

# **Soundscape fishing: spatial variability in a low-frequency fish chorus in the southern California kelp forest**

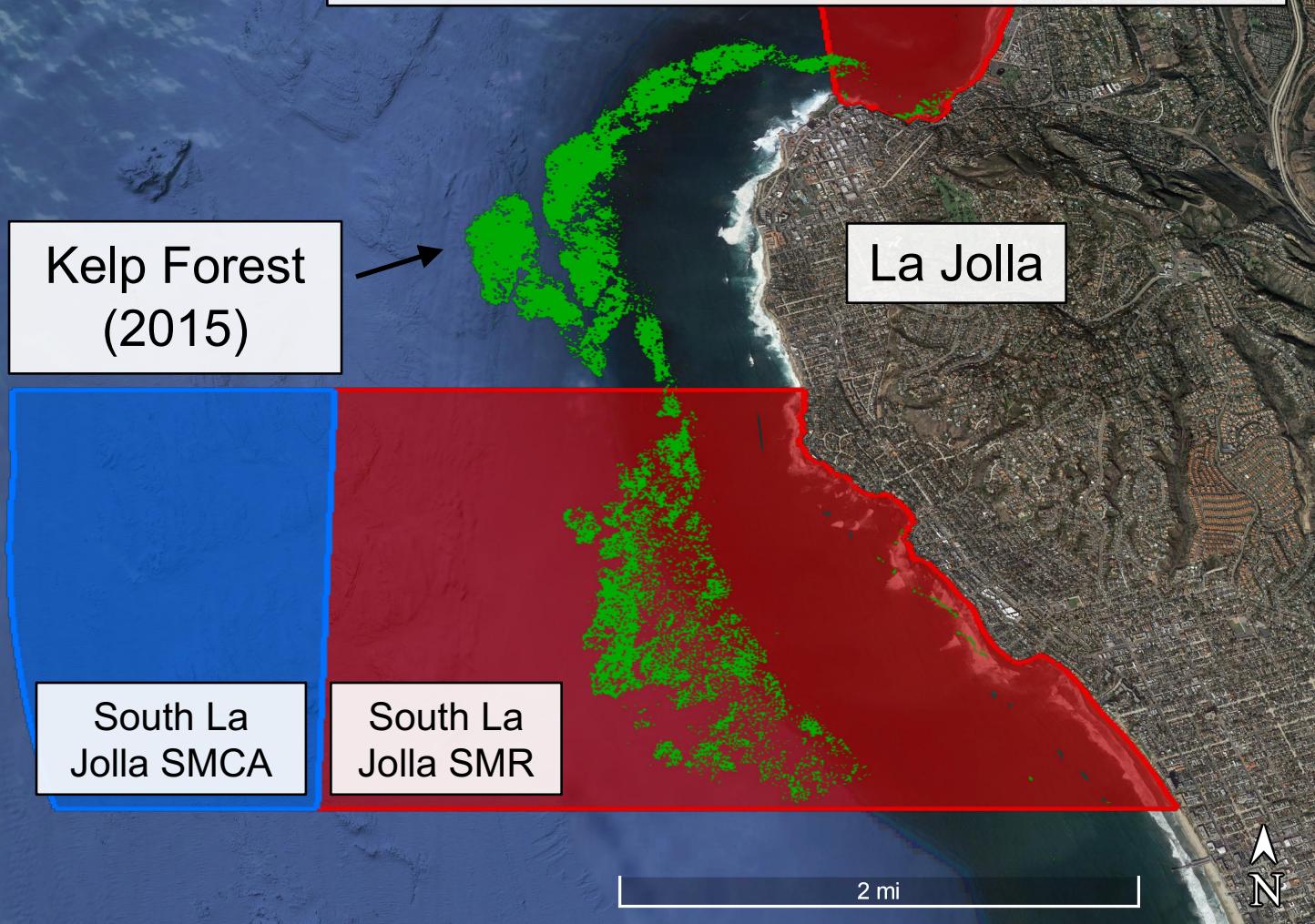
Camille Pagniello, Jack Butler, Gerald D'Spain, Jules Jaffe, Ed Parnell and Ana Širović

Scripps Institution of Oceanography  
University of California San Diego



# Kelp Forest

# San Diego Marine Protected Areas



Google Earth

Data USGS

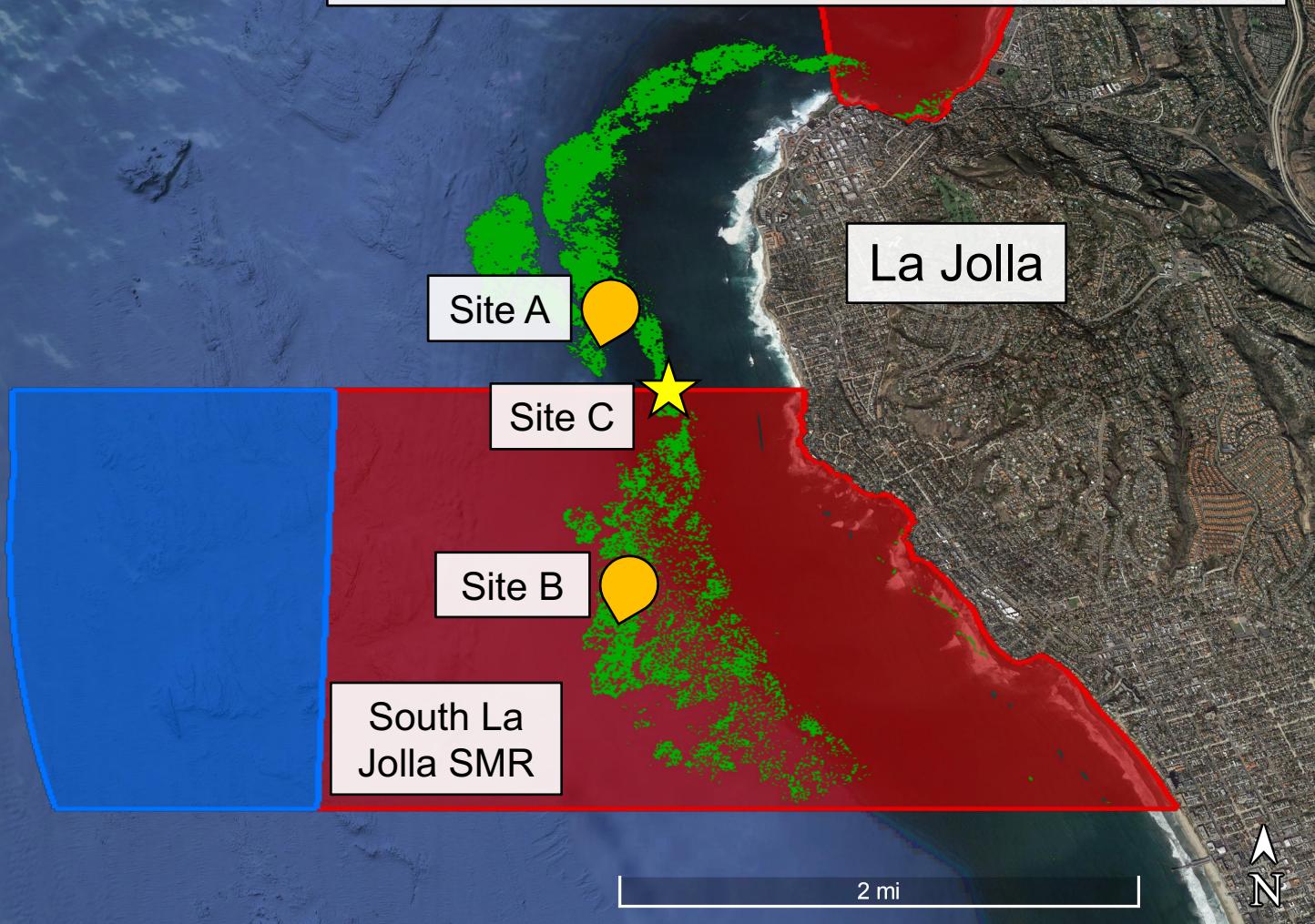
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Data CSUMB SFML, CA OPC

