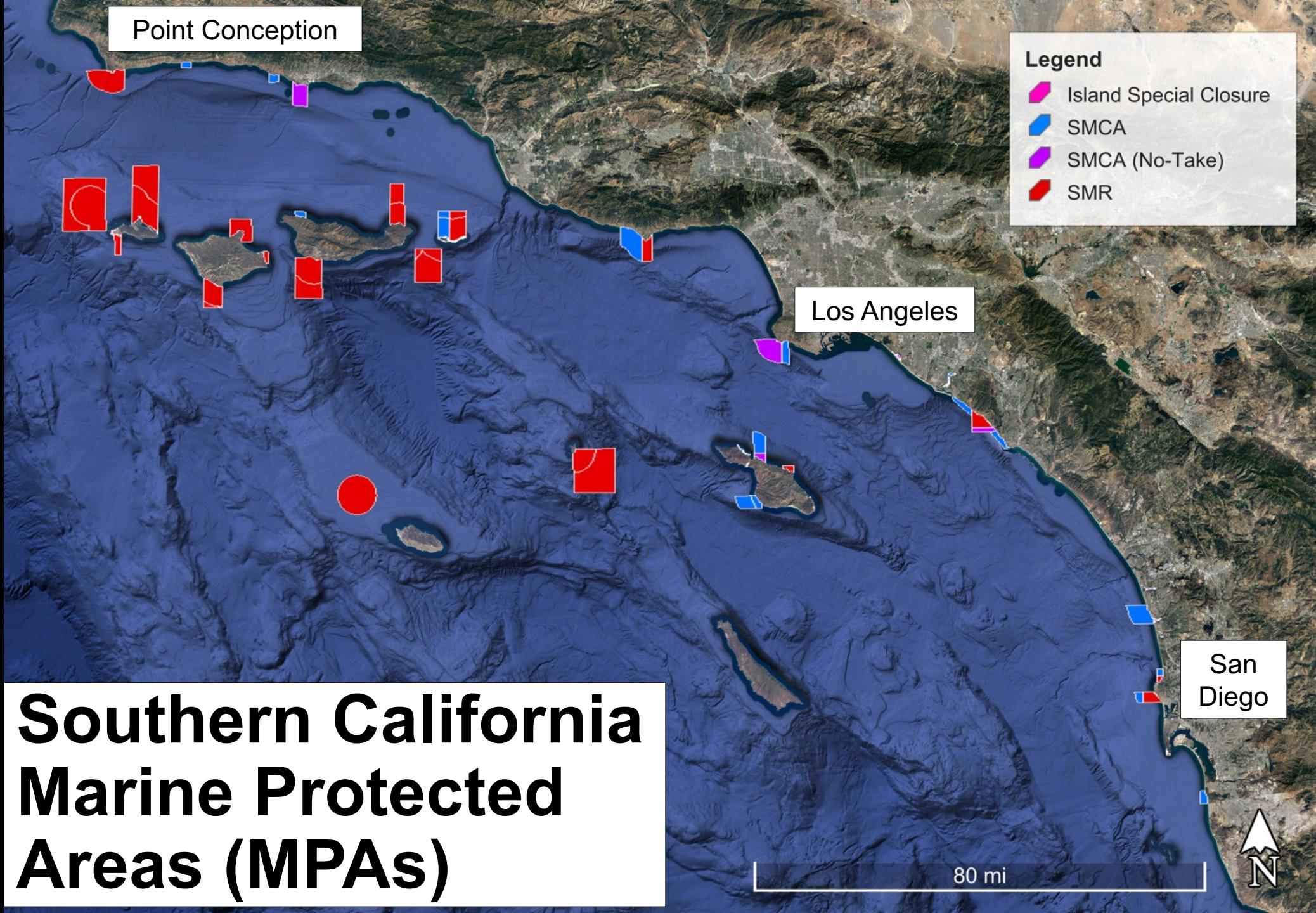


# FishOASIS: A passive acoustic-optical imaging system for fish sound identification

**Camille Pagniello**

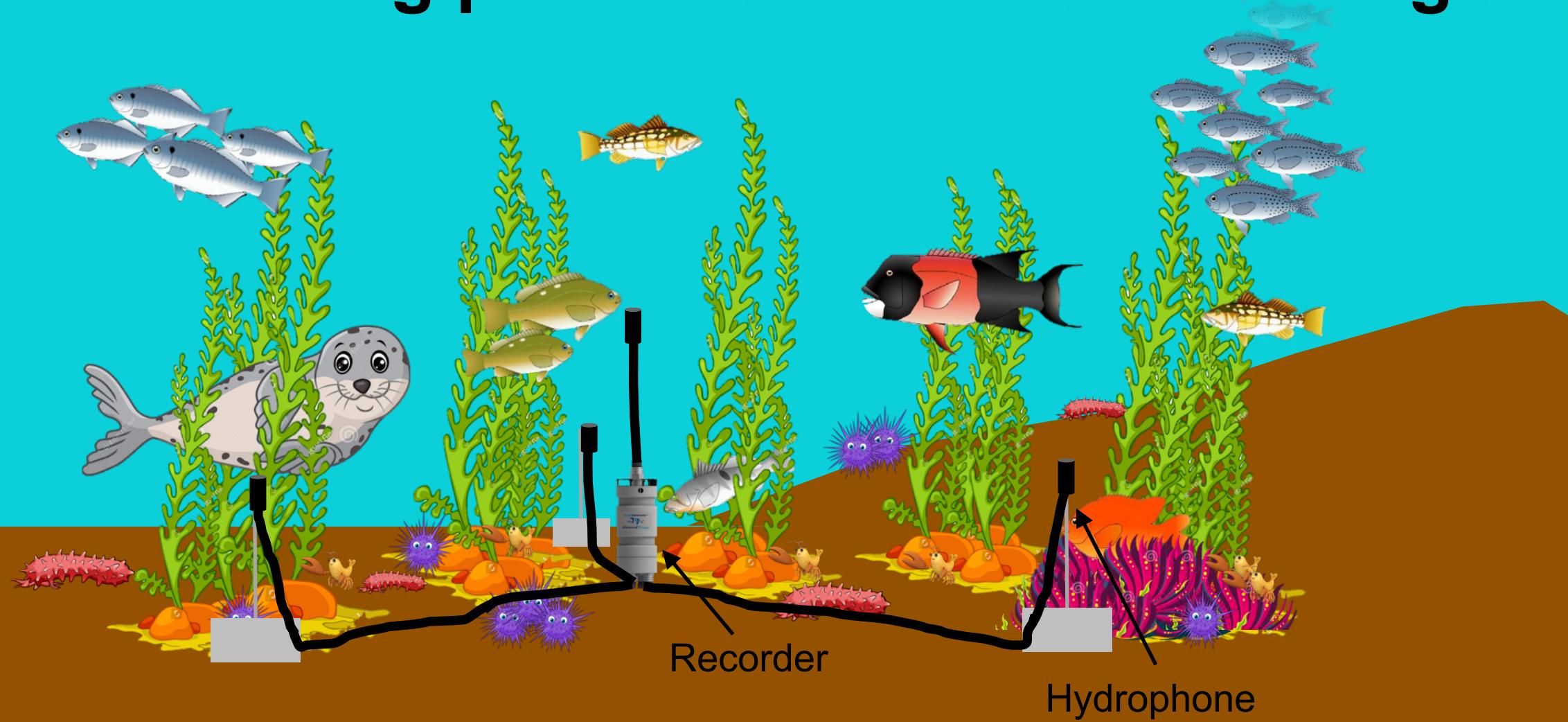
Ph.D Candidate in Oceanography - Applied Ocean Sciences

Scripps Institution of Oceanography



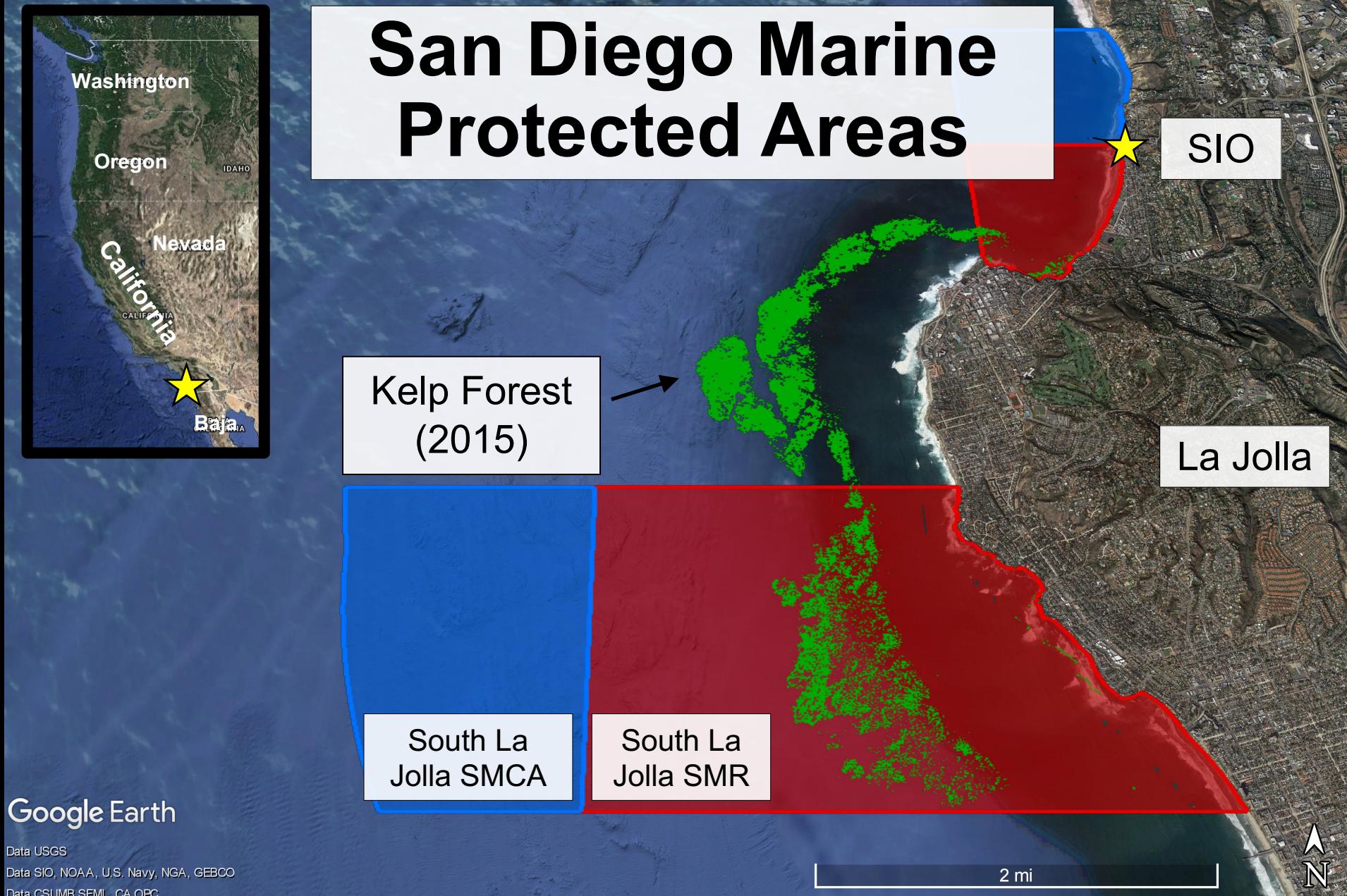
# Southern California Marine Protected Areas (MPAs)

