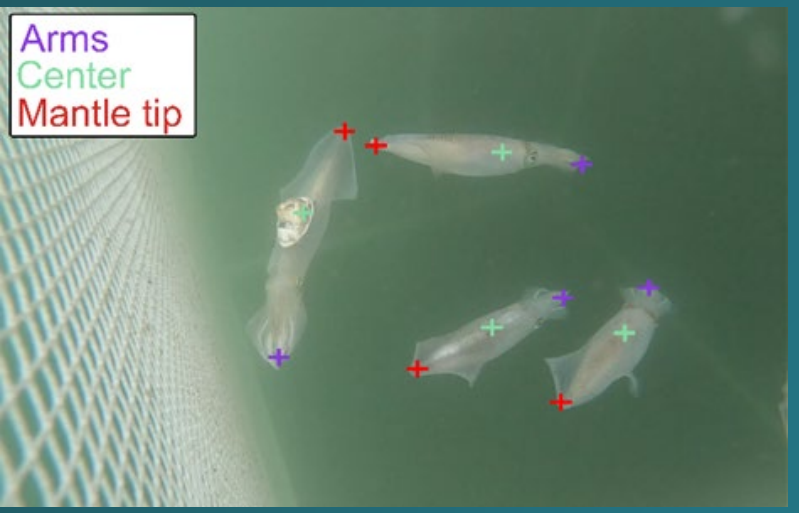


**Swimming kinematics from sub-second to daily time scales**

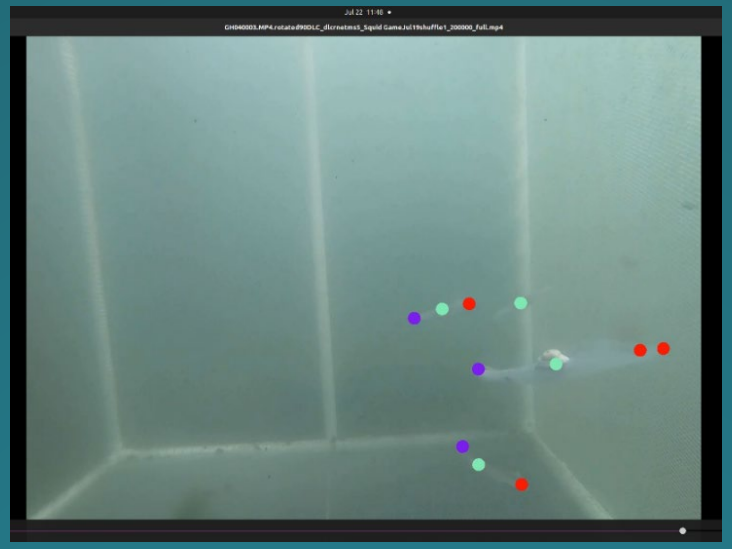
# Impacts of pile driving on schooling squid