SMR: prohibits damage or take of all marine resources

SMCA: allows some recreational and/or commercial take of marine resources

# San Diego Marine Protected Areas



Google Earth

Data USGS

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Data CSUMB SFML, CA OPC

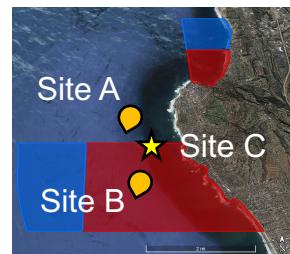
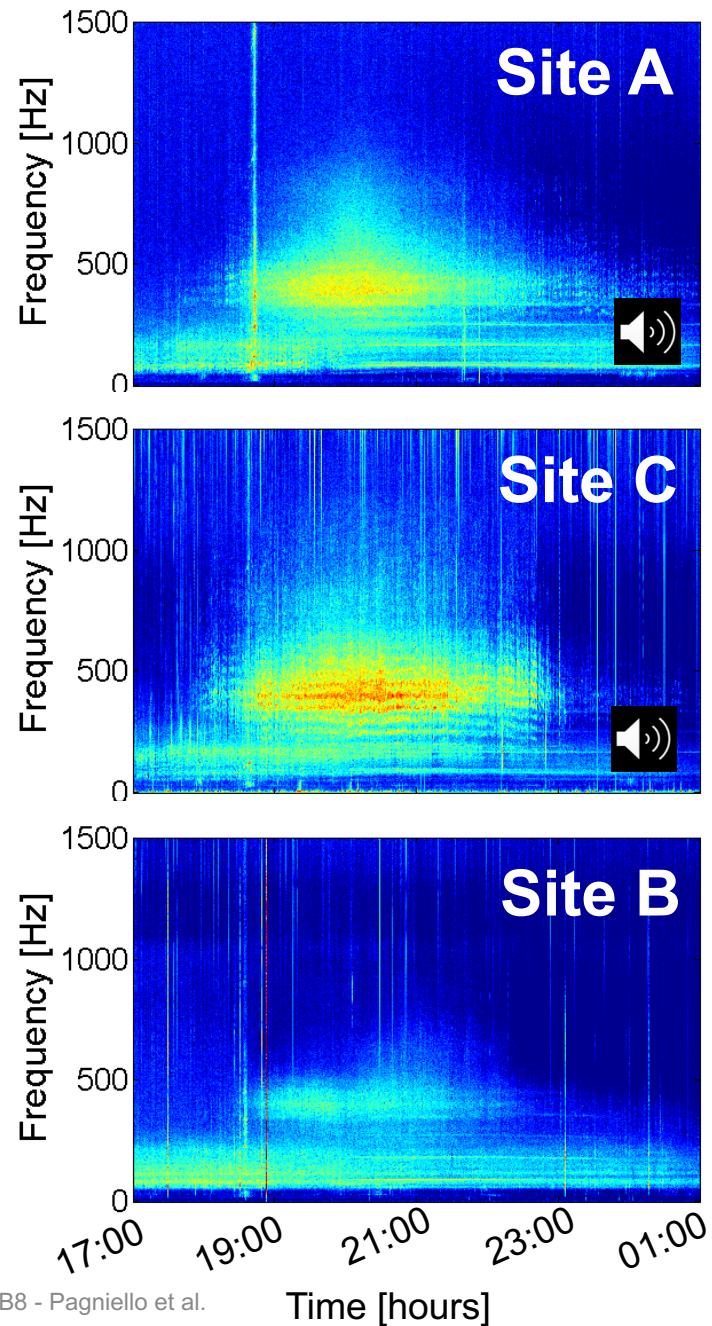
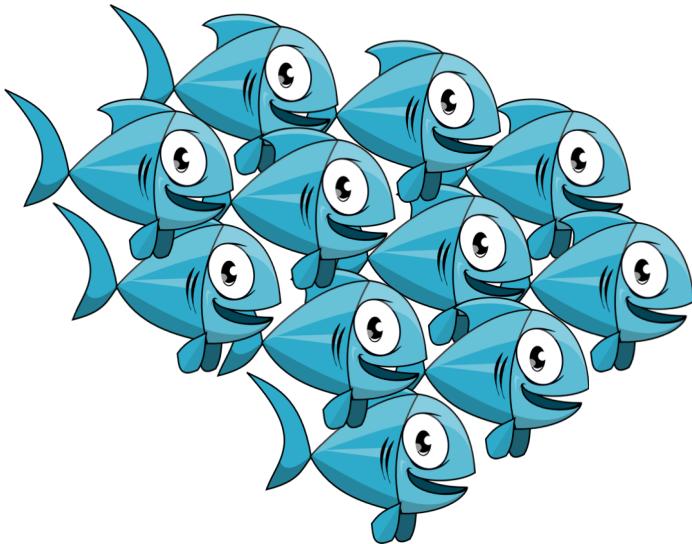
2 mi



**SMR:** prohibits damage or take of all marine resources

**SMCA:** allows some recreational and/or commercial take of marine resources

# A low-frequency fish chorus!



# Objectives

- Who?

- identify the chorusing fish species
- 

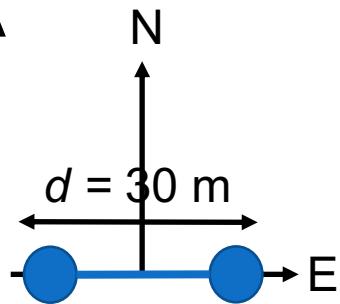
- Where? & When?

- locate the fish chorus
- diel and seasonal variability of location

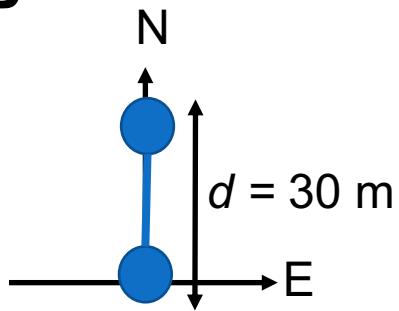
- What?

- identify drivers of chorus spatial distribution
- e.g., bathymetry, temperature, kelp etc.

