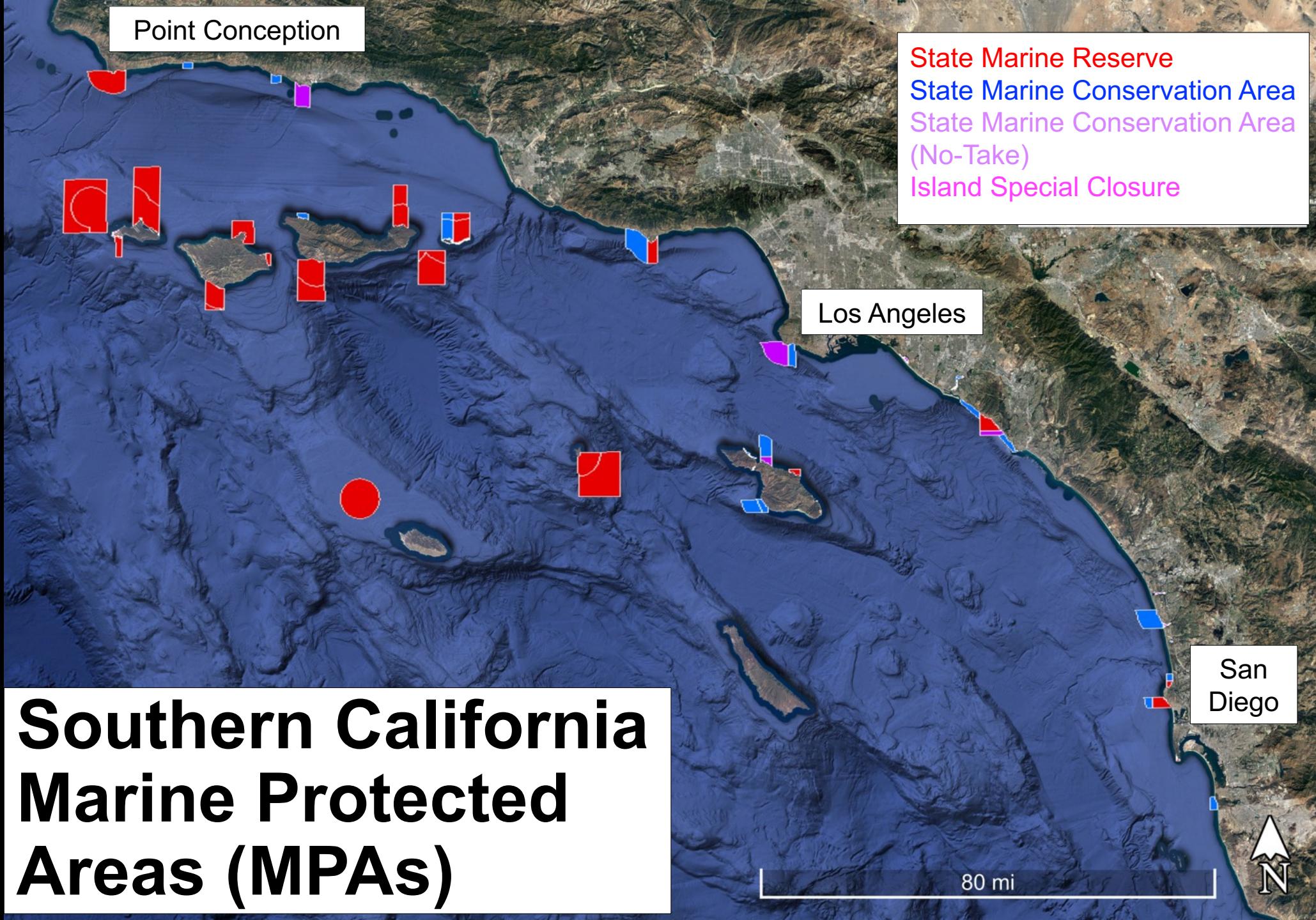


Using a passive acoustic-optical imaging system to monitor fish presence and behavior in marine protected areas