# Can habitat species diversity and abundance be quantified using passive acoustic monitoring?





# San Diego Marine Protected Areas



SMR: prohibits damage or take of all marine resources

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

# Known Soniferous Kelp Forest Fish

known soniferous fish species: 19

total number of fish species: 265<sup>1</sup>



Sablefish



Plainfin midshipmen



Pacific herring



Pacific sardine



Staghorn sculpin



Pile perch



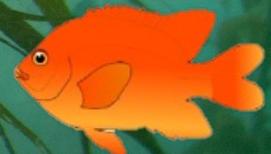
Ocean sunfish



Giant sea bass



Pink salmon



Garibaldi



White seabass



Gulf corvina



White croaker



Kelp rockfish



Gopher rockfish



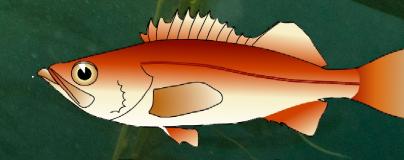
Black-and-yellow rockfish



Black rockfish



China rockfish

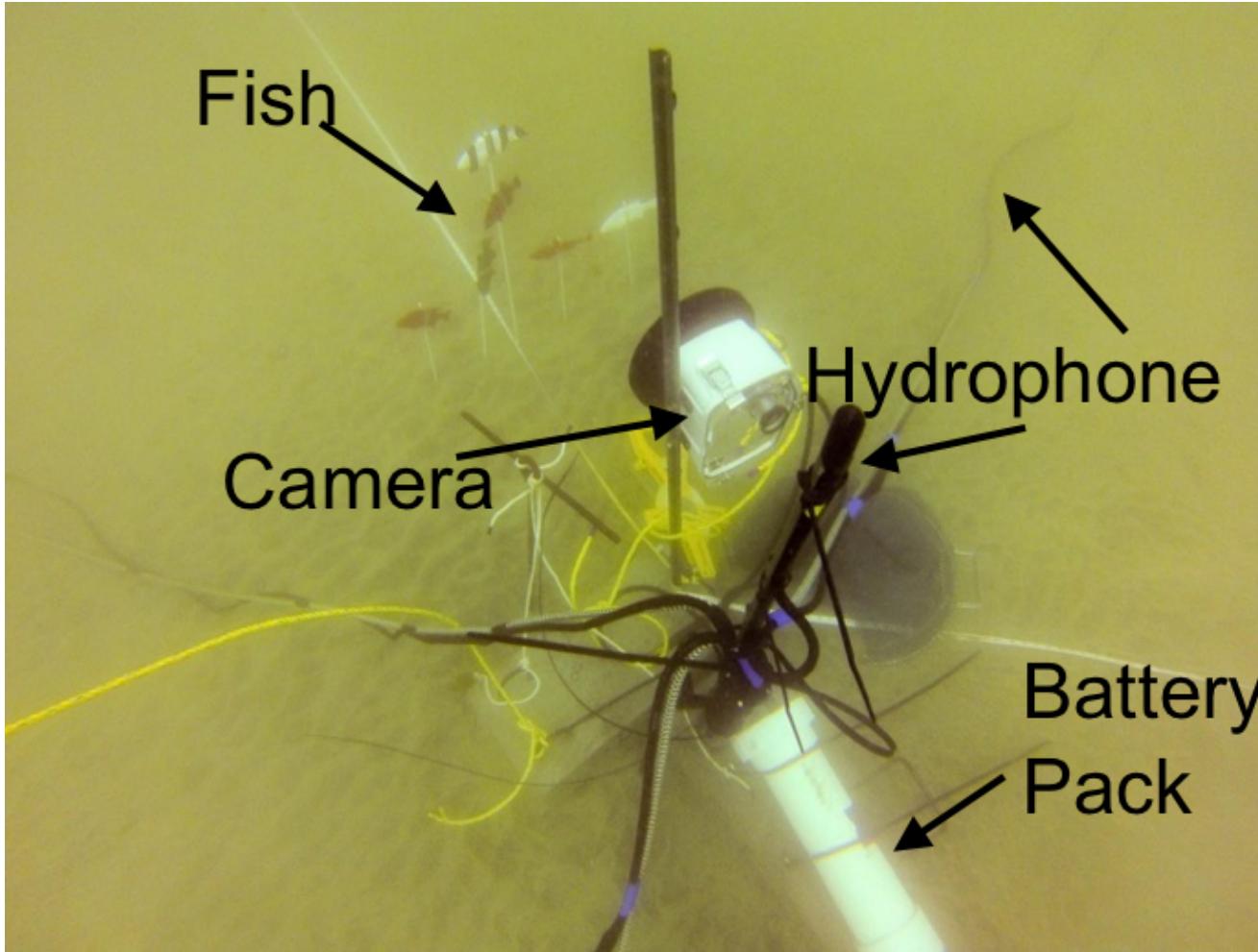


Bocaccio

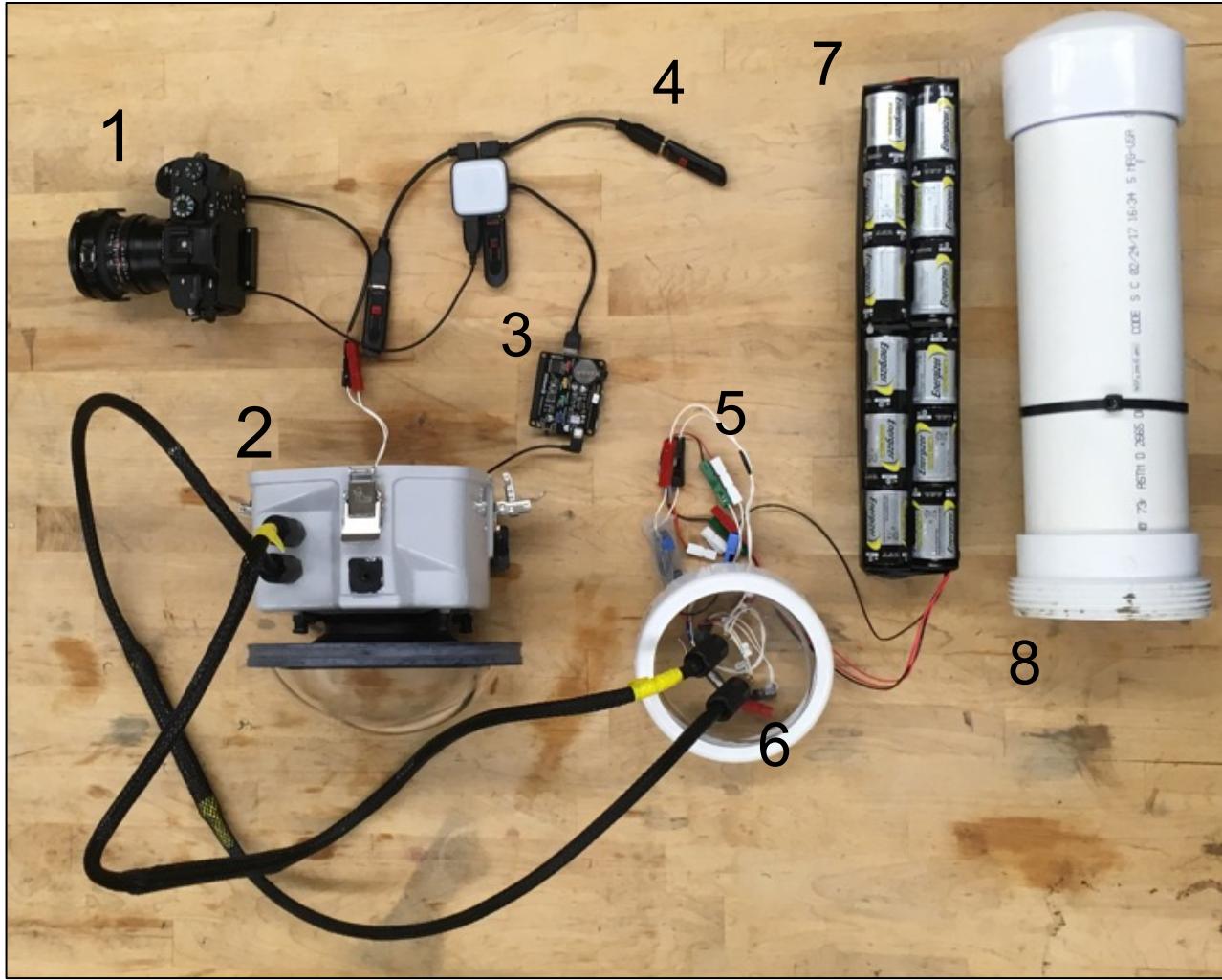
# Ideal System Requirements

1. deployment length capable of capturing episodic and long-duration events
2. capture good images in poor light conditions
3. time-aligned acoustic and image data
4. easy to use and flexible for various deployment configurations
5. as economic as possible, allowing for widespread use