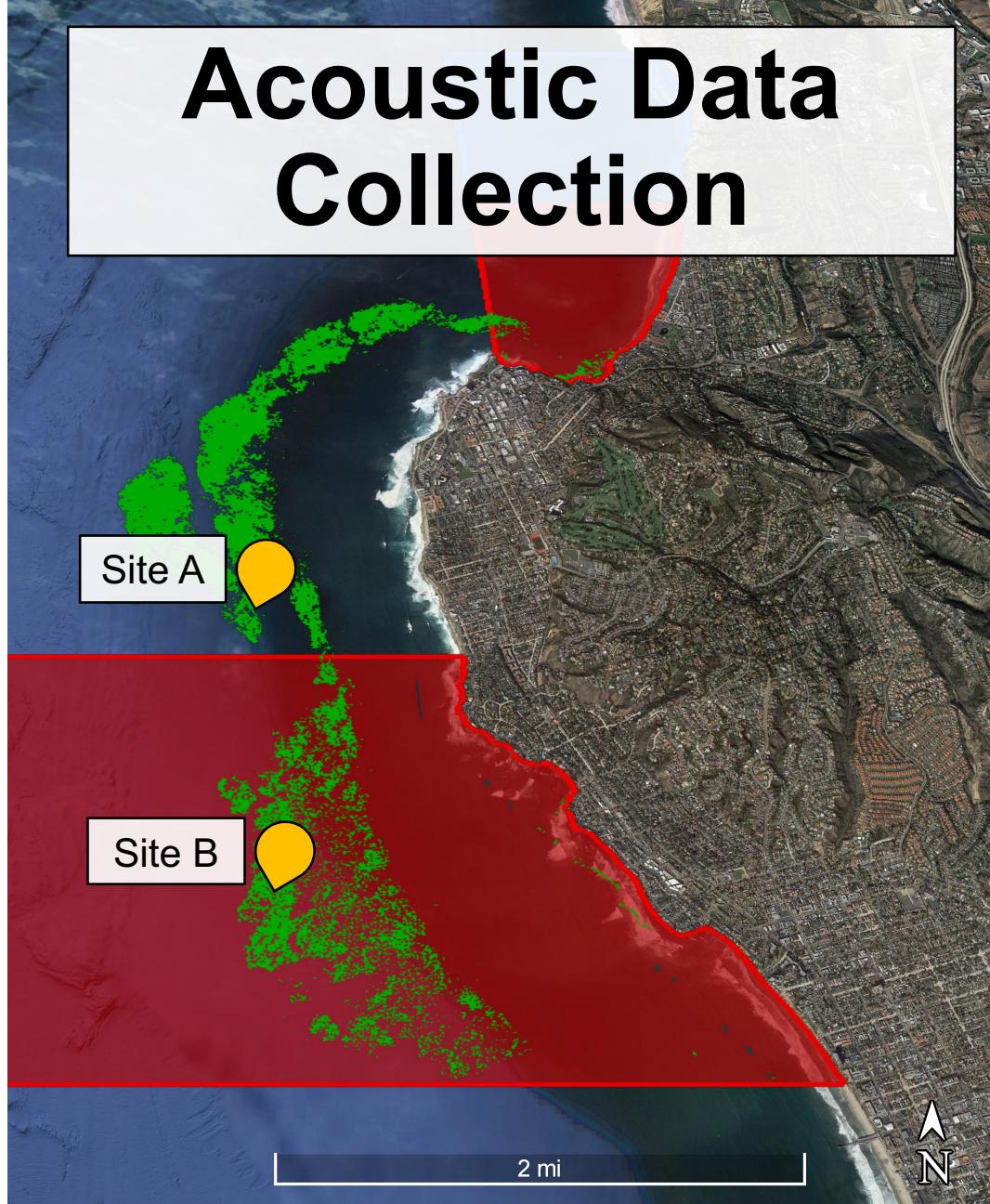
**Site A**



**Site B**

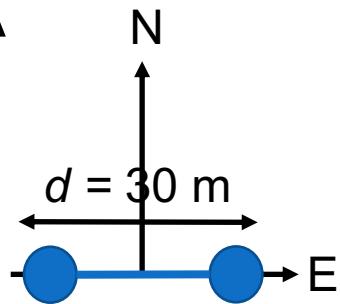


# Acoustic Data Collection

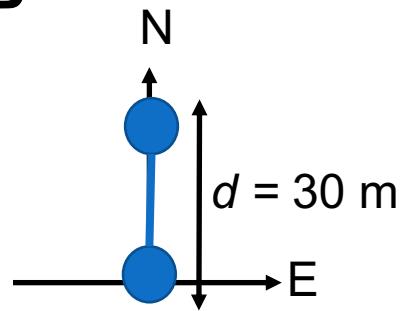


May-August, 2015-2017

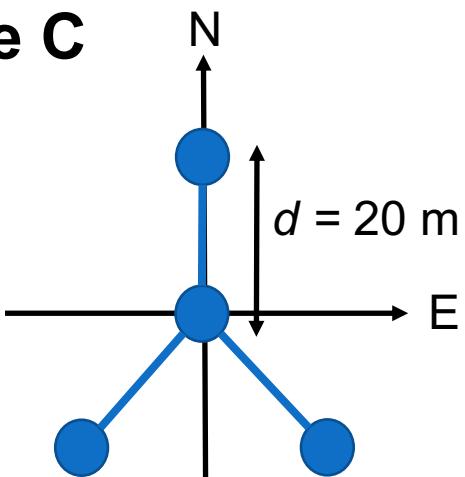
## Site A



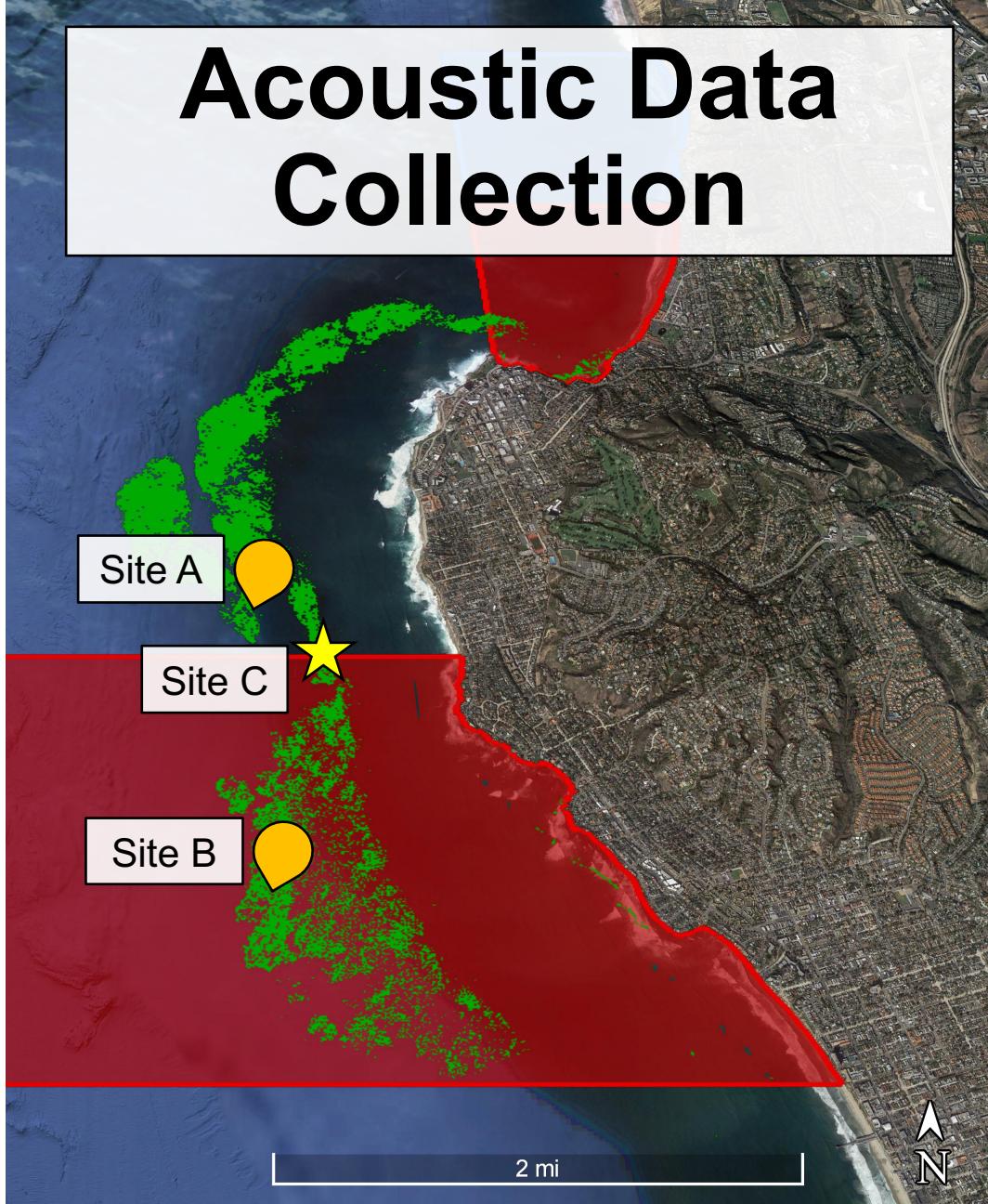
## Site B



## Site C



# Acoustic Data Collection



May-August, 2015-2017

# Where are the fish?

## Frequency Beamforming

- search in bearing  $\Theta$  for a plane-wave signal
- matching received data across the array with model signal
- linear (Bartlett) beamformer output:

$$\vec{B}_{bartlett}(w, \vec{\theta}) = \vec{w}^*(\vec{\theta}) \vec{K}(w, \vec{\theta}) \vec{w}(\vec{\theta}) \quad \text{where,}$$

$\vec{d}(\omega) = [d_1(\omega), d_2(\omega)]$  is the data vector

$\vec{w}(\vec{\theta}) = [w_1(\vec{\theta}), w_2(\vec{\theta})]$  is the replica vector (i.e., plane-wave)

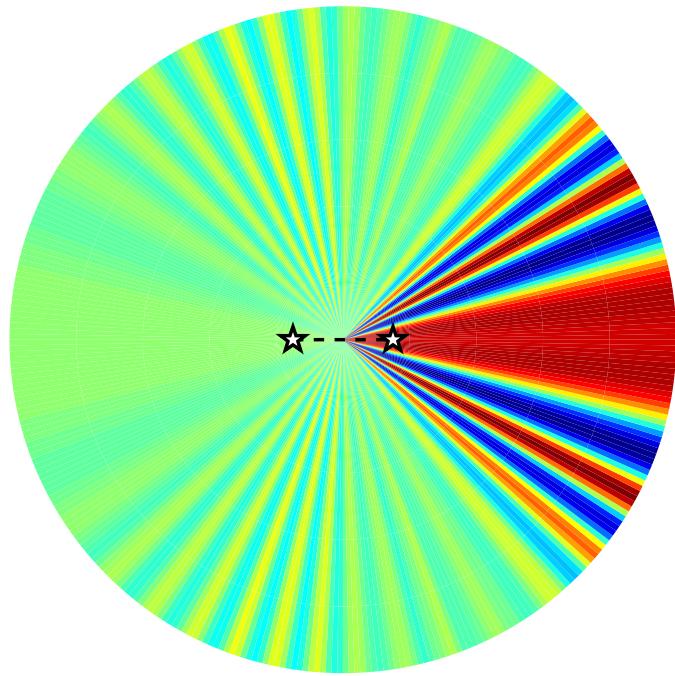
$\vec{K}(w, \vec{\theta}) = \frac{1}{L} \sum_{l=1}^L \vec{d}(\omega) \vec{d}^*(\omega)$  is the cross-spectral density matrix

# Example

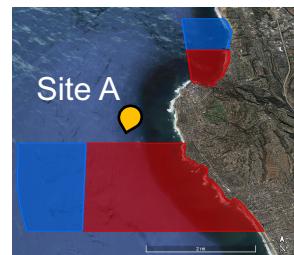
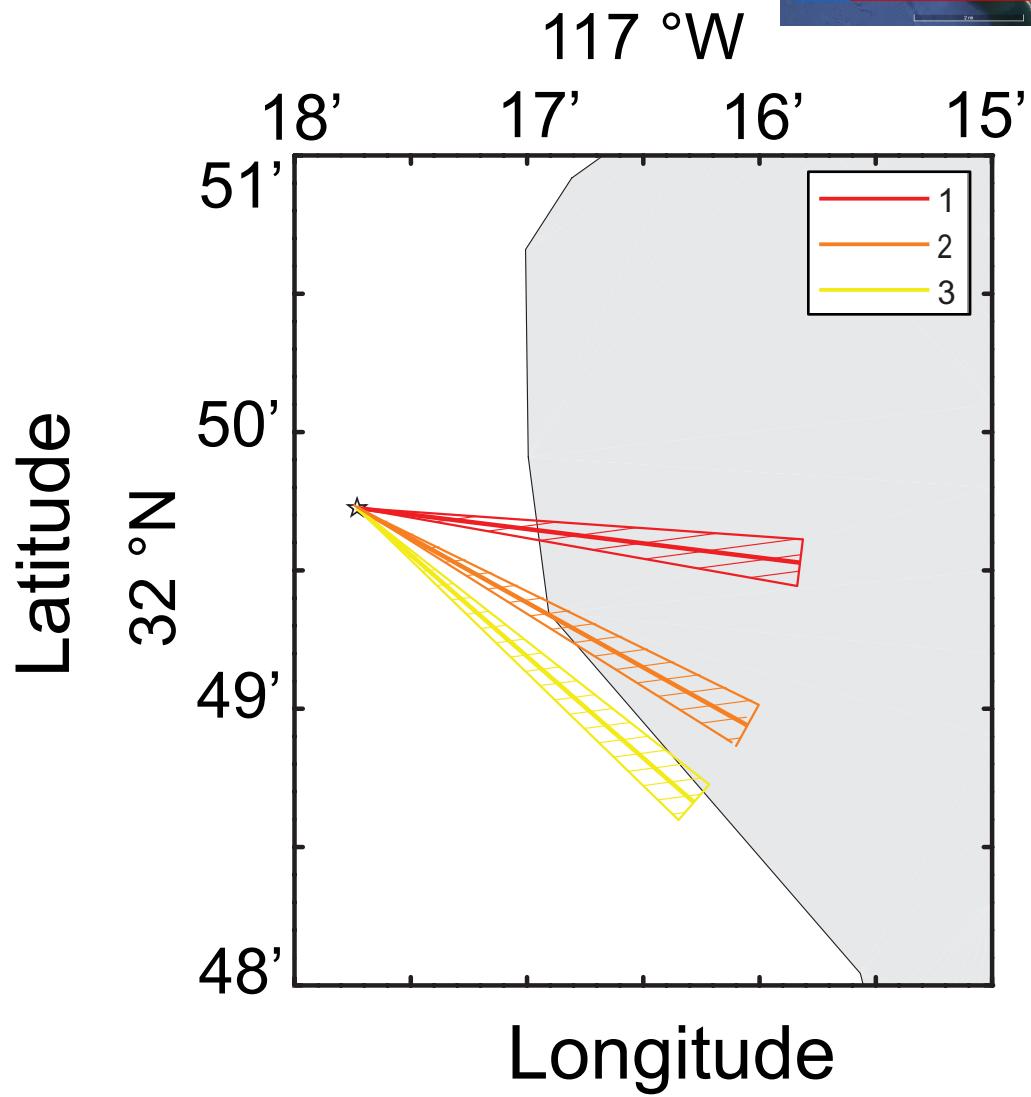
*Beamforming*