## Using machine learning to track (1) area of school and (2) orientation of animal

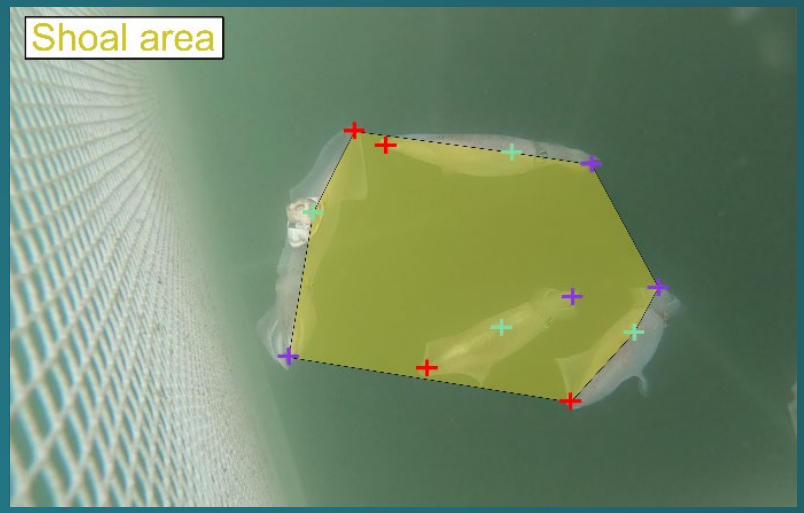
1) Labeled subset of videos



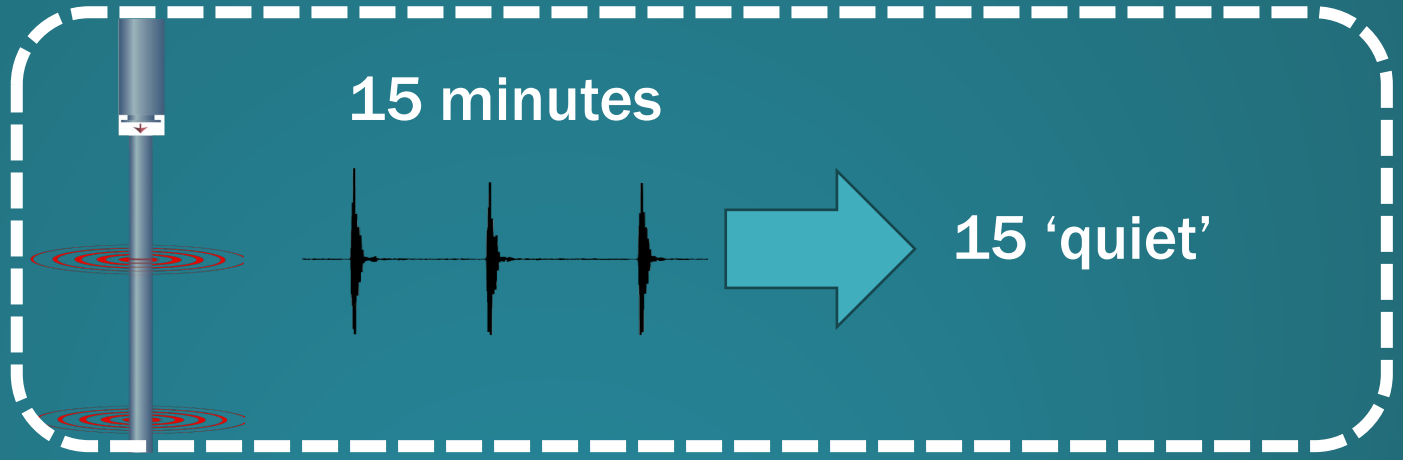

2) Trained a tracking model

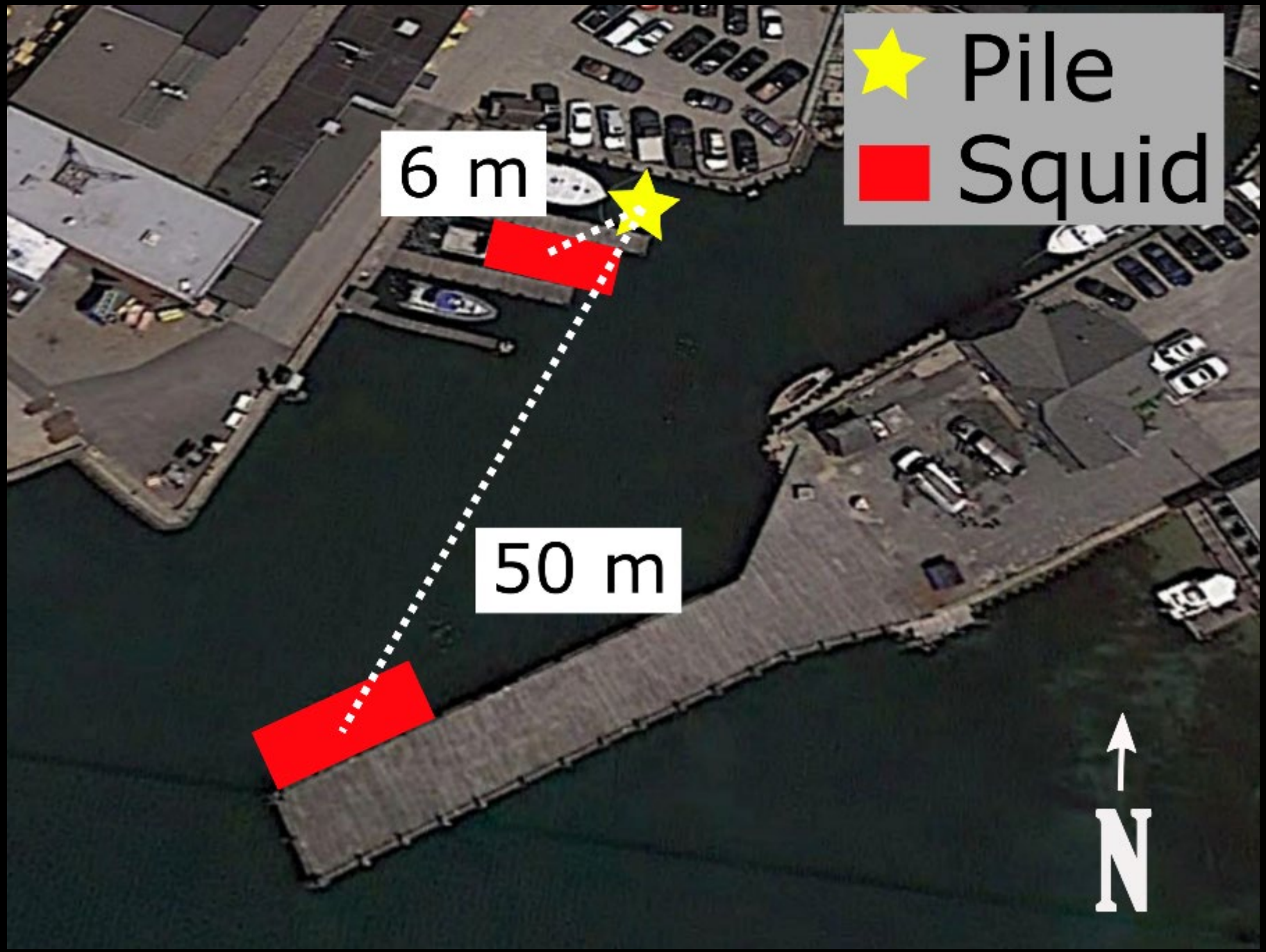


3) 2D convex polygon around squid school




Repeated 5x
IH1-5



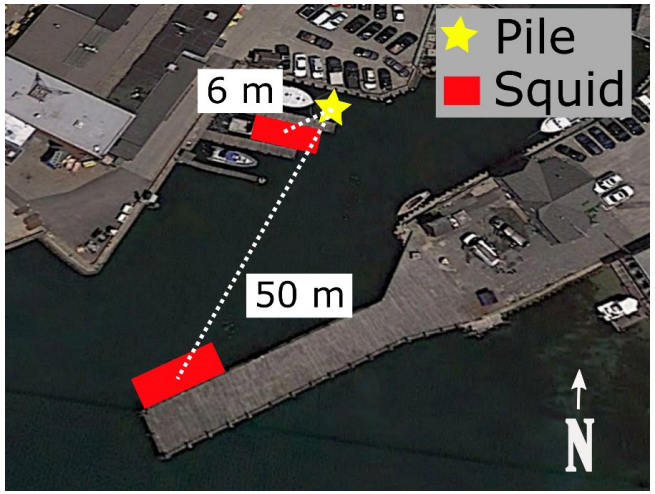

Pile
Squid
6 m
50 m
N

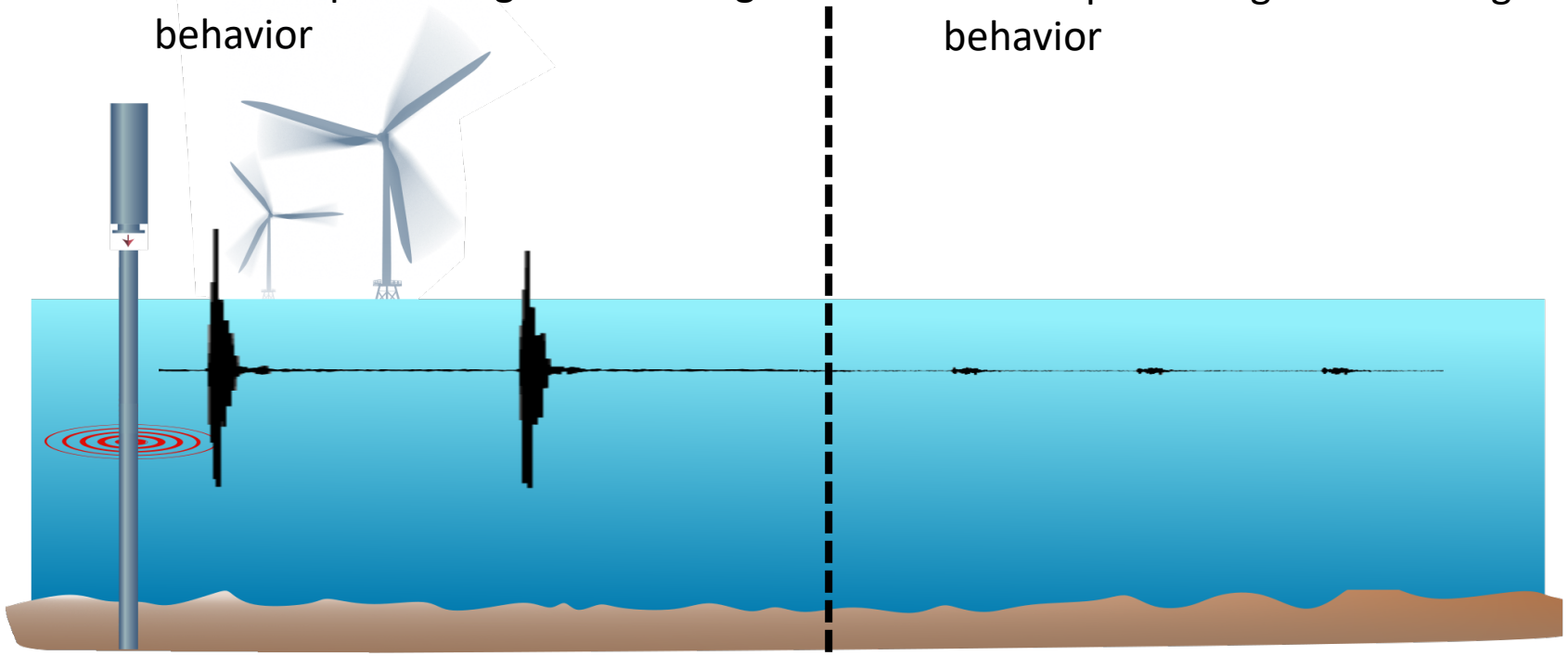
## Near Site

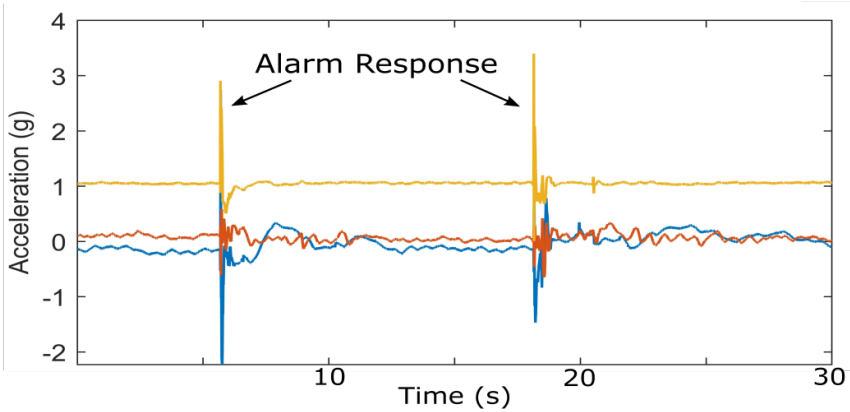
- 112 – 123 dB re 1 µm $s^{-2}$ peak-to-peak (~1 km distance)
- 69 % of squid changed swimming behavior

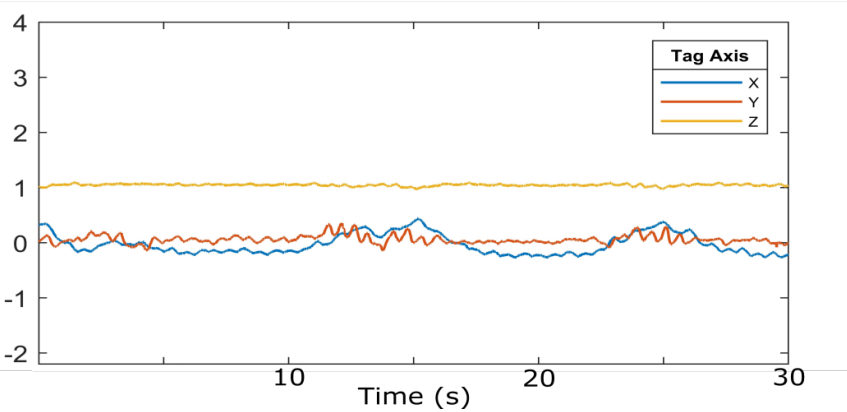
## Far Site

- 96 dB re 1 µm $s^{-2}$ peak-to-peak (2-3 km distance)
- 0% of squid changed swimming behavior