# FishOASIS: Fish Optical and passive Acoustic Sensor Identification System



# Optical Imaging System – Hardware

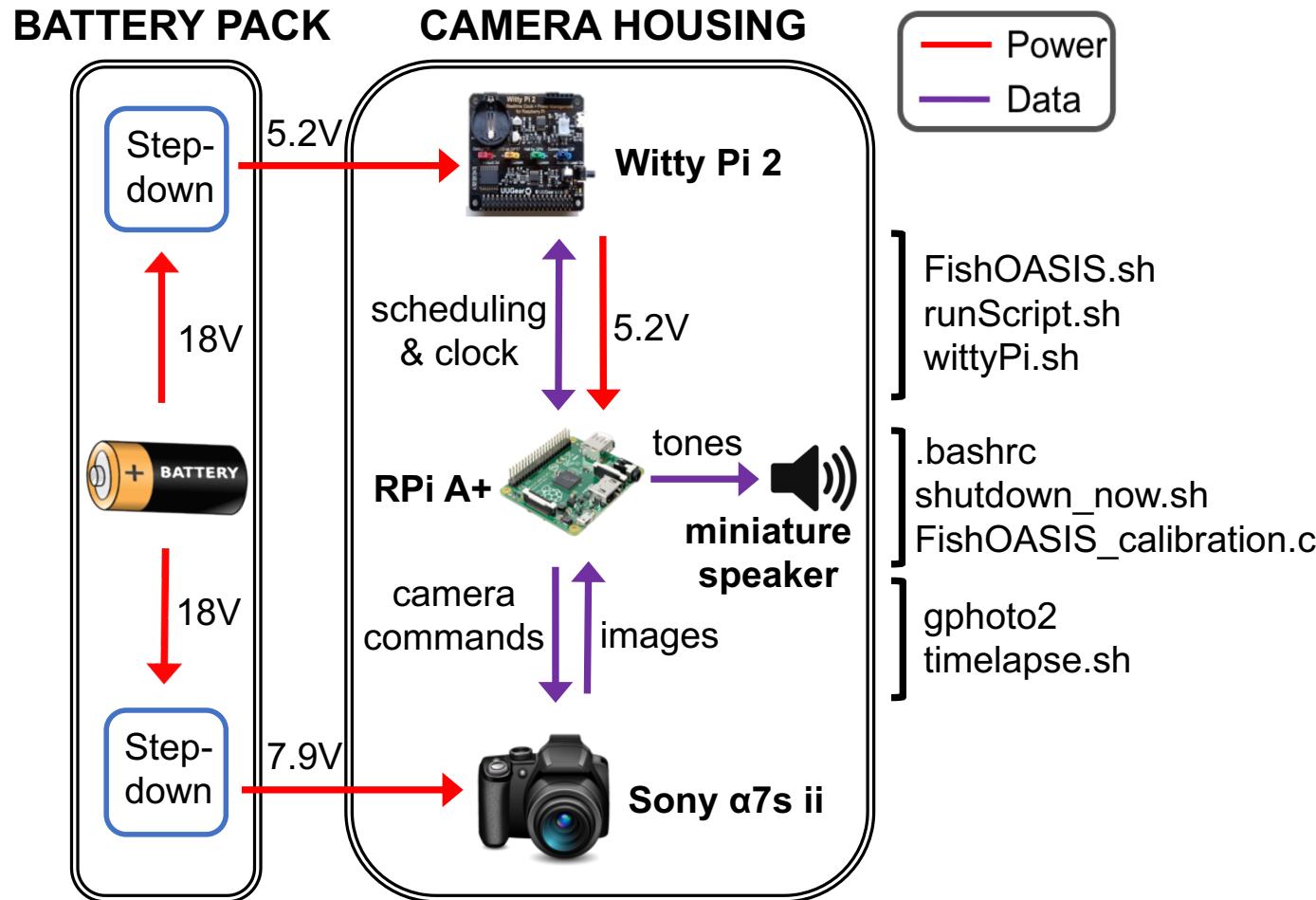


## Components:

- 1) Sony a7s II camera with fisheye lens
- 2) custom-built Ikelite camera housing
- 3) Raspberry Pi A+ with witty Pi real-time clock and power management board
- 4) 256 GB USB flash data storage x 3
- 5) step-down converters x 2
- 6) wet-mateable bulkhead connectors
- 7) battery bank
- 8) PVC battery housing

(not pictured) HOBO light and temperature logger, miniature speaker

# Optical Imaging System – Software

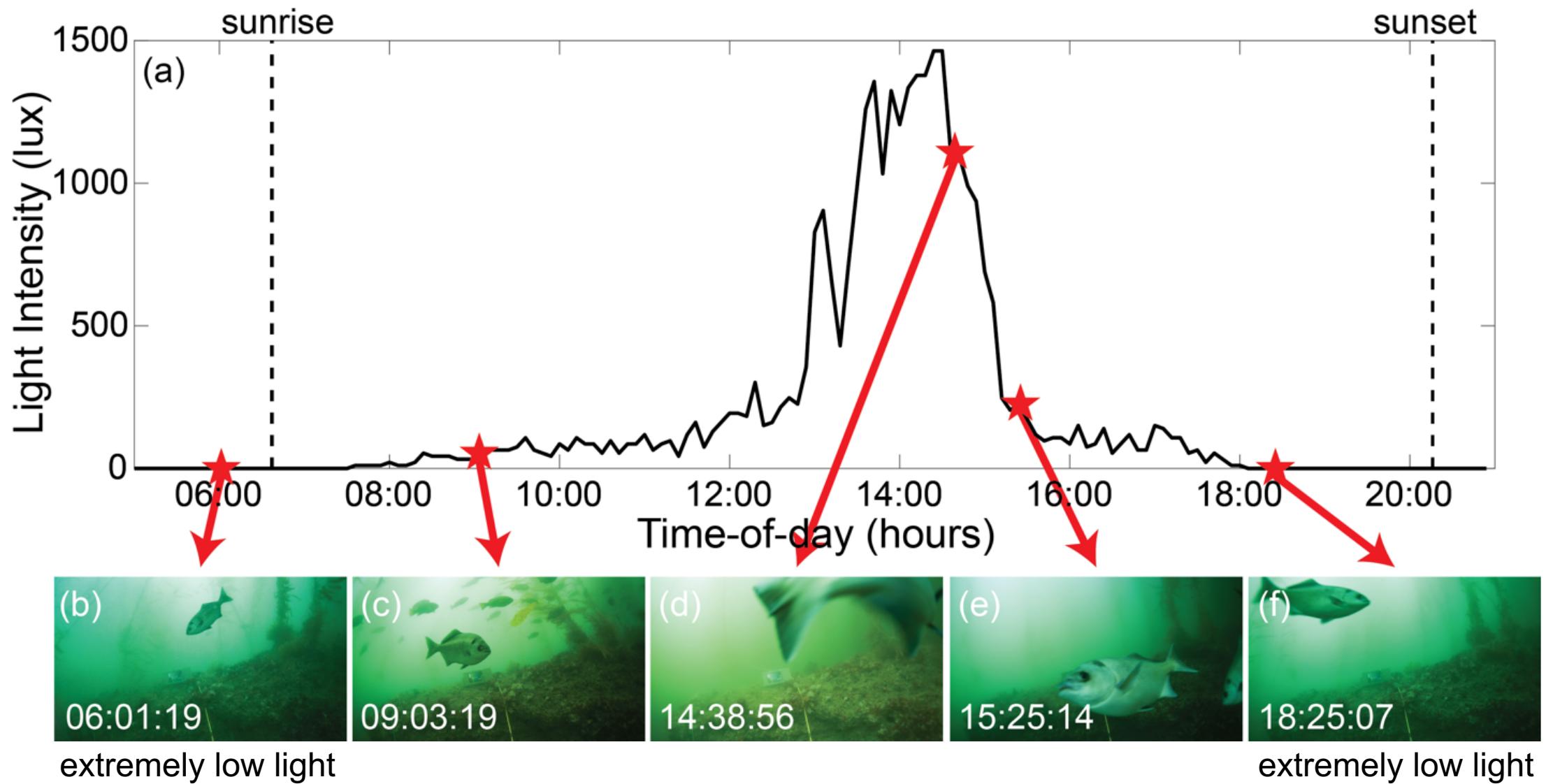


## Components:

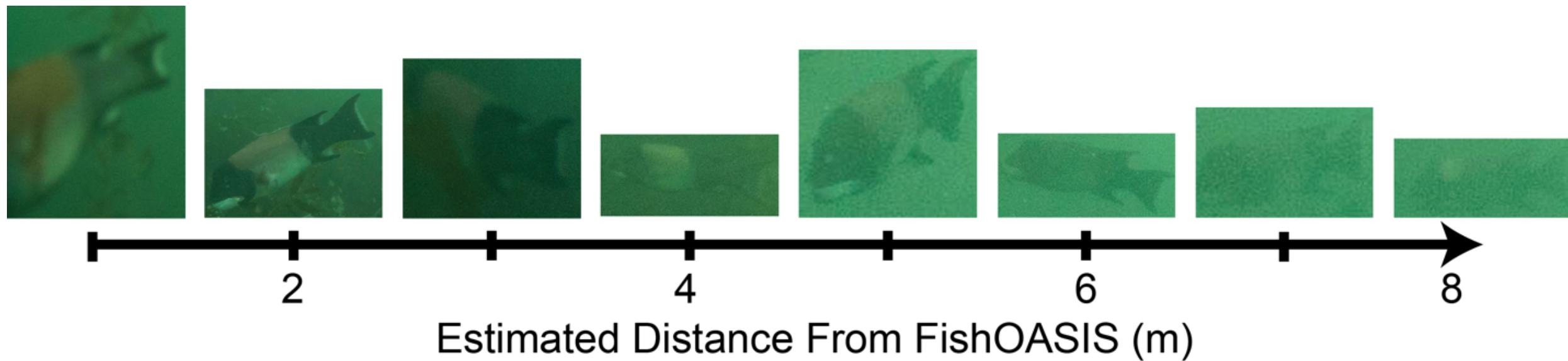
- Bourne shell (.sh) scripts manage camera actuation, sampling and data storage
- command-line client gphoto2 allows camera to be controlled via USB
- GPIO access C library WiringPi outputs simple tones at 610 and 690 Hz through miniature speaker