June 8, 2017 from 20:04 to 20:34

## Site A



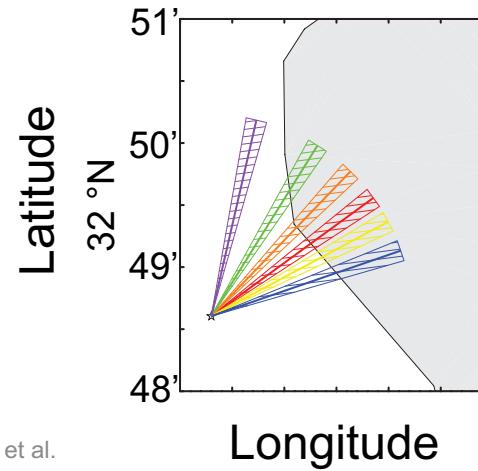
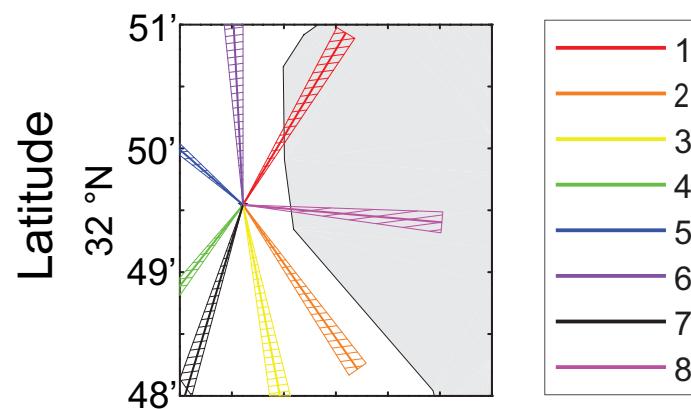
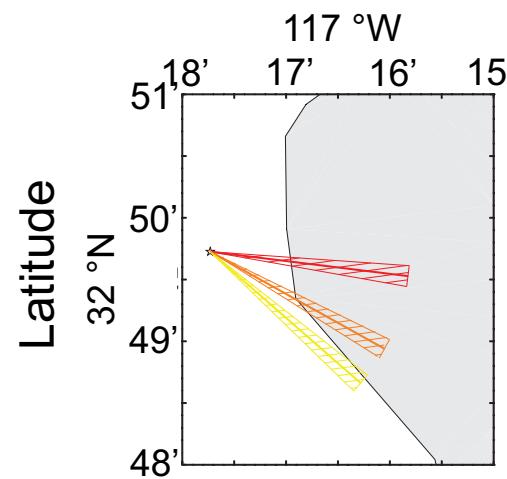
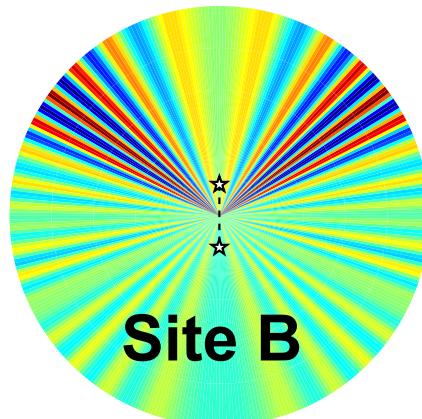
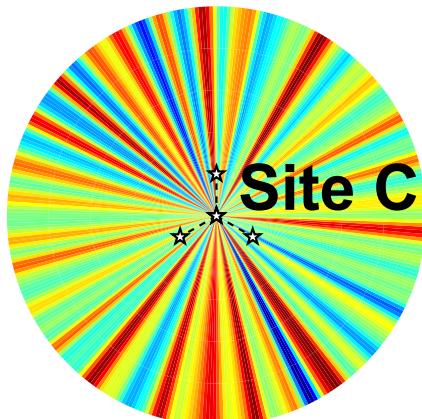
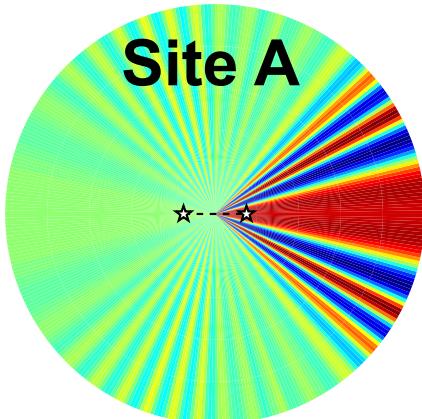
Ambiguity Surface