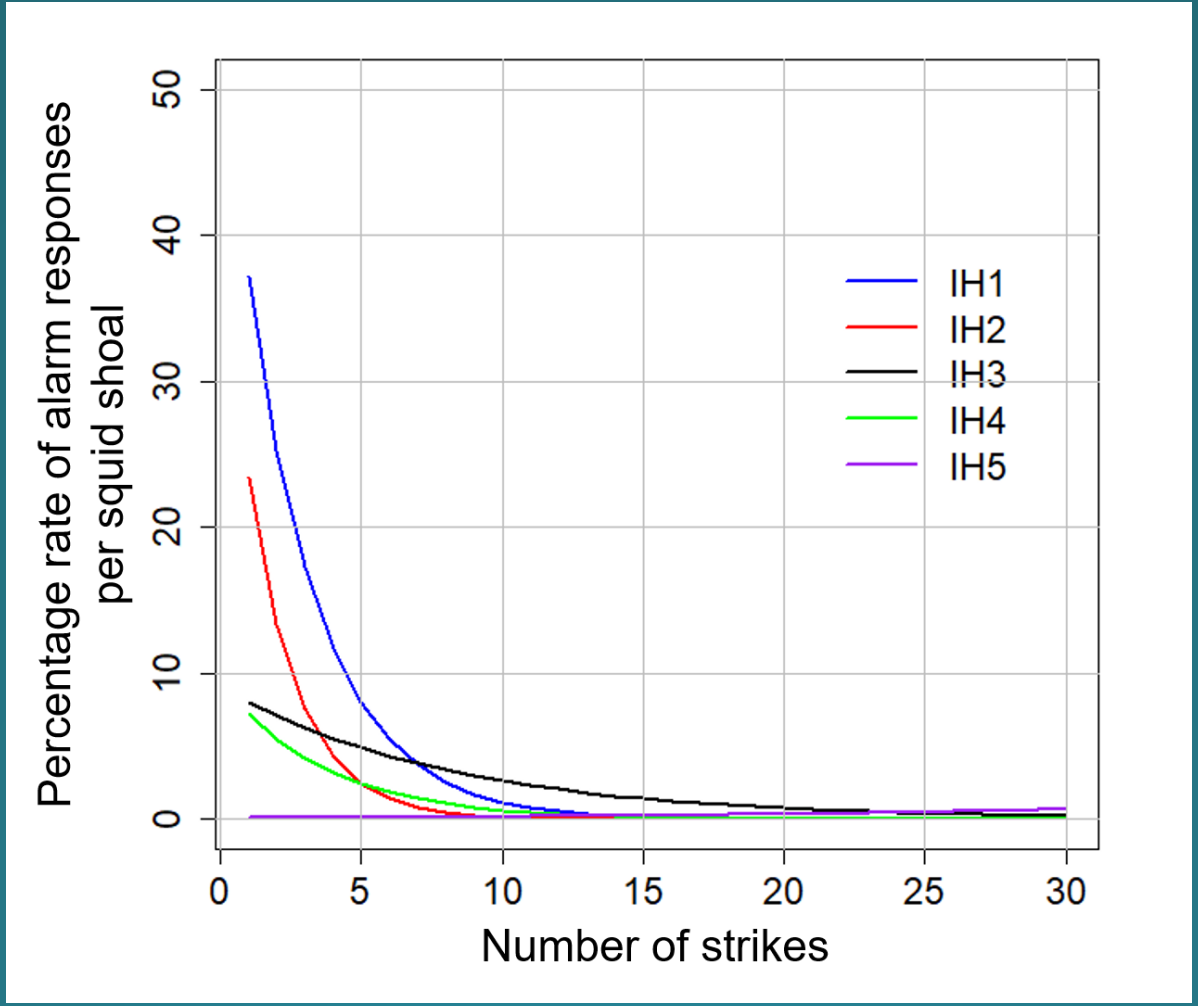


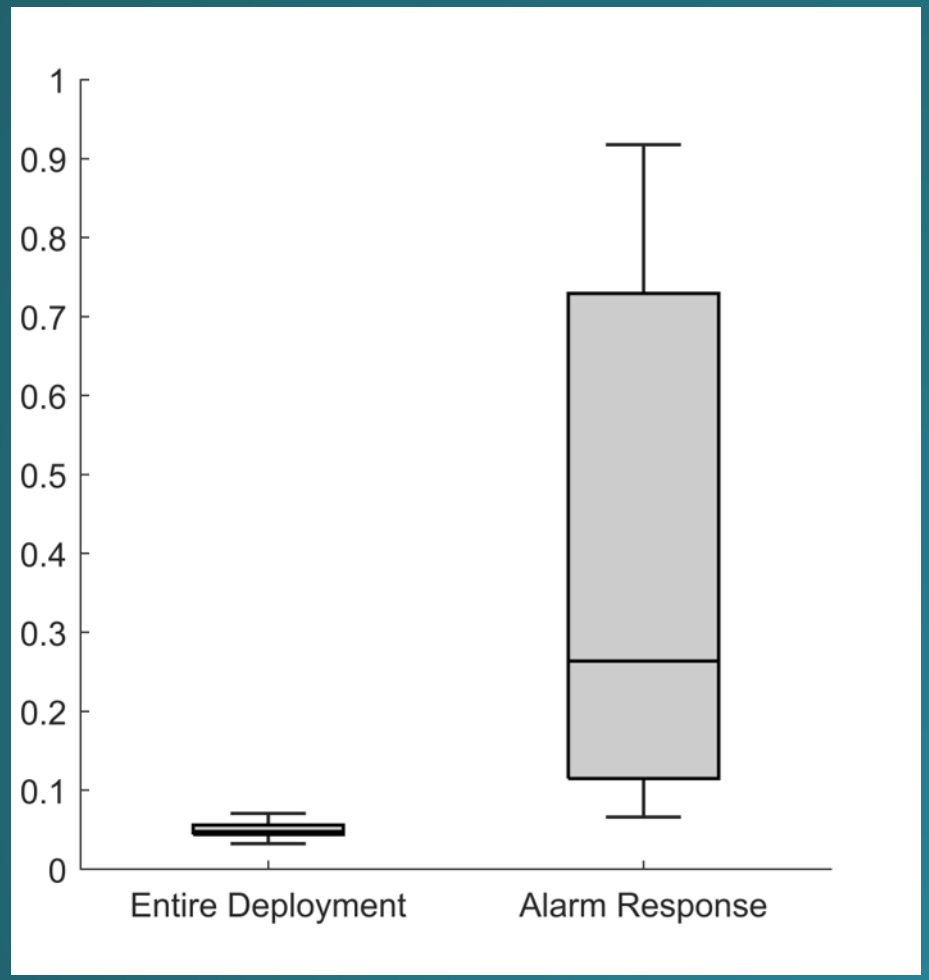


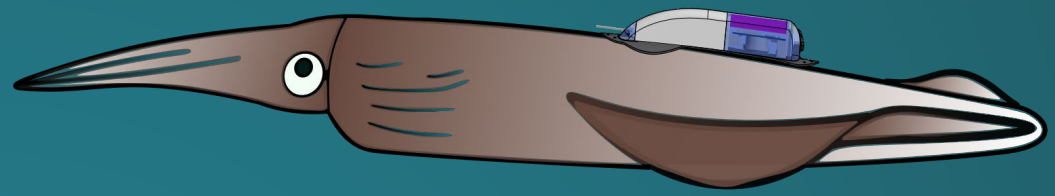



# Alarm responses rates of field squid decreases similarly to 'laboratory' data



# Short term alarm responses do increase energy usage

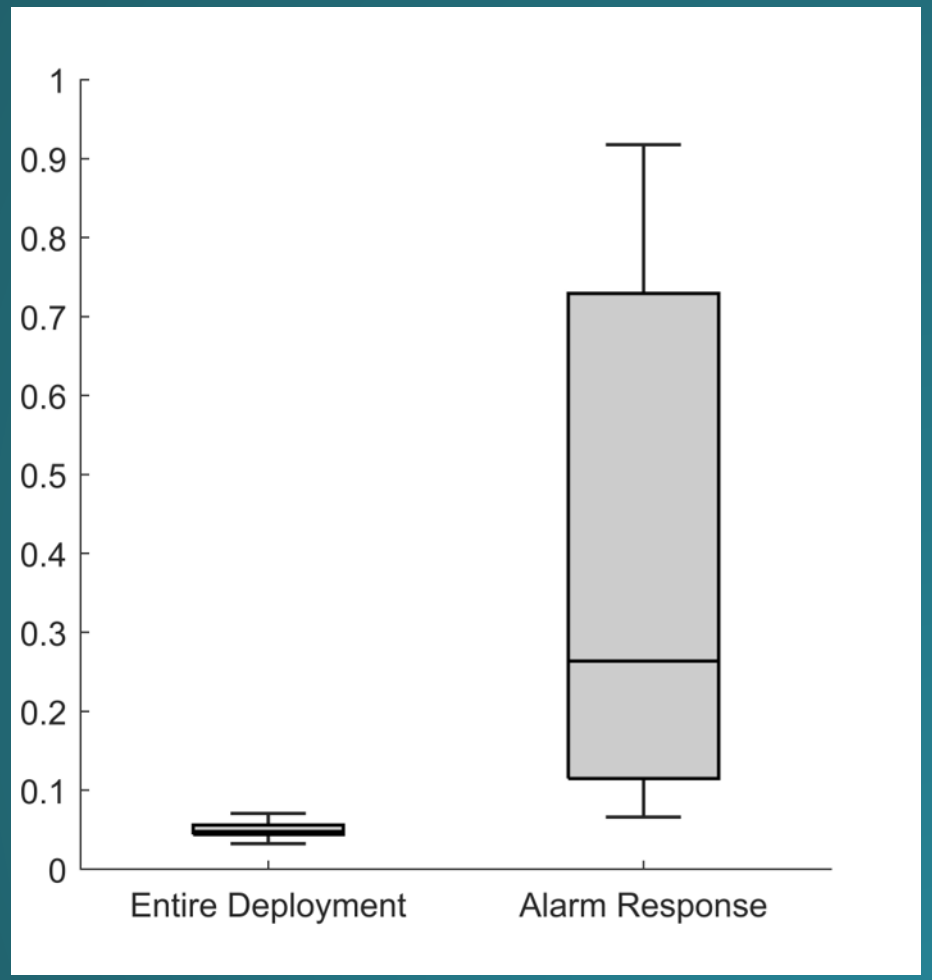


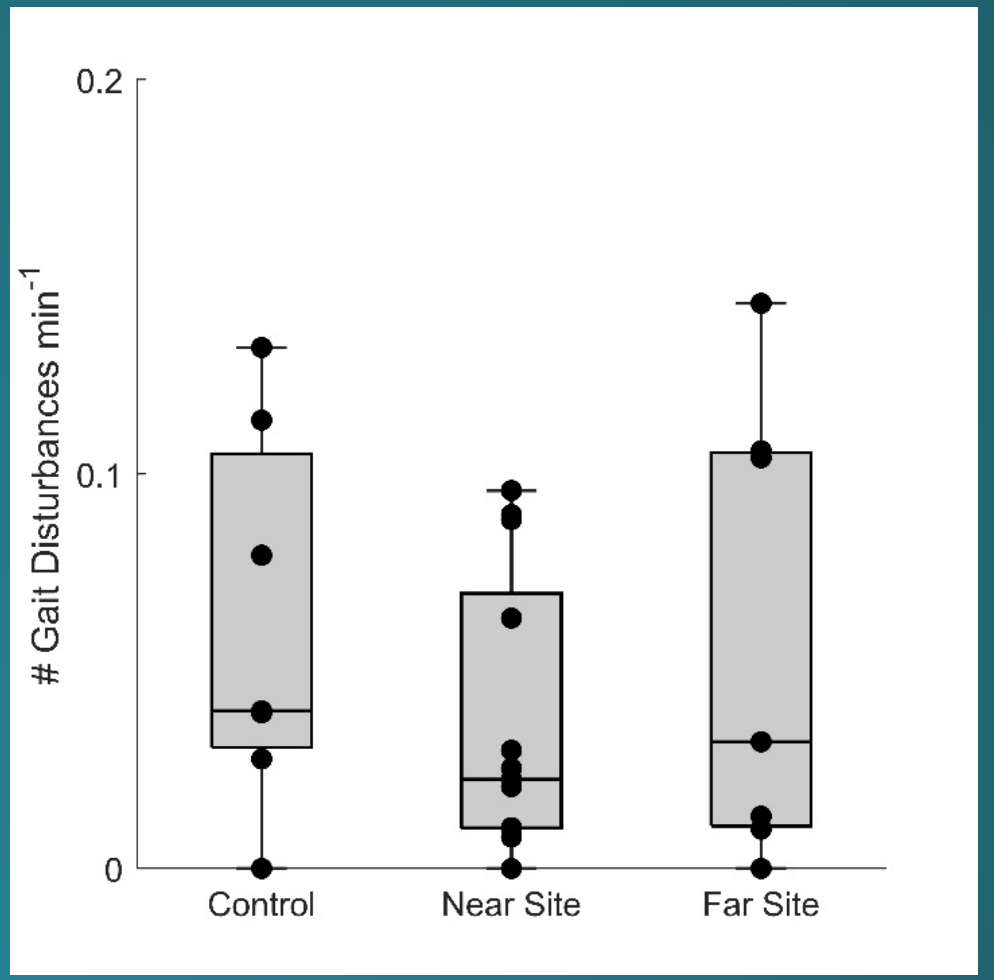



32 squid tagged during noise exposures (20 noise, 12 control)
1101 min of kinematic were collected during IH

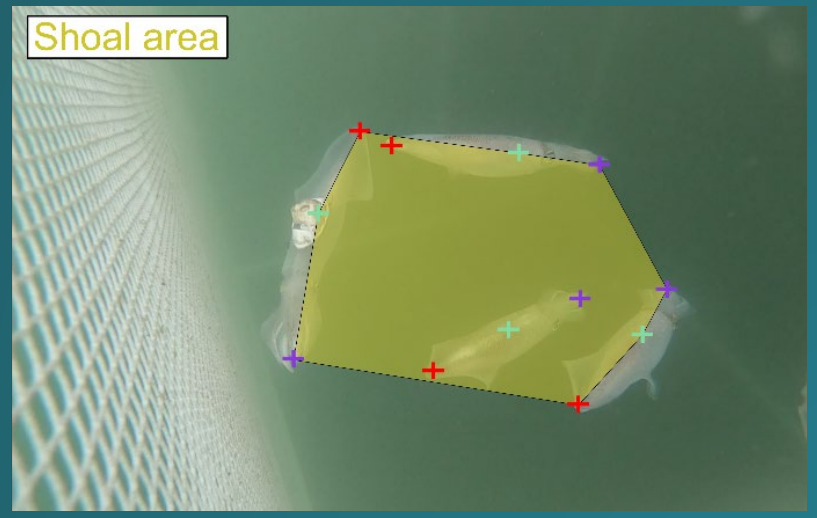
# …But rate of gait disturbances was similar to no sound control (and far site)