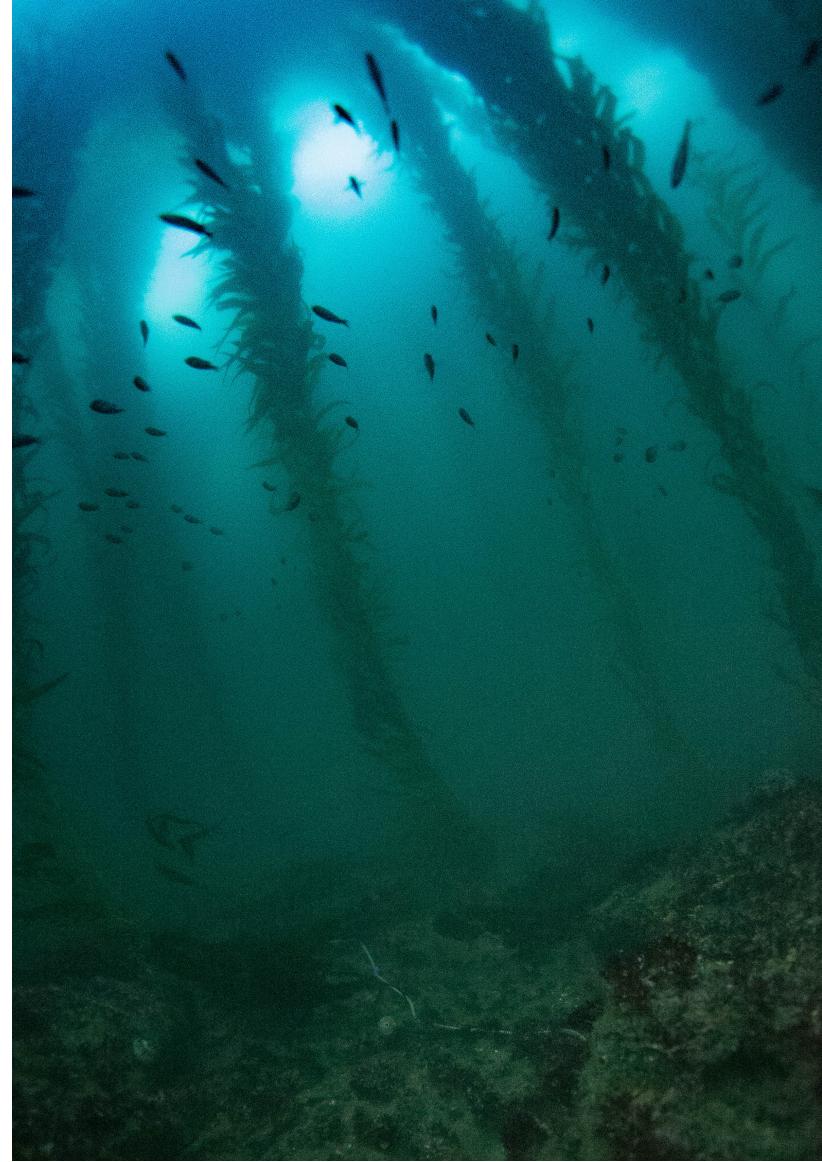
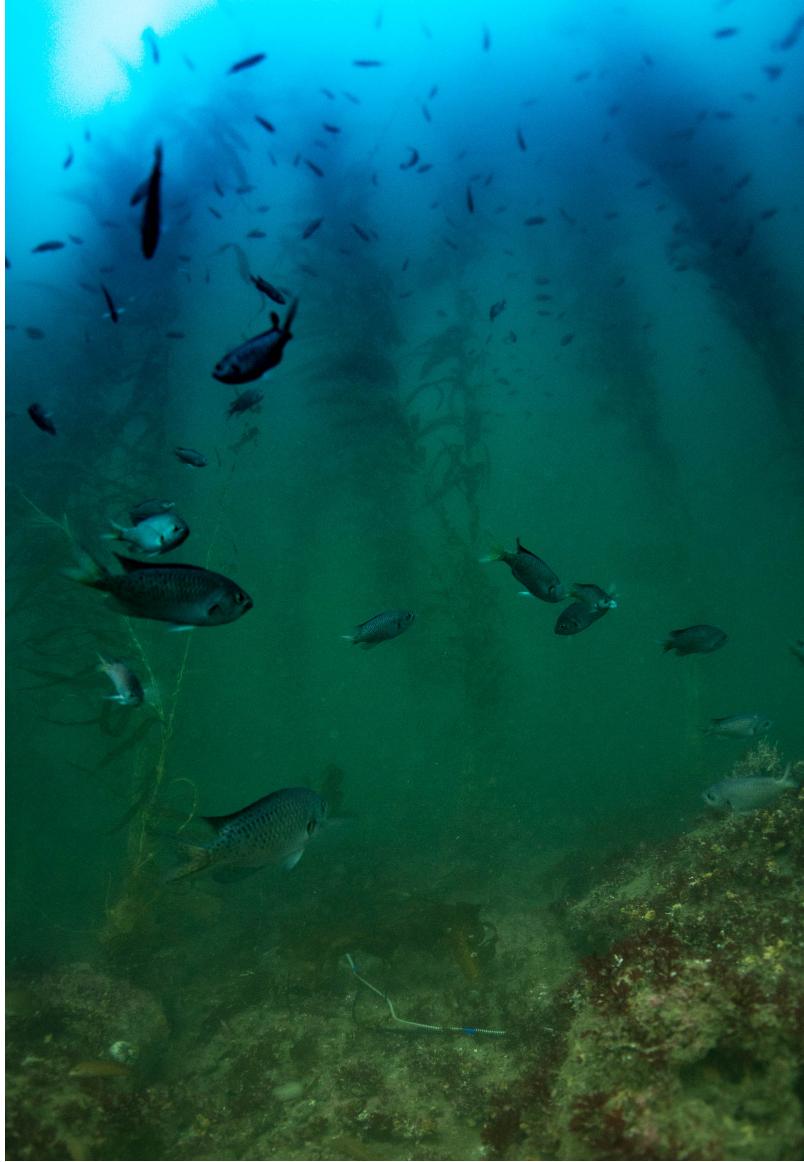
<https://github.com/cpagniel/FishOASIS/>

# Picture Quality – Ambient Light



# Picture Quality – Fish Distance

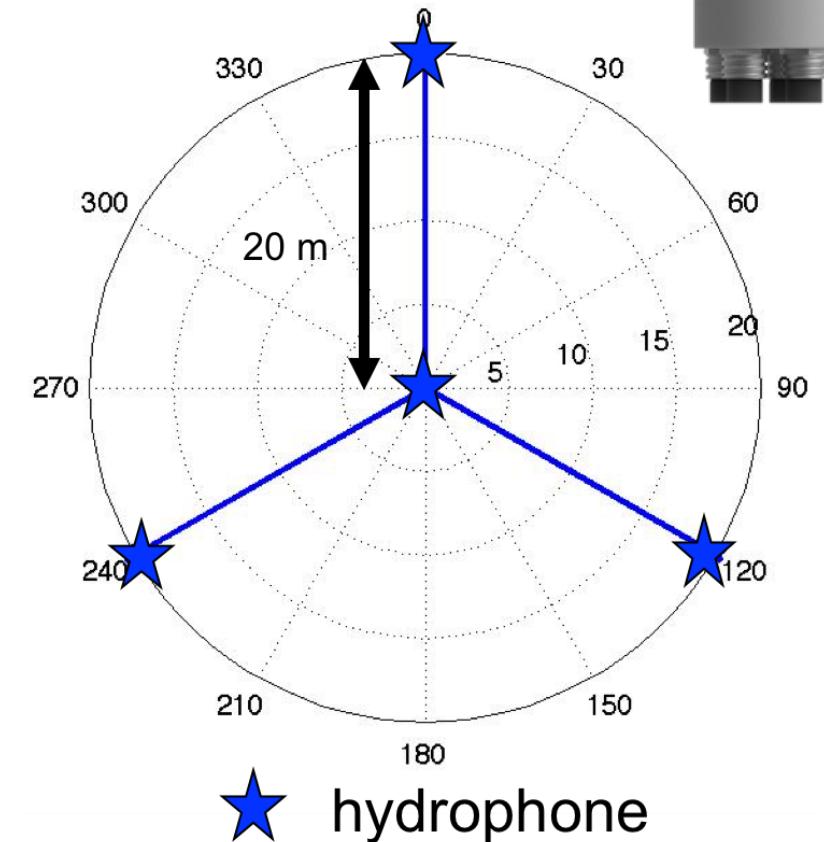
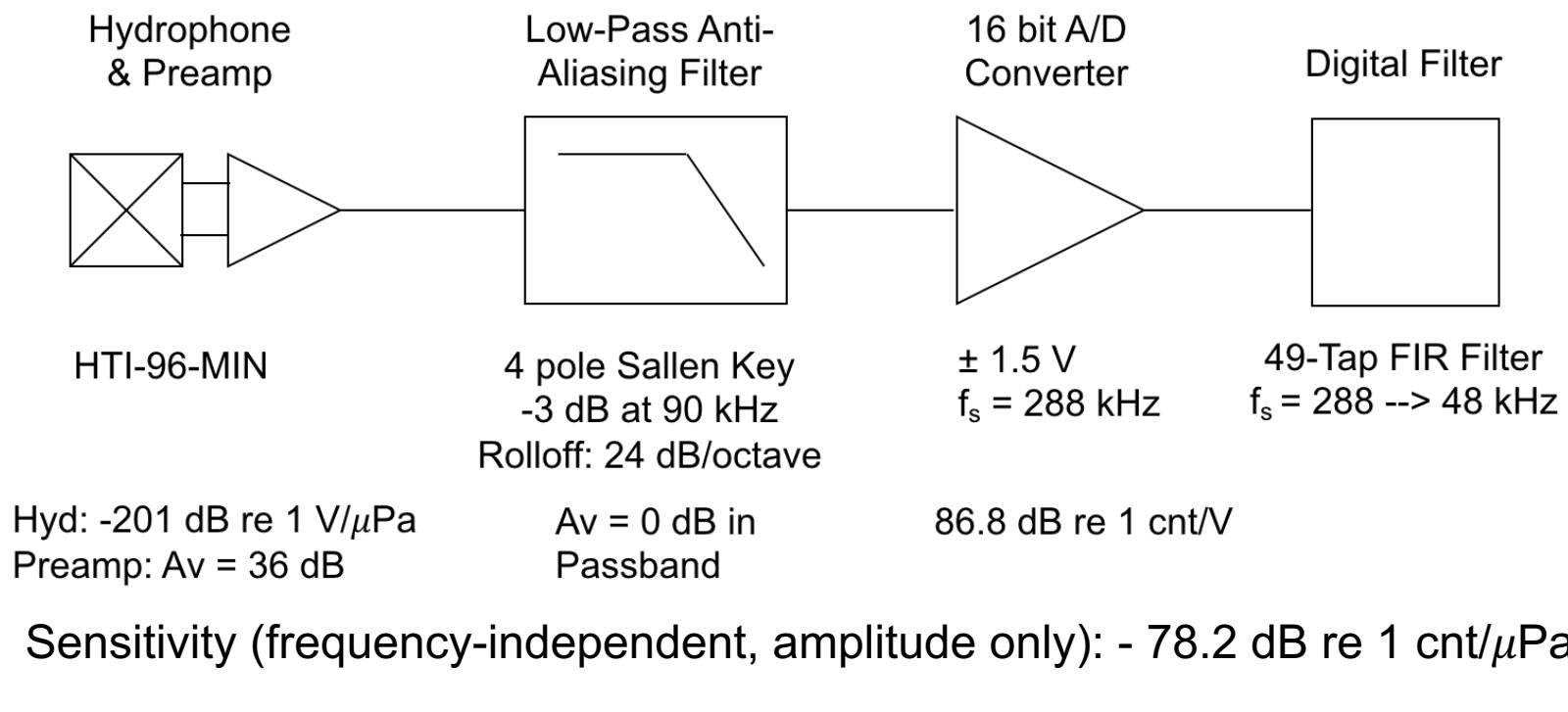