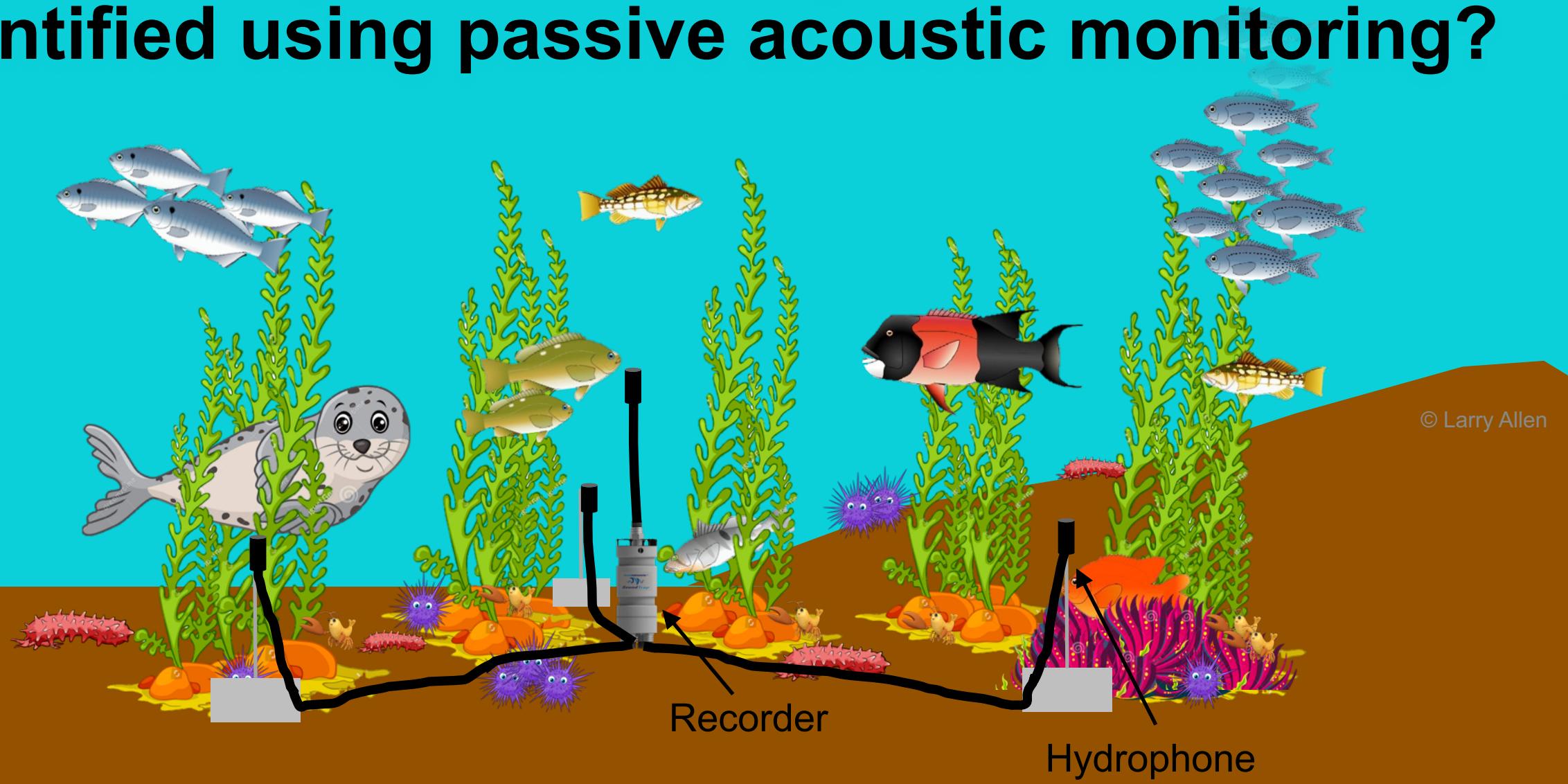
Camille M.L.S. Pagniello, Jack Butler, Addison Sherwood, Annie Rosen, Paul L.D. Roberts, P. Ed Parnell, Jules S. Jaffe and Ana Širović