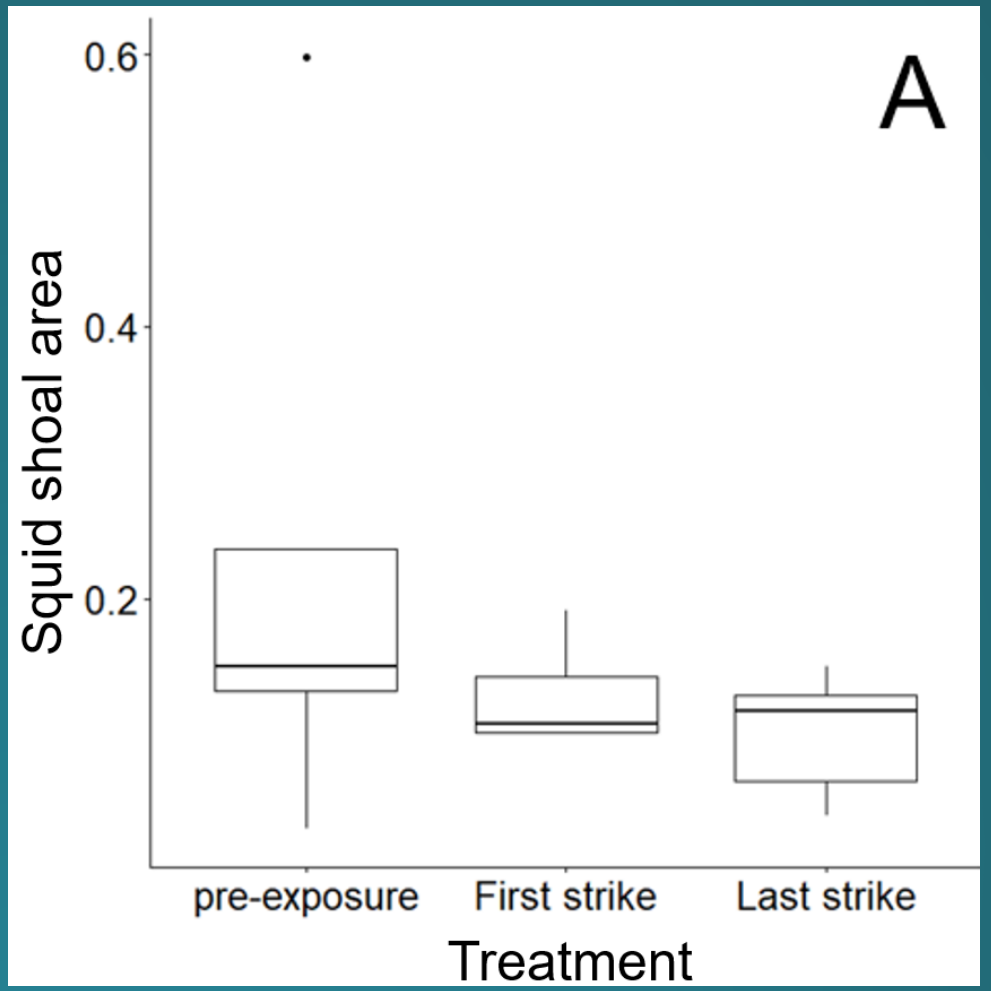
Rate of PD 'disturbance' was not unnaturally high



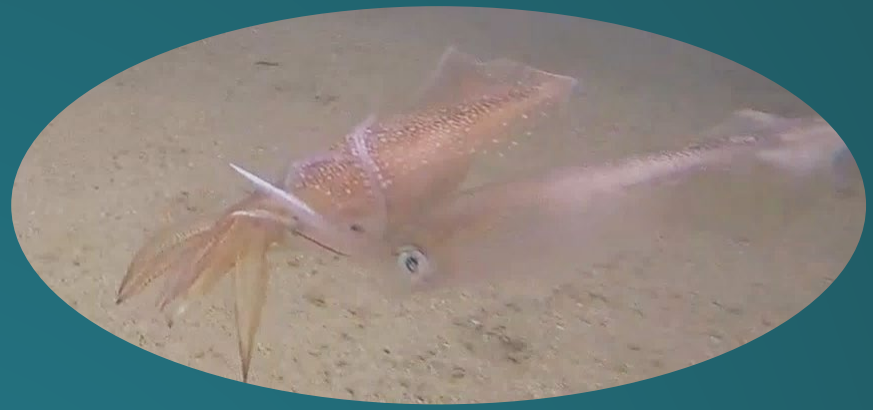
# School area **does not change** significantly during pile driving



# Summary

- Context is key
- Some dramatic responses….
- Squid generally resilient to pile driving noise




Block Island Wind Farm

Field Team:
Madison Schumm
Sierra Jarriel
Nadege Aoki
Nathan Formel
Jenni Stanley
Kelsey Chenoweth
Prajna

Construction Crew:
The Schultz Company

WHOI Facilities:
Kerry Strom
Rick Galat

WHOI Dive Office:
Ed O'Brien
Kim Malkoski

Squid: Marine Biological Laboratory


Woods Hole Oceanographic Institution

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# In-situ Approach to Characterize Effects of Pile Driving on the Presence and Behavior of a Commercially Important Fish Species, the Black Sea Bass (*Centropristis striata*).

Photo: Robert Michelson


Nathan Formel, Nadege Aoki, Seth Cones, Sierra Jarriel, Youenn Jézéquel, Jenni Stanley, and Aran T. Mooney

Email: nathan.formel@whoi.edu


Photo: DEME

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https://www.tideranch.com/

# Black Sea Bass (BSB)

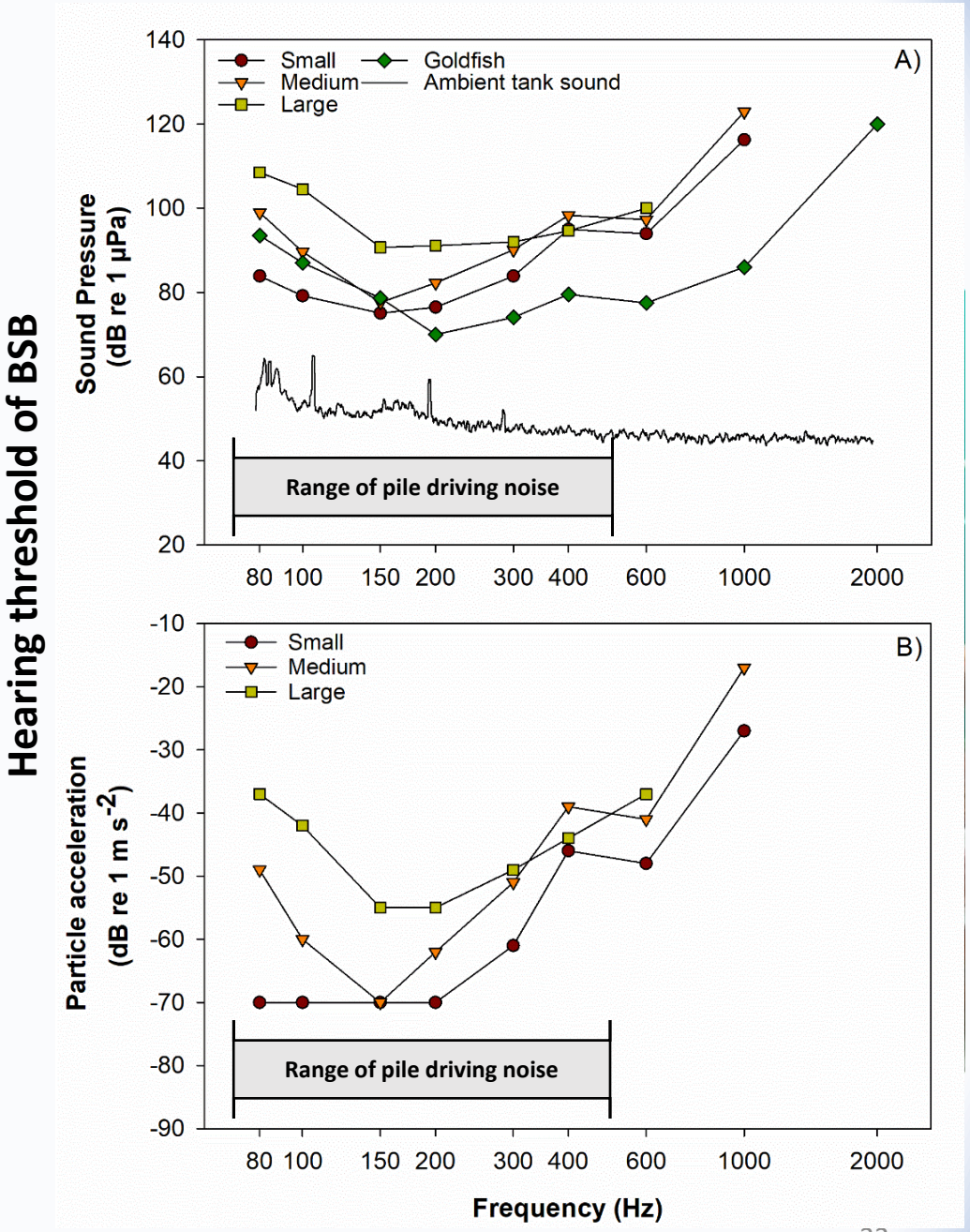
Commercially and recreationally important fish species

Hearing range overlaps with noise produced by pile driving (Stanley et al., 2020)

- Juveniles had more sensitive hearing than adults

Demonstrated behavioral responses to pile driving (PD) sounds in tanks (Stanley et al., 2023)

How do they respond to PD in situ?