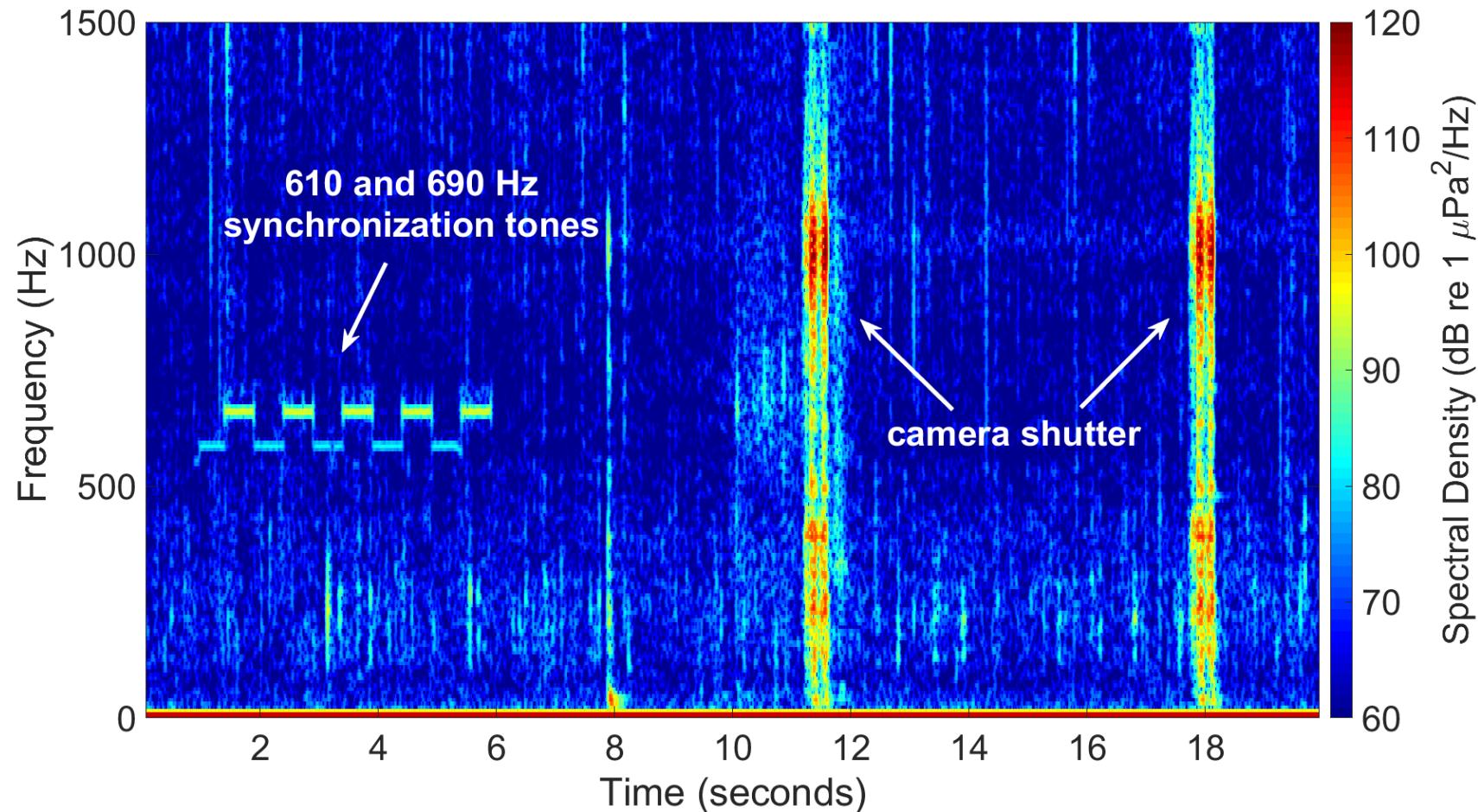
# Picture Quality – Fish Position in Water Column

# Passive Acoustic System

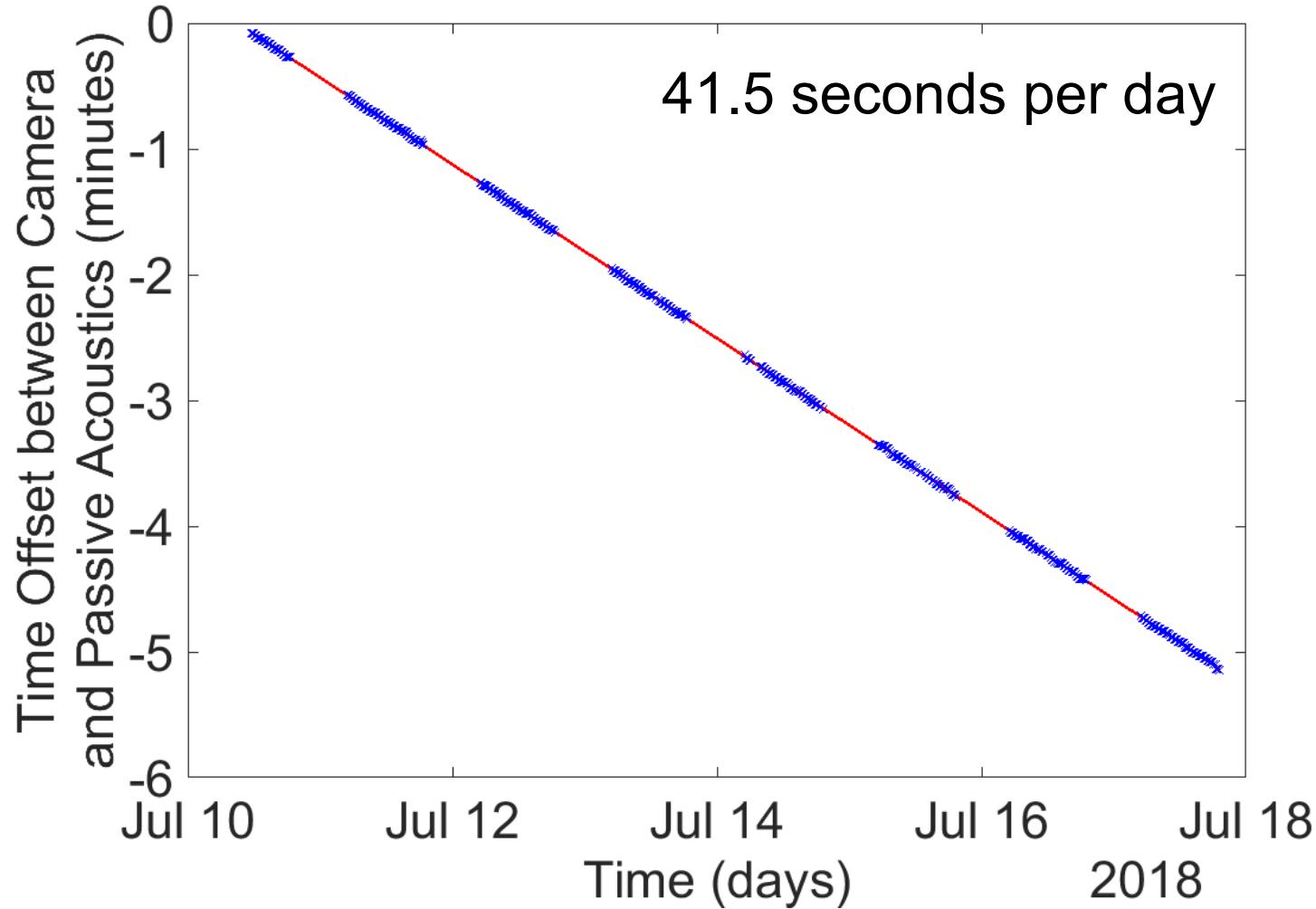
SoundTrap ST4300 256 GB acoustic recorder



# Time Synchronization of Optical Imaging and Passive Acoustic System



# Time Synchronization of Optical Imaging and Passive Acoustic System



# Diversity of Fish Species

1 camera, 13 days, 17,101 images

fish species: 20

known fish: 9601

unknown fish: 1264



Señorita  
(*Oxyjulis californica*)



Juvenile



Rock Wrasse  
(*Notorynchus cepedianus*)



Halfmoon  
(*Medialuna californiensis*)



Kelp Perch  
(*Brachystistius frenatus*)



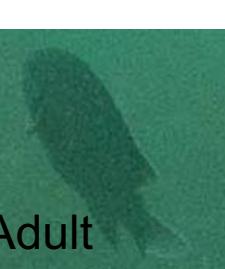
Juvenile

Pacific Barracuda  
(*Sphyraena argentea*)



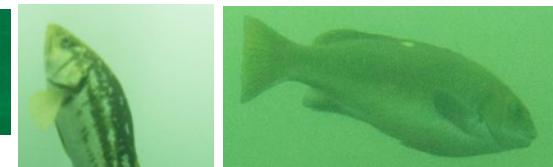
Garibaldi

(*Hypsypops rubicundus*)