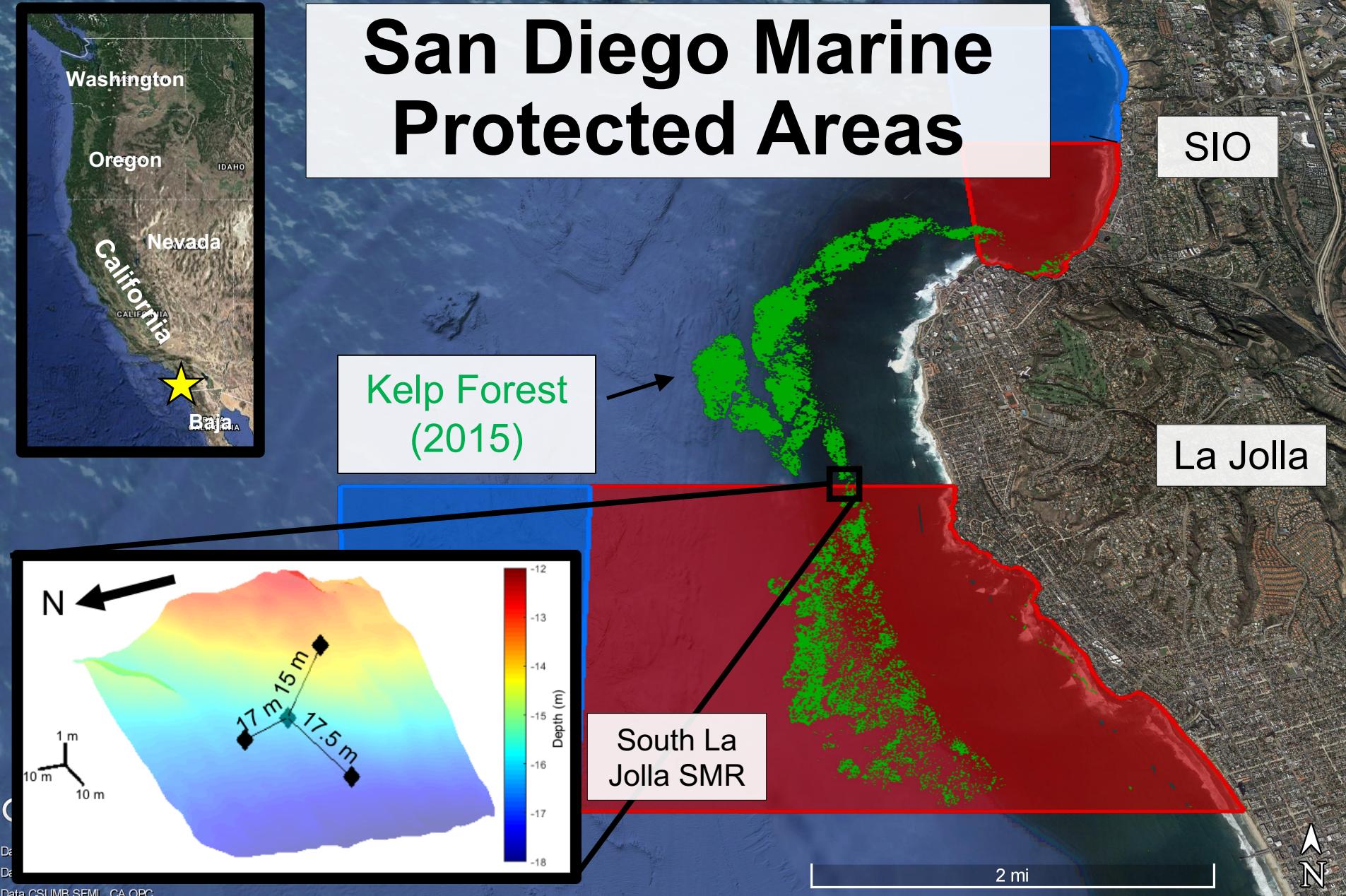
Scripps Institution of Oceanography
University of California San Diego



Southern California Marine Protected Areas (MPAs)

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





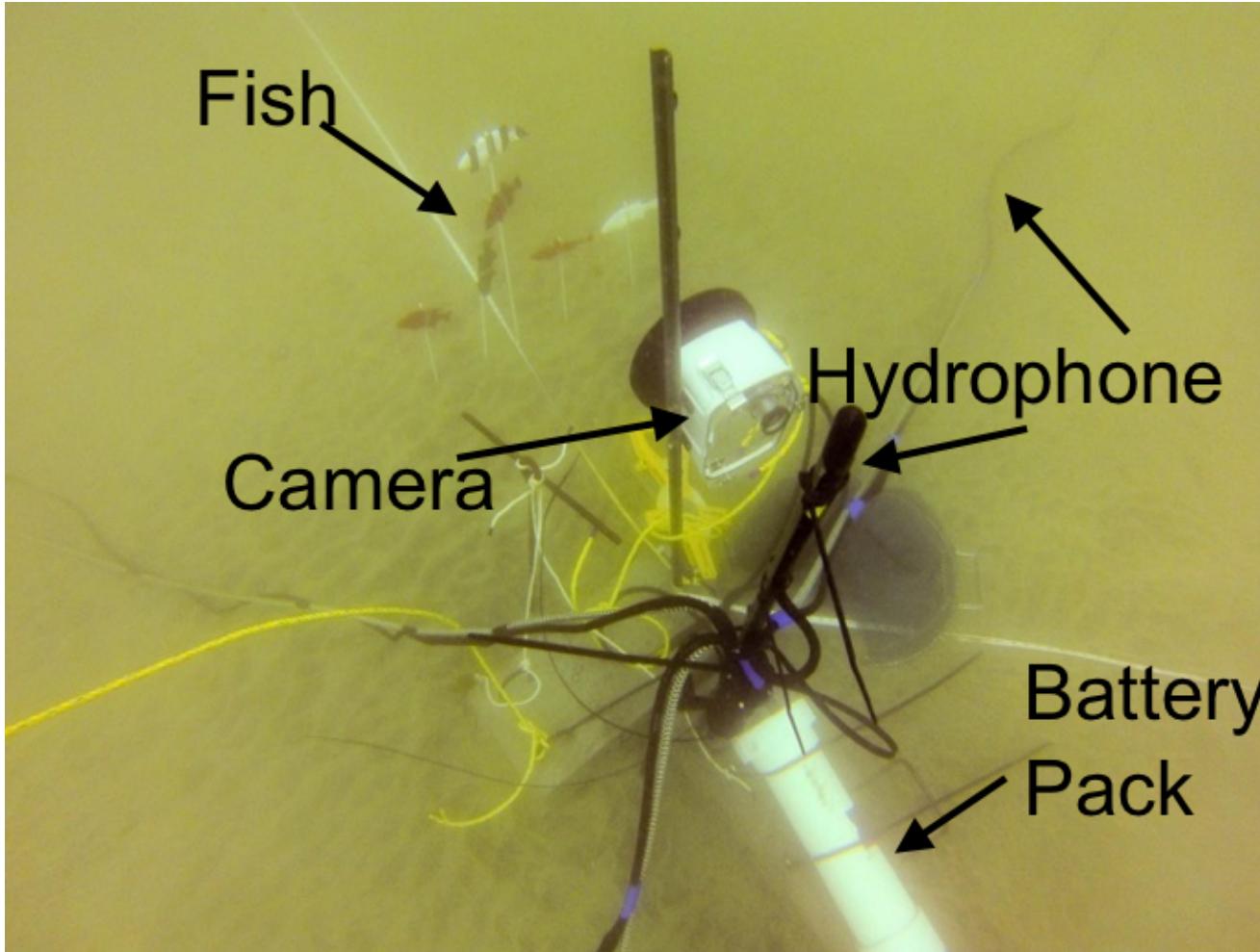
SMR: prohibits damage or take of all marine resources

