3D advection, diffusion, and mortality of Nassau Grouper eggs and larvae observed with a novel plankton imaging system

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DEPARTMENT OF ENVIRONMENT CAYMAN ISLANDS GOVERNMENT
REEF www.REEF.org

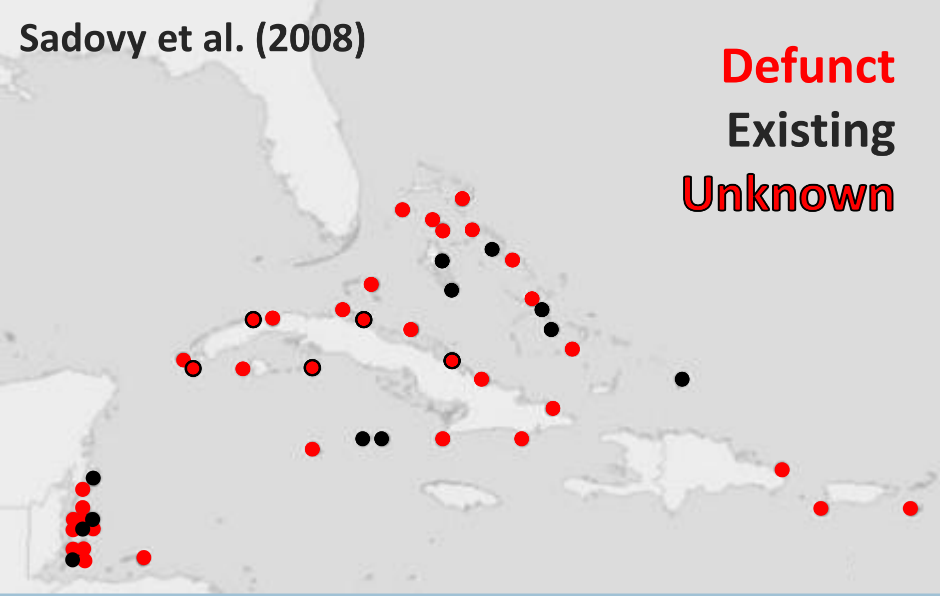
Spawning aggregations: beautiful but challenging to manage

1. Highly desirable   2. Easy to catch (predictable, dense)   3. Long-lived

Introduction

Video: Berkley White (Backscatter/REEF)

Overfishing spawning aggregations



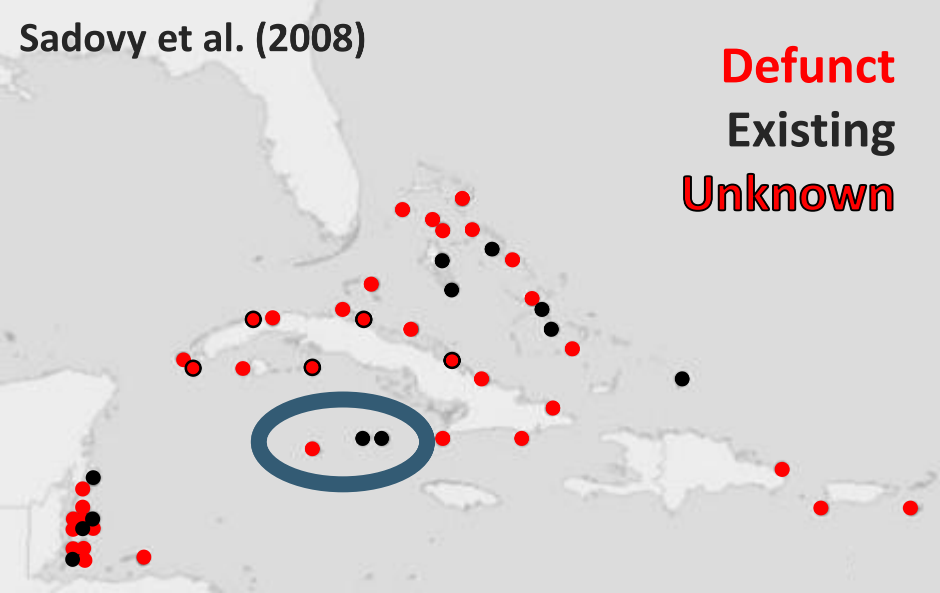
RED LIST

CRITICALLY ENDANGERED

CR

Sadovy et al. (2018), NMFS (2016)

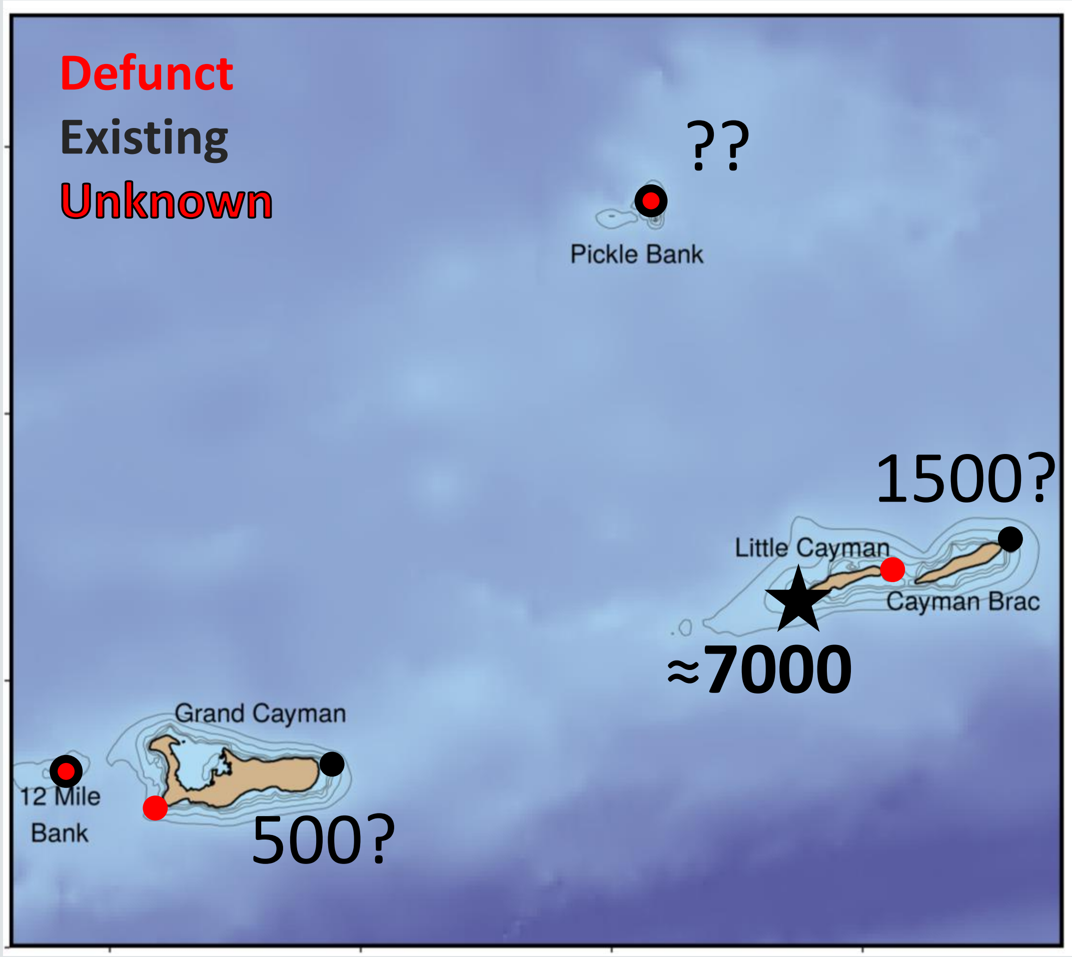
Overfishing spawning aggregations



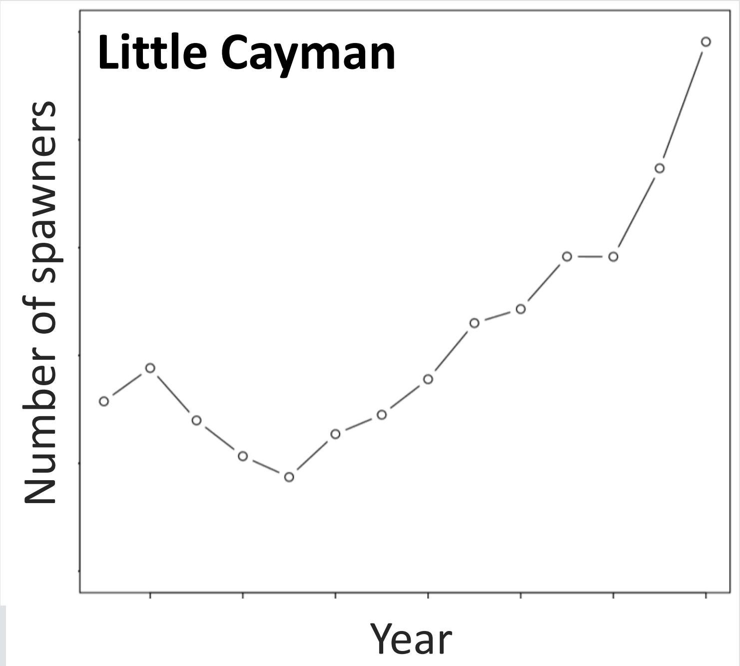
Introduction

Sadovy et al. (2018), NMFS (2016)

Aggregations in the Cayman Islands

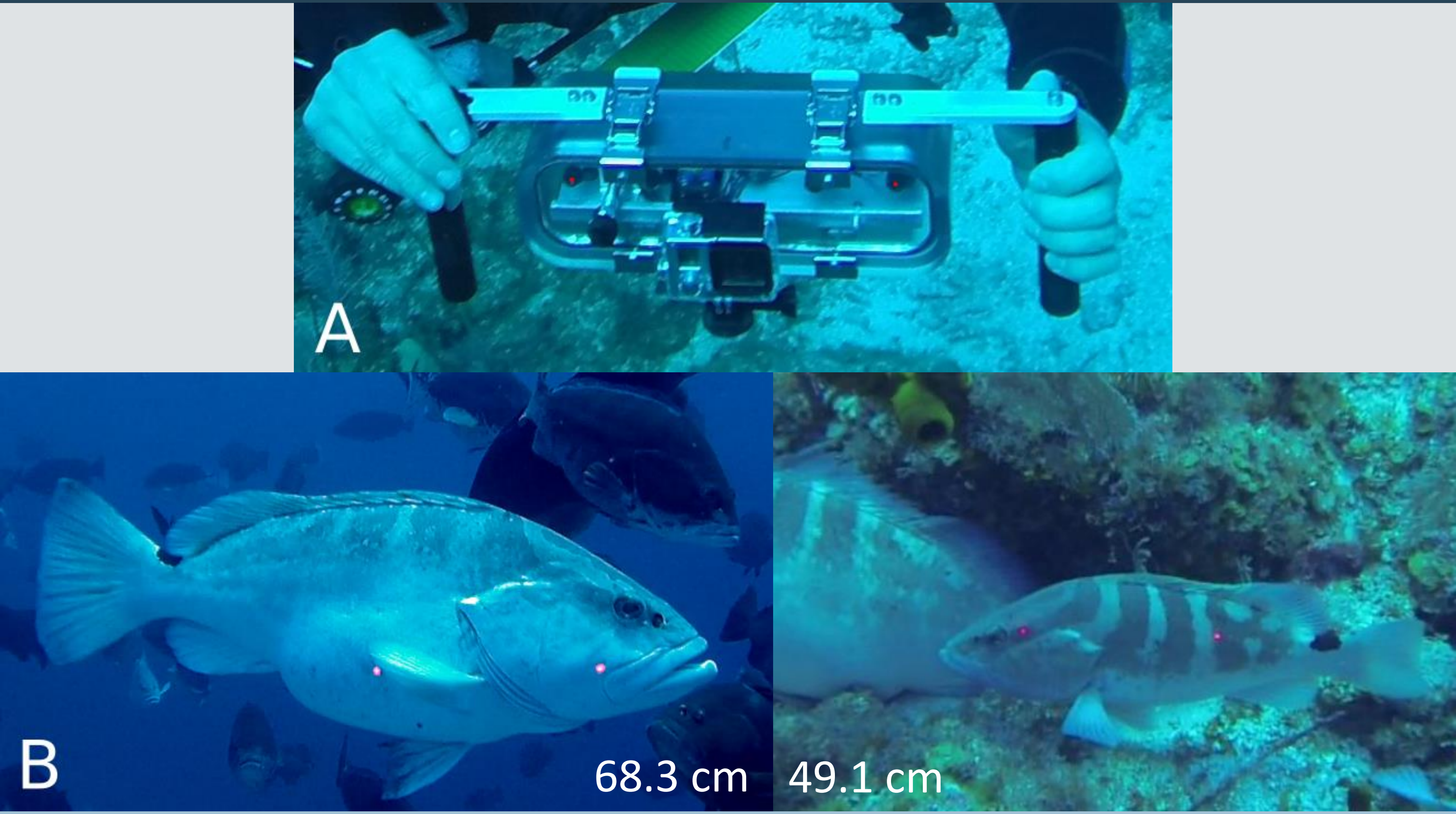


Mixed success since protection in 2003



Bush et al. (2006); Waterhouse et al. (in prep)

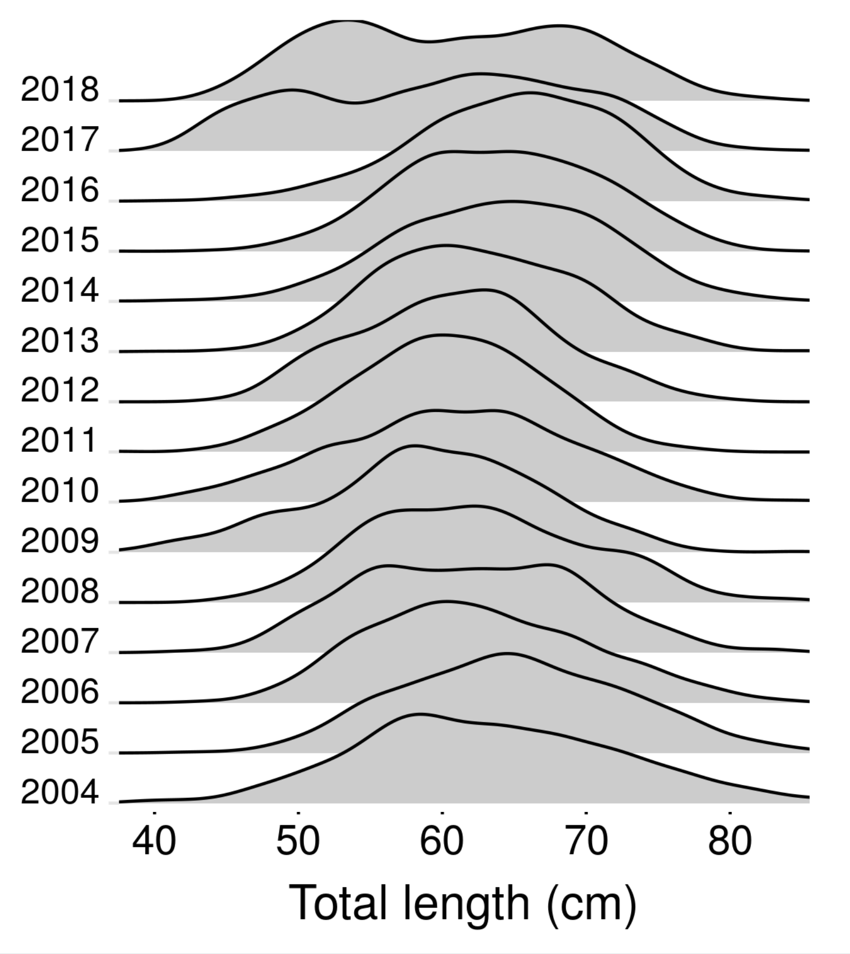
Length data without killing fish



Method #1

Stock et al. (in prep)