Adult  
Blacksmith

(*Chromis punctipinnis*)



Opaleye

(*Girella nigricans*)



Adult Terminal

California Sheephead  
(*Semicossyphus pulcher*)



Adult Initial



Kelp Bass

(*Paralabrax clathratus*)



Sargo

(*Anisotremus davidsonii*)



Barred sand bass  
(*Paralabrax nebulifer*)

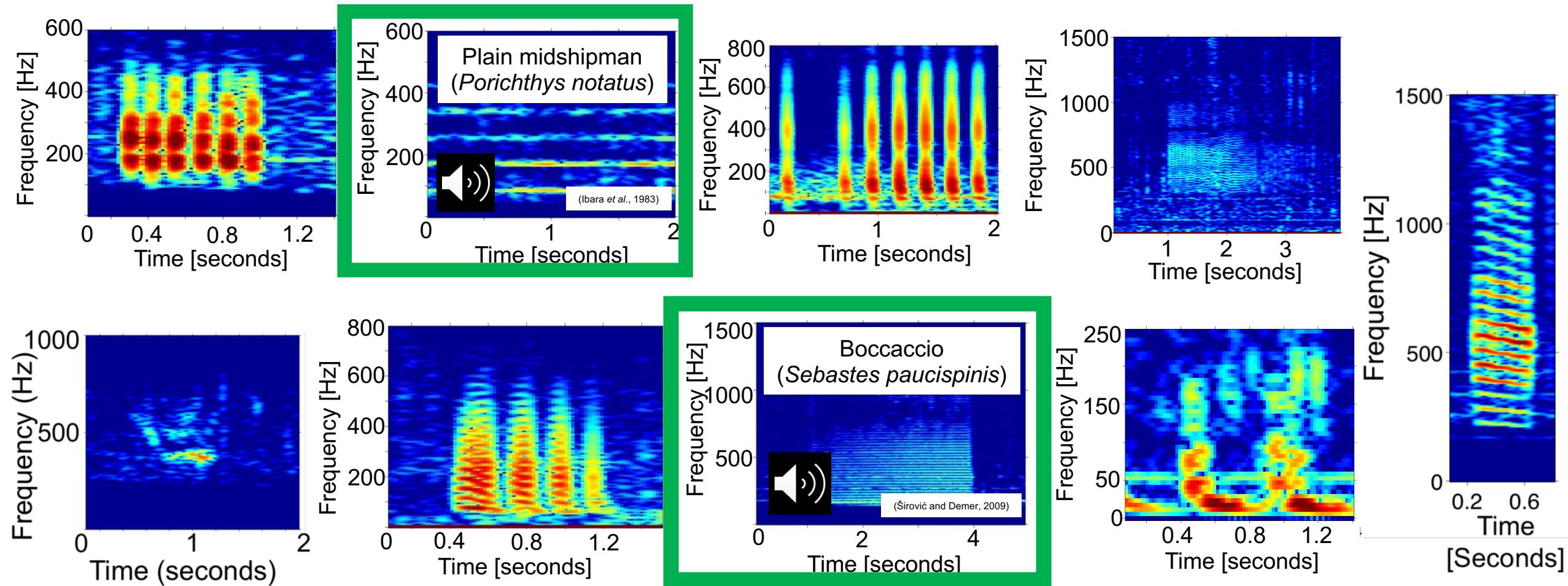


Black Surfperch  
(*Embiotoca jacksoni*)



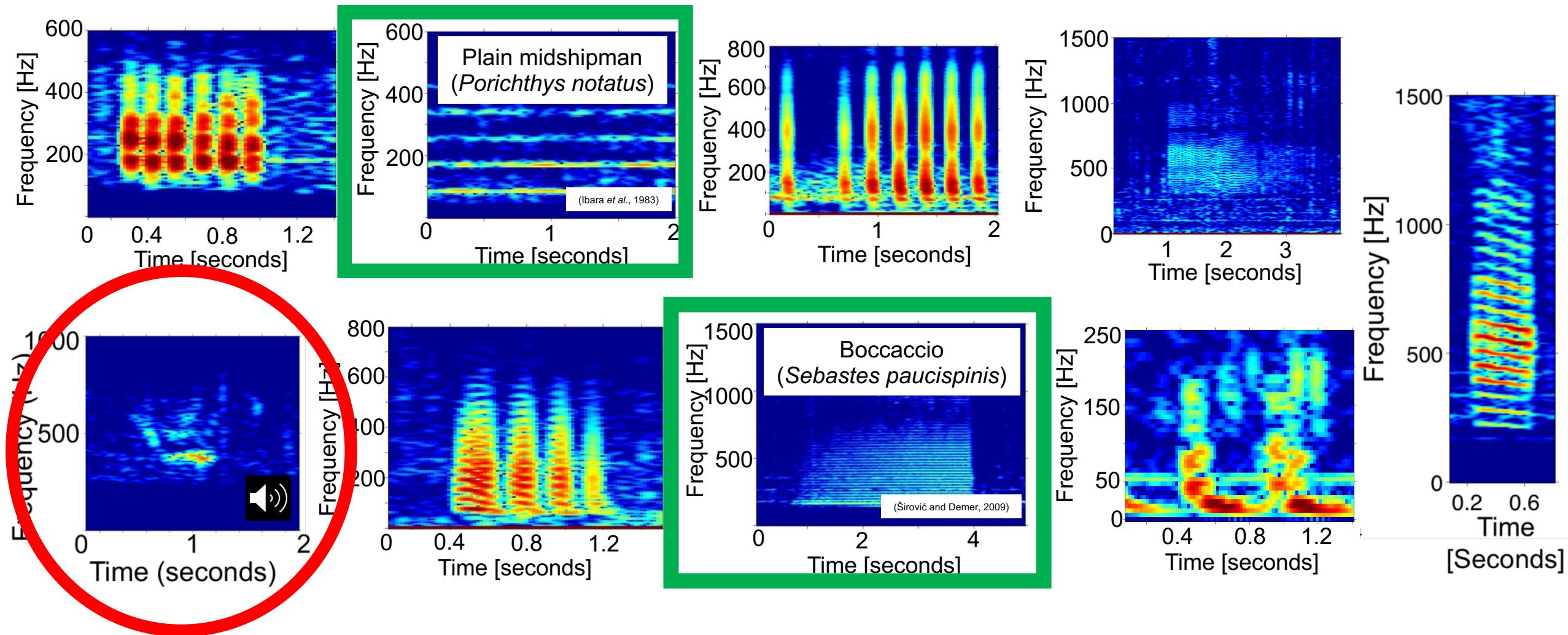
Yellowtail Amberjack  
(*Seriola dorsalis*)

# Diversity of Fish-Like Sounds



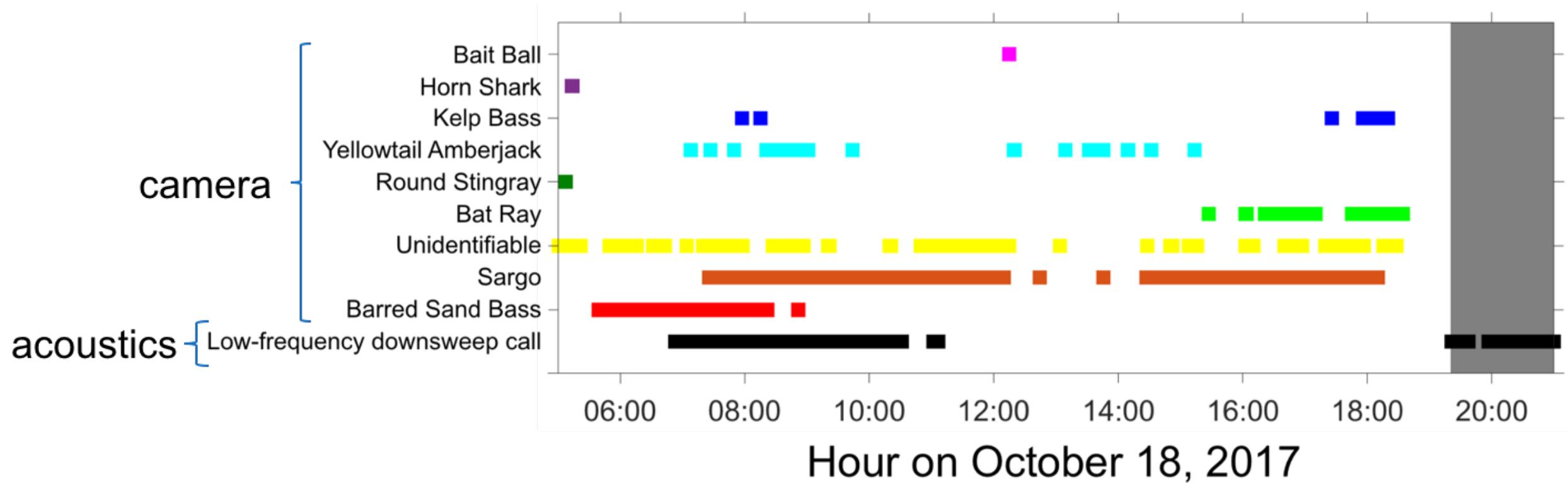
Kaiser-Bessel window with  $\alpha = 2.5 w$ ,  $F_s = 4 \text{ kHz}$ ,  $NFFT = 512$ , overlap = 90%; band pass filter = 400-800 Hz.  
Color represents spectral density (dB re 1  $\mu\text{Pa}^2/\text{Hz}$ ).