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

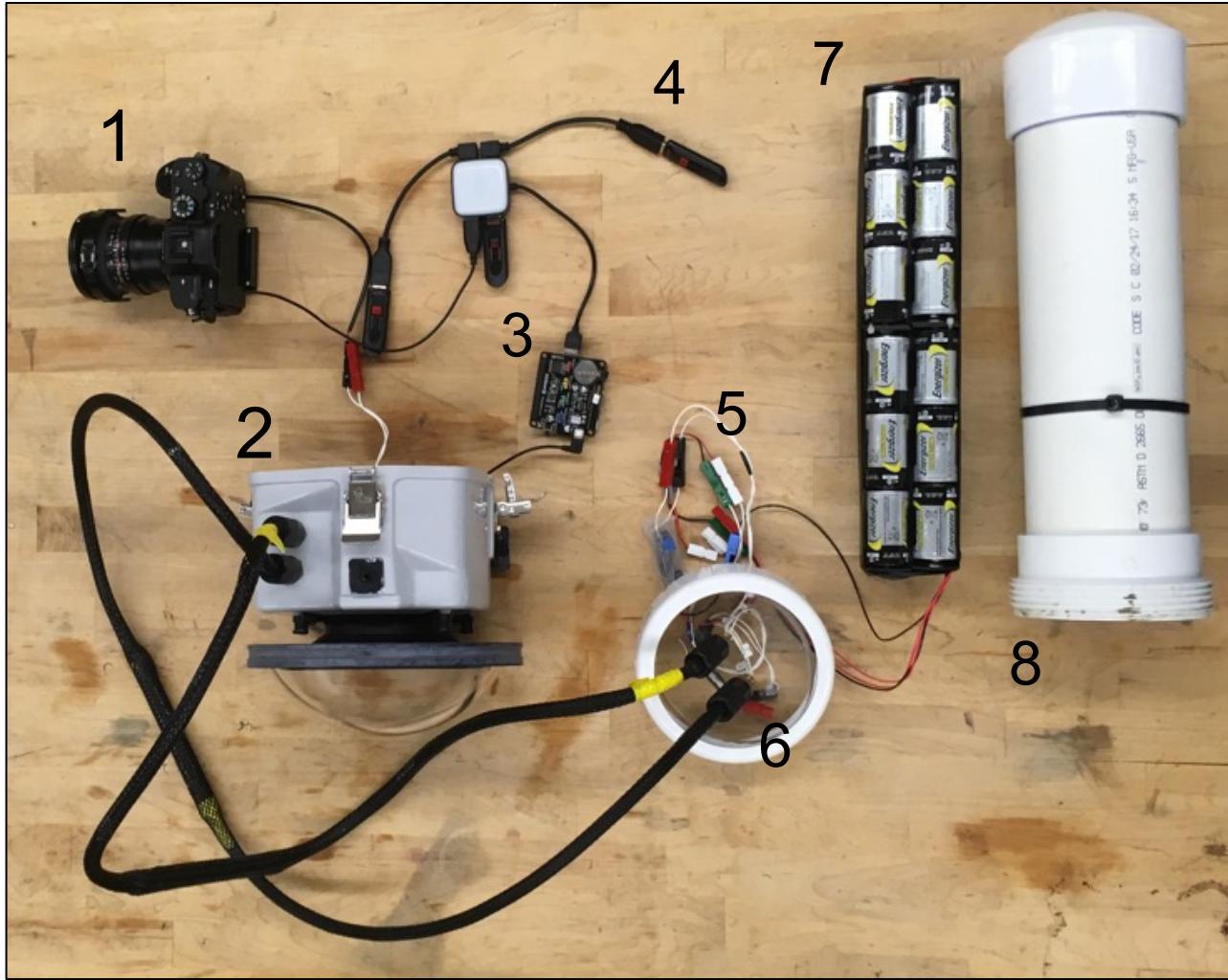
Ideal Passive Acoustic-Optical Imaging System Requirements