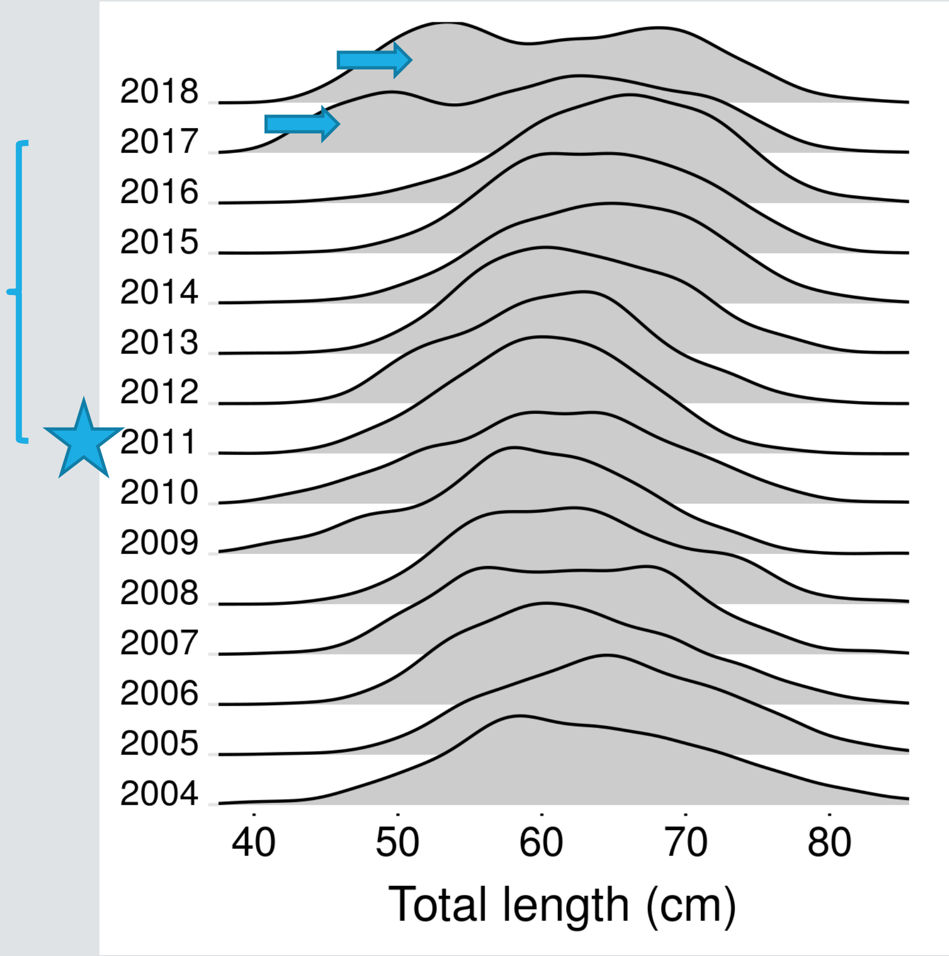
Length data



Stock et al. (in prep)

Huge recruitment pulse in 2011

5-7 years to maturity

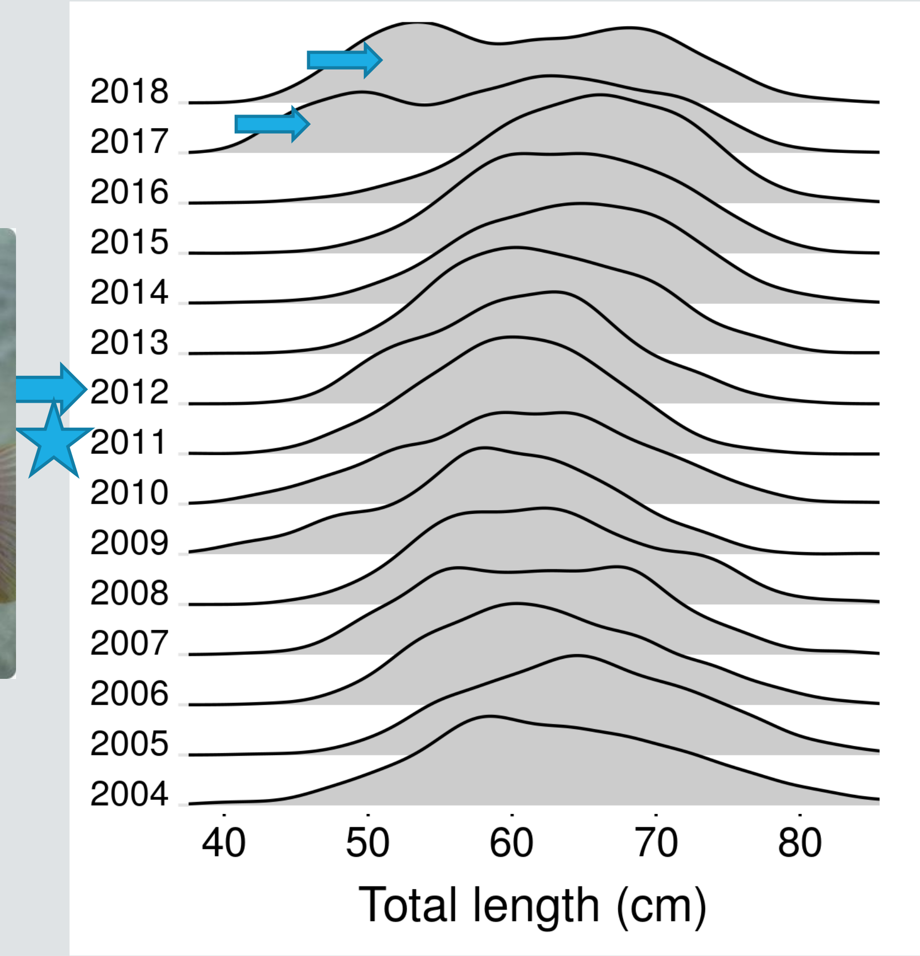


Result #1

Stock et al. (in prep)

Huge recruitment pulse in 2011

1-year-old fish



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Stock et al. (in prep)

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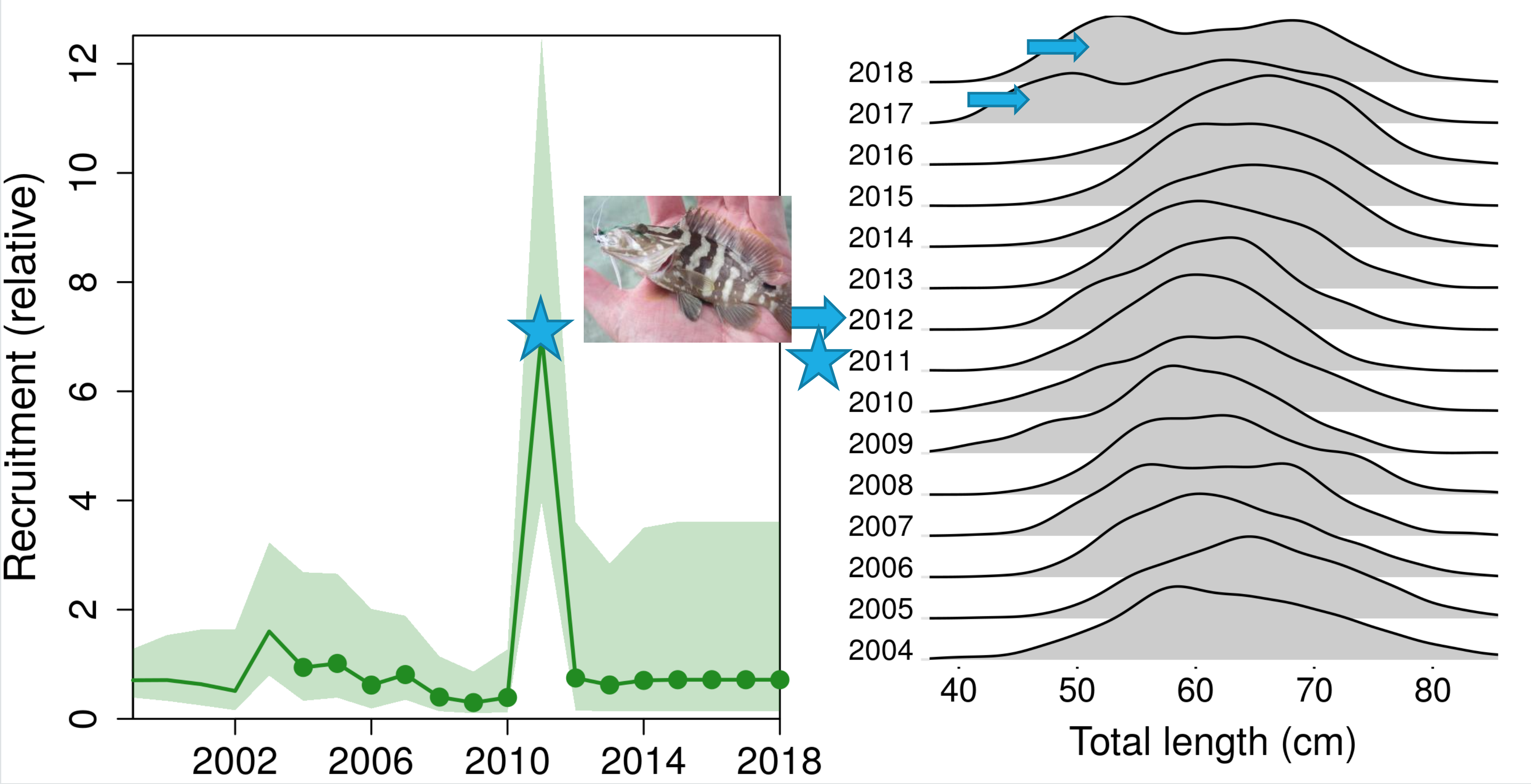


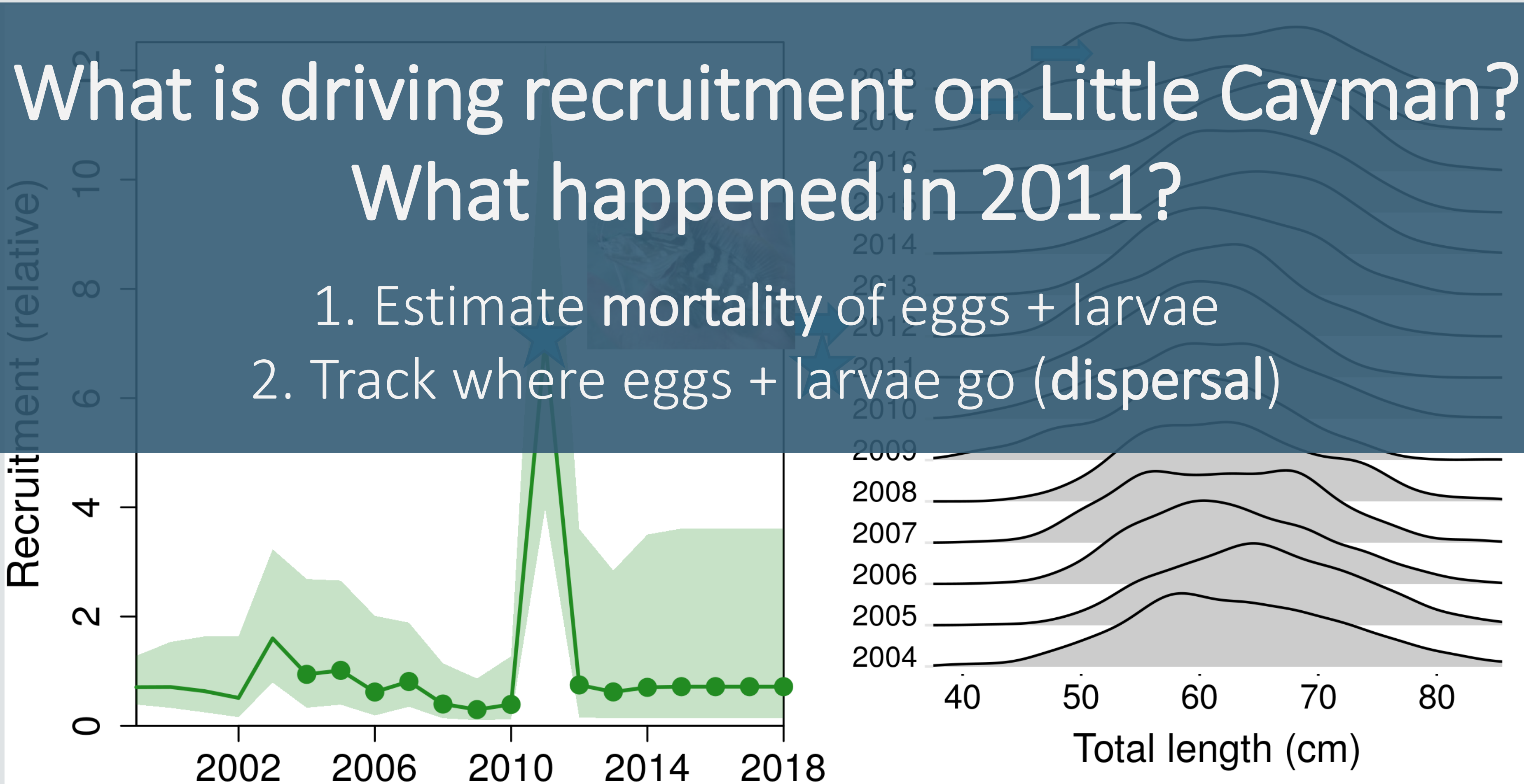
Result #1

Stock et al. (in prep)

Questions

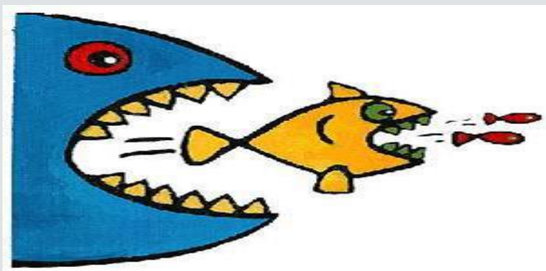
What is driving recruitment on Little Cayman?
What happened in 2011?

1. Estimate **mortality** of eggs + larvae
2. Track where eggs + larvae go (**dispersal**)



Stock et al. (in prep)