# Diversity of Fish-Like Sounds

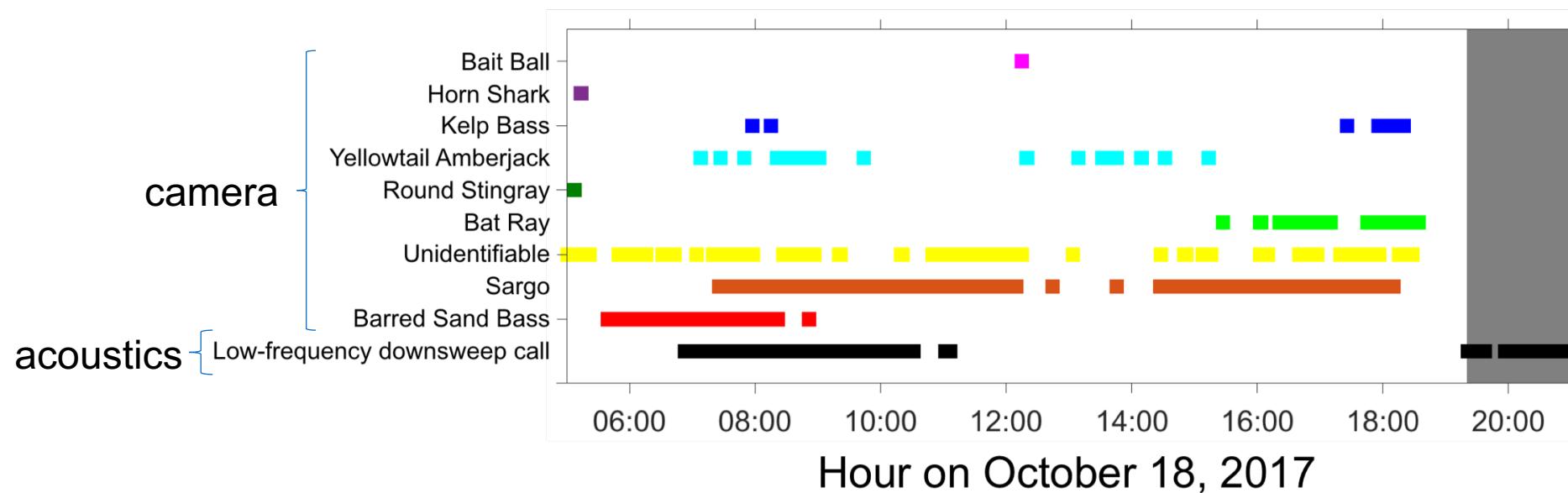


Kaiser-Bessel window with  $\alpha = 2.5 w$ ,  $F_s = 4 \text{ kHz}$ , NFFT = 512, overlap = 90%; band pass filter = 400-800 Hz.  
Color represents spectral density (dB re 1  $\mu\text{Pa}^2/\text{Hz}$ ).

# Species-Sound Association



# Species-Sound Association



Observed: # of calls within  $\pm 5$  seconds of images with at least one fish

Expected: # of images with at least one fish

	Barred Sand Bass	Sargo	Un-identifiable	Bat Ray	Round Stingray	Yellowtail Amberjack	Kelp Bass	Horn Shark	Bait Ball	No Fish	Total
Observed	11	18	4	0	0	1	1	0	0	52	87
Expected	114	353	128	43	1	25	21	4	1	2418	3108

## Multinomial Goodness-of-Fit Test by Monte-Carlo Simulations

95% Confidence Interval, 100,000 trials  
p-value = 0.0009

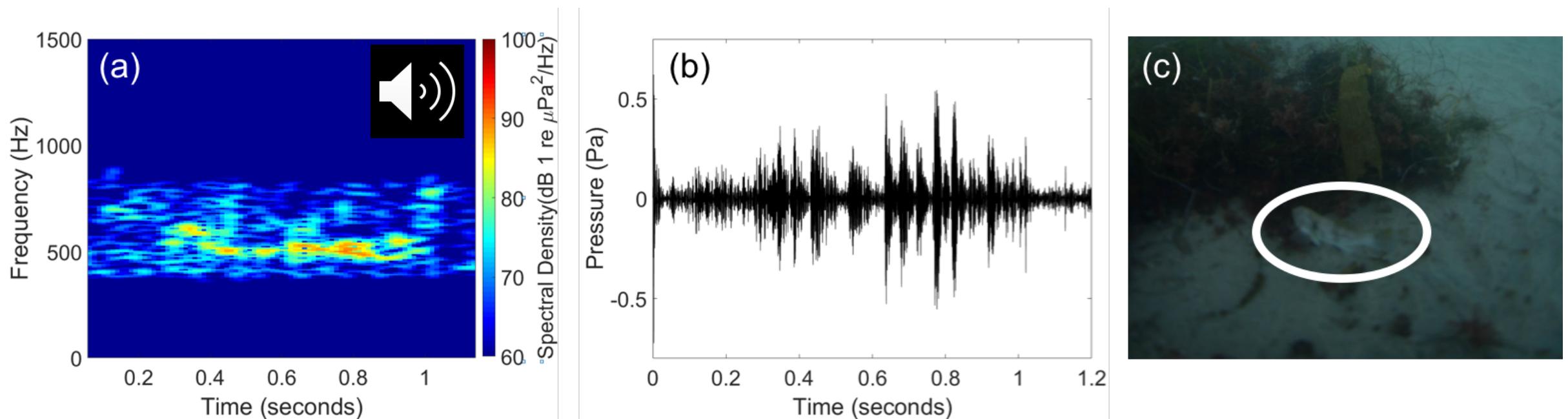


## Post-hoc tests: Exact binomial test for each category vs. sum of all other categories with Bonferroni correction

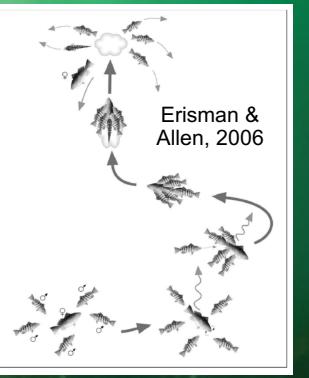
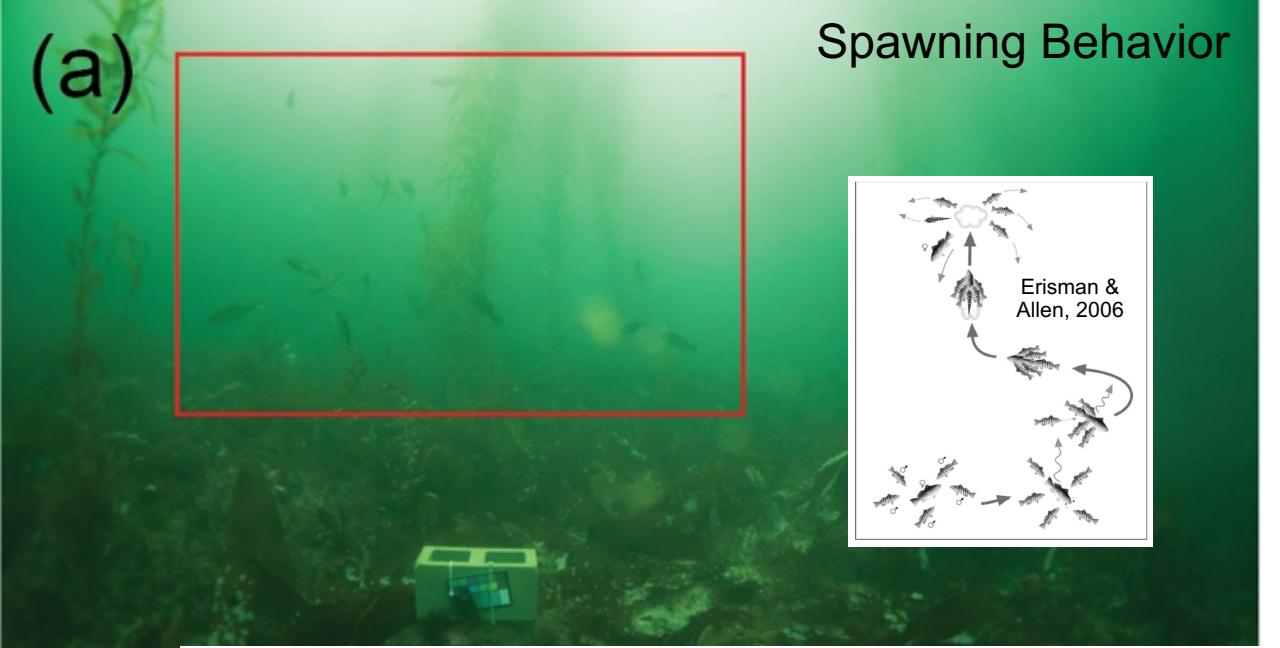
$\alpha = 0.005$