# Example

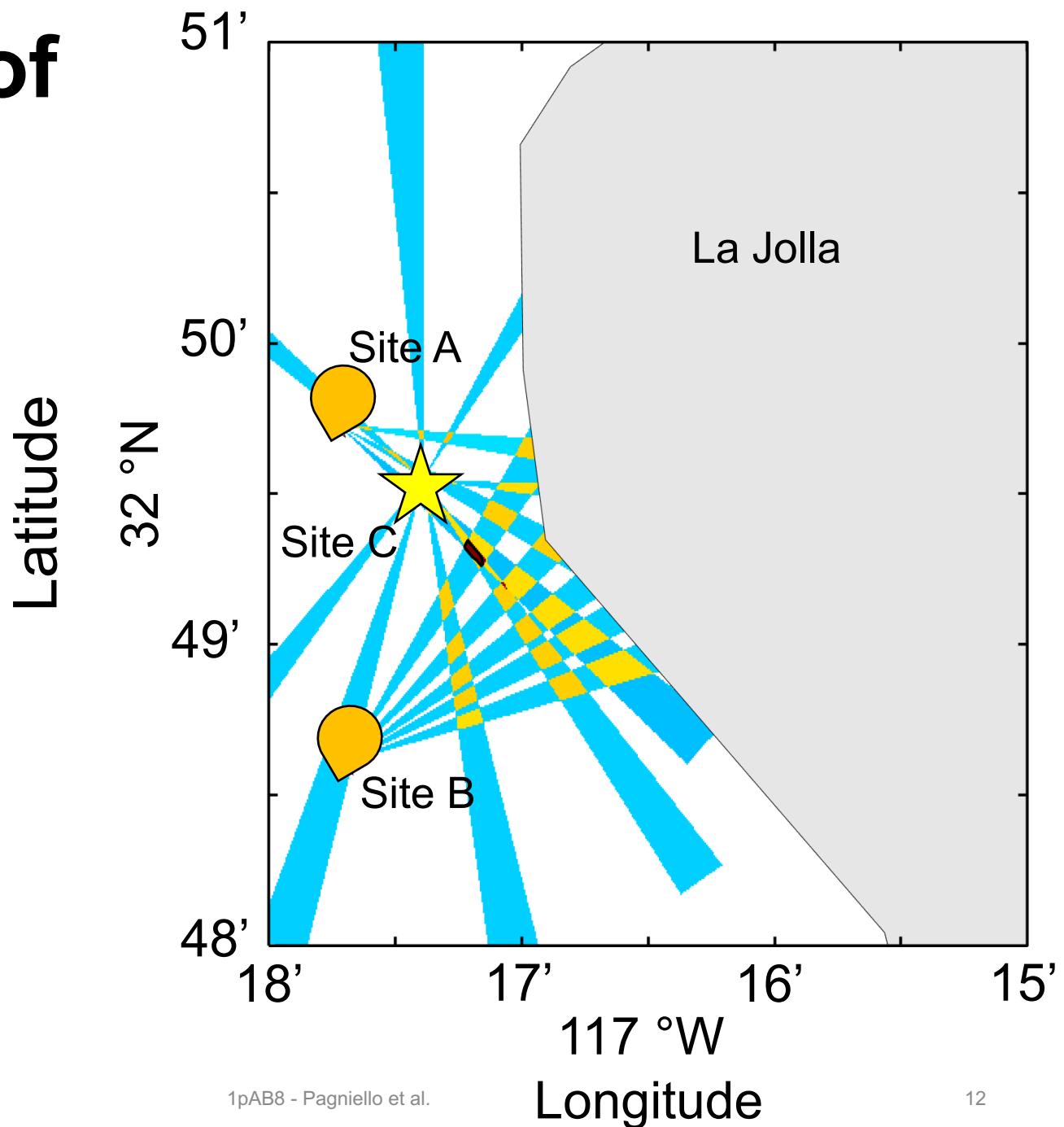
## Beamforming

June 8, 2017 from  
20:04 to 20:34



# Location of chorus

June 8, 2017 from  
20:04 to 20:34

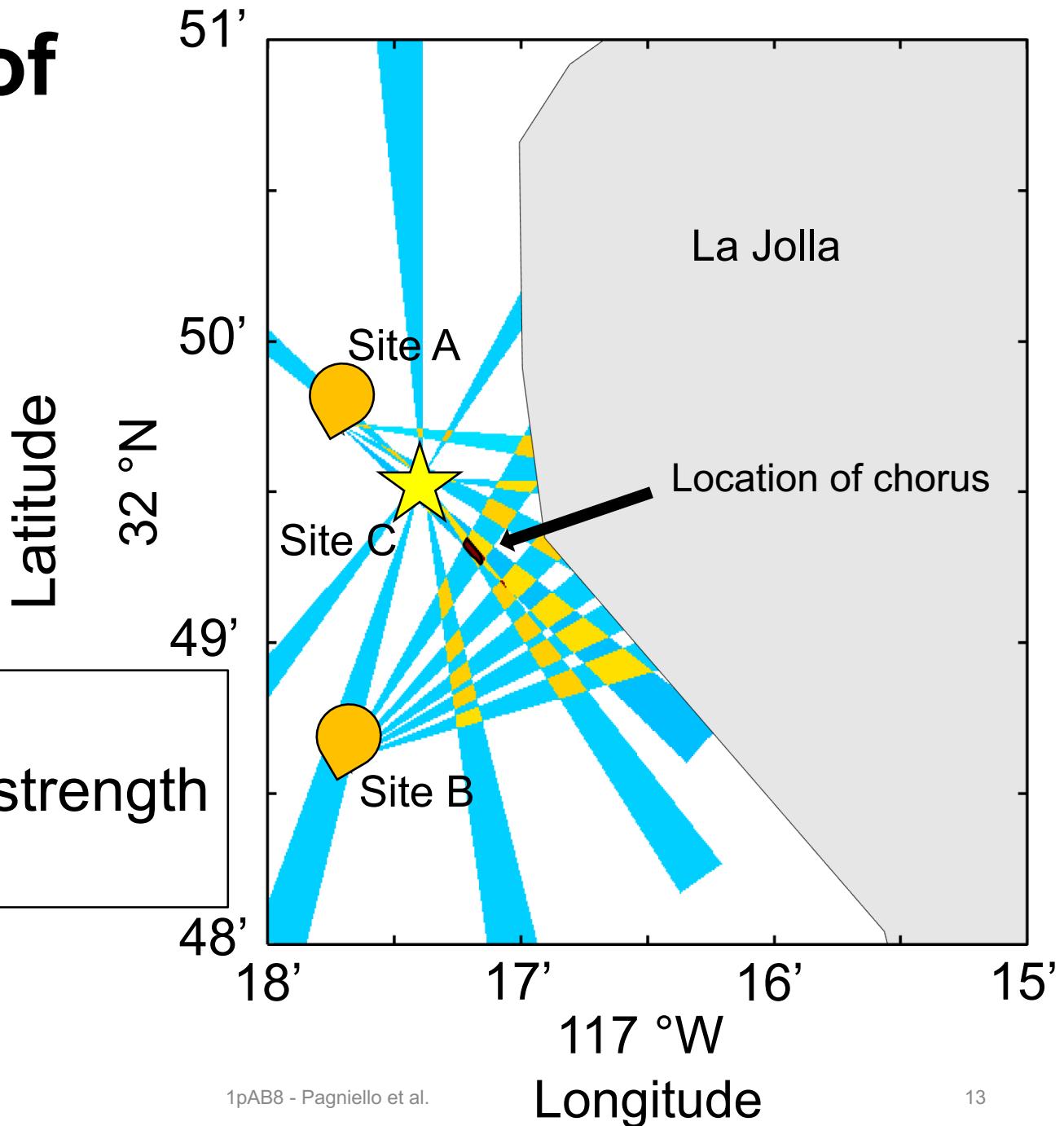


# Location of chorus

June 8, 2017 from  
20:04 to 20:34

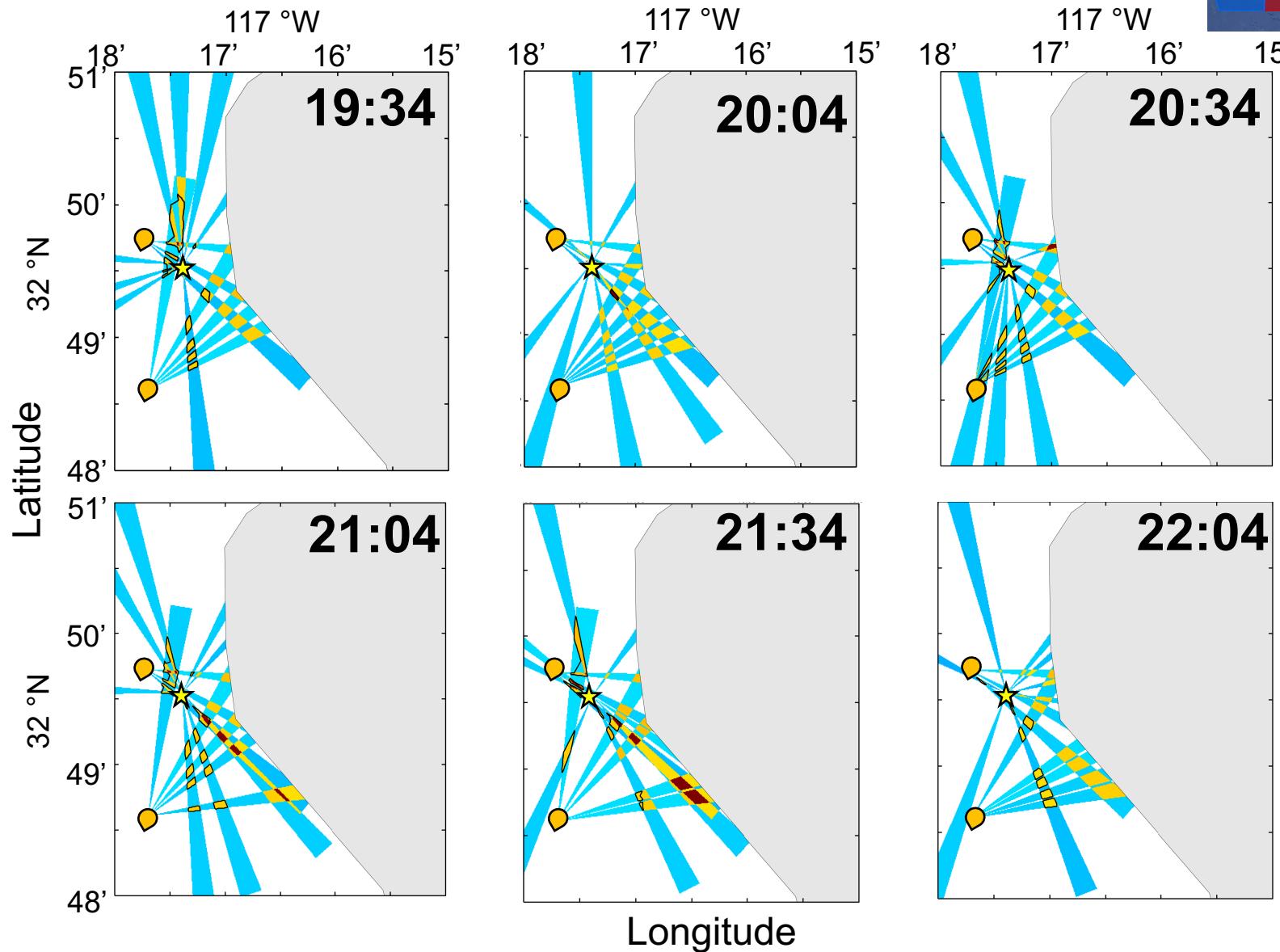
Area must be:

- > 60% beam strength
- depth > 10 m



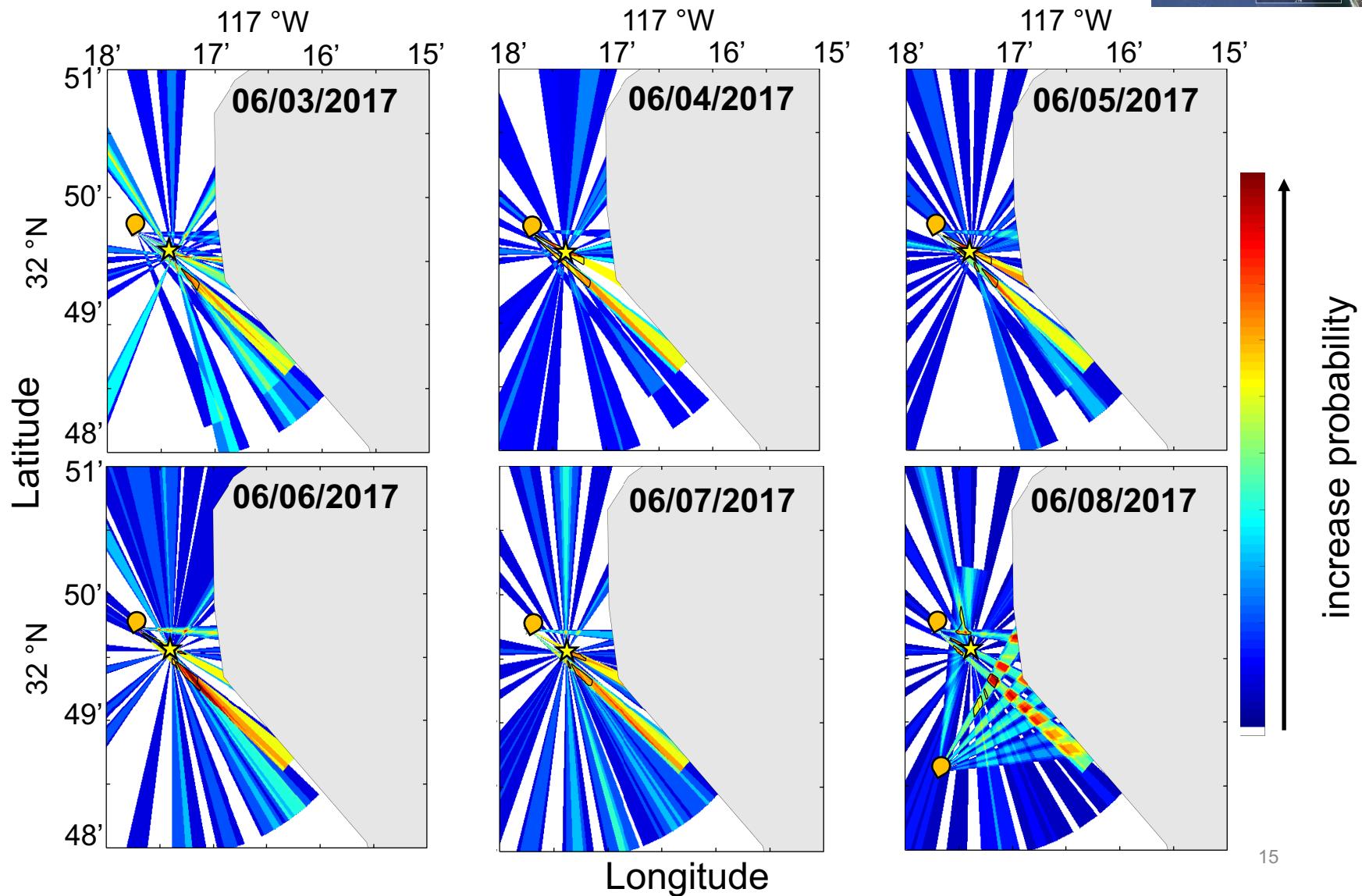
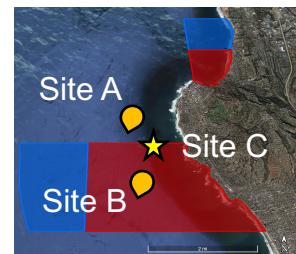
# Location of the chorus