Stanley et al. 2020

# Experimental overview

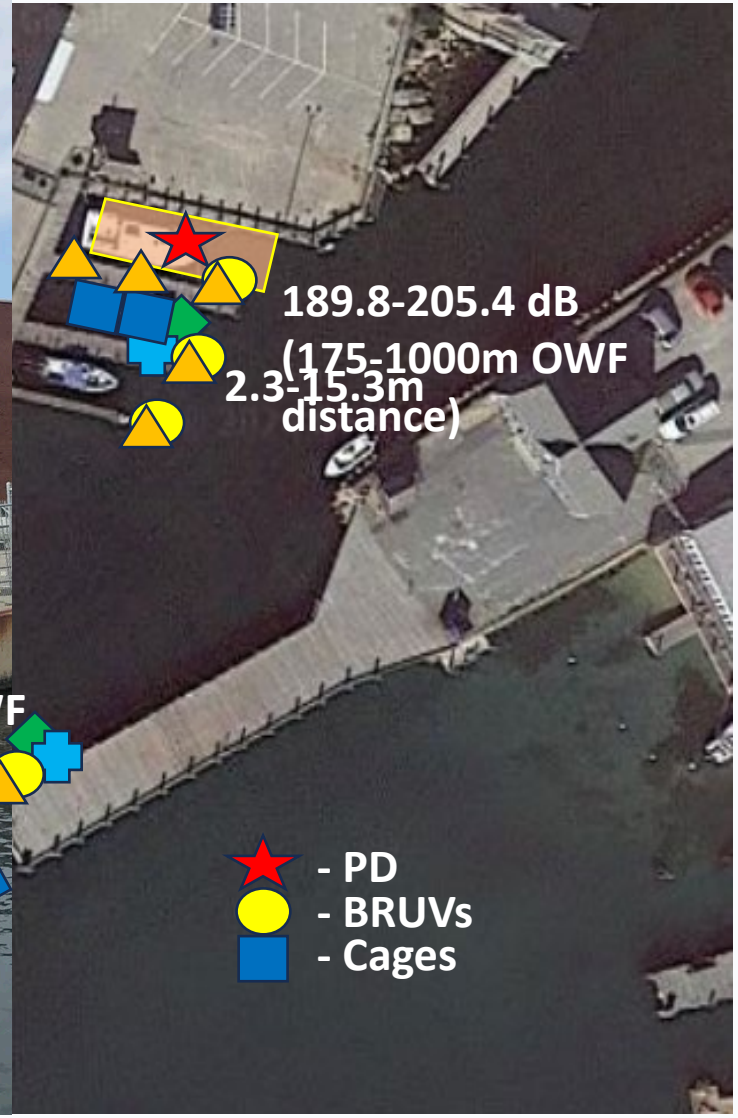
Developed a novel field experiment for actual pile driving

- Received sound levels provide a key comparison to OWF

Two approaches used to monitor BSB behavior in response to pile driving

- Baited remote underwater video (BRUV) to monitor free-ranging juvenile and adult BSB
- Video monitoring of adult BSB in-water cages

# Experimental overview






(Bailey etal 2010)

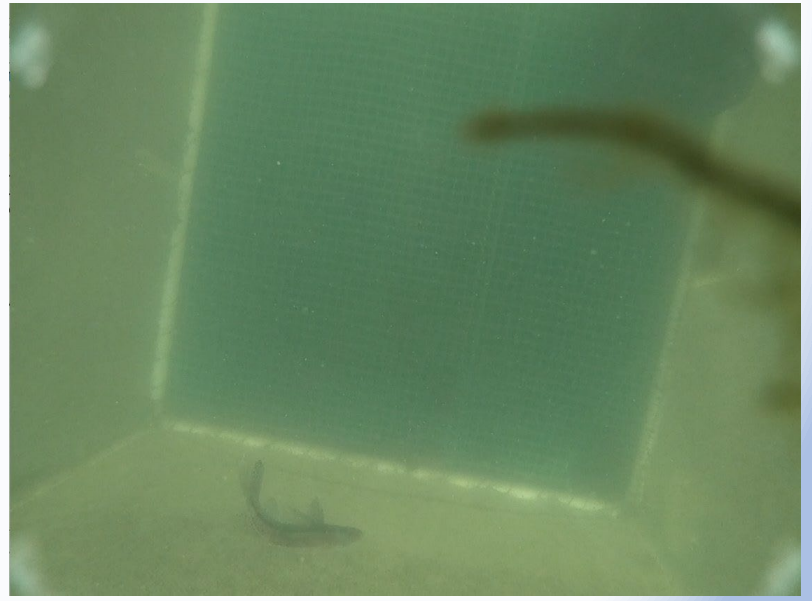
# Method for Cage Study

One day prior to pile driving, two adult BSB were placed in each of four in-water cages

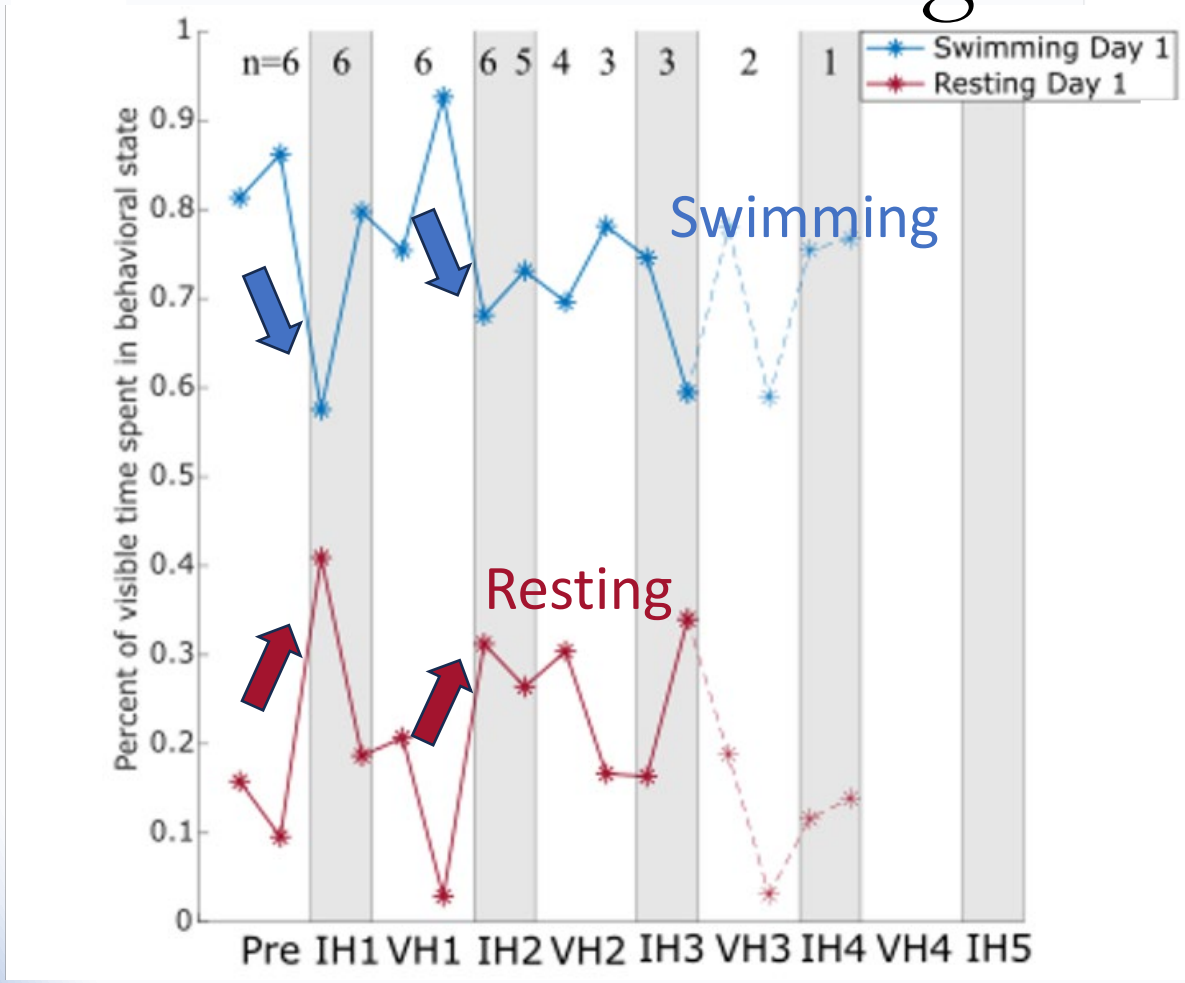
On the day of pile driving an underwater video camera was attached to the cage lid and wall to allow observation of the animals inside. Videos were collected daily.

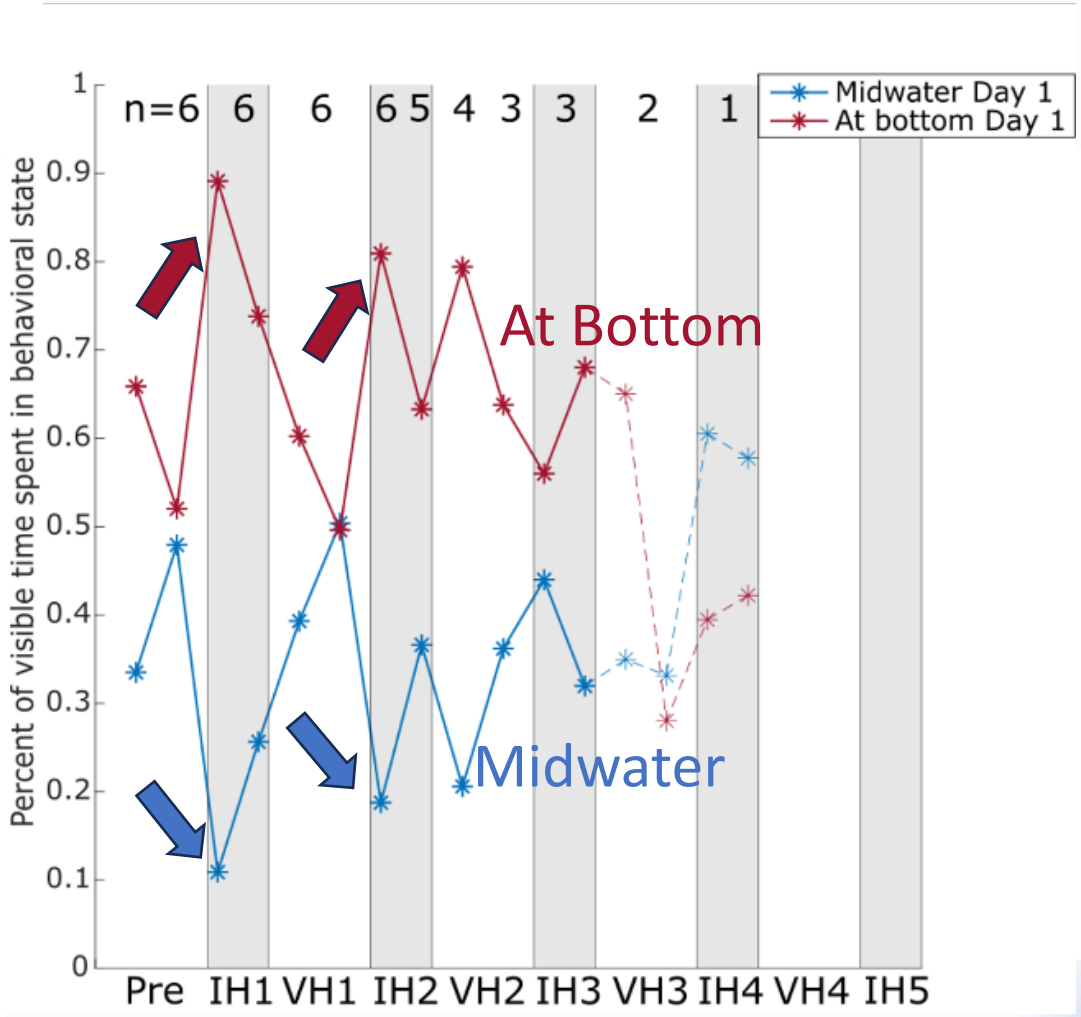
Each pair of fish were exposed to two consecutive days of PD.

Videos were manually observed and analyzed for fish behavior (swimming, hovering, resting) and position (midwater, bottom) in the cage



# Cage Study Results
# Onset of PD led to increased "sheltering" behavior in near cages



# Method for BRUV Study

Prior to pile driving four BRUVs were placed on the seafloor with average distances of 4.8m, 8.4m, 12.8m, and 54.8m from the site of the pile driving.