Objective #1



Mortality

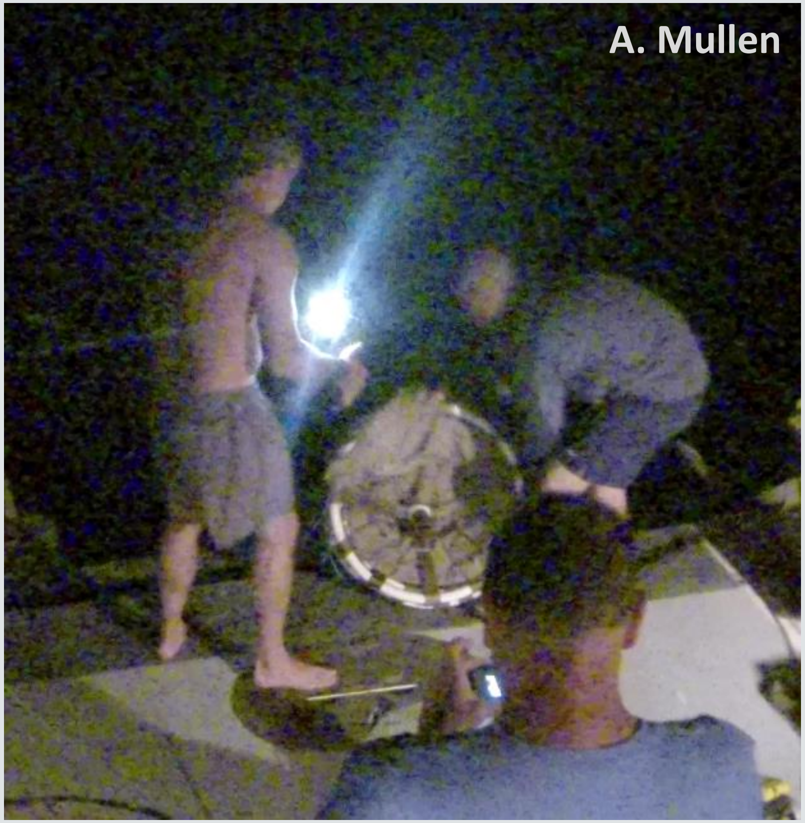
Dispersal

1. Fit a biophysical model of dispersal to provide **field estimates of diffusivity and mortality**

Dispersal = Advection + **Diffusion** - **Mortality**

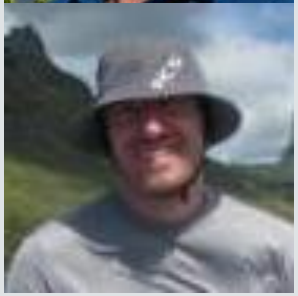
Objective #2

2. **Test assumption** that drifters track eggs + larvae

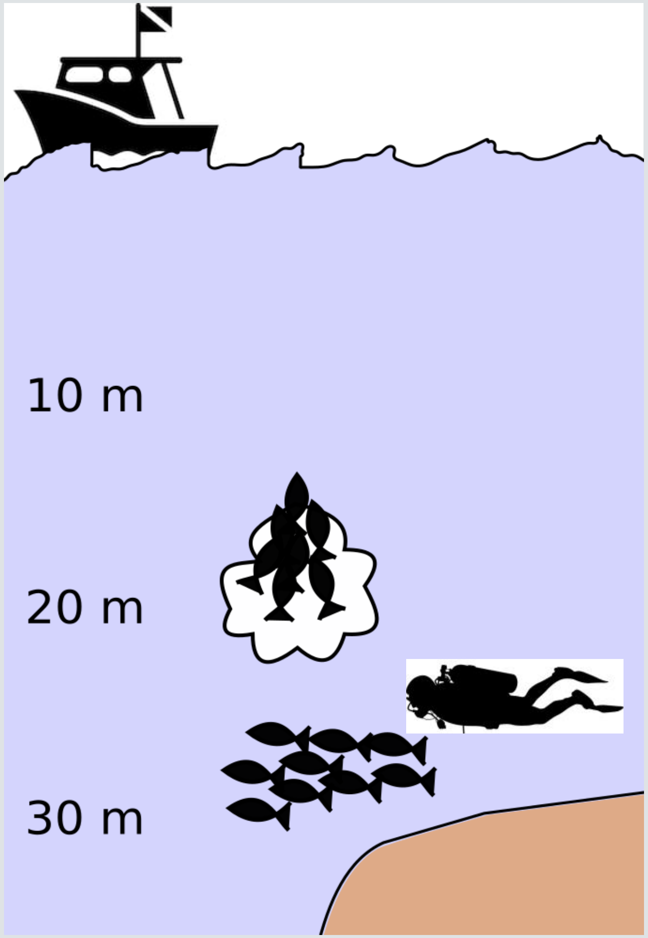


Objective #3

3. Demonstrate abilities of a **novel plankton imaging system**



1. Divers observe spawning



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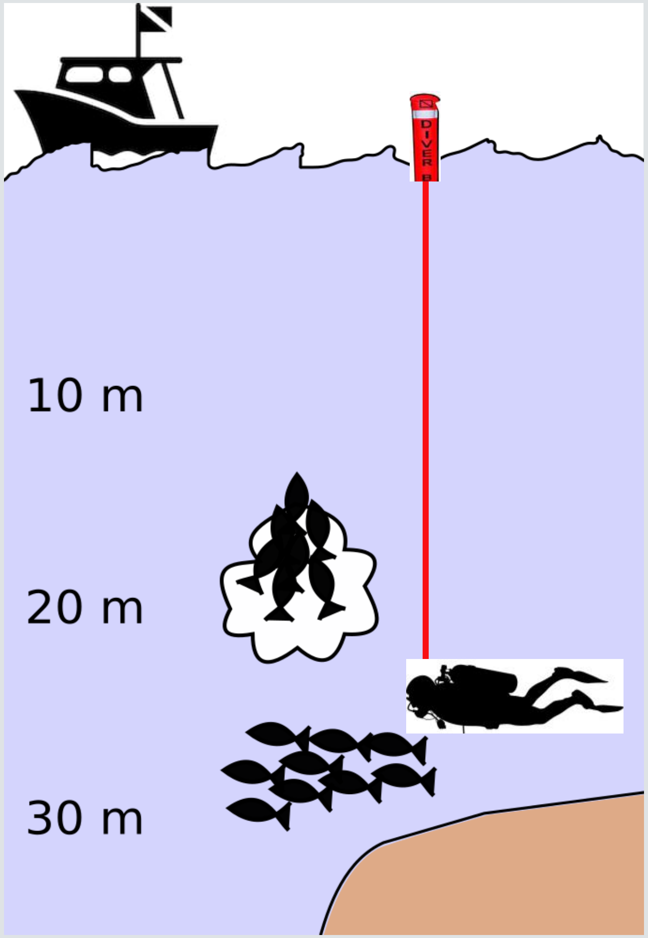
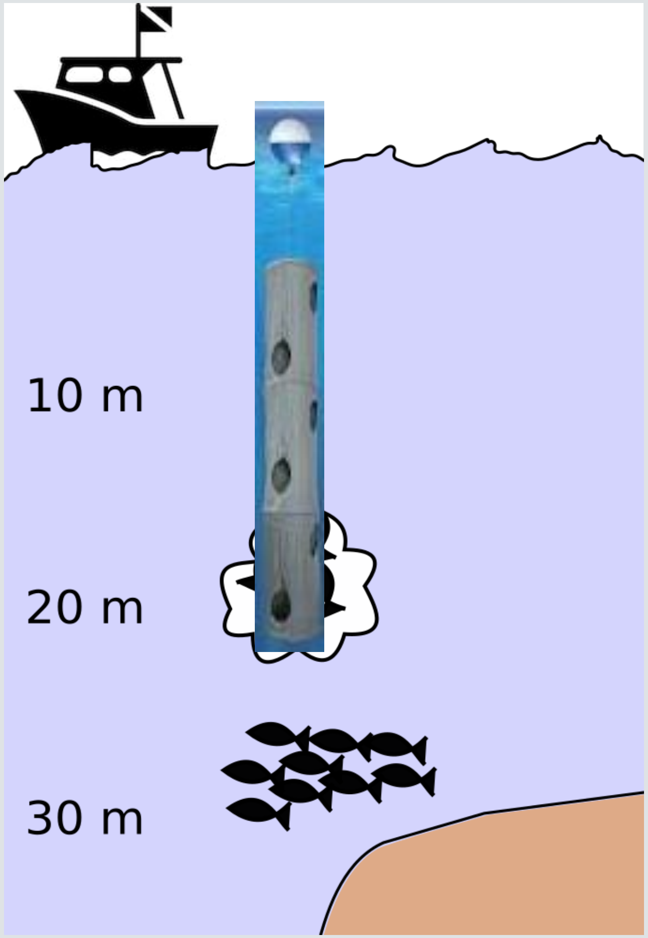


Methods

2. Drifters mark egg patch



3. Tow microscope around drifters

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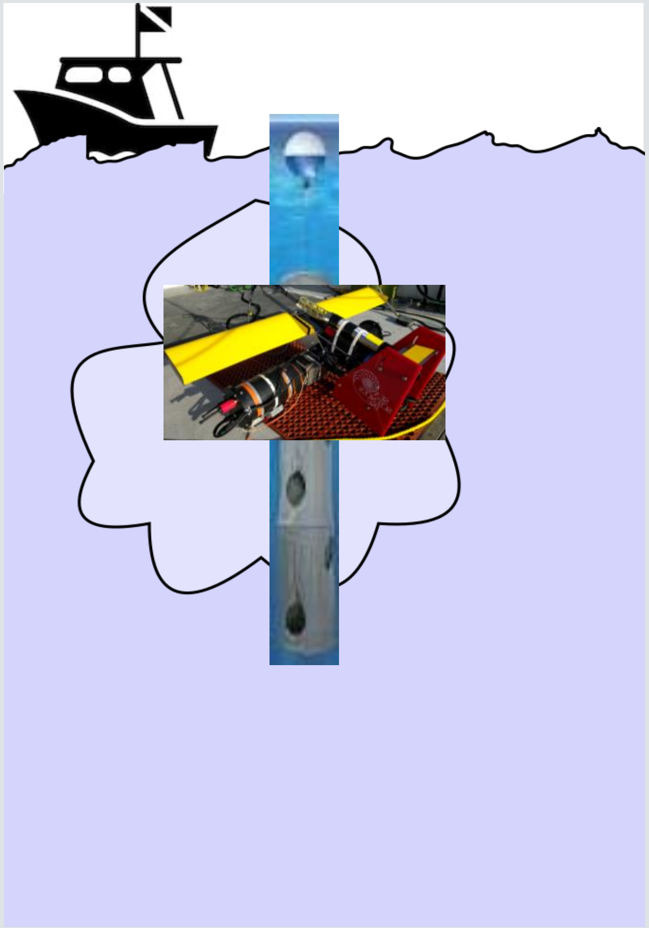
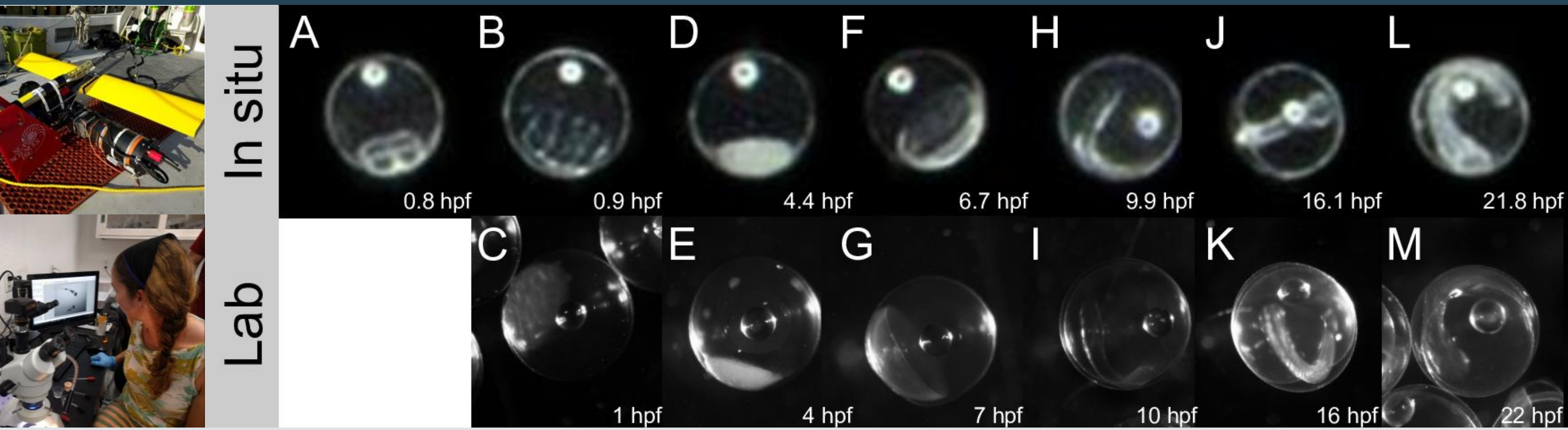


Egg and larval development



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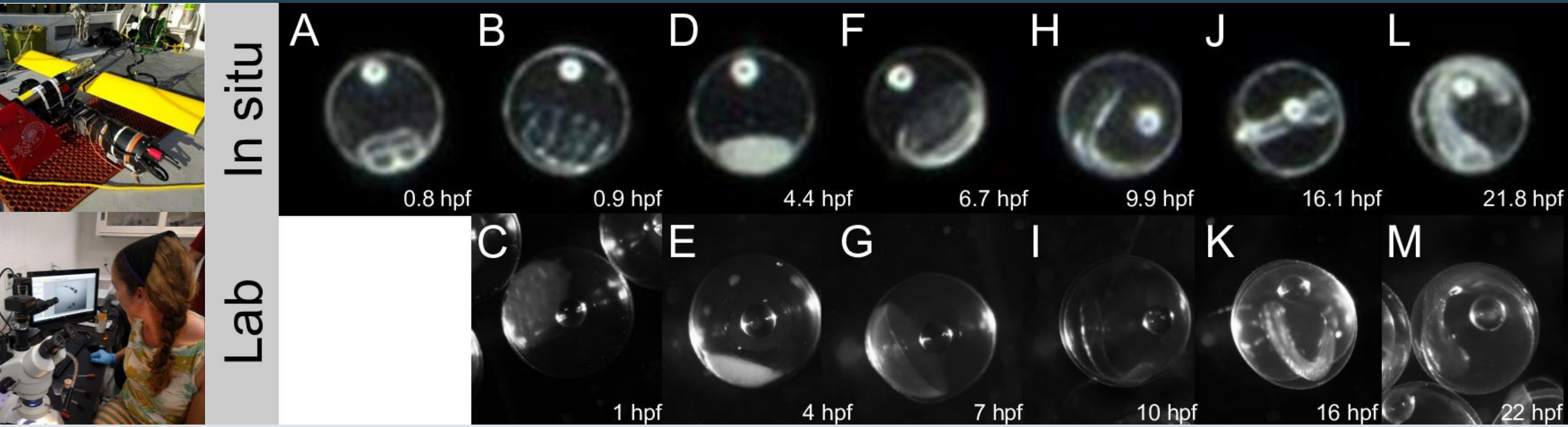
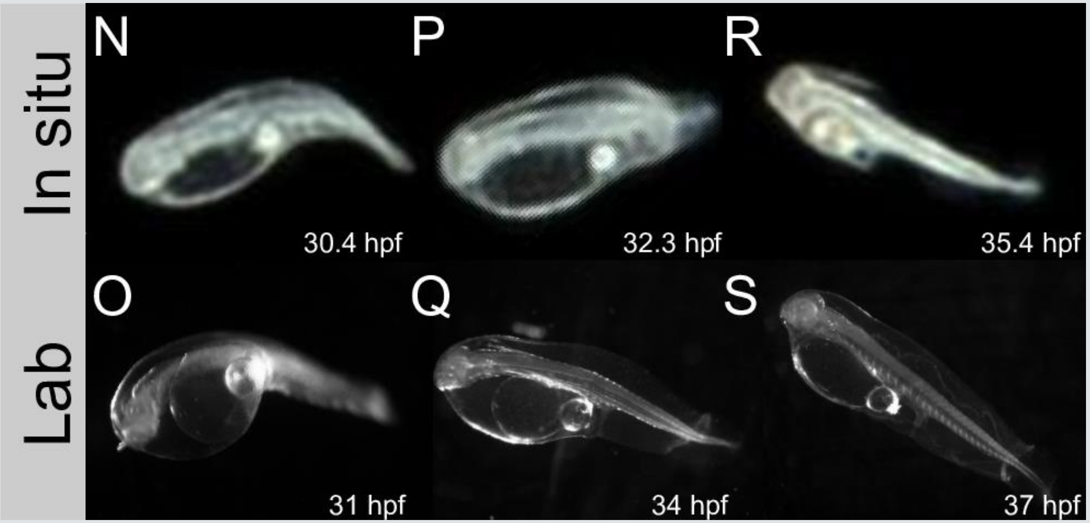
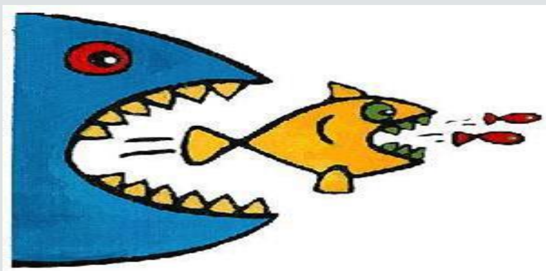