Semi-hourly variability – June 8, 2017



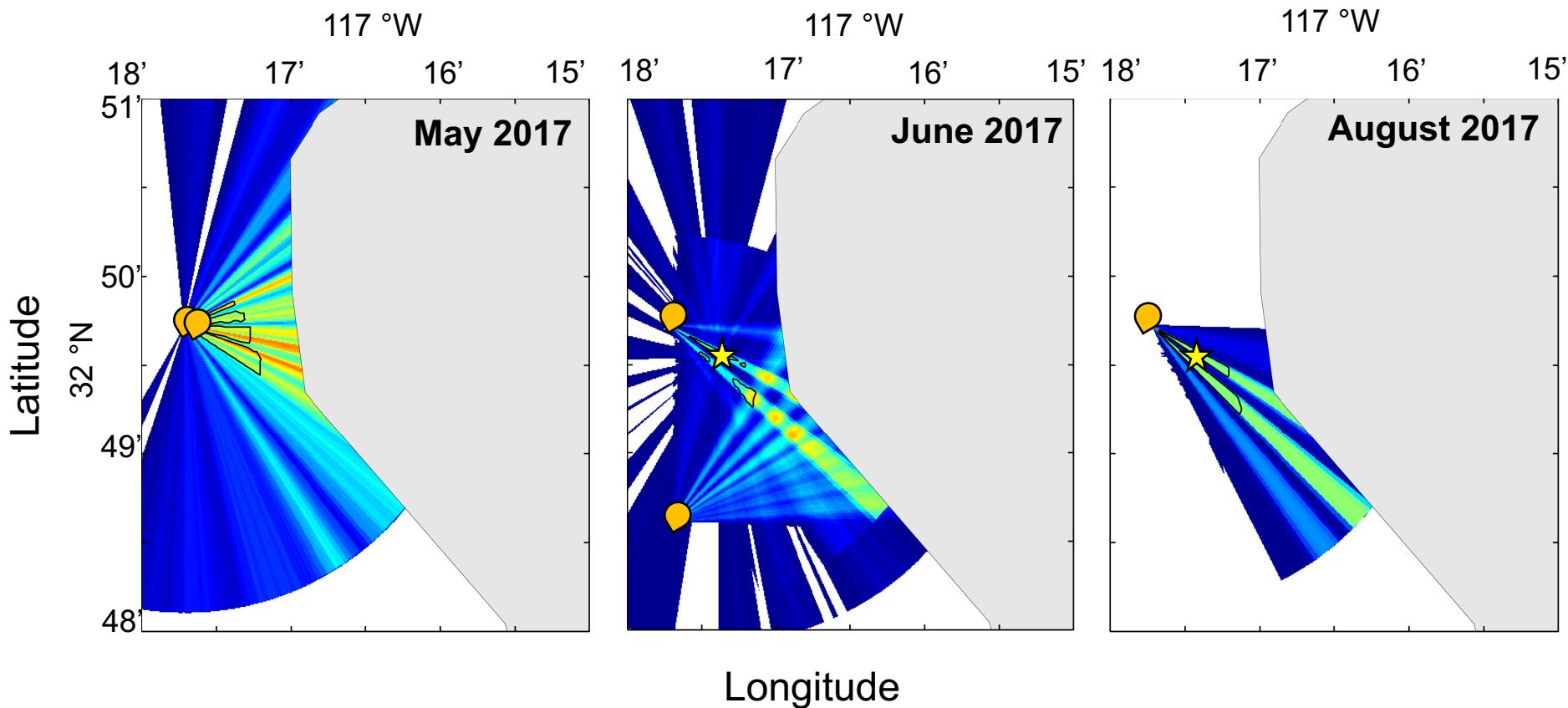
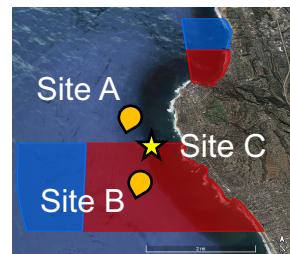
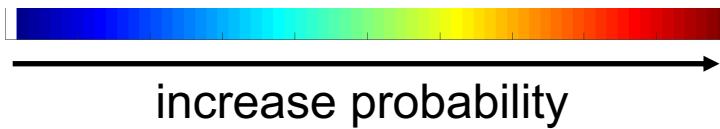
# Location of the chorus

*Daily variability*



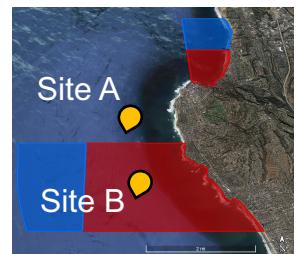
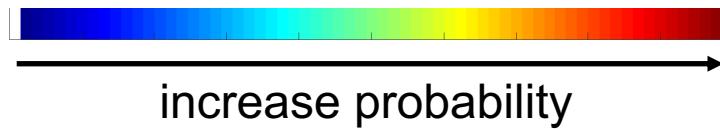
# Location of chorus