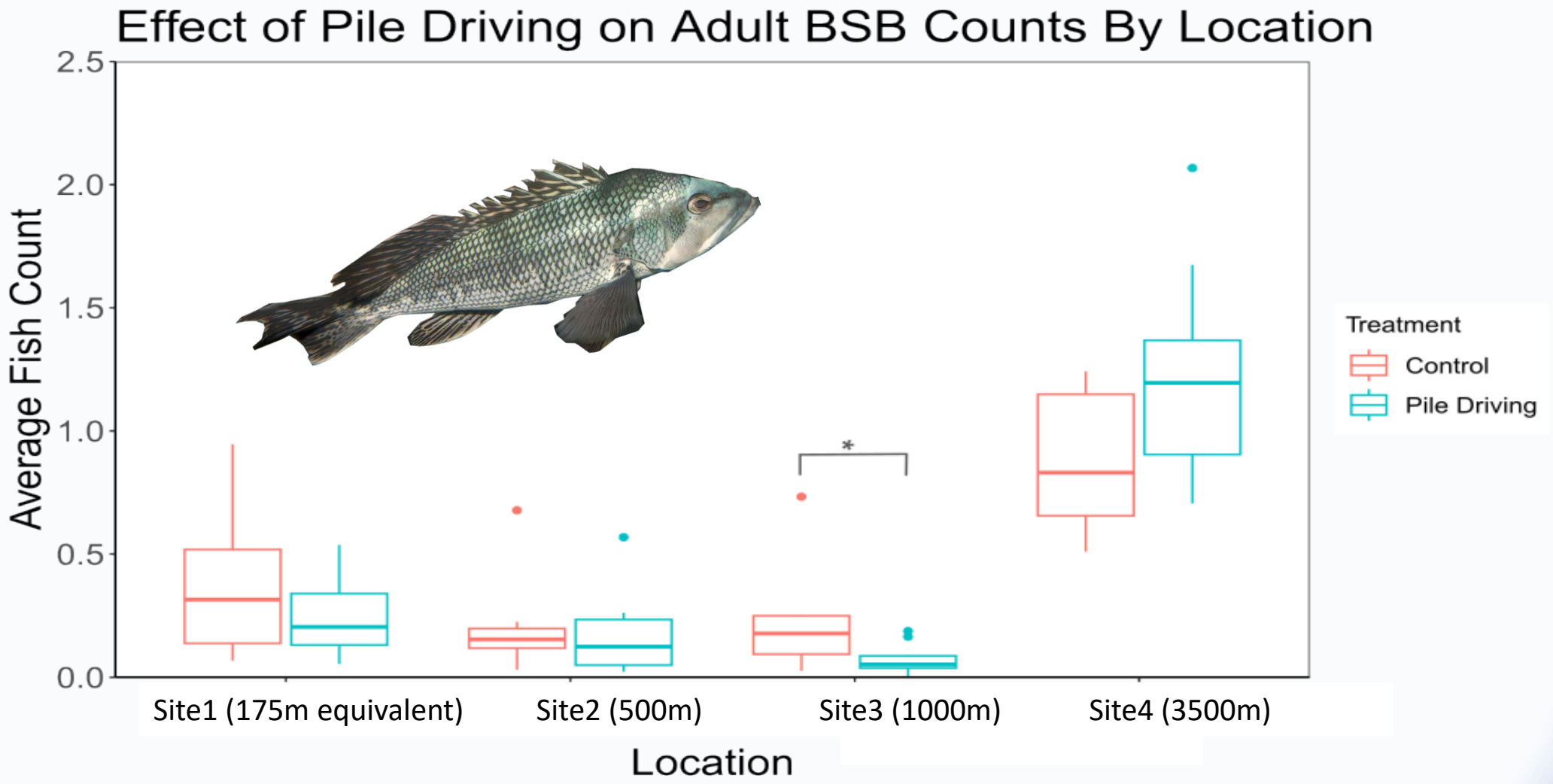
Each BRUV was baited with 0.1kg chopped squid and placed in the water 30min. prior to the beginning of pile driving.

152 videos were collected (457 hours of footage).

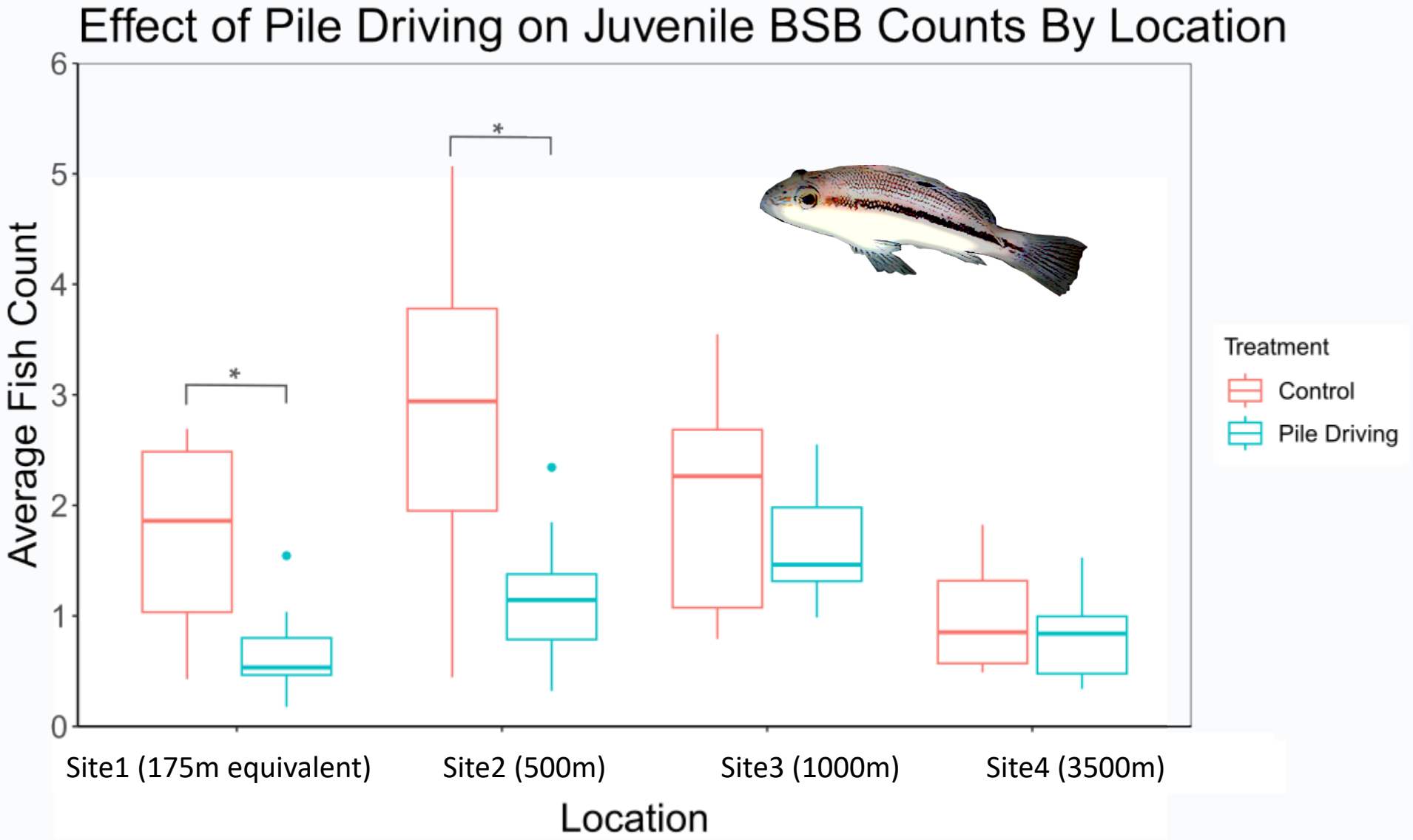
YOLO, a machine-learning real-time object detection algorithm, was trained to detect adult and juvenile BSB

Detections were tabulated resulting in continuous fish counts

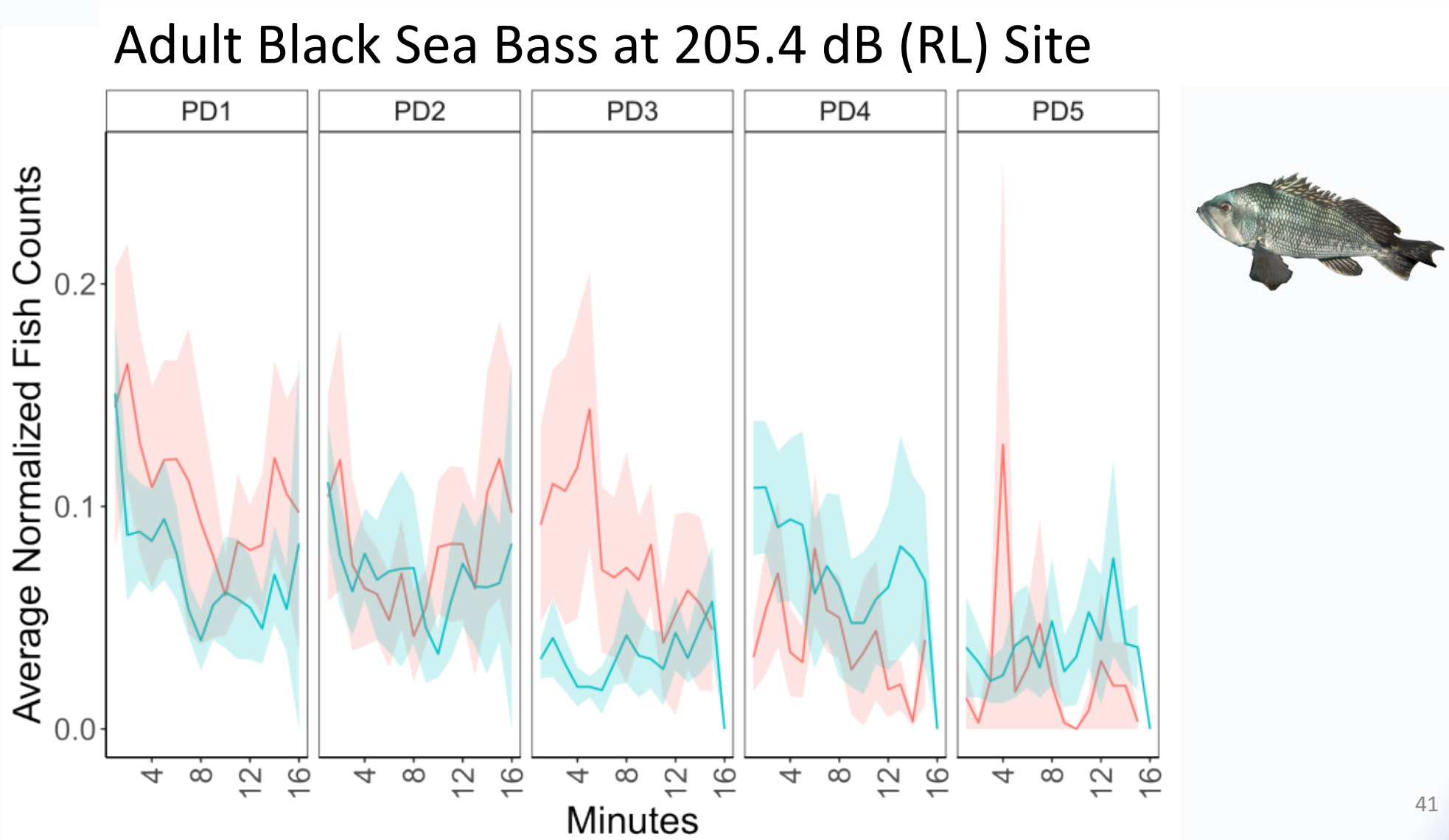
# Distance/received level: No substantial effects of PD for adults