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

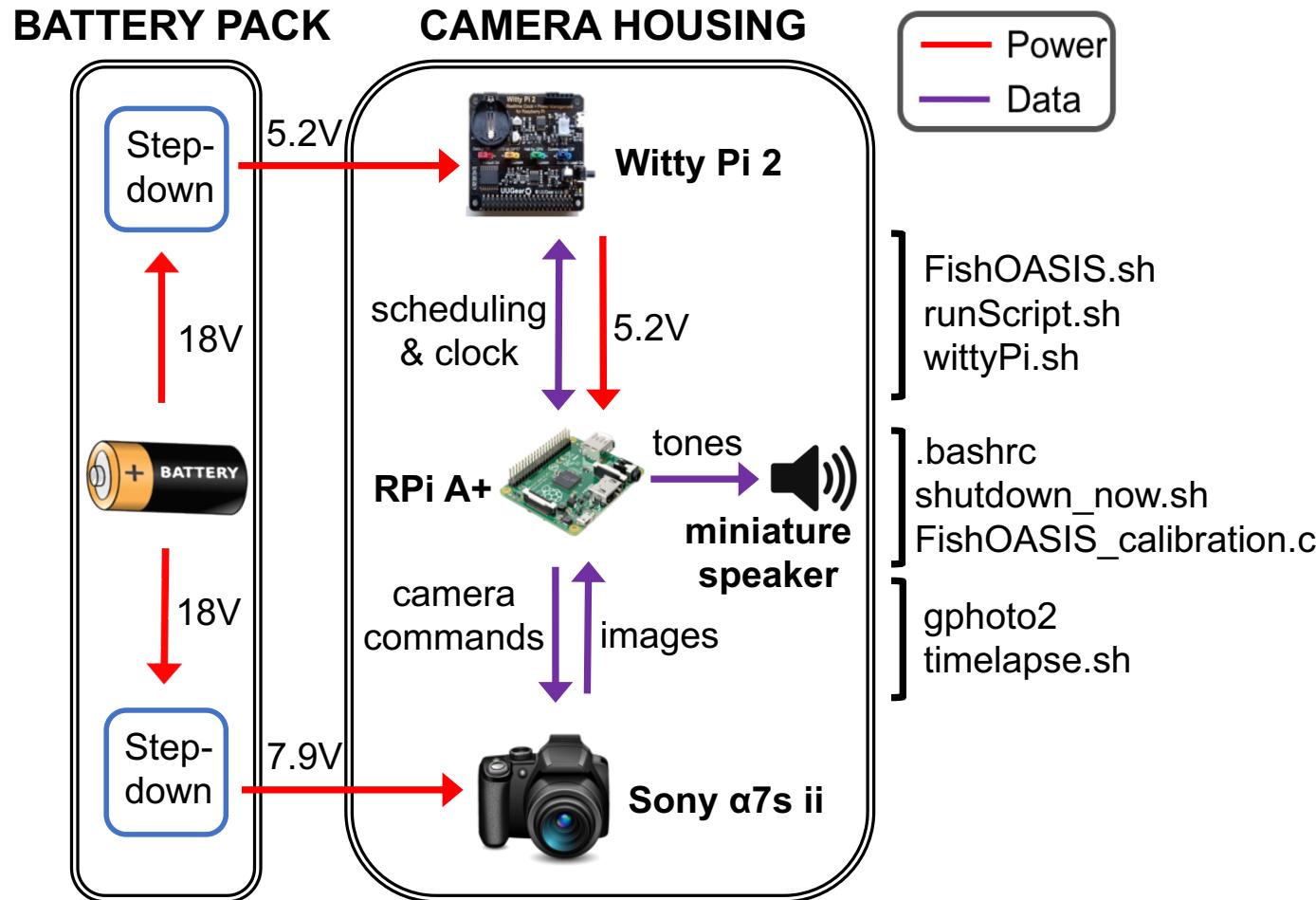


Components:

- 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/>

Image Quality: Ambient Light

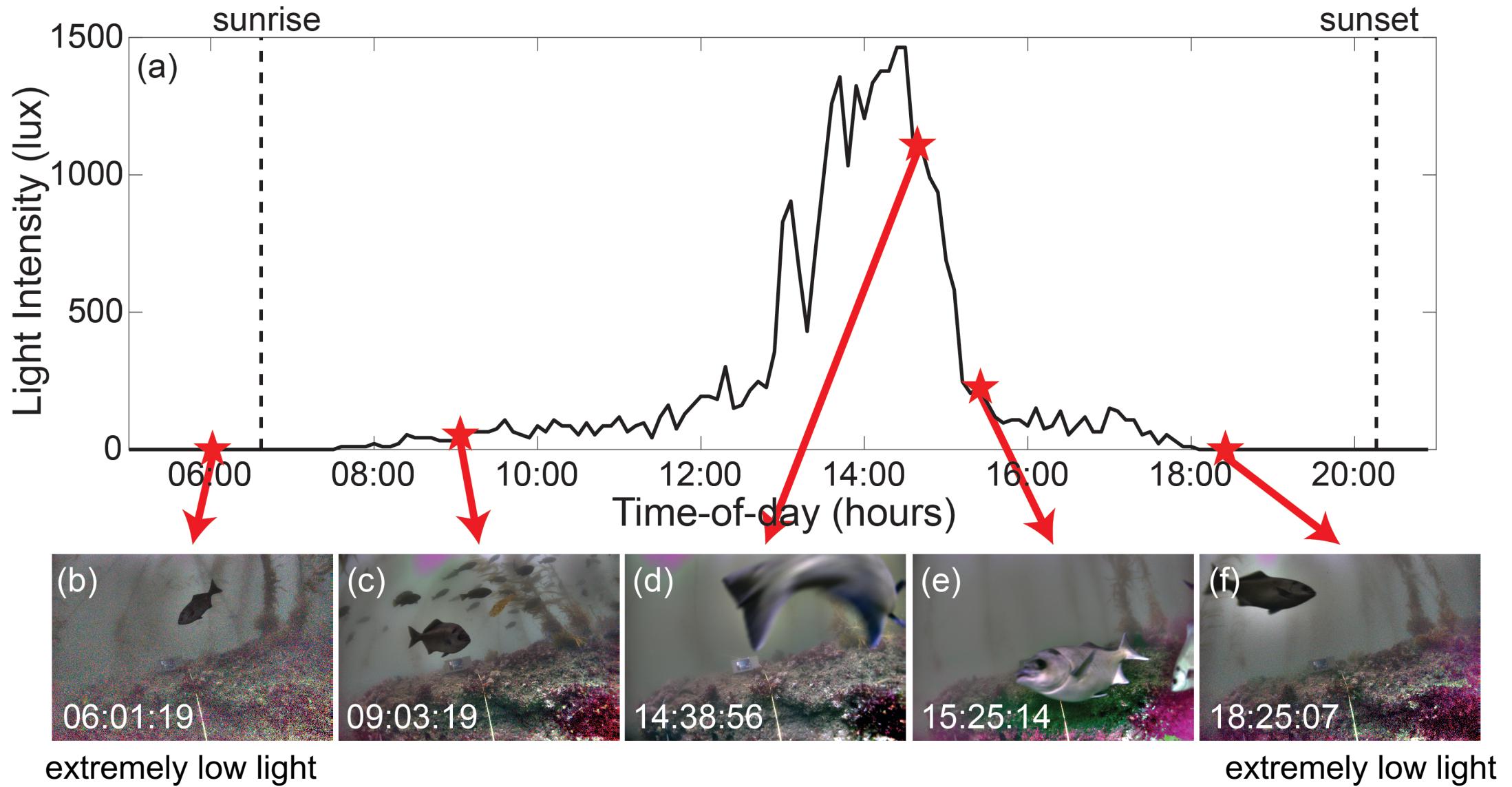
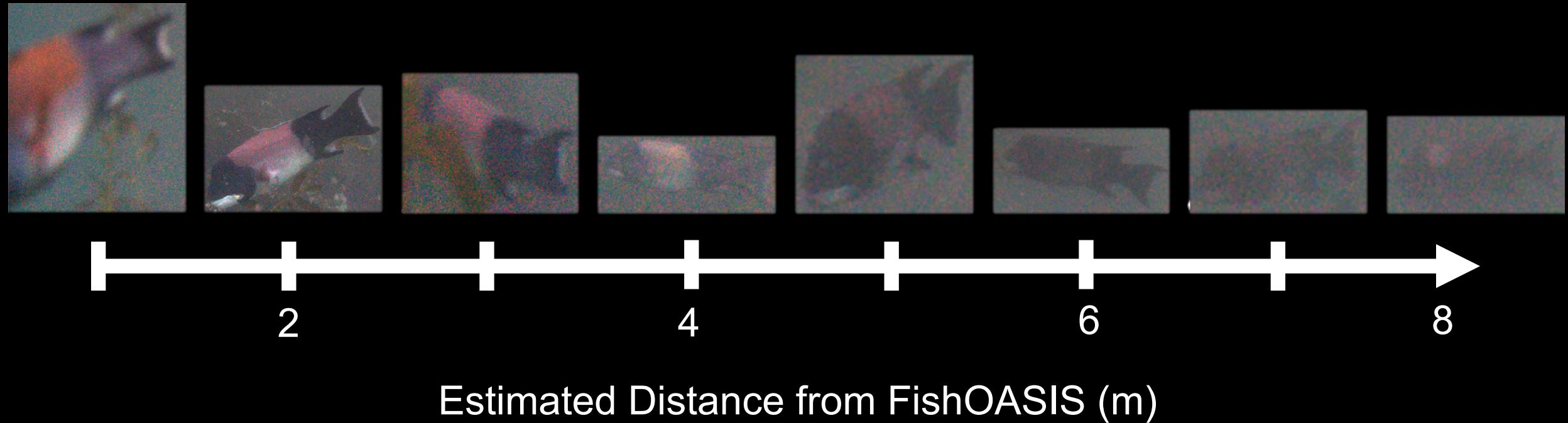