*Monthly variability*

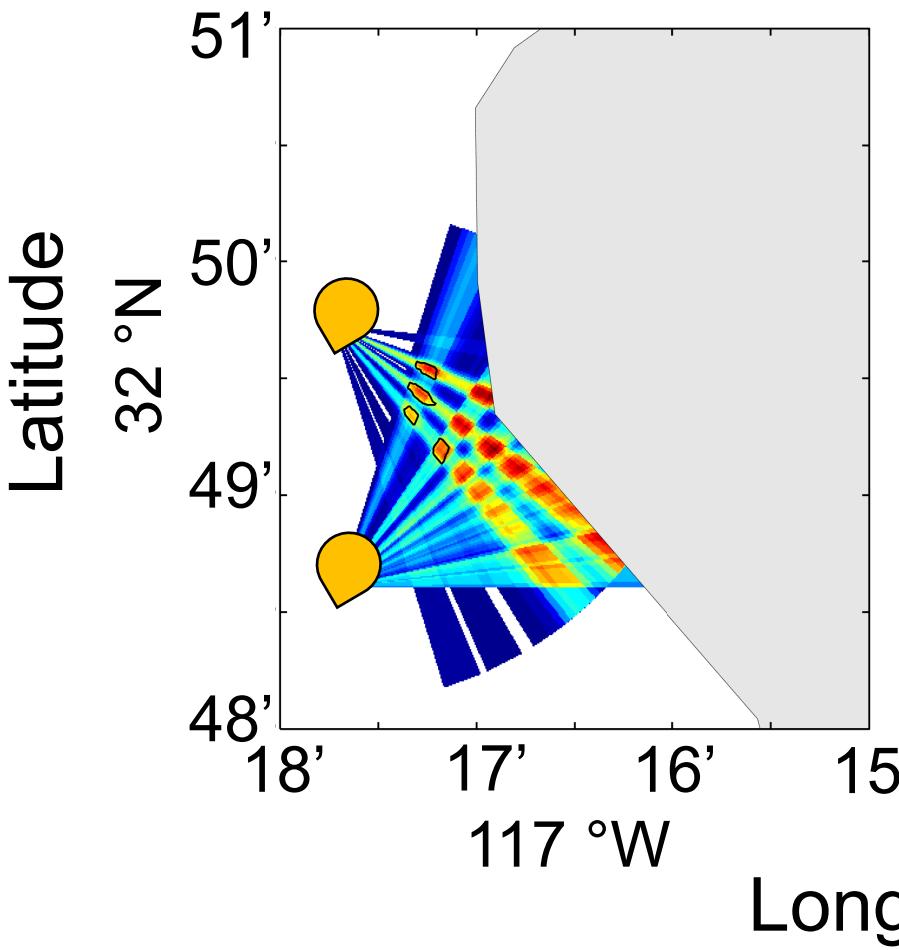


# Location of chorus

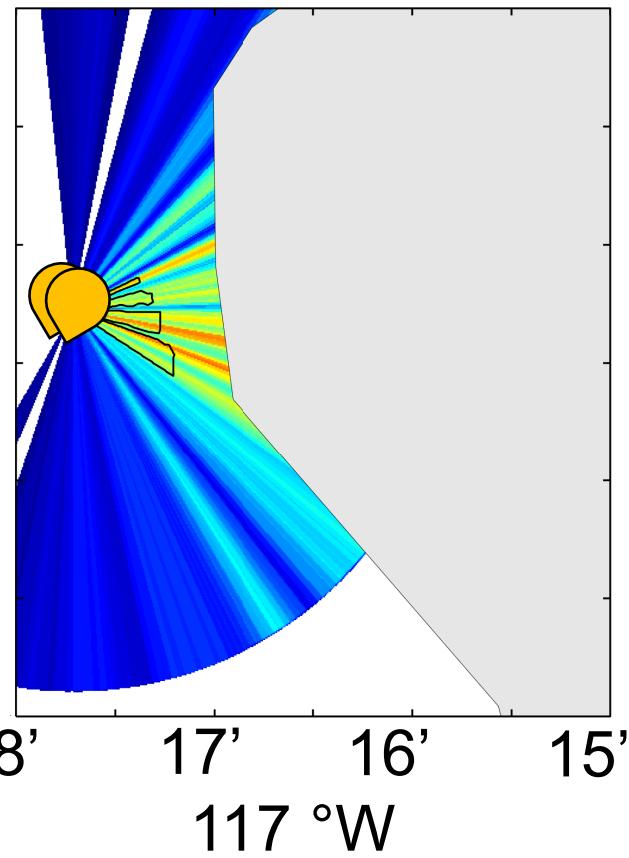
*Inter-annual variability*



May 2015

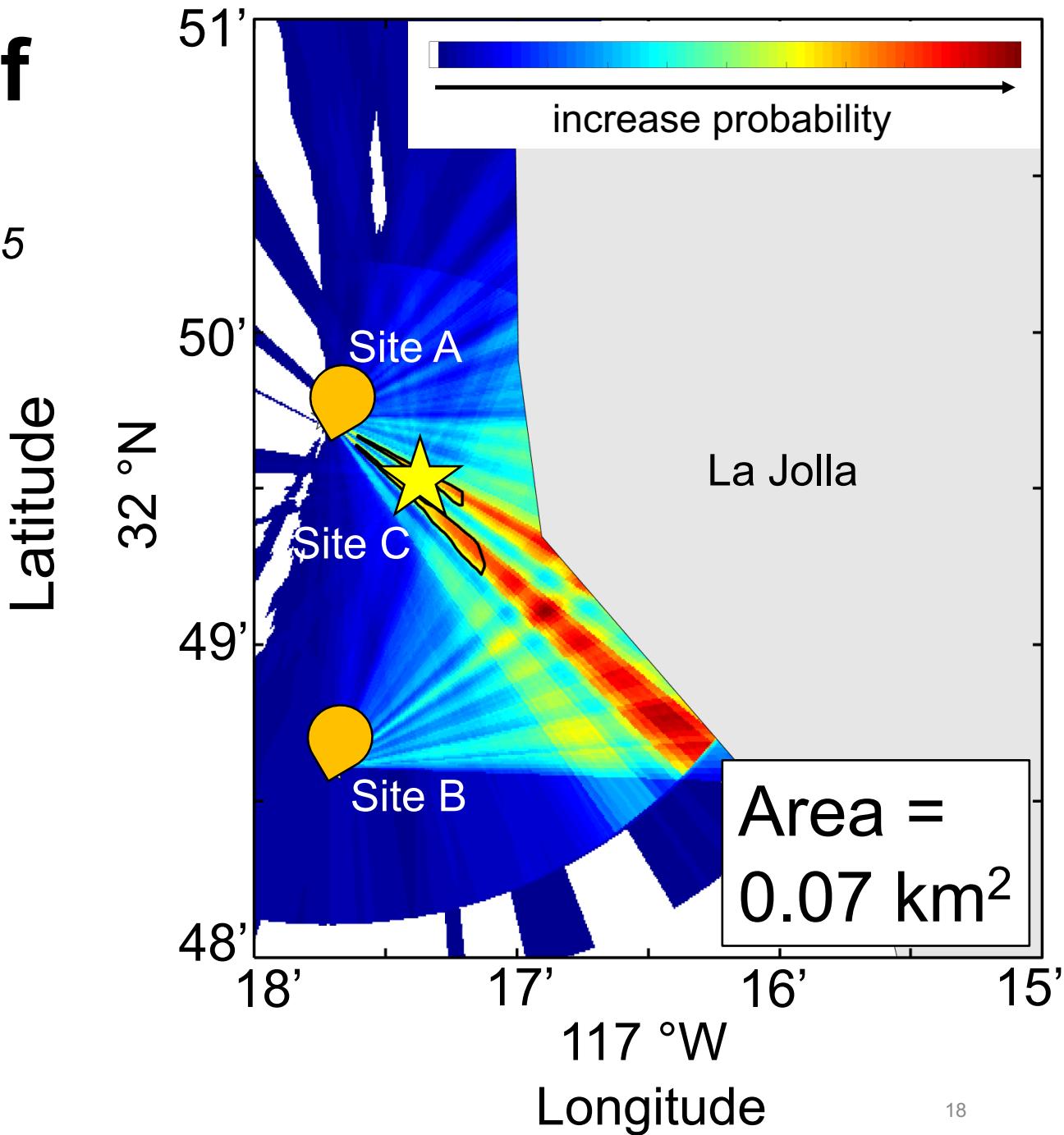


May 2017



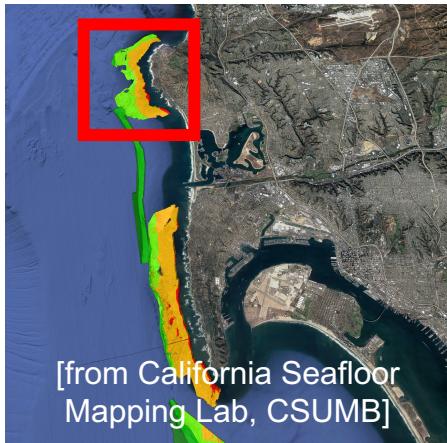
# Location of chorus

Average from May 2015  
to August 2017

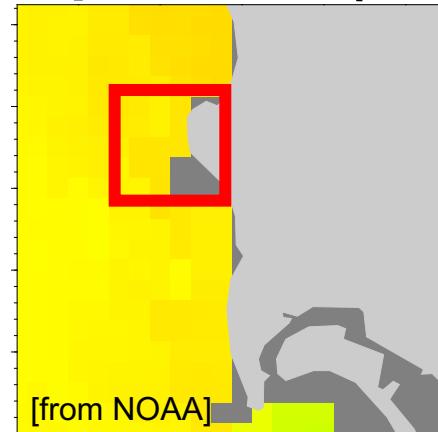


# Environmental factors

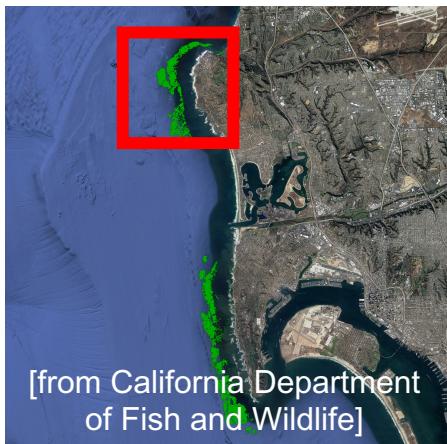
**Bathymetry**



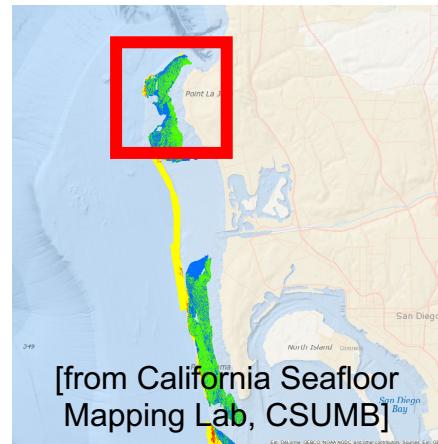
**Sea Surface Temperature (SST)**



**Kelp**

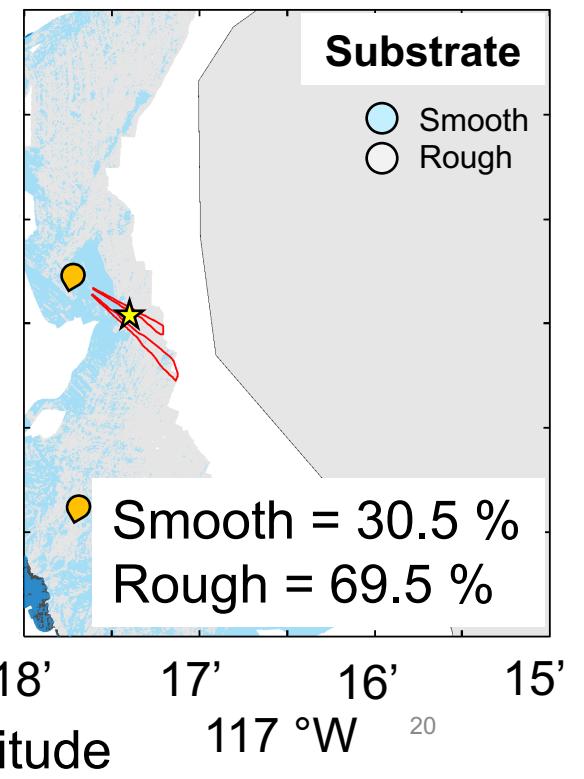
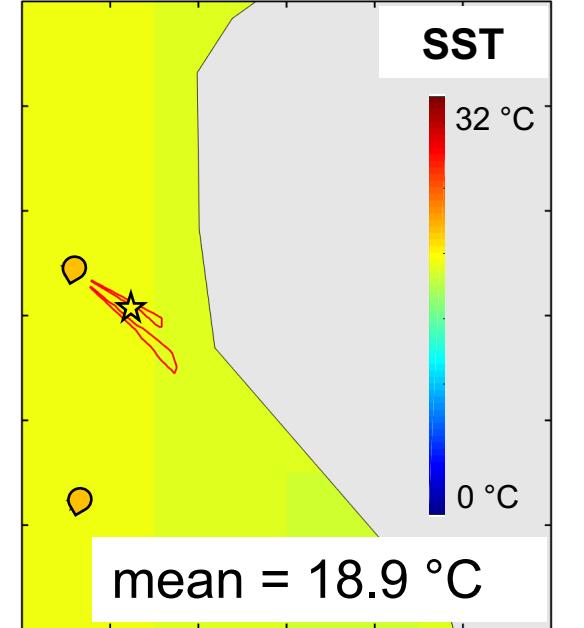
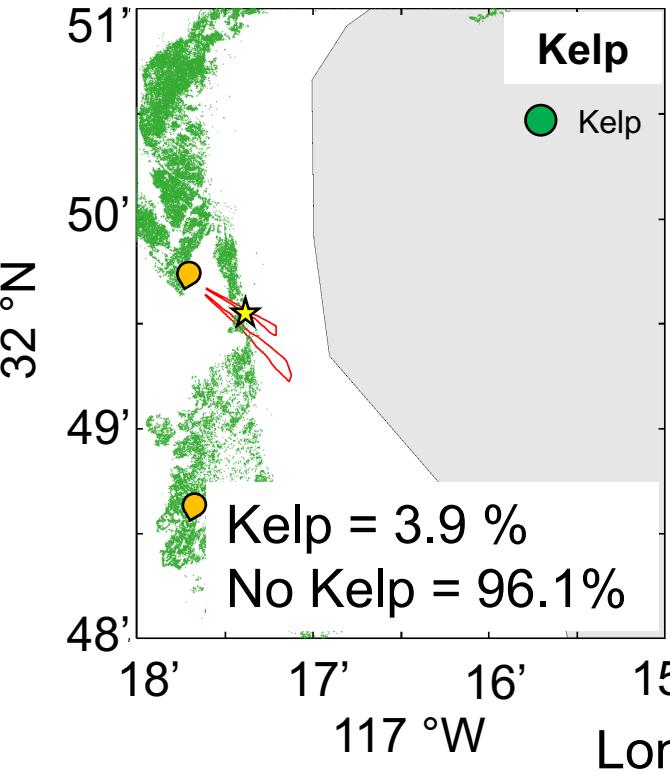
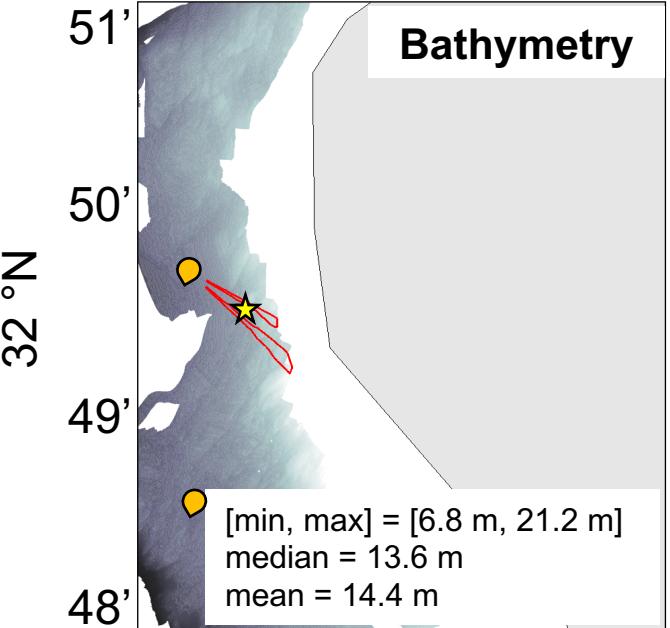