# Distance/received level: Reduced juvenile counts at closest sites

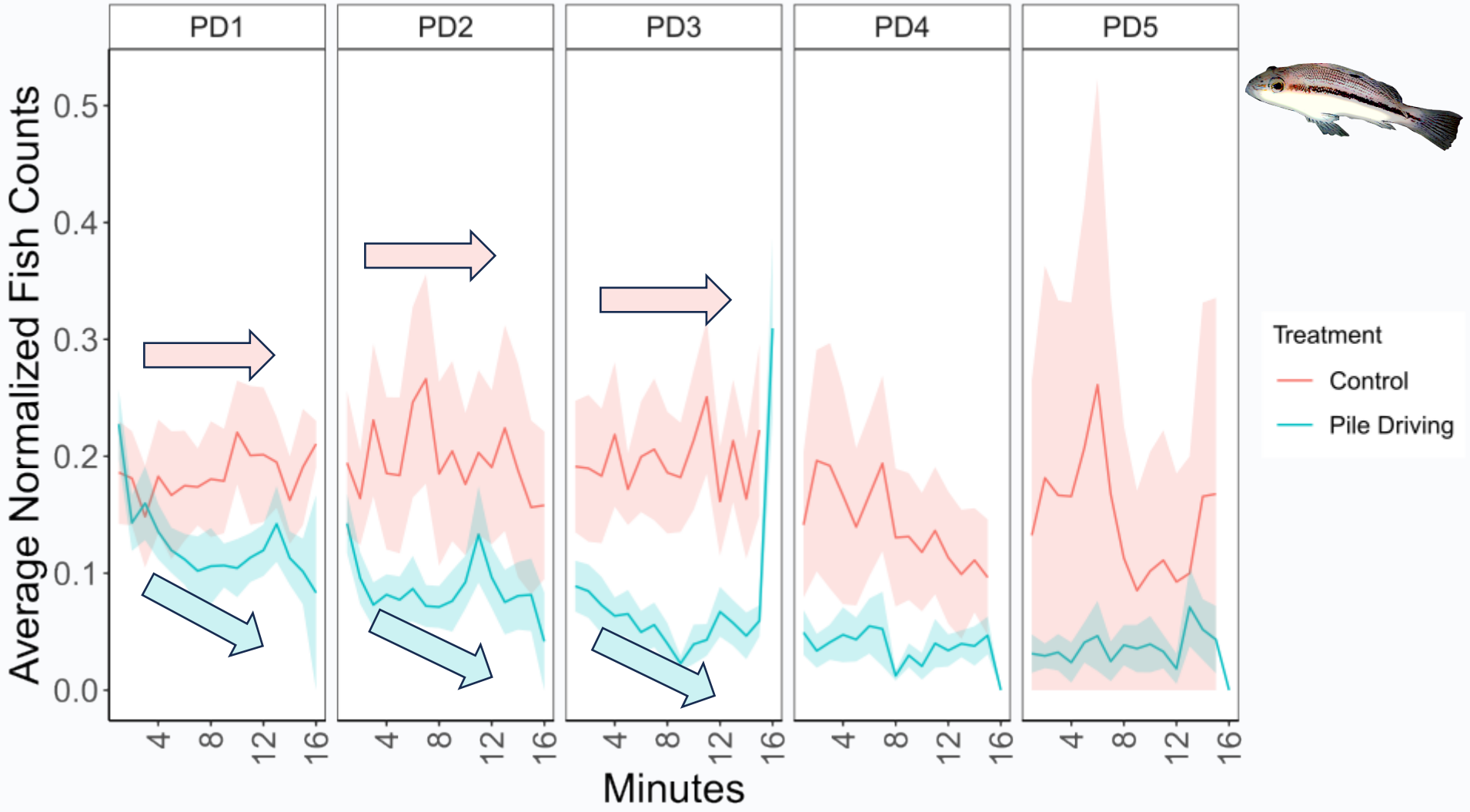


# Fish Counts Across Consecutive Pile Driving Events
# No effect for Adult BSB

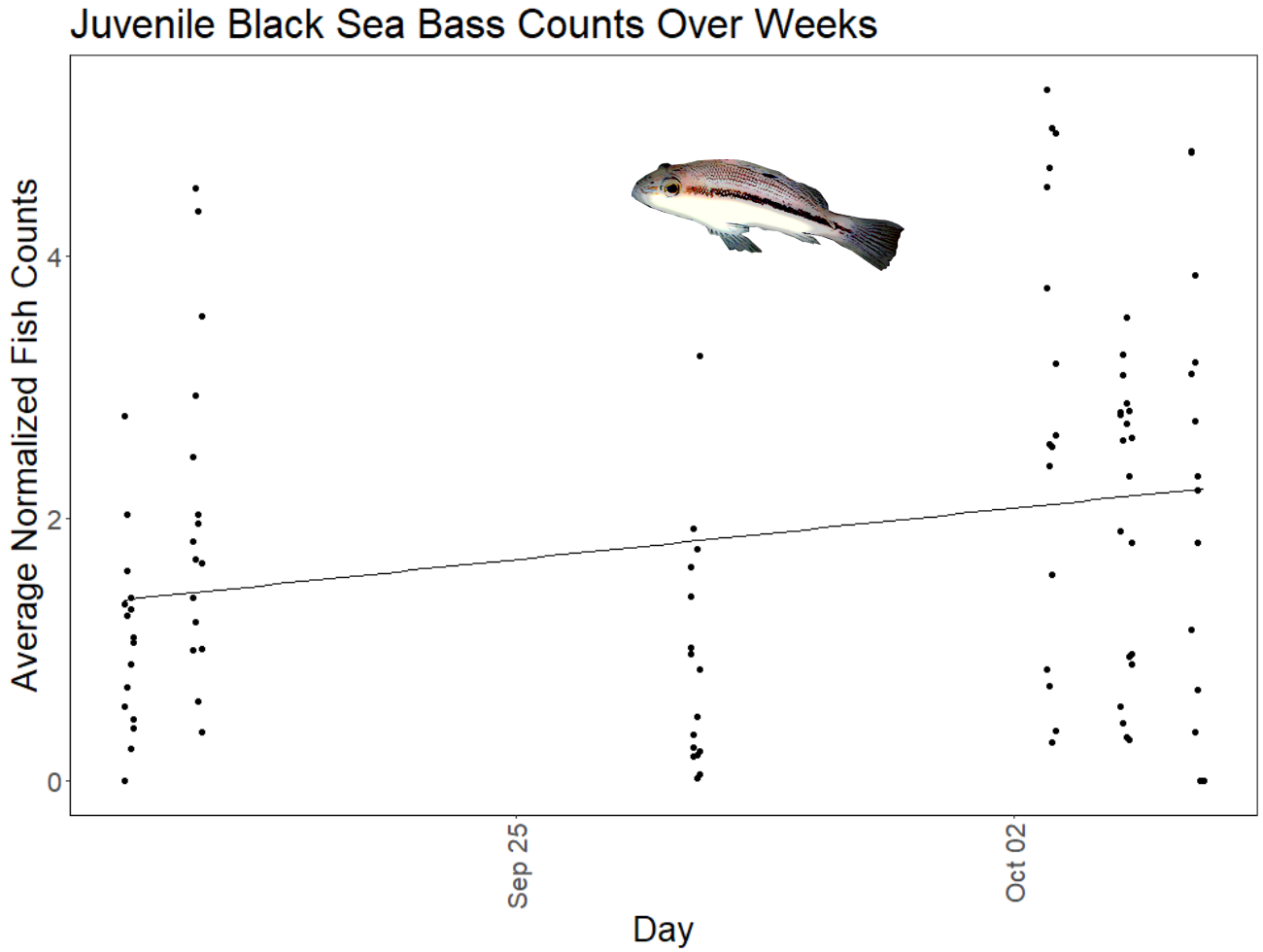


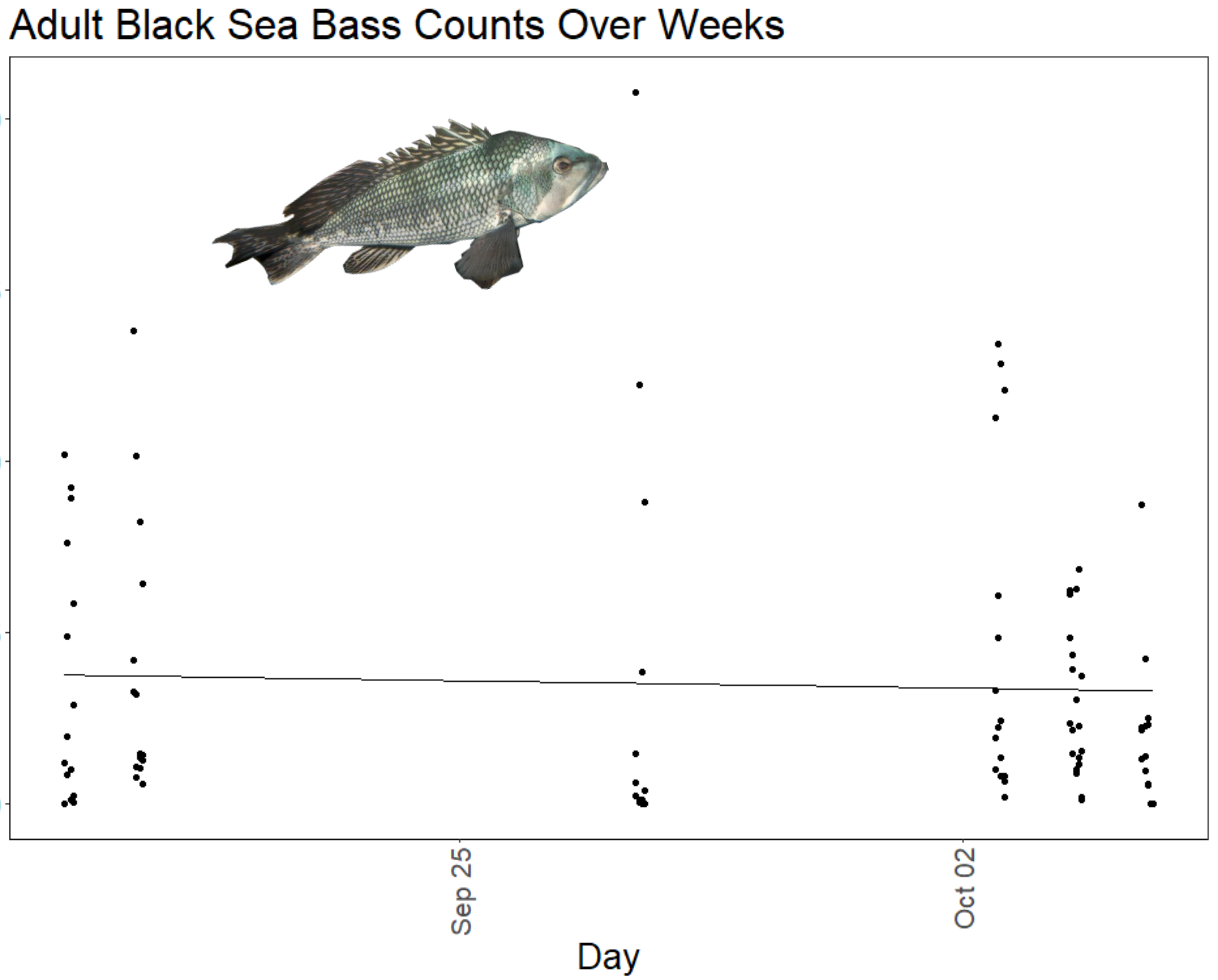
# Fish Counts Across Consecutive Pile Driving Events