Image Quality: Fish Distance



Diversity of Fish Species

1 camera, 13 days, 17101 images

fish species: 20



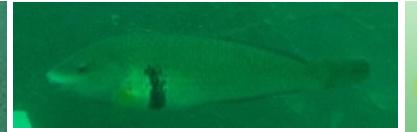
Señorita
(*Oxyjulis californica*)



Juvenile



Adult



Rock Wrasse
(*Notorynchus cepedianus*)



Halfmoon
(*Medialuna californiensis*)



Kelp Perch
(*Brachyistius frenatus*)



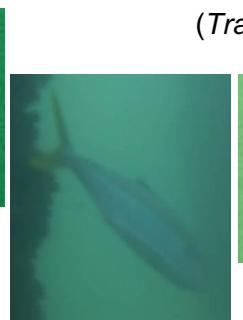
Pacific Barracuda
(*Sphyraena argentea*)



Sevengill Shark
(*Notorynchus cepedianus*)



Black Surfperch
(*Embiotoca jacksoni*)



Yellowtail
(*Seriola dorsalis*)



Shovelnose Guitarfish
(*Rhinobatos productus*)

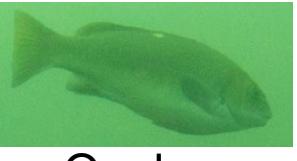
known fish: 9601



Rock Wrasse
(*Notorynchus cepedianus*)



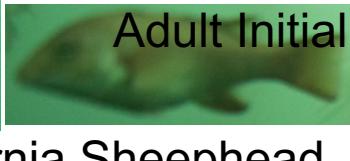
Kelp Bass
(*Paralabrax clathratus*)



Opaleye
(*Girella nigricans*)



Adult Terminal



Adult Initial



Jack Mackerel
(*Trachurus symmetricus*)



Sargo
(*Anisotremus davidsonii*)



Garibaldi
(*Hypsypops rubicundus*)



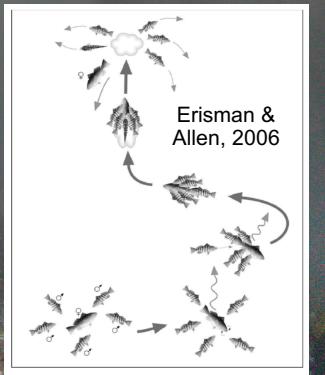
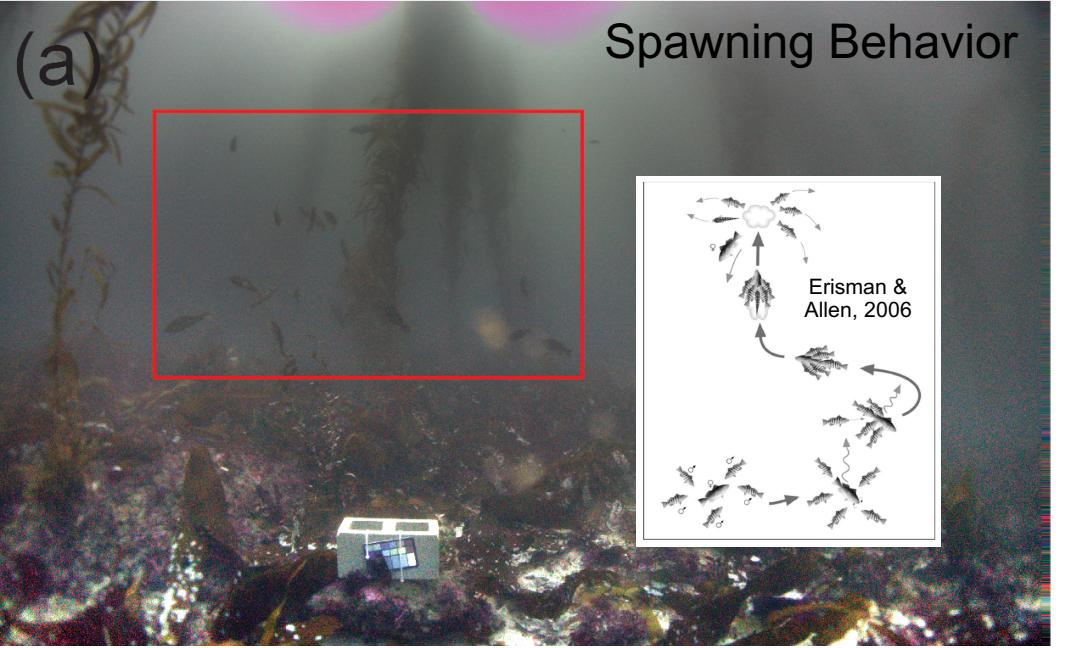
Painted
Greenling
(*Oxylebius pictus*)