**Substrate**



# Habitat at average location of chorus

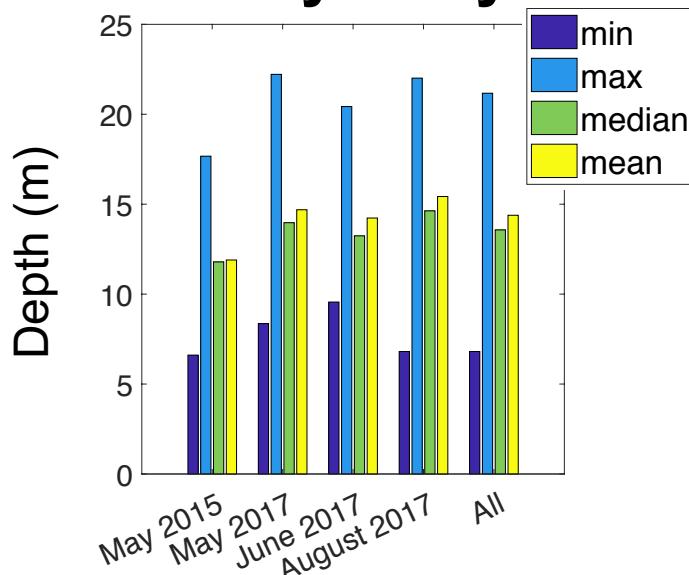
Latitude



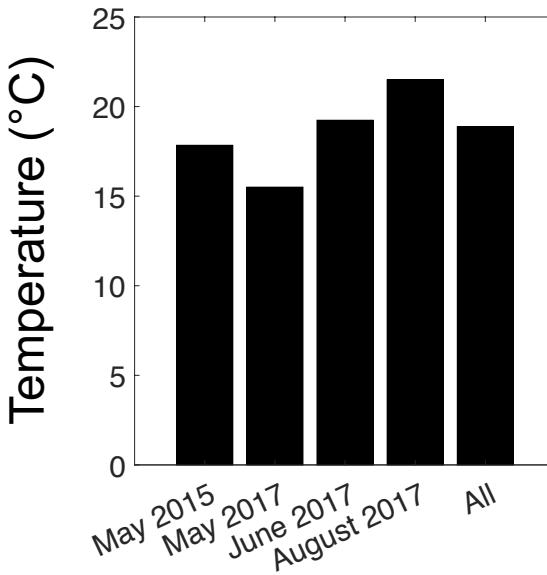
Longitude

# Habitat at locations of chorus

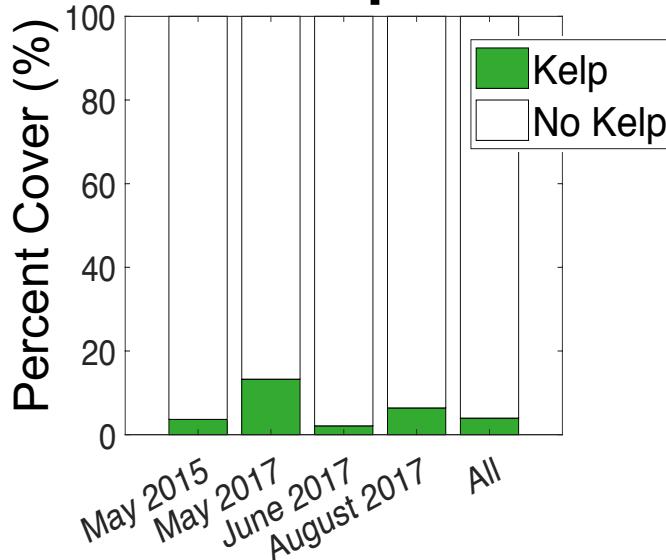
## Bathymetry



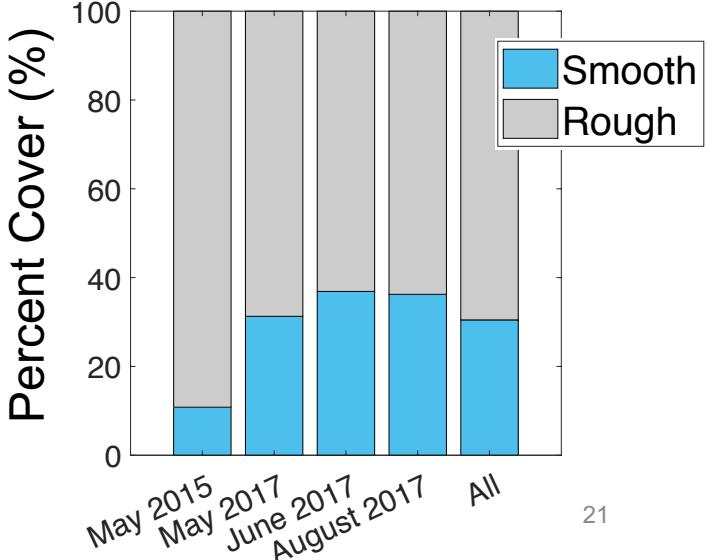
## Mean SST



## Kelp



## Substrate



# Conclusions

- **What?** low-frequency (300-1200 Hz) fish chorus
- **When?** May through September
- **Where?**
  - location of the chorus:
    - likely within 0.07 km<sup>2</sup> area in the La Jolla kelp forest
    - location relatively constant over all time scales
  - habitat:
    - rough substrate
    - ~ 20 °C SST
    - less than 10% kelp cover
    - water depth between 5 and 25 m

# Acknowledgements

- Divers:
  - K.C. Cameron
  - M. Costa
  - M. Cimino
  - P. Lertvilai
  - B. Frable
  - R. Walsh
  - S. Brody
- Funding:
  - Sea Grant (R/HCME-28)
  - NSERC PGS D-3



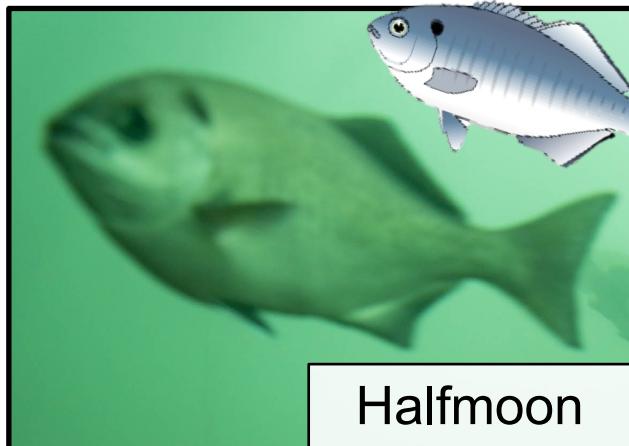
# Thank you!



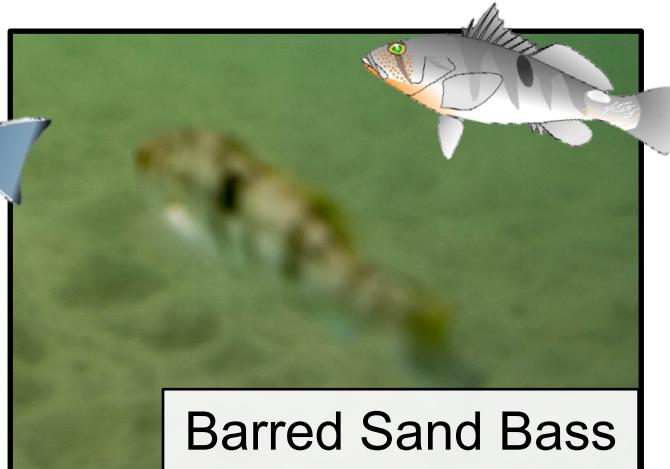
Questions?

# Who is the chorusing fish?

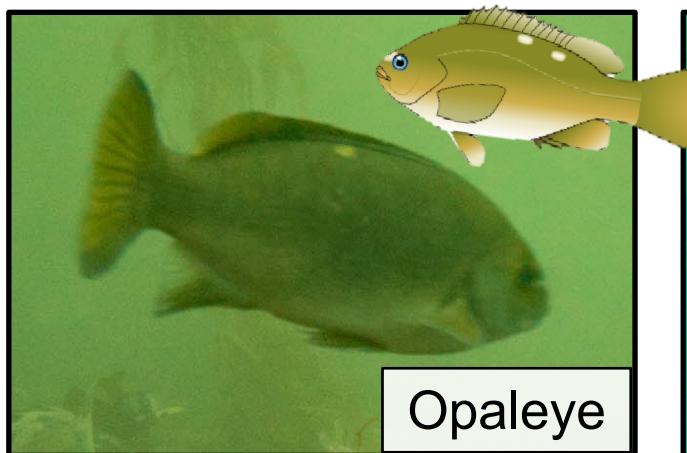
Possible candidates include:



Halfmoon



Barred Sand Bass

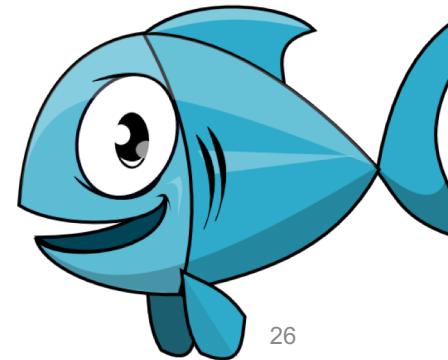
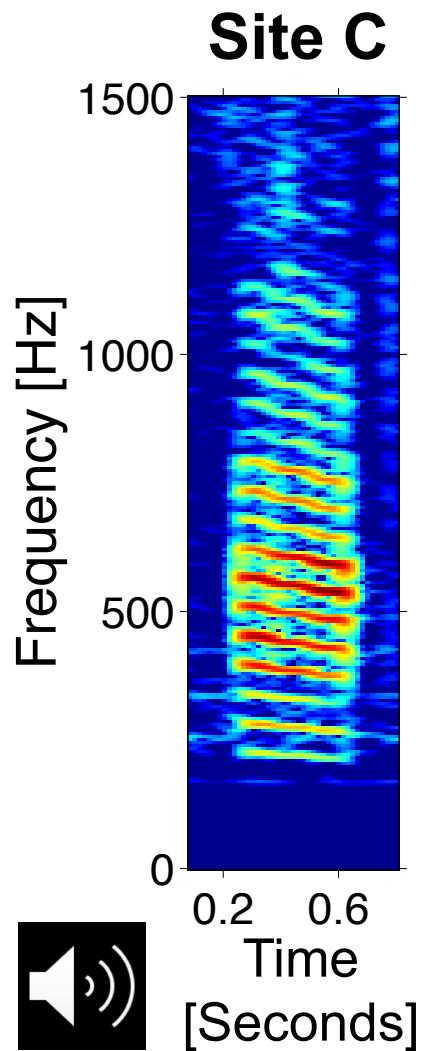


Opaleye



Kelp Bass

# An unknown fish call



# FishOASIS v2

## BATTERY PACK CAMERA HOUSING