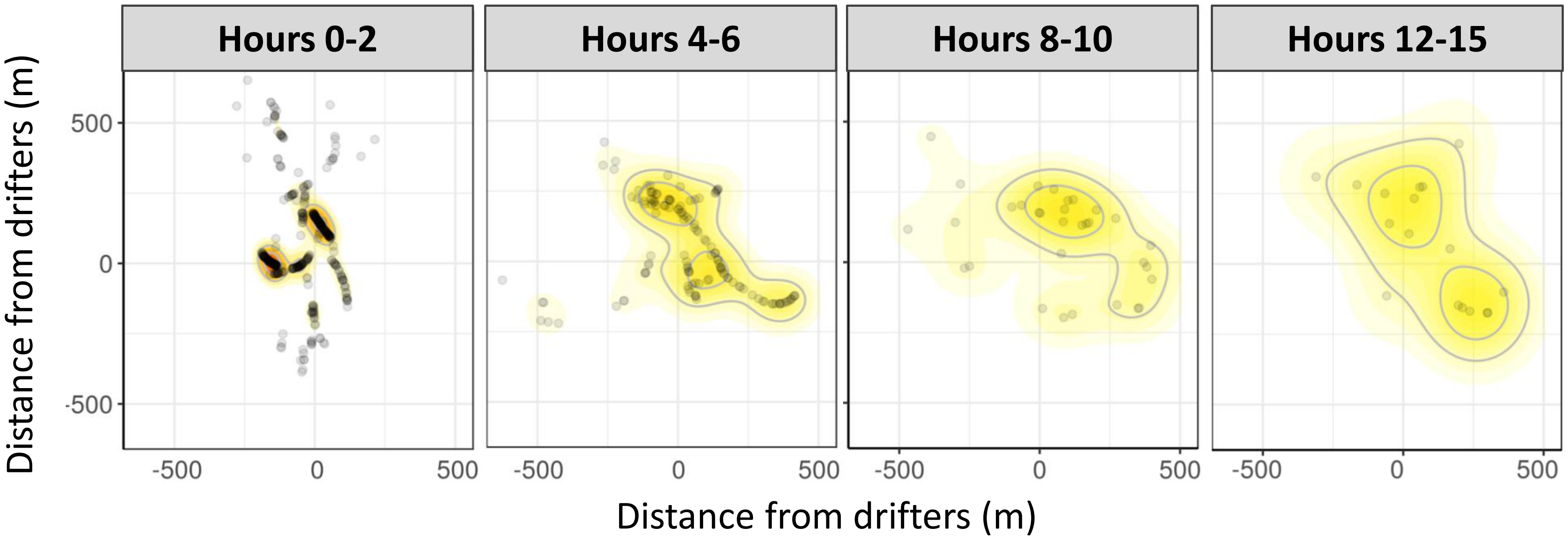
Results

Study objectives

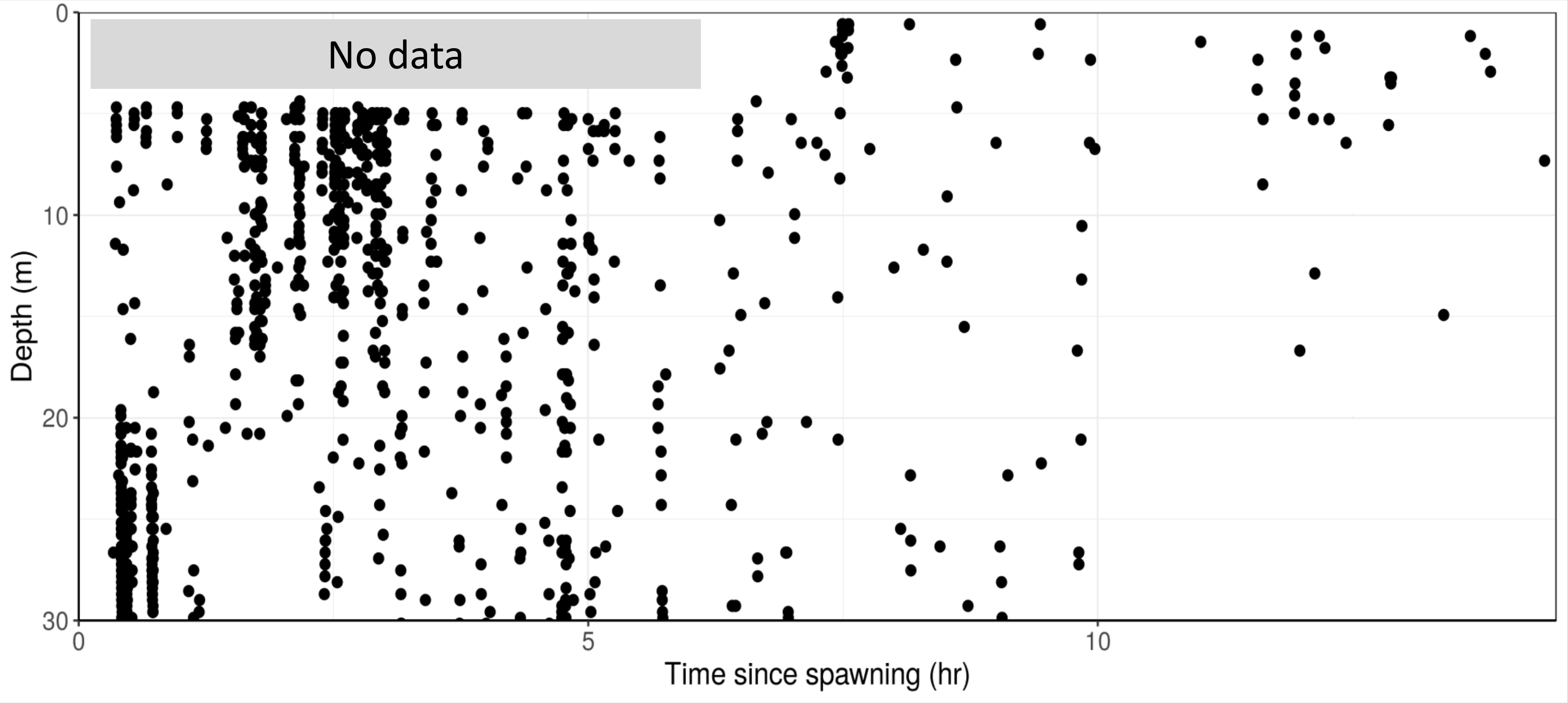


1. Provide **field estimates of diffusivity and mortality**
2. **Test assumption** that eggs + larvae follow currents
3. Demonstrate abilities of a **novel plankton imaging system**

Night #1: Horizontal diffusion

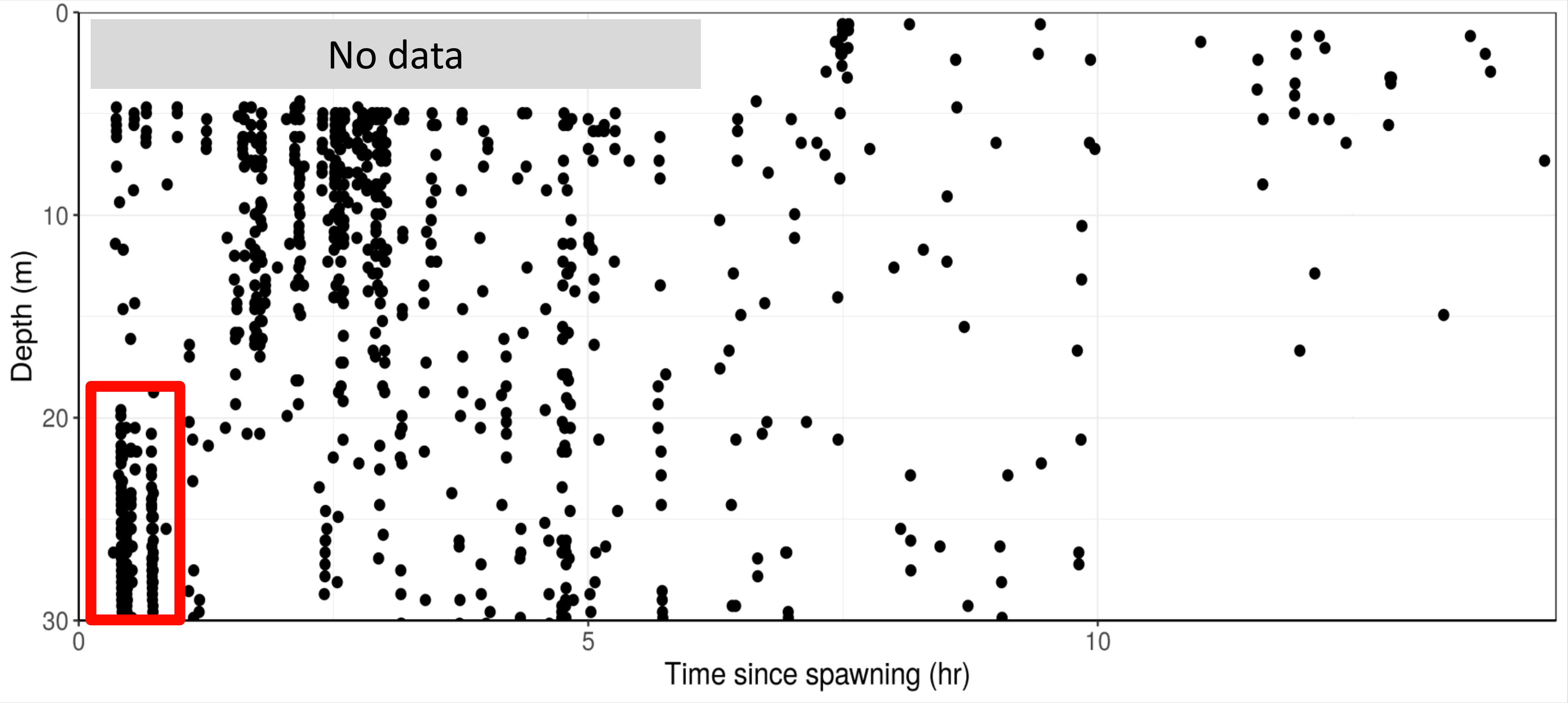


Night #1: Vertical diffusion



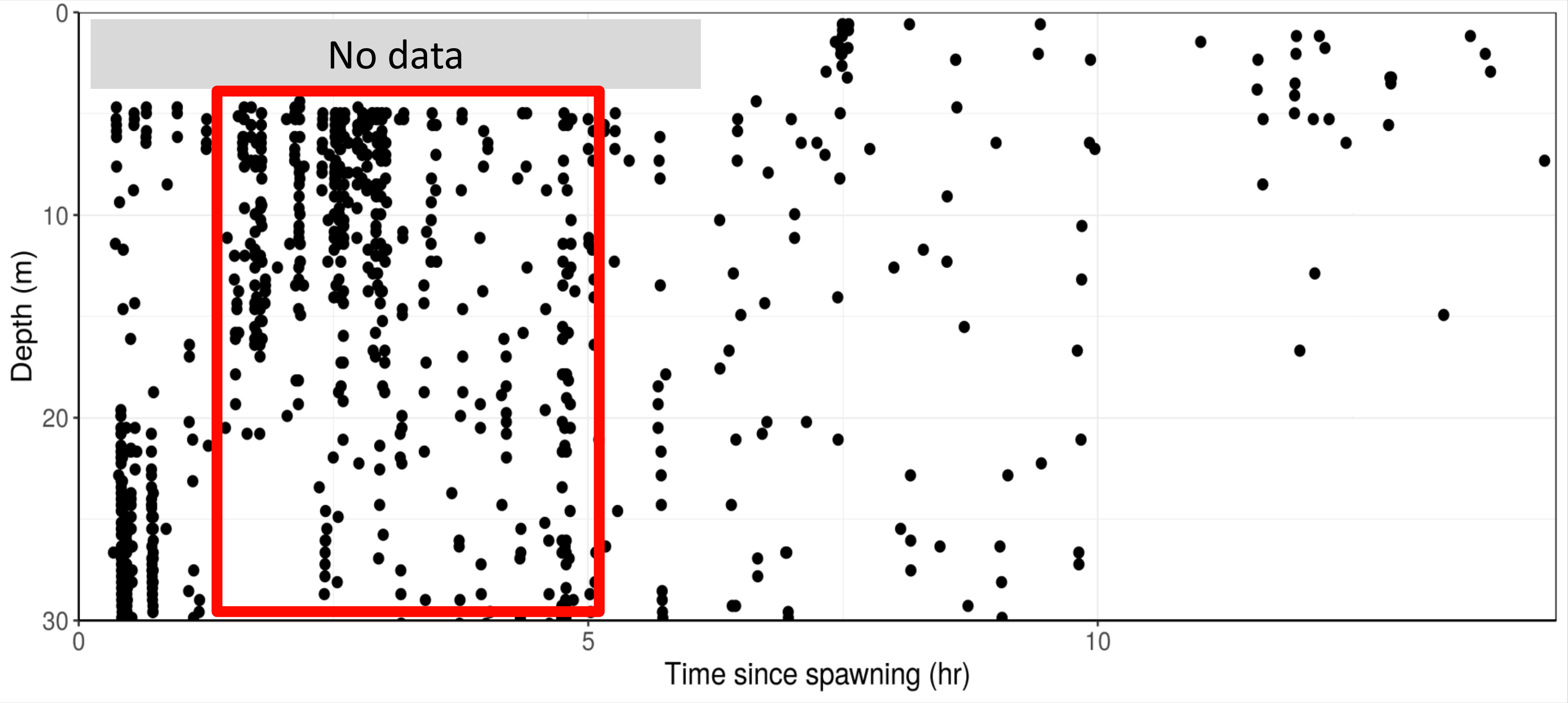
Results

Night #1: Vertical diffusion



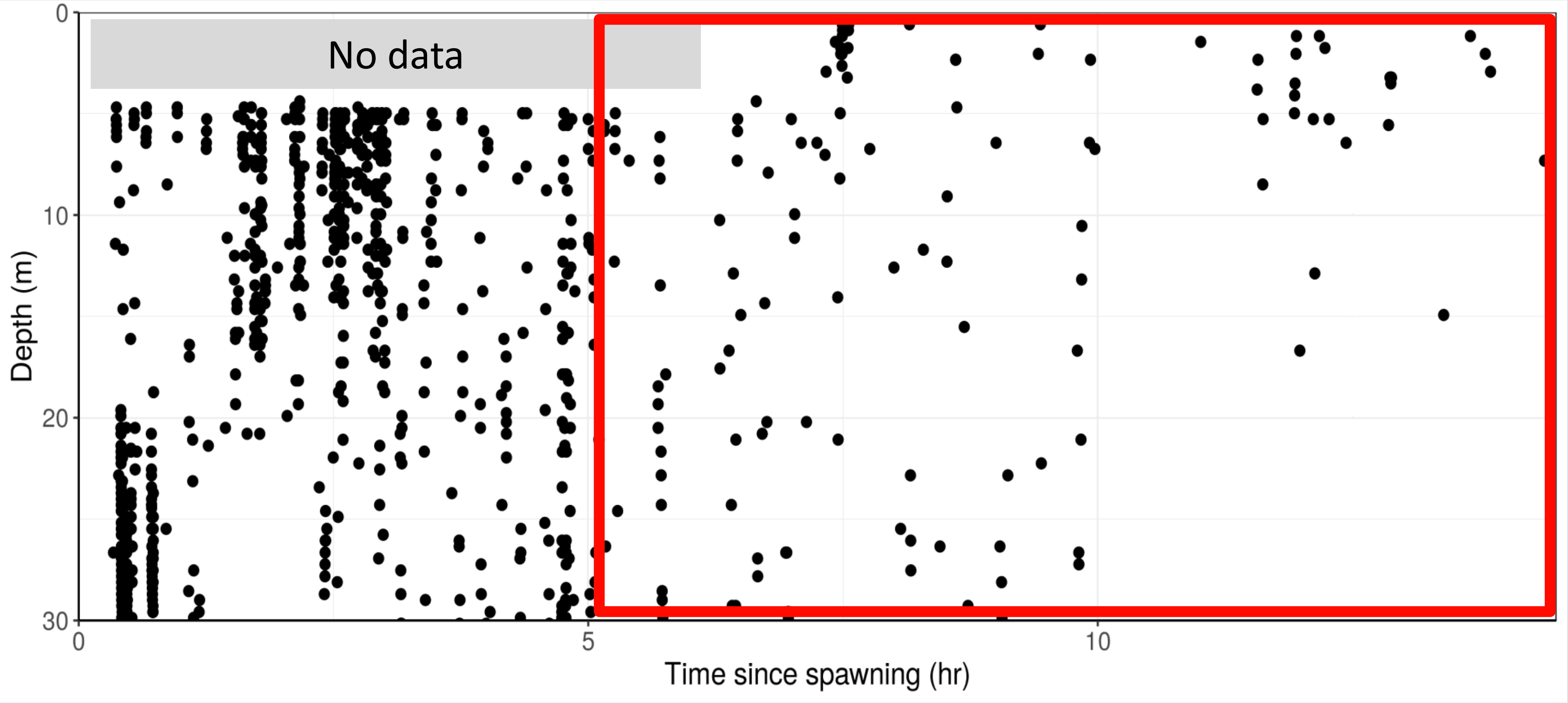
Results

Night #1: Vertical diffusion



Results

Night #1: Vertical diffusion



Results

Night #1: 3D diffusion-mortality

$$\frac{\partial C}{\partial t} = K_x \frac{\partial^2 C}{\partial x^2} + K_y \frac{\partial^2 C}{\partial y^2} + K_z \frac{\partial^2 C}{\partial z^2} - \mu t$$

Change in egg Concentration **=** **Diffusion** **—** **Mortality**

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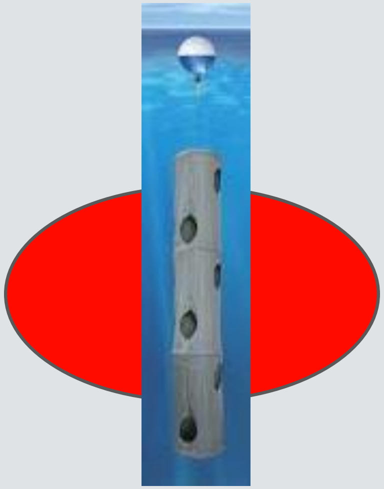