## Juvenile Black Sea Bass at 205.4 dB (RL) Site

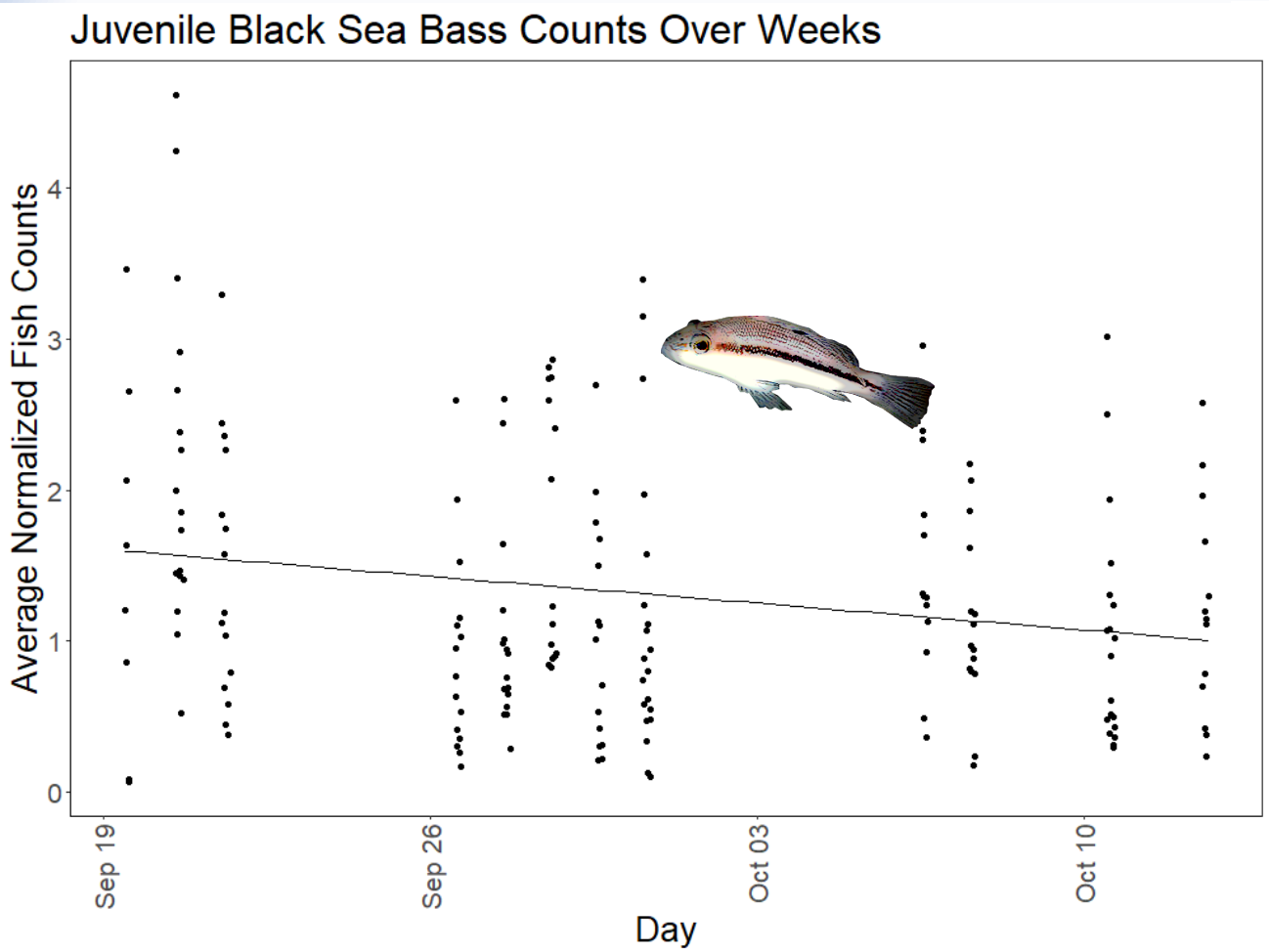


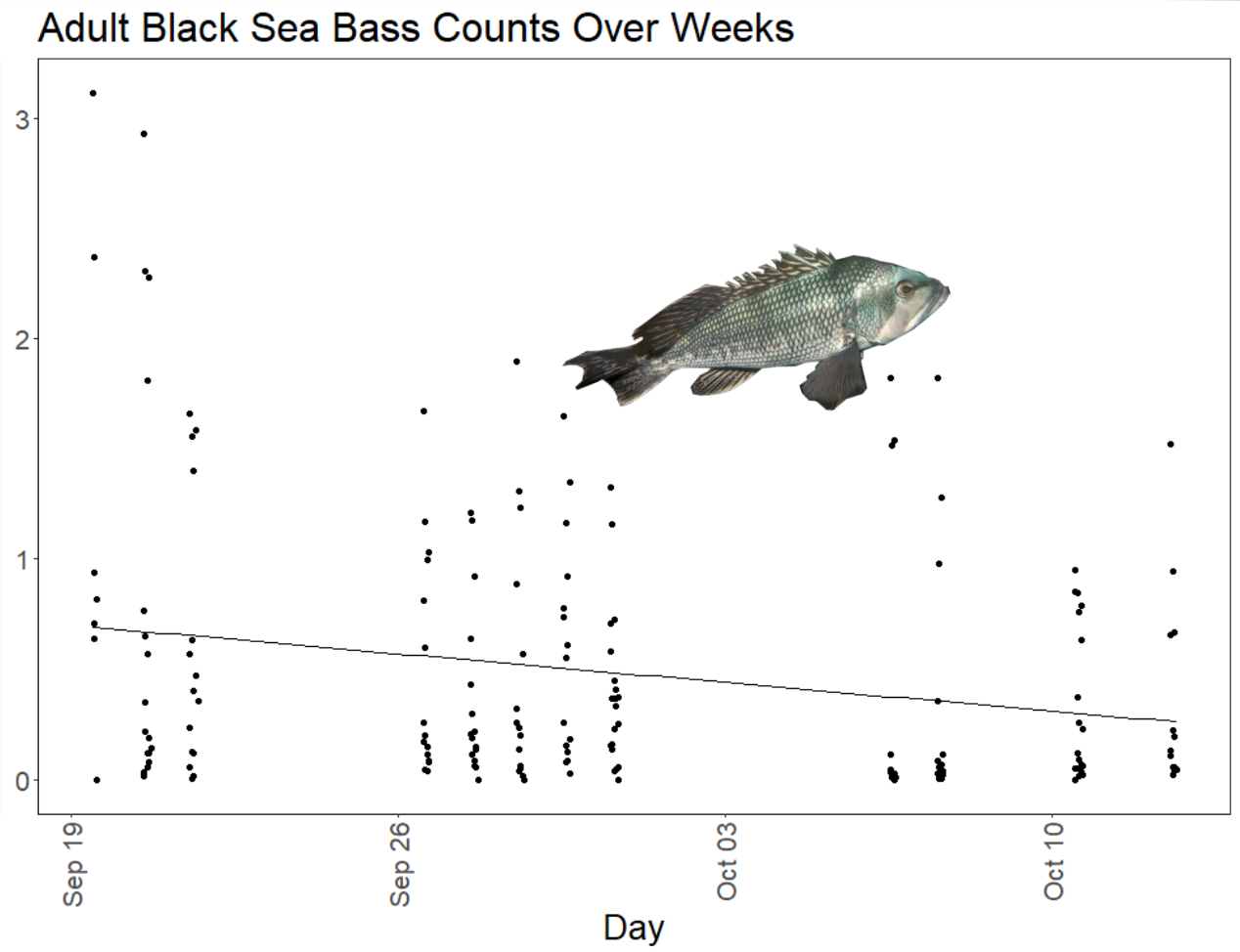
# Fish Counts Over Time w/o Pile Driving



# Fish Counts Over Time During Pile Driving



# Do we have to worry about black sea bass?

Adult black sea bass demonstrate behavioral changes during pile driving

- Increased sheltering

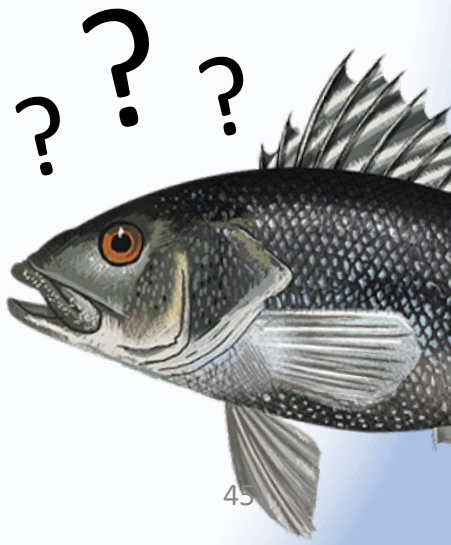
Juvenile black sea bass are less abundant during pile driving at near sites

- Sound pressure levels at near cages and closest BRUV approximate OWF construction at distance of ~175m

Juvenile sea bass are less abundant with continued pile driving

- Juveniles appear more sensitive to PD
- Long-term affect to both juveniles and adults?

Potential displacement and impacts to foraging behavior



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# Questions

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