p-value = 0.0003 for Barred Sand Bass  
p-value >  $\alpha$  for all other fish

# Barred sand bass (*Paralabrax nebulifer*)

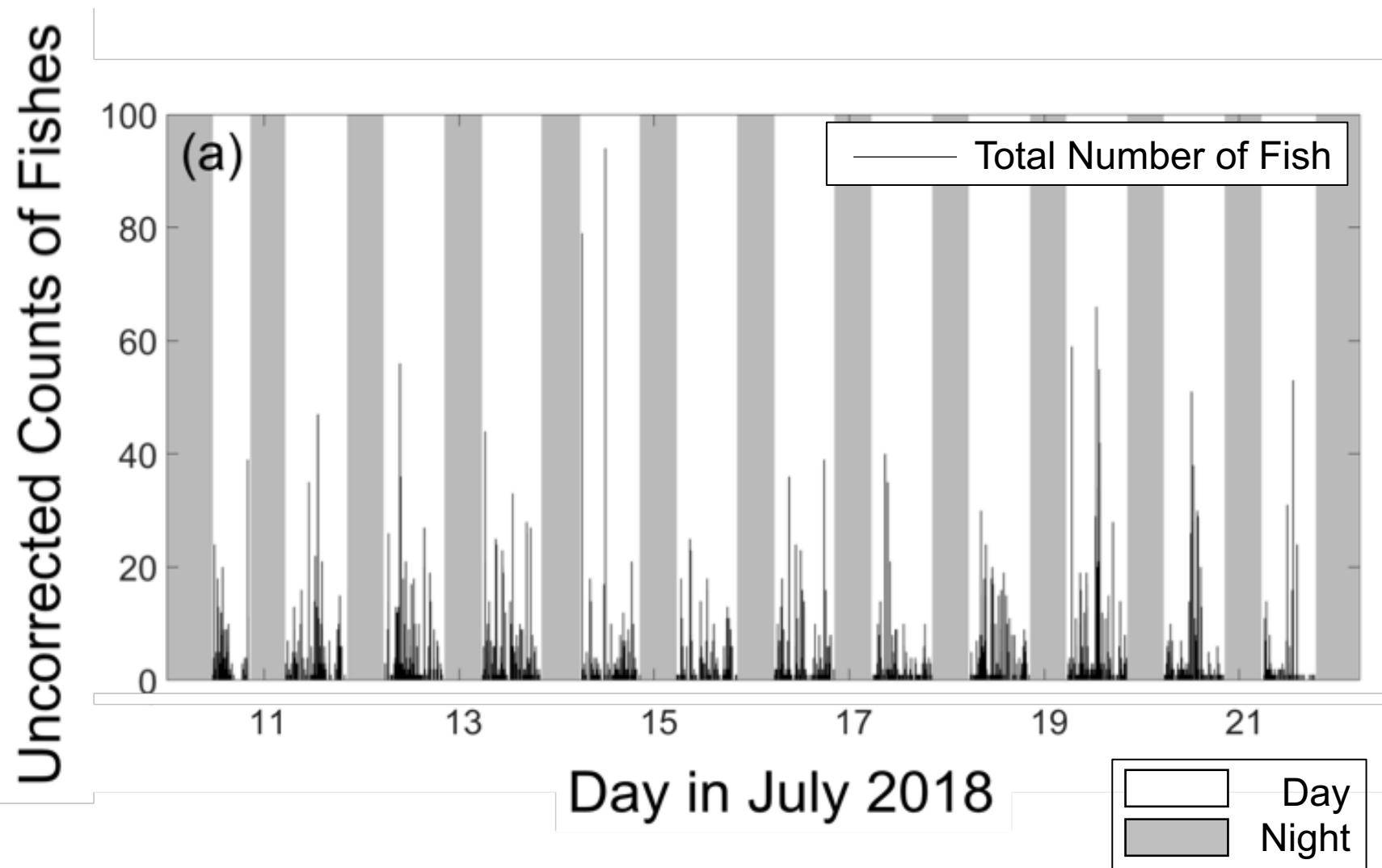


Kaiser-Bessel window with  $\alpha = 2.5$  w,  $F_s = 4$  kHz, NFFT = 512, overlap = 90%; band pass filter = 400-800 Hz.  
Color represents spectral density (dB re  $1 \mu\text{Pa}^2/\text{Hz}$ ).

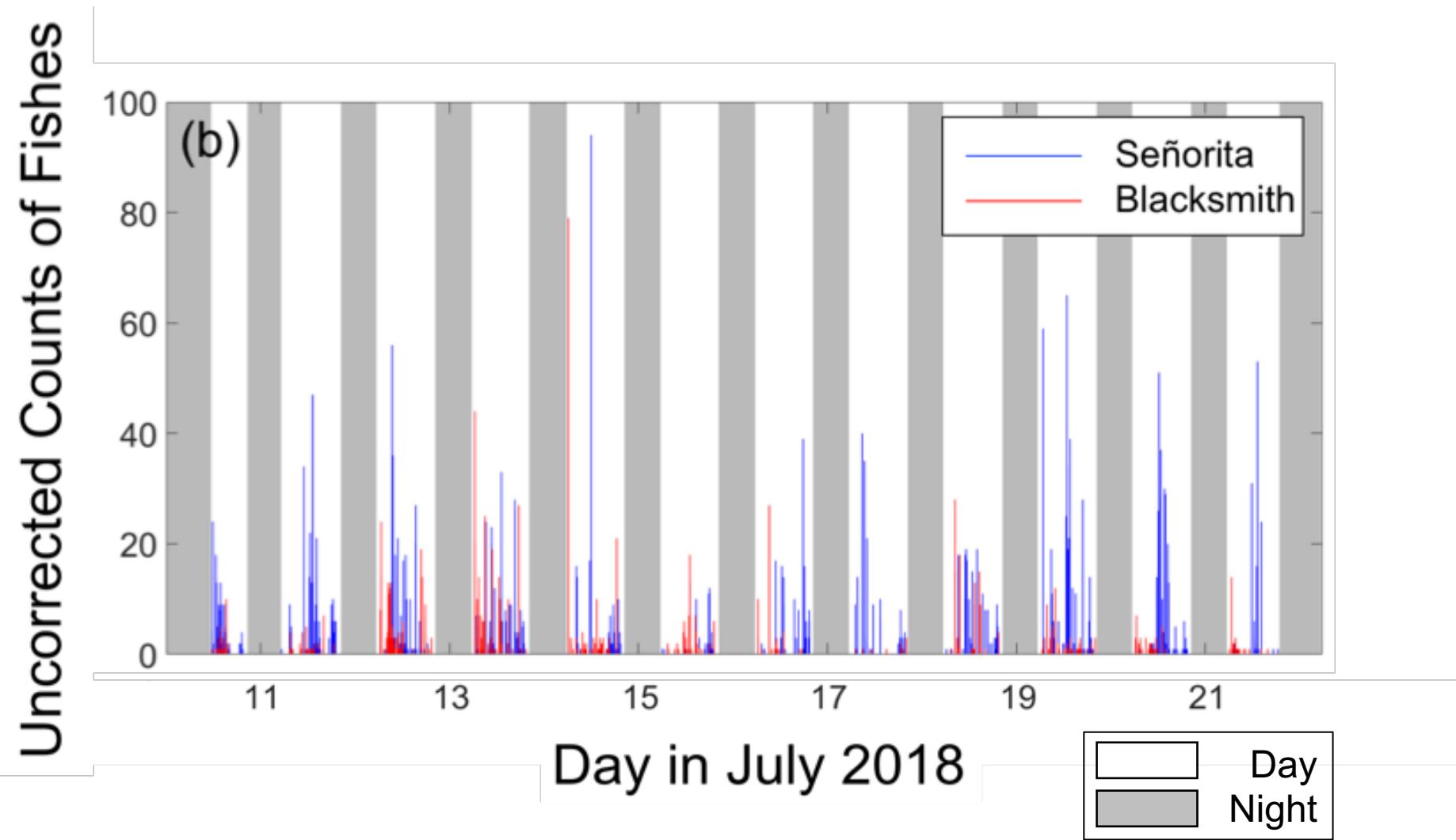


## Behavioral Observations Of Fishes

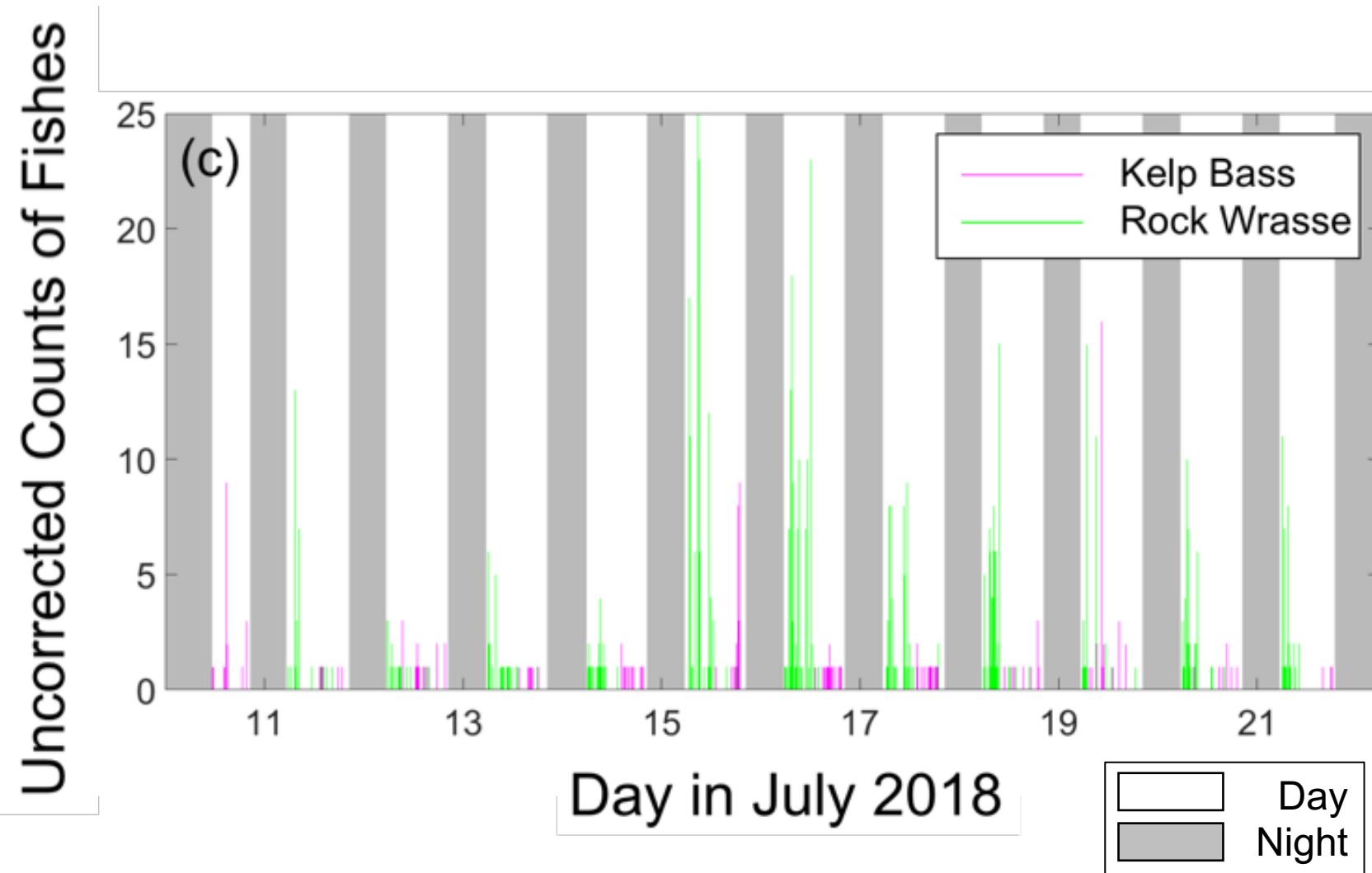
# Time Series Of Occurrences Of Fishes



# Time Series Of Occurrences Of Fishes



# Time Series Of Occurrences Of Fishes



# **Capabilities of FishOASIS**

- deployment length capable of capturing episodic and long-duration events
- optically identify soniferous species of fish
- capture good images in poor light conditions
- time synchronization of the camera and passive acoustic systems
- user-defined sampling protocol

## **Cost of FishOASIS**

- optical imaging system: approx. \$4,350 (\$2,335 for Sony α7s II camera) (USD in 2017)
- passive acoustic system: \$7,905 (USD in 2017)

## **Contributions**

- one of the very few combinations of passive acoustic/optical imaging systems since Kronengold et al. (1964)

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  - P. Roberts
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  - J. Jaffe
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