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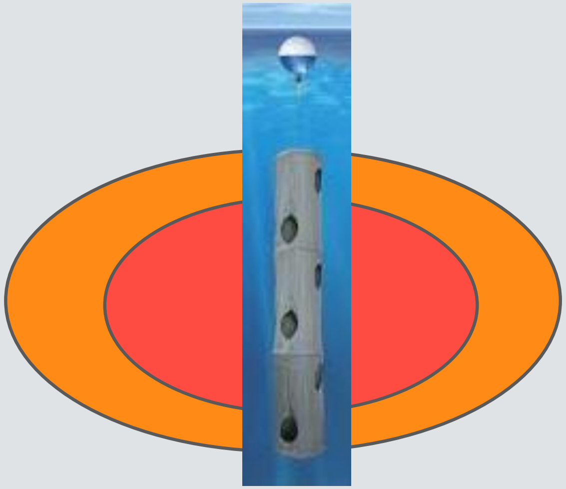

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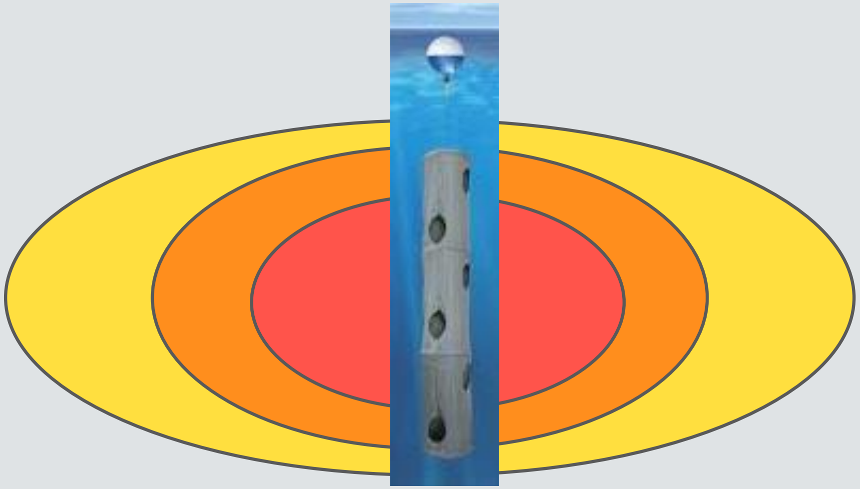

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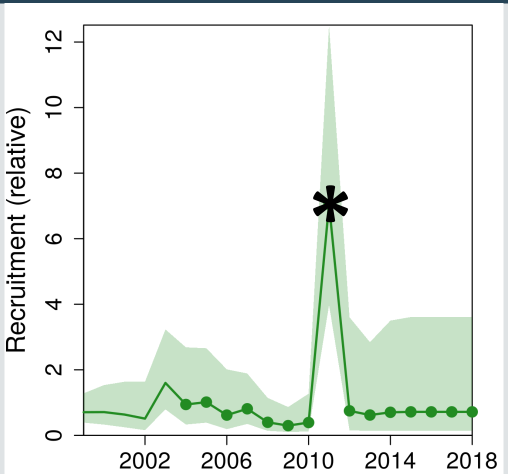
Parameter estimates useful for biophysical models of dispersal

K_x ($m^2 hr^{-1}$)	K_y ($m^2 hr^{-1}$)	μ (hr^{-1})
14900 (12000–19000)	49100 (40800–60500)	0.172 (0.148–0.197)

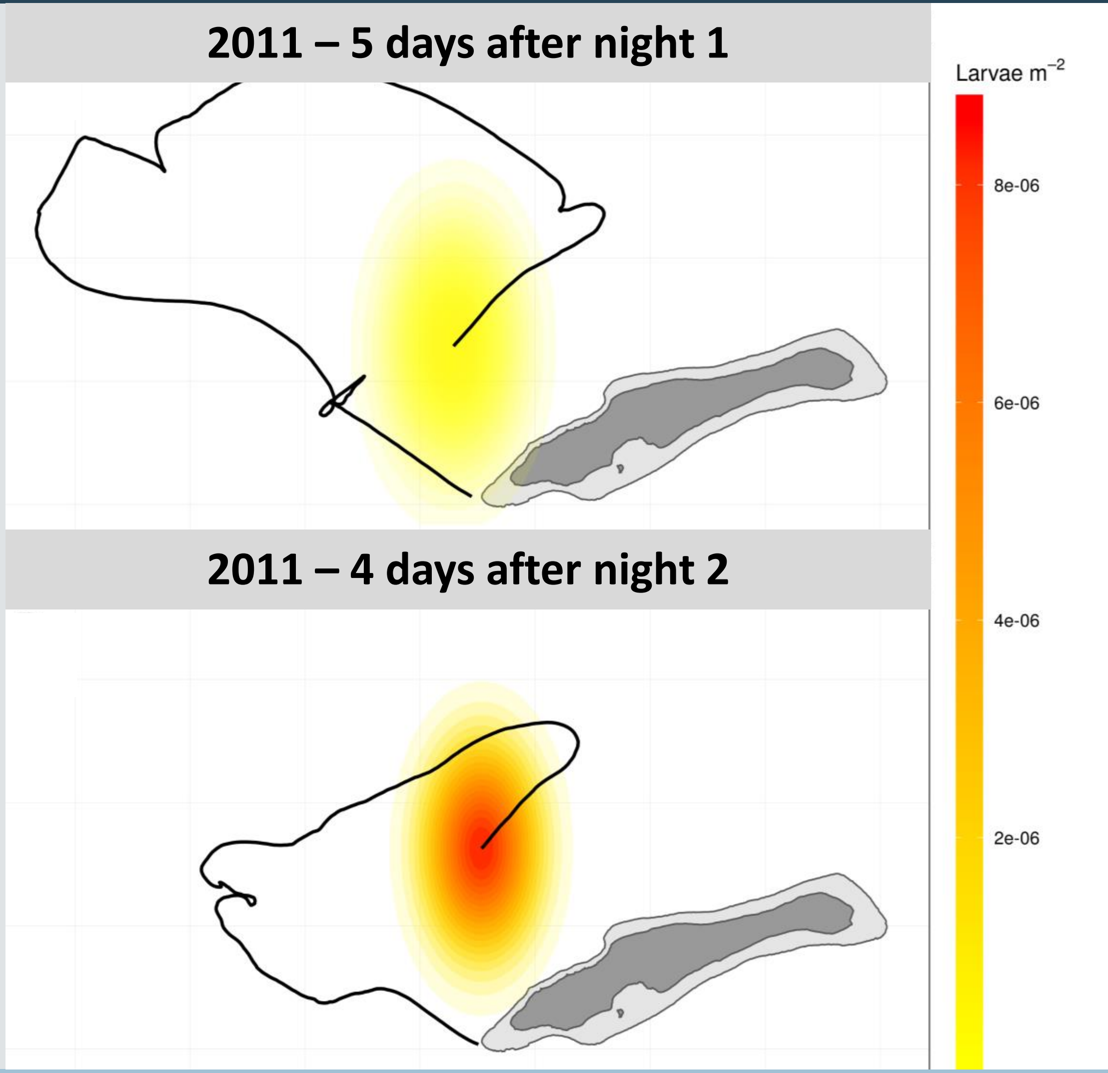
1.6% of the eggs survive

24 hours to hatching

What was special about 2011?



Use model to estimate *larval concentration around 2011 drifters*



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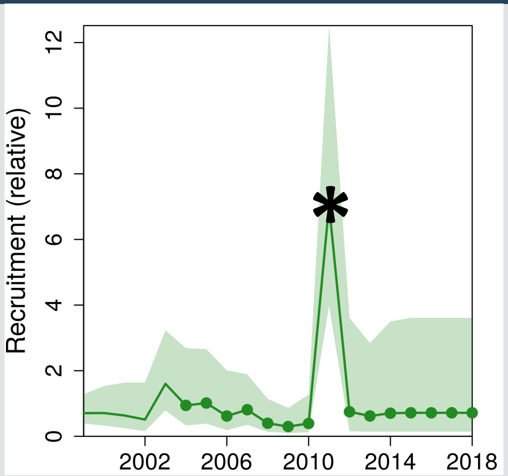
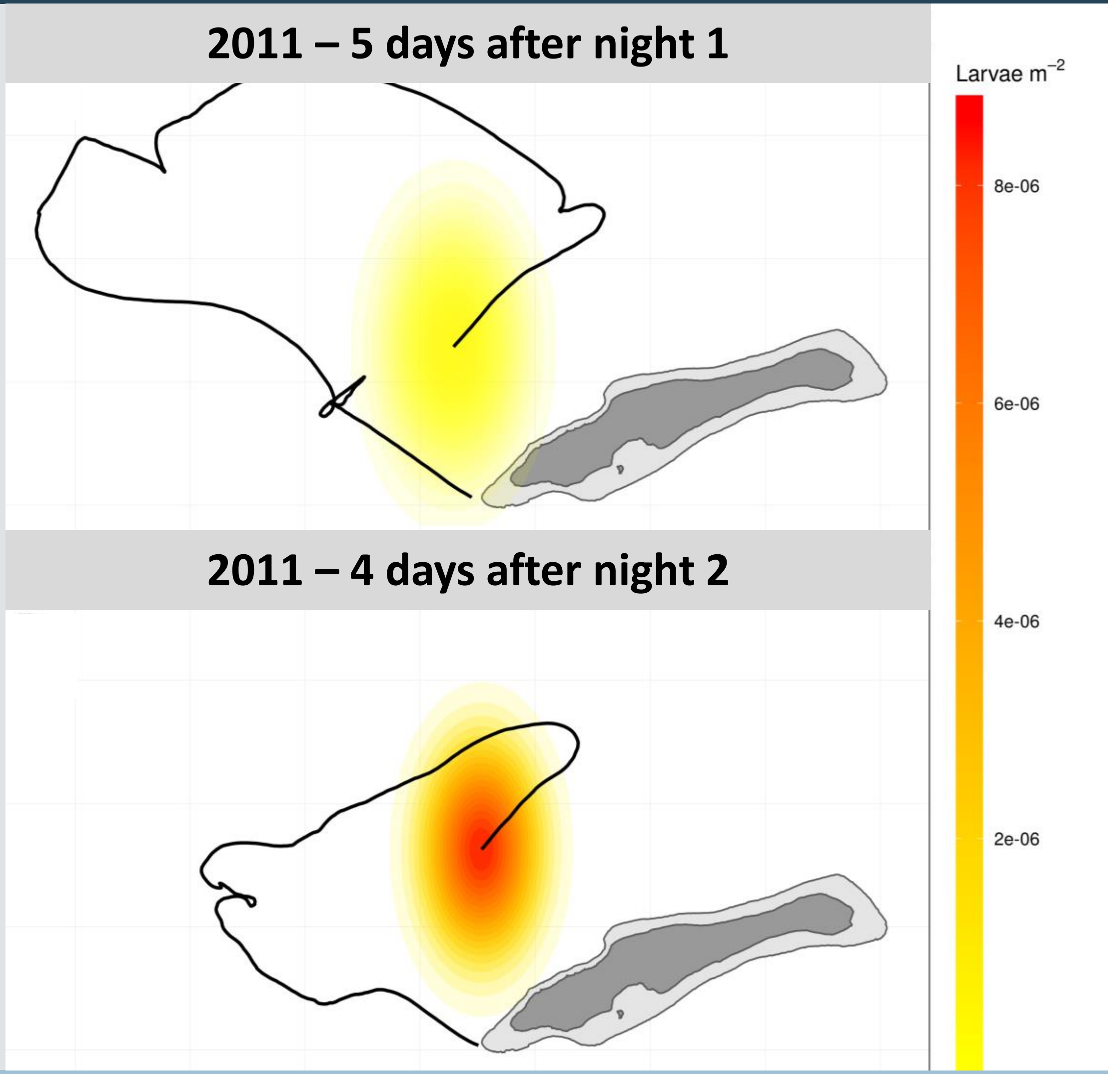


Use model to estimate
larval concentration around 2011 drifters

Currents returned larvae to Little Cayman in 2011



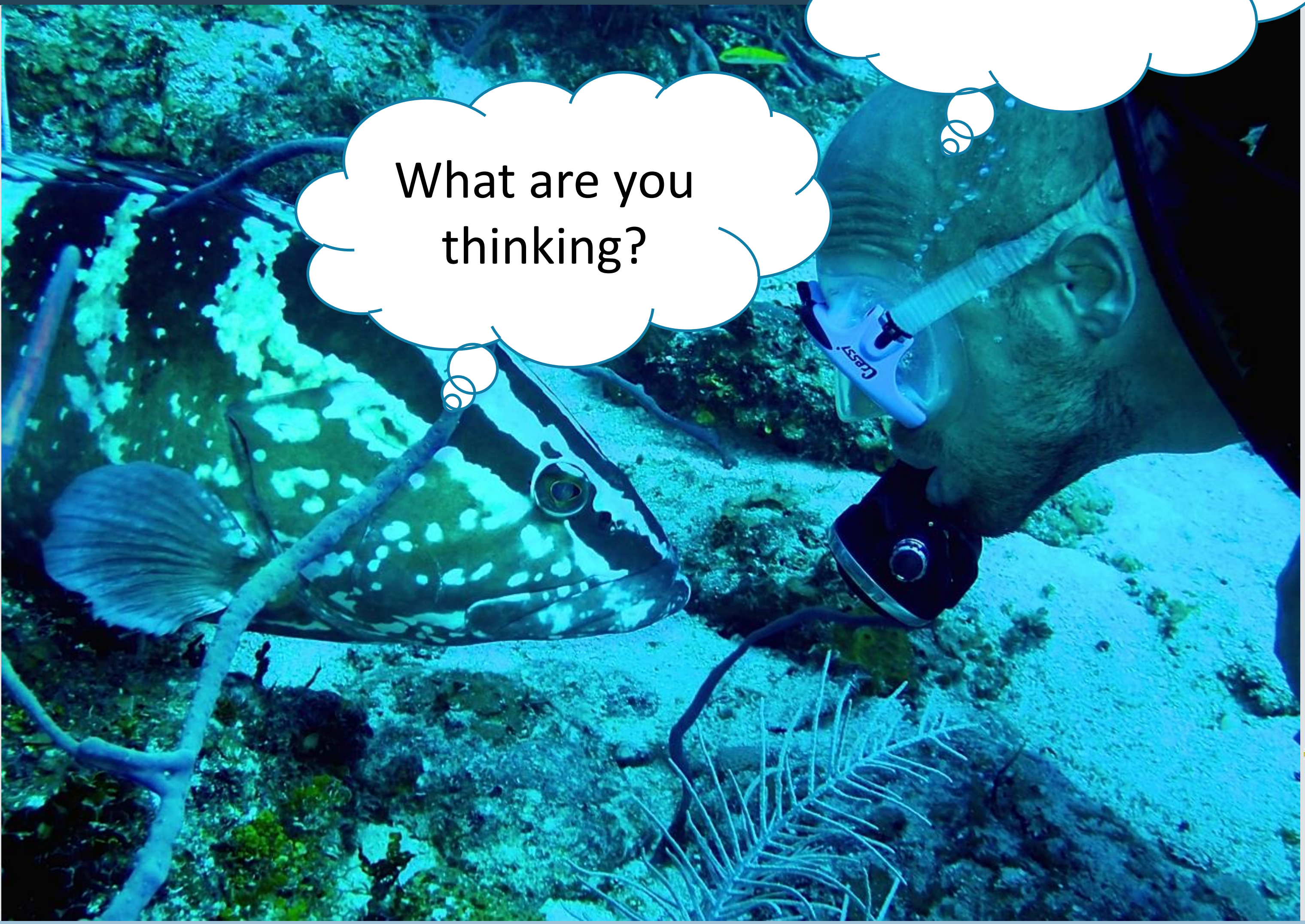
Conclusion

1. Demonstrated ability of novel imaging system to observe **3D positions of individual eggs and larvae**
2. Confirmed that **drifters track eggs beyond hatching**
3. Provided rare **field estimates of diffusivity and mortality** for eggs of a tropical reef fish
4. Predicted concentration of eggs and larvae around 2011 drifter tracks. **Favorable currents allowing larvae to return to Little Cayman may have led to the strong 2011 year class**

Thanks for staying awake!

Conclusion

Questions?



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EST 1958
SOUTHERN·CROSS·CLUB

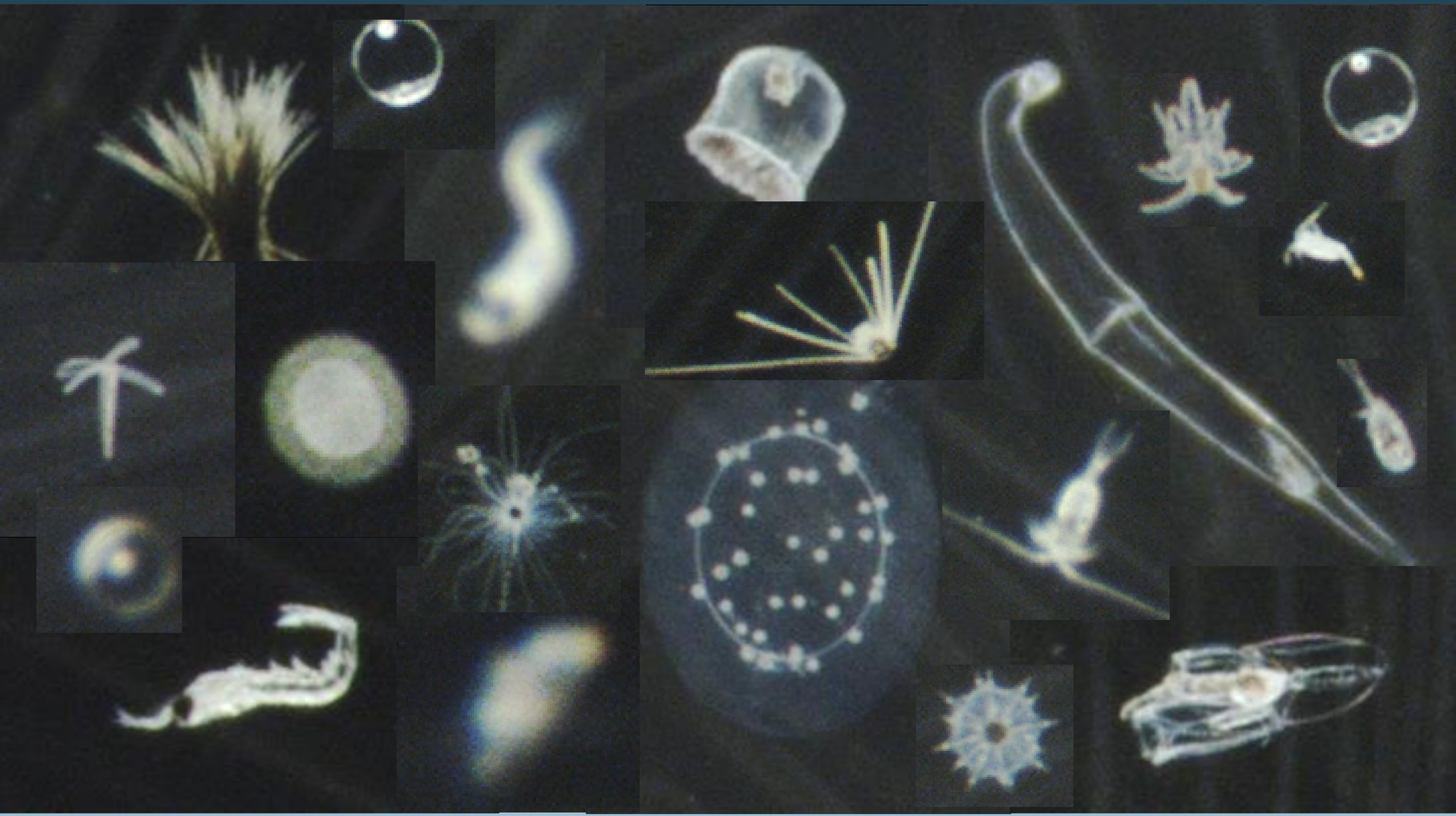
Little Cayman
BEACH RESORT

FRONTIERS of INNOVATION
FISP
SCHOLARS PROGRAM

NSF

GUY HARVEY
OCEAN
FOUNDATION

4. Find fish eggs (hint: 3)



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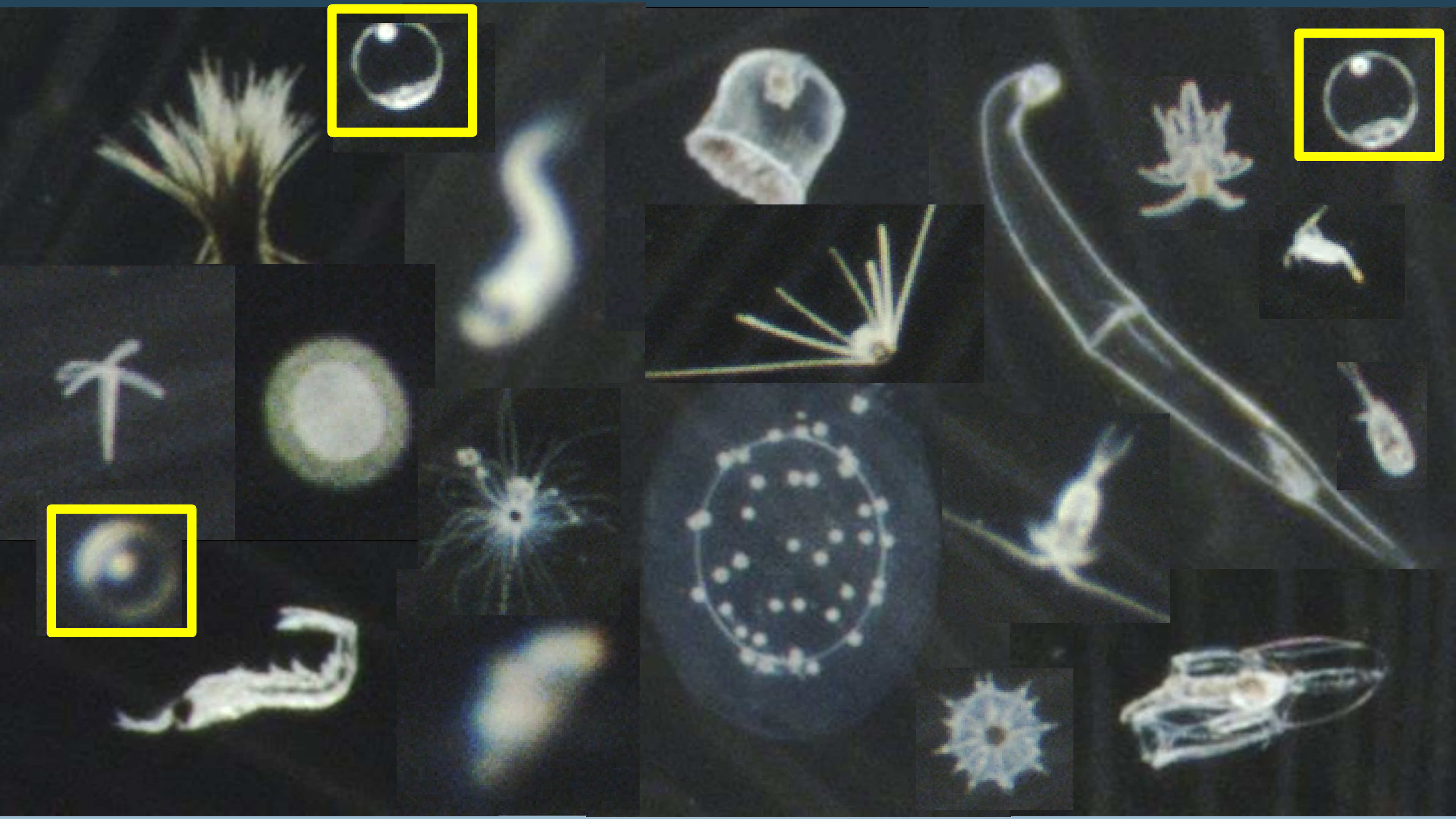
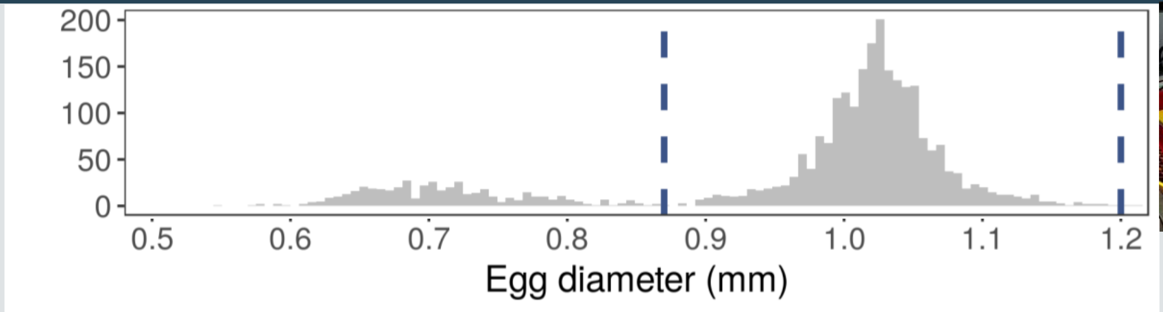
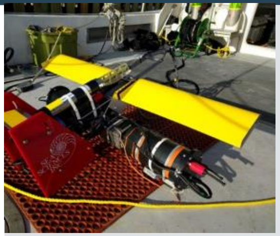


5. Classify eggs by size





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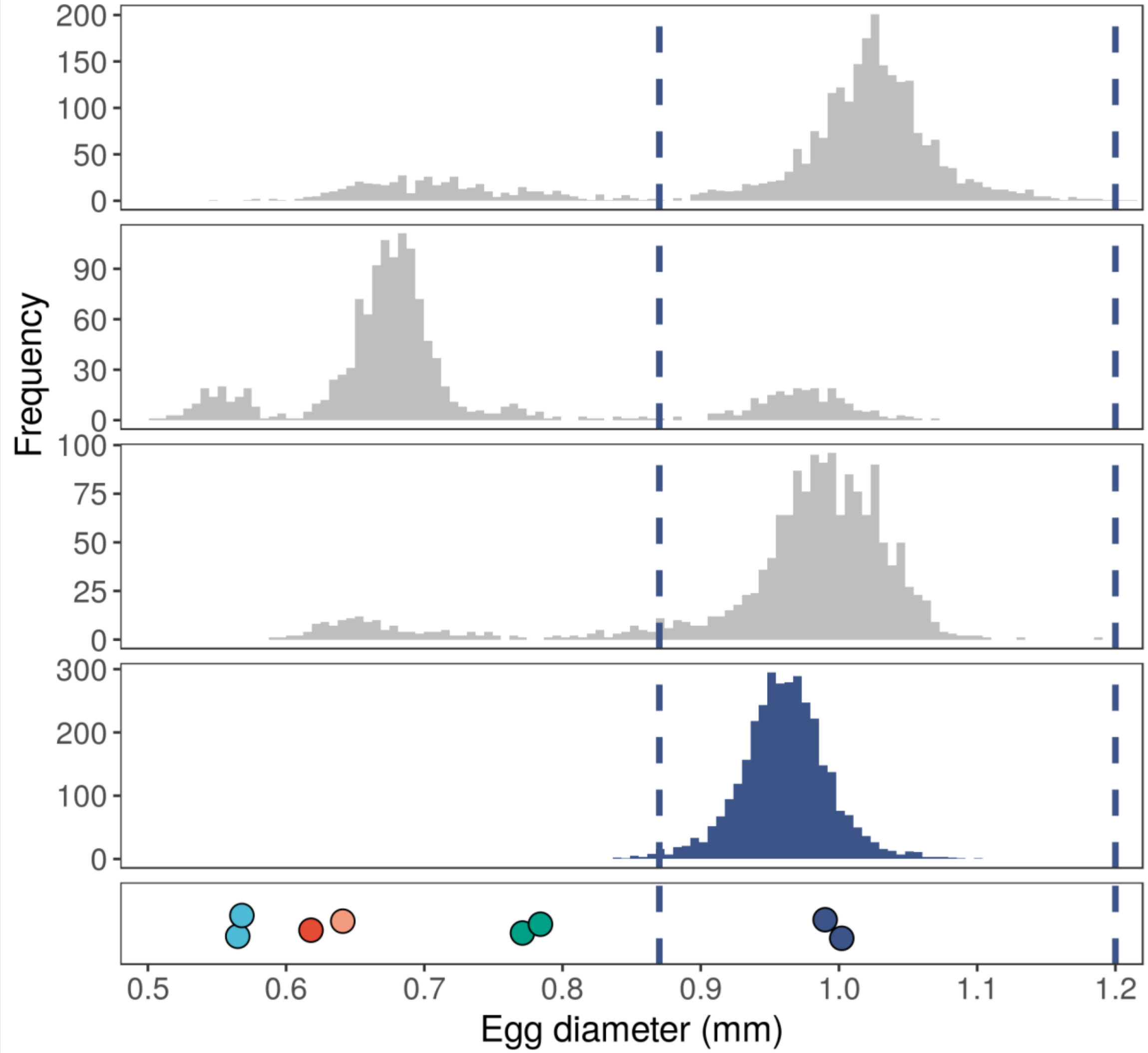

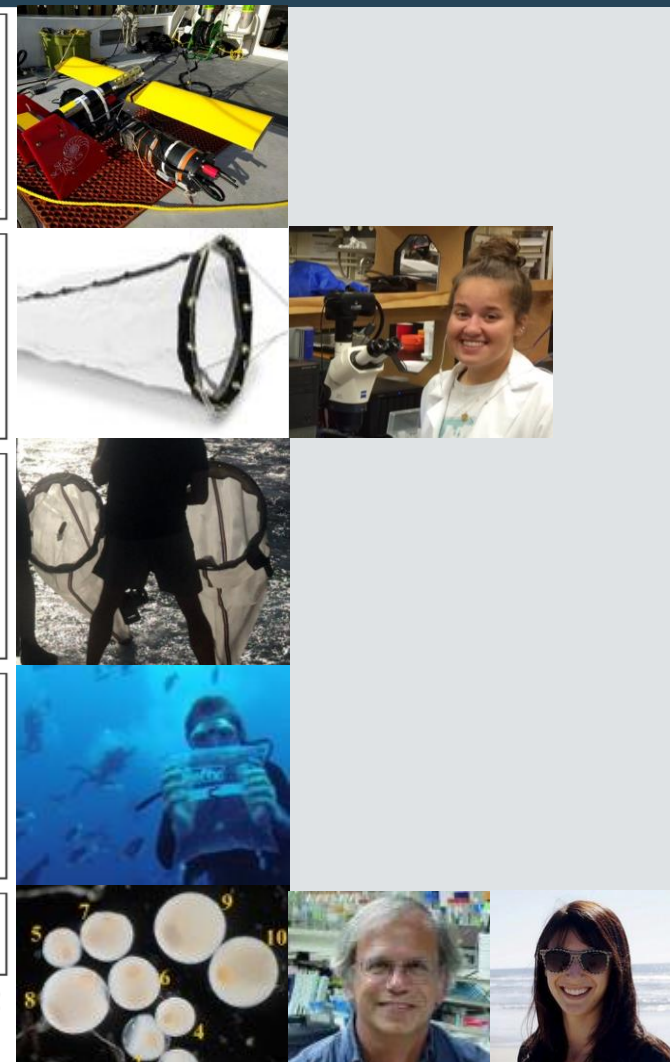

Methods

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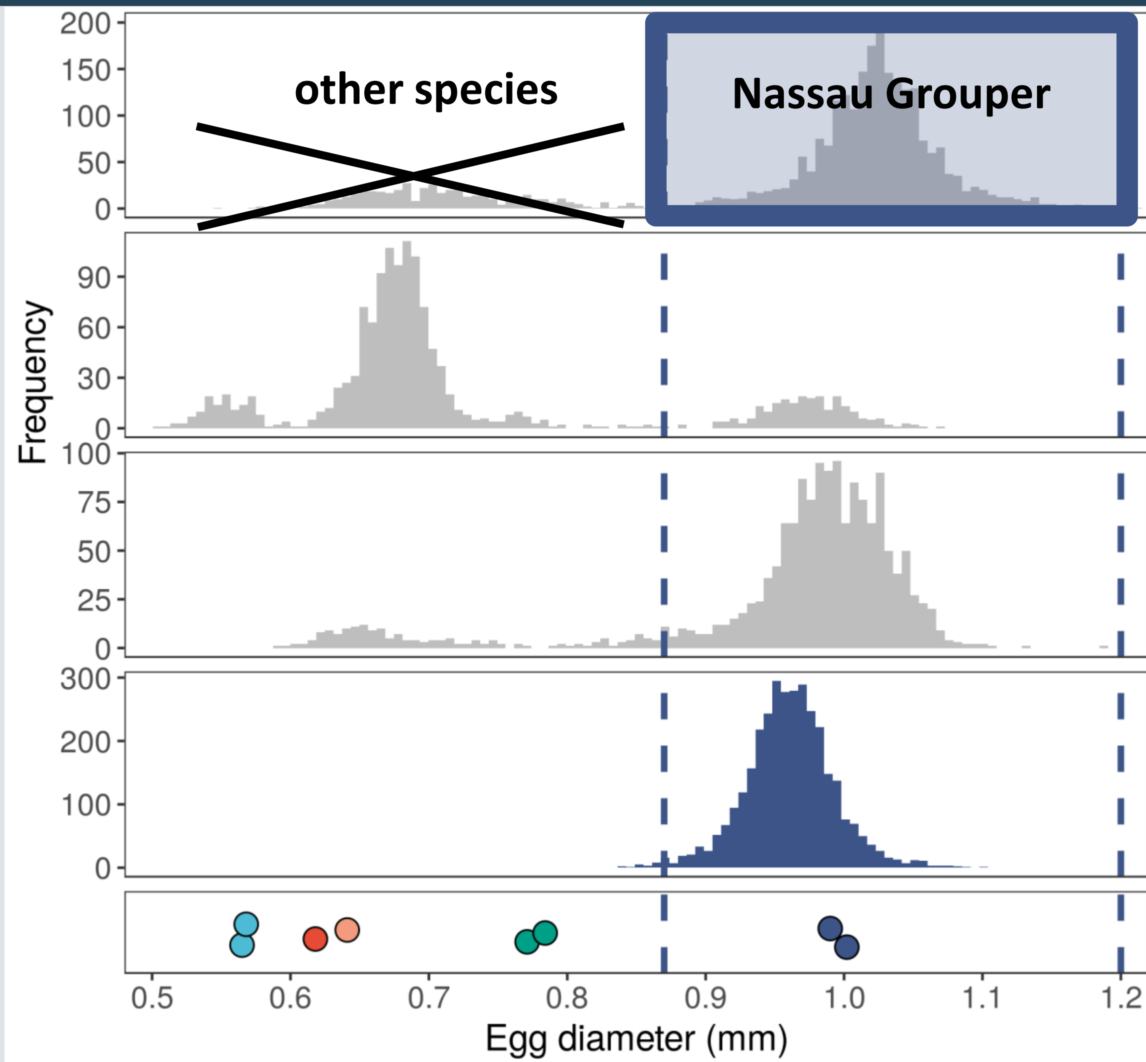
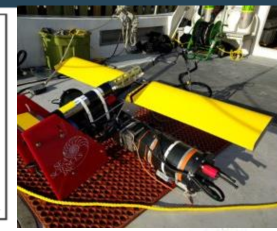
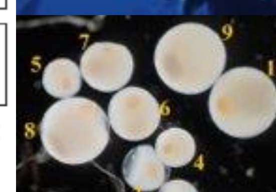
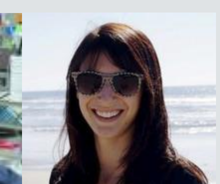
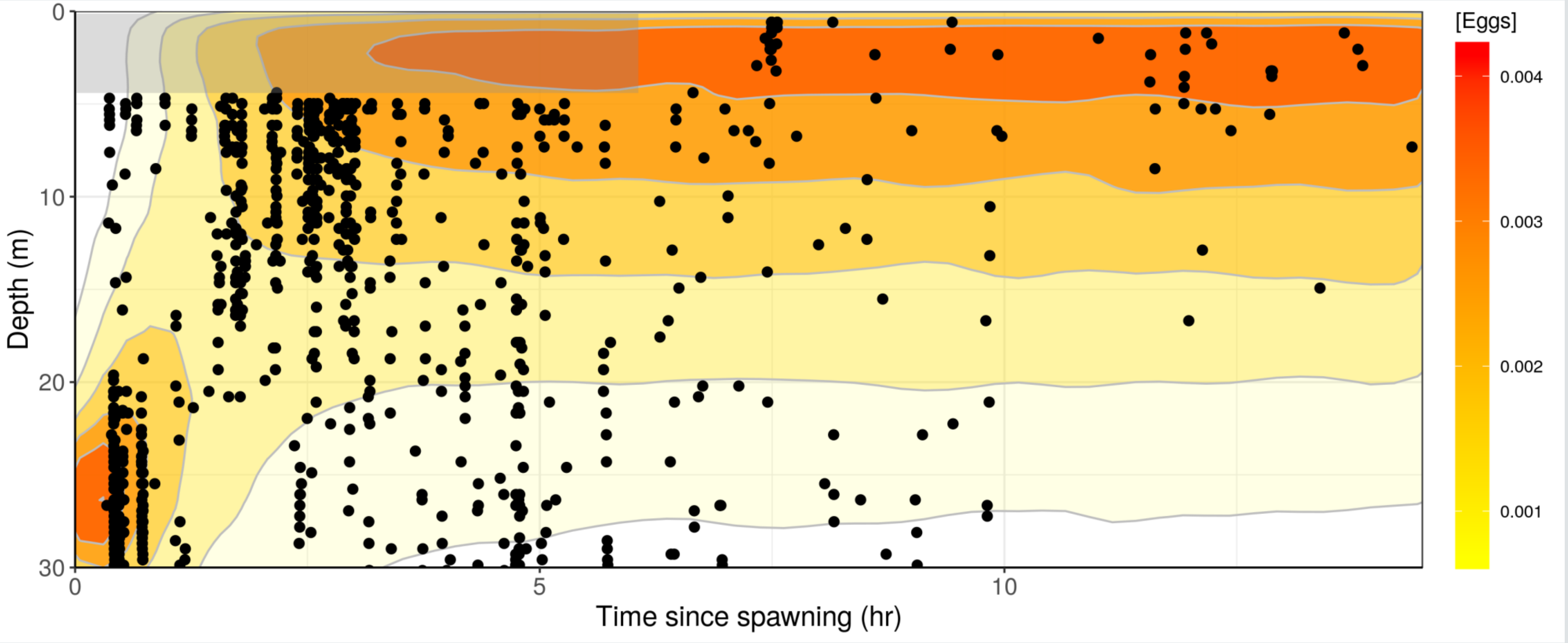




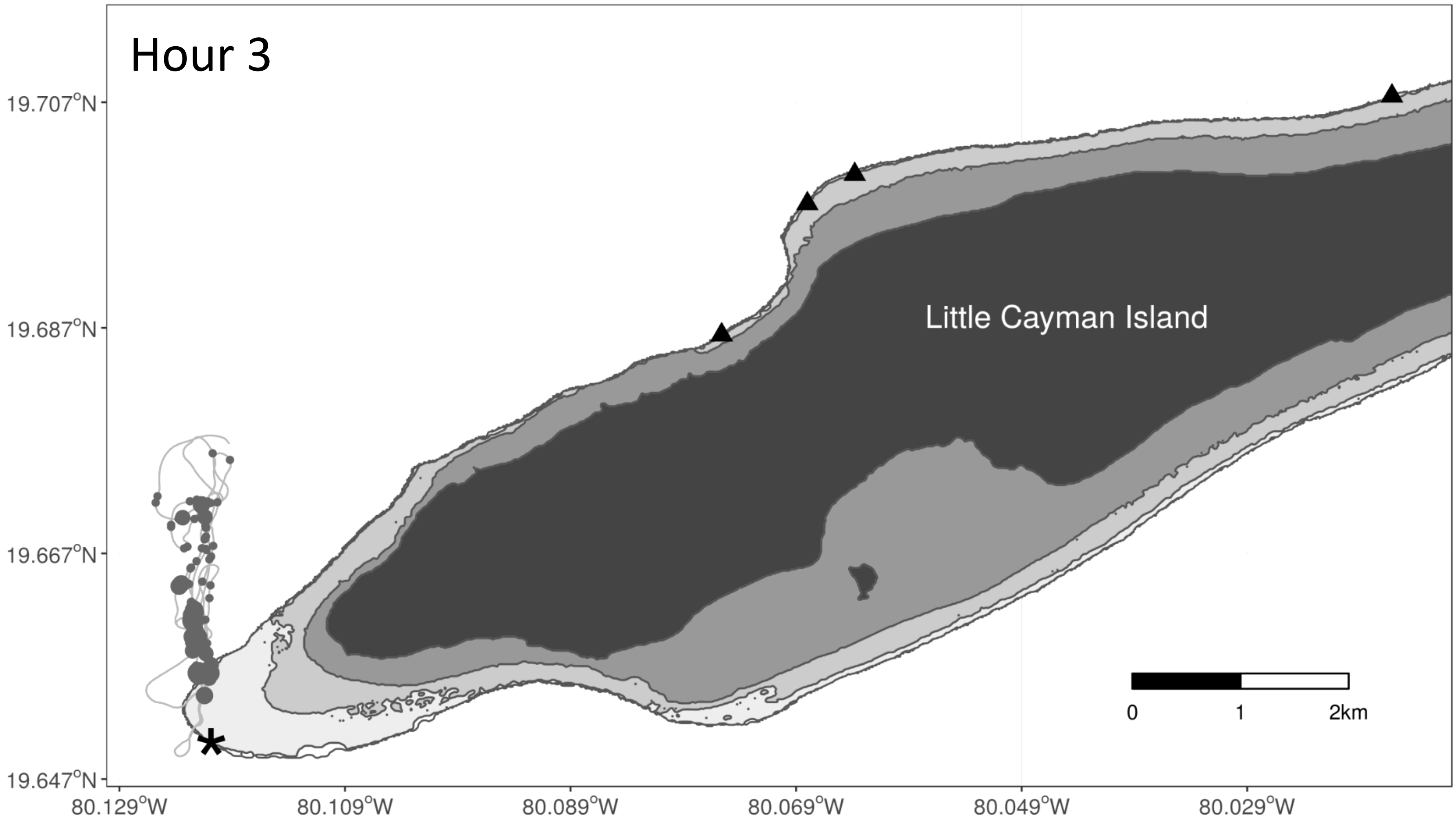




Night #1: Vertical model



Larvae also returned in 2017, night 2



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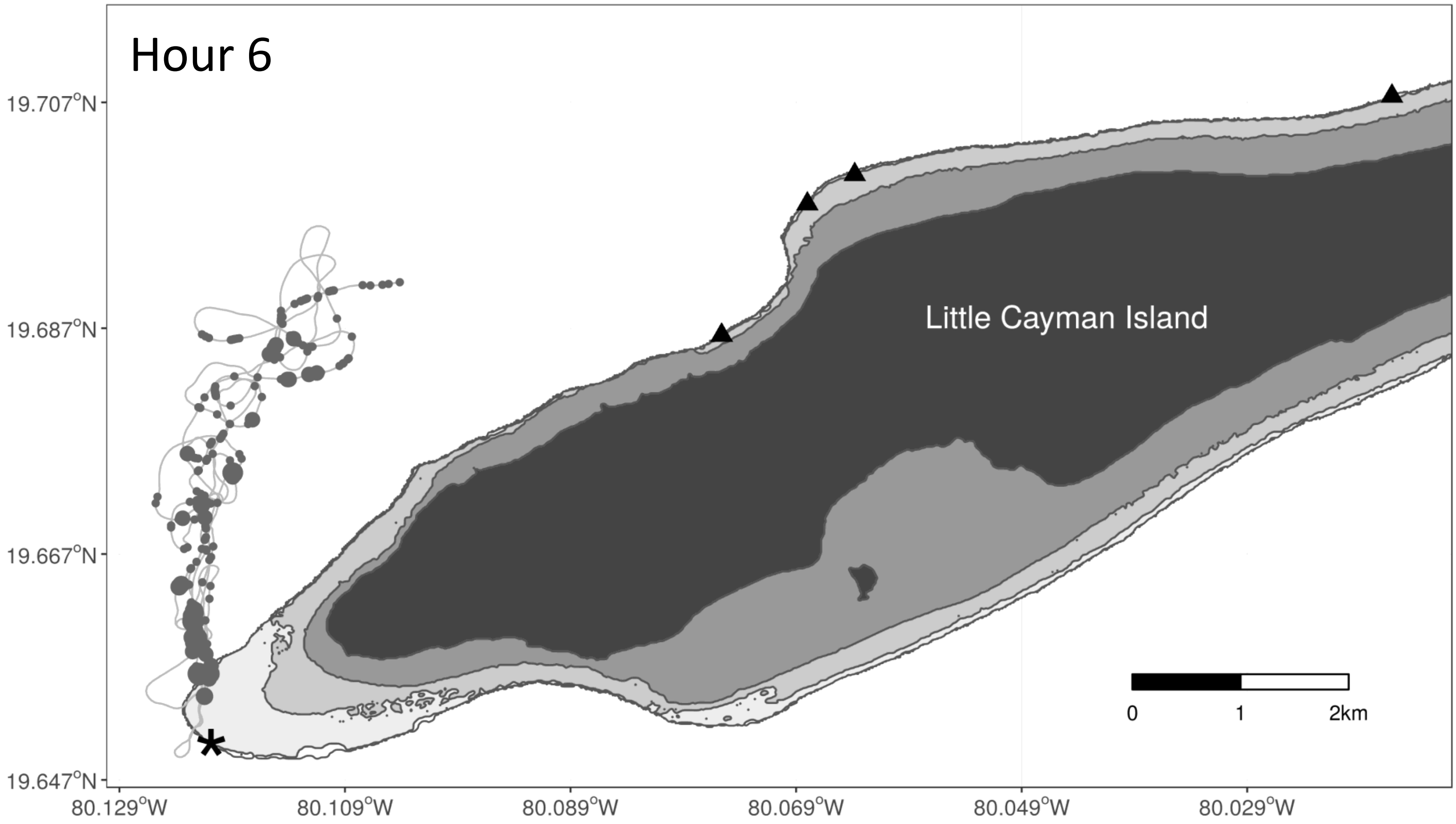
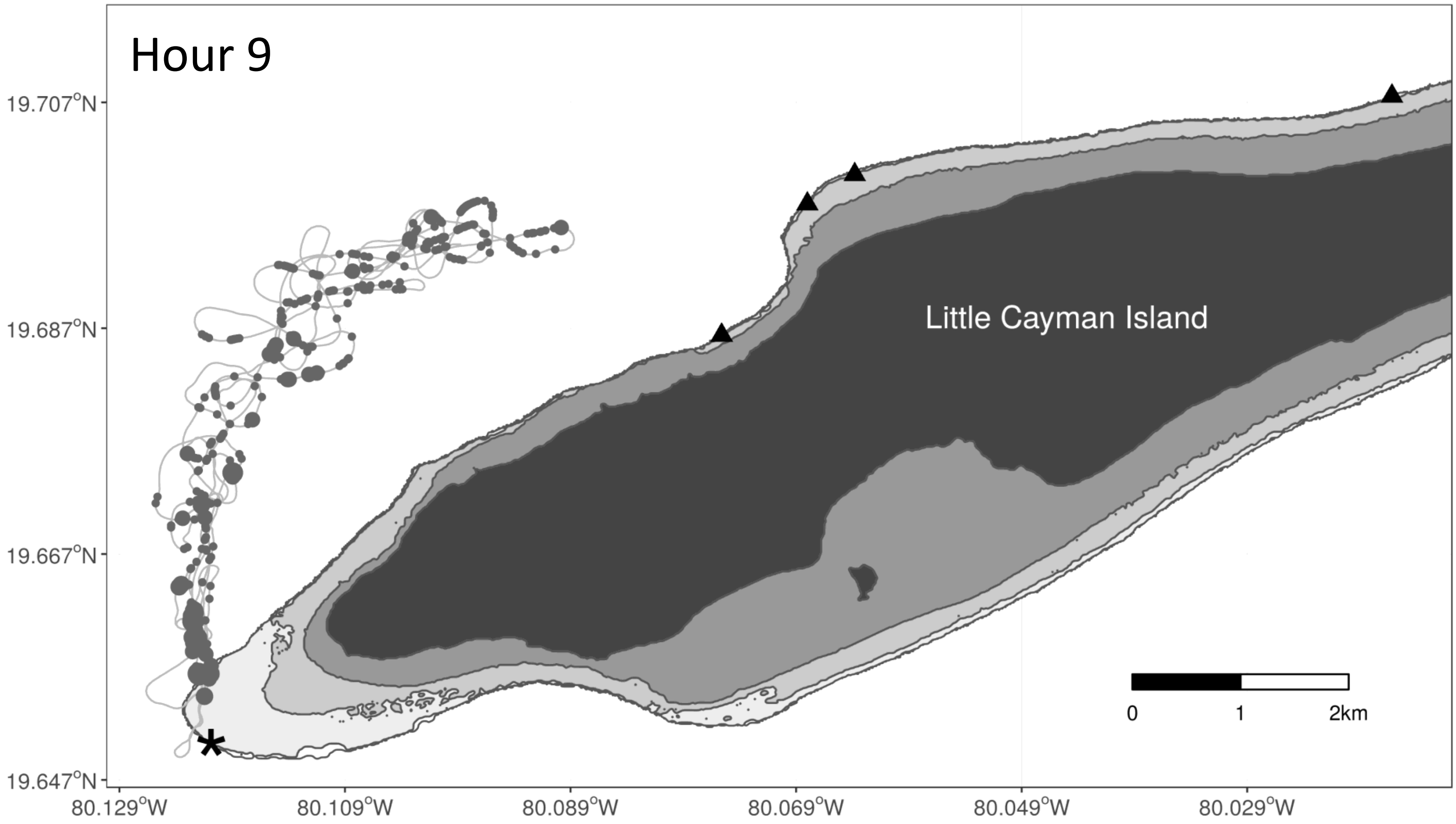


Results

Larvae also returned in 2017, night 2



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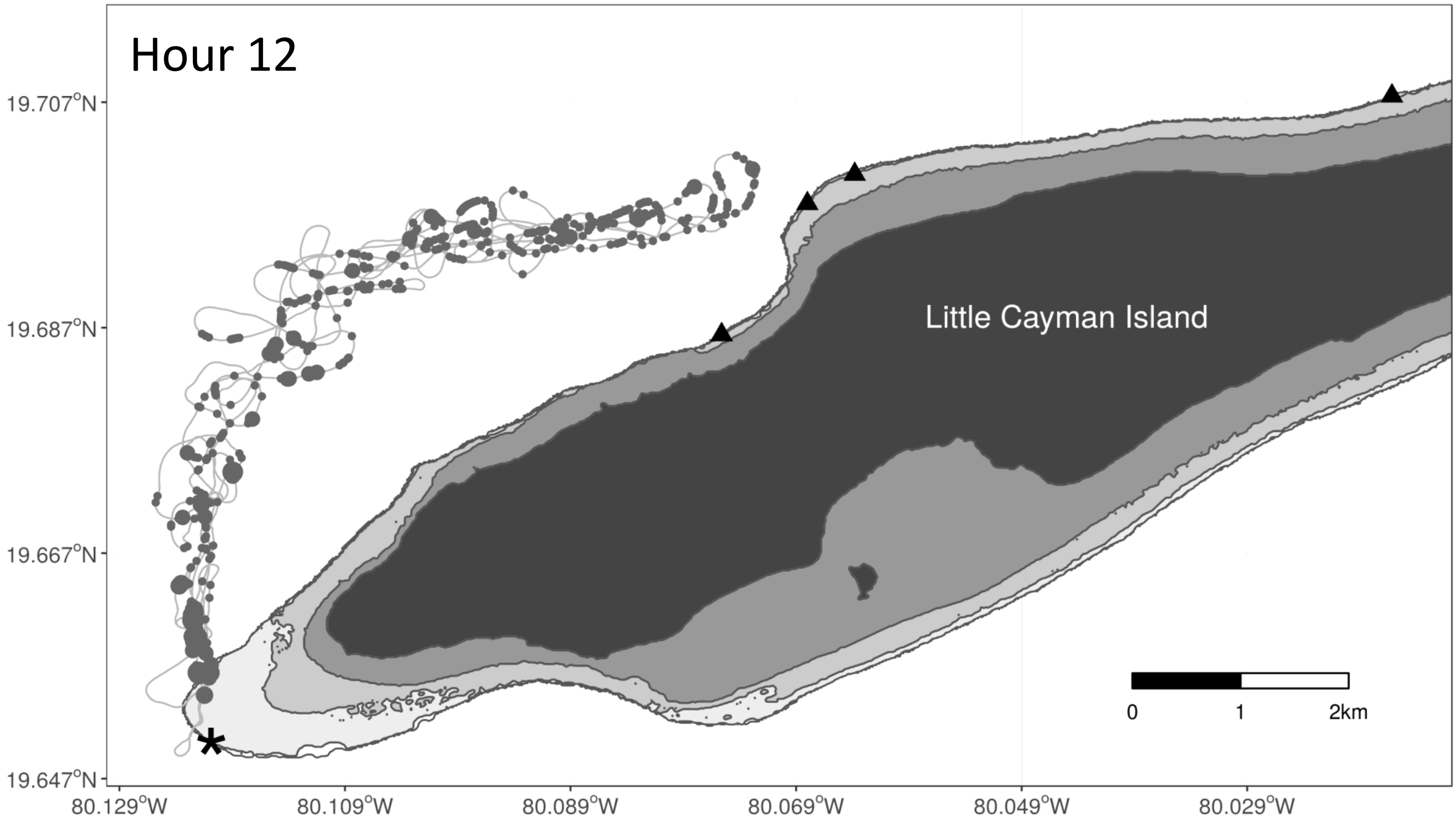

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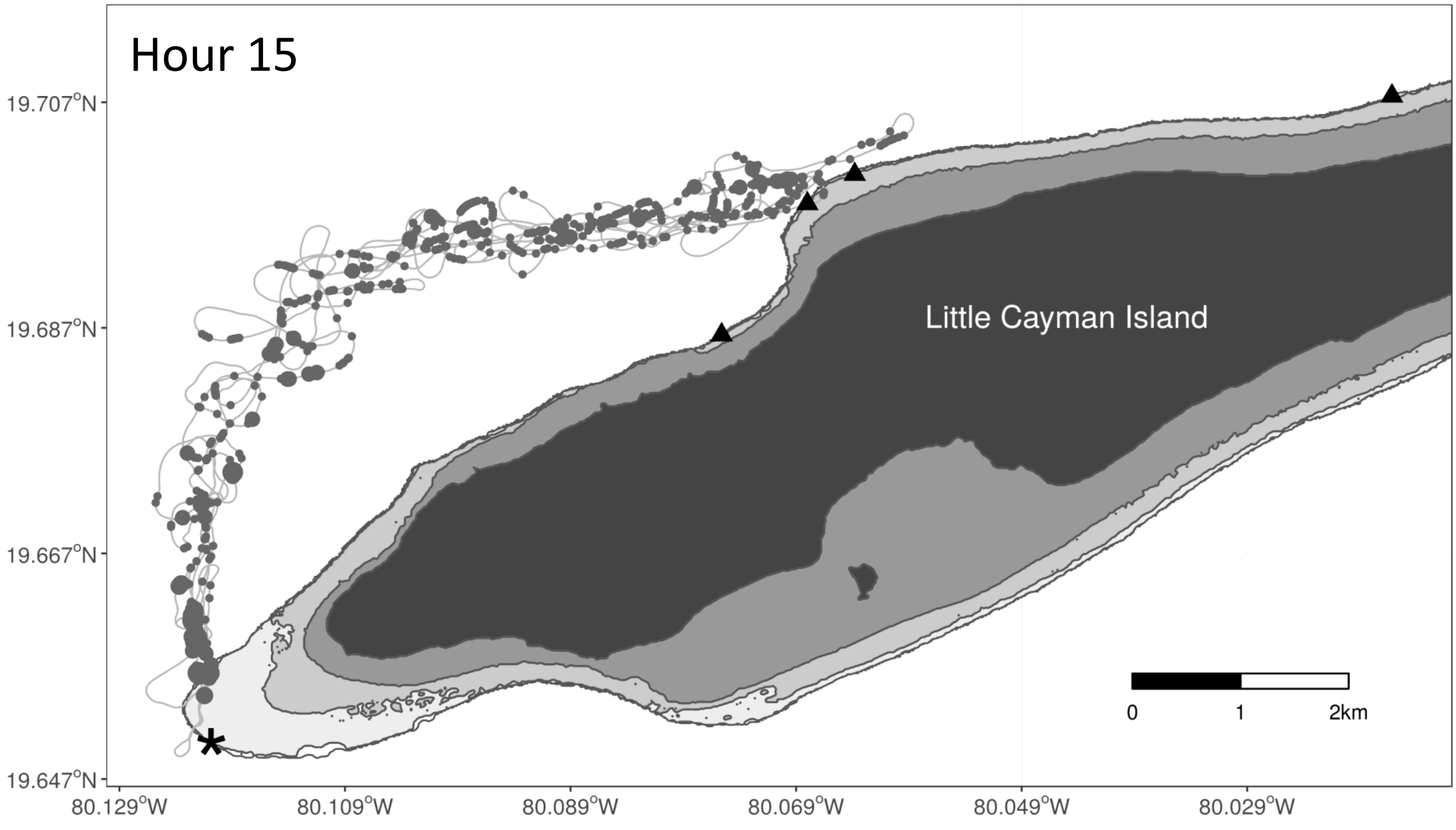
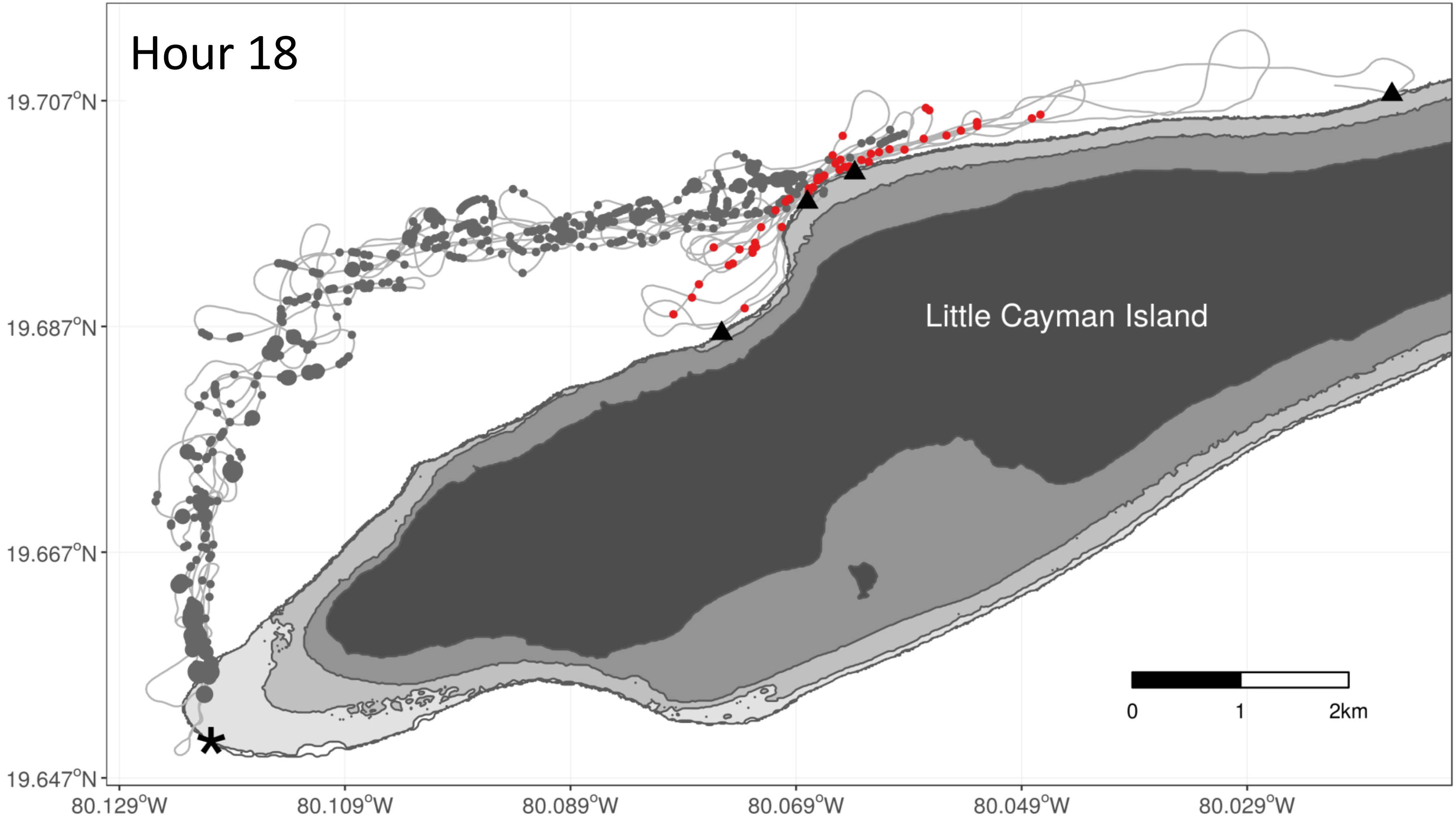
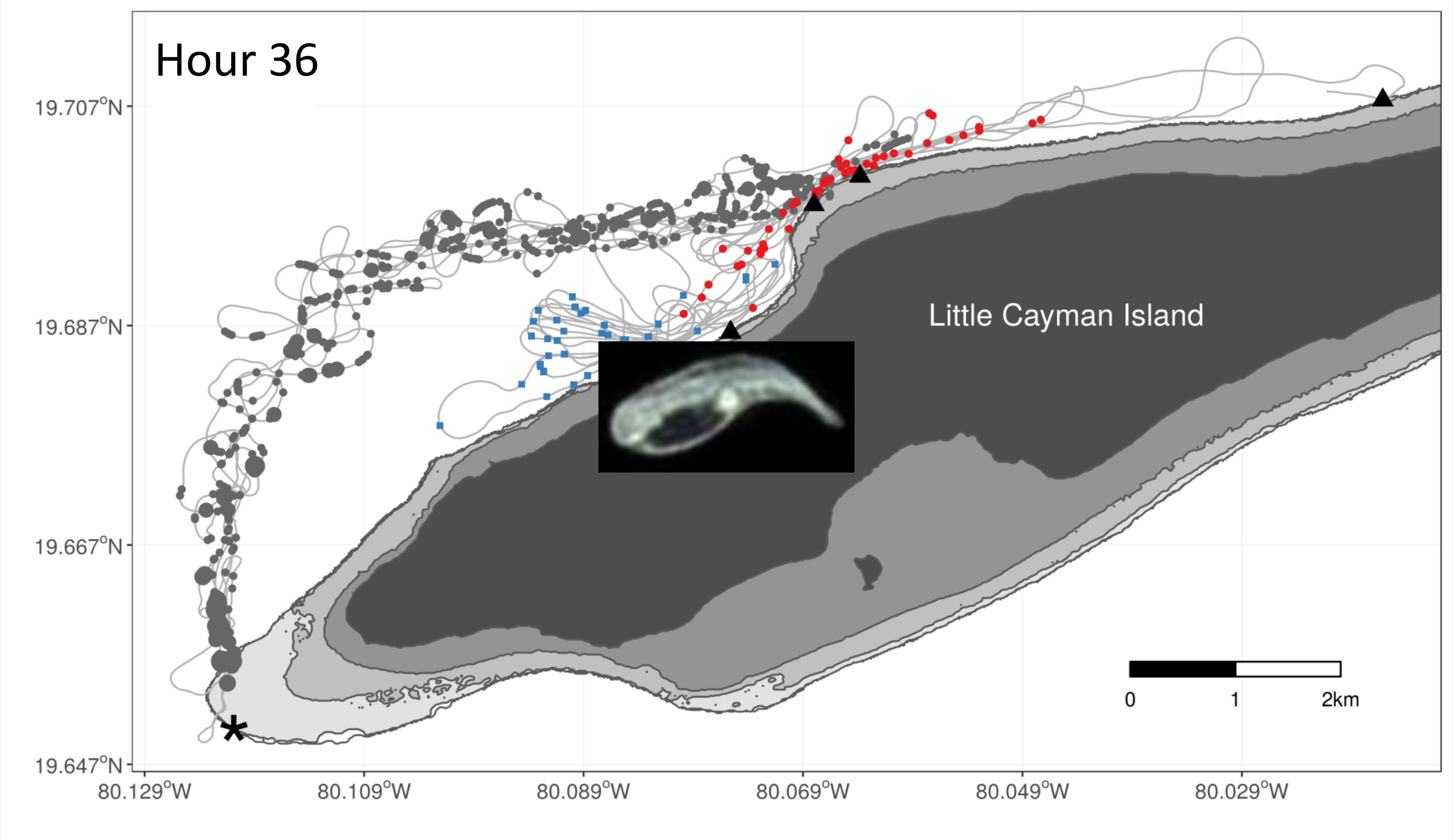


Results

Smooshed out horizontally



Did the larvae return too soon?



Results