White Seabass
(*Atractoscion nobilis*)

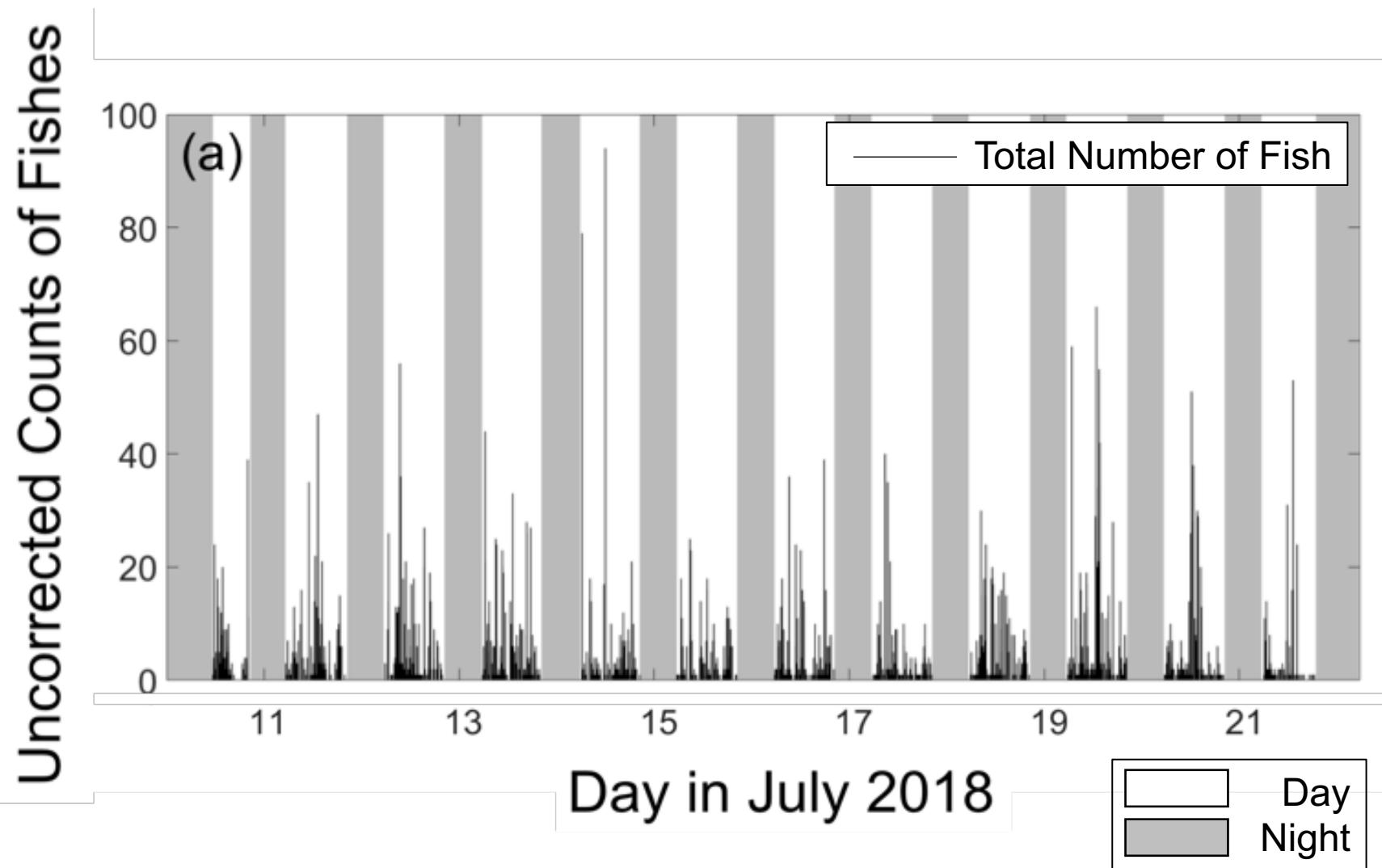


Barred
Sand Bass
(*Paralabrax nebulifer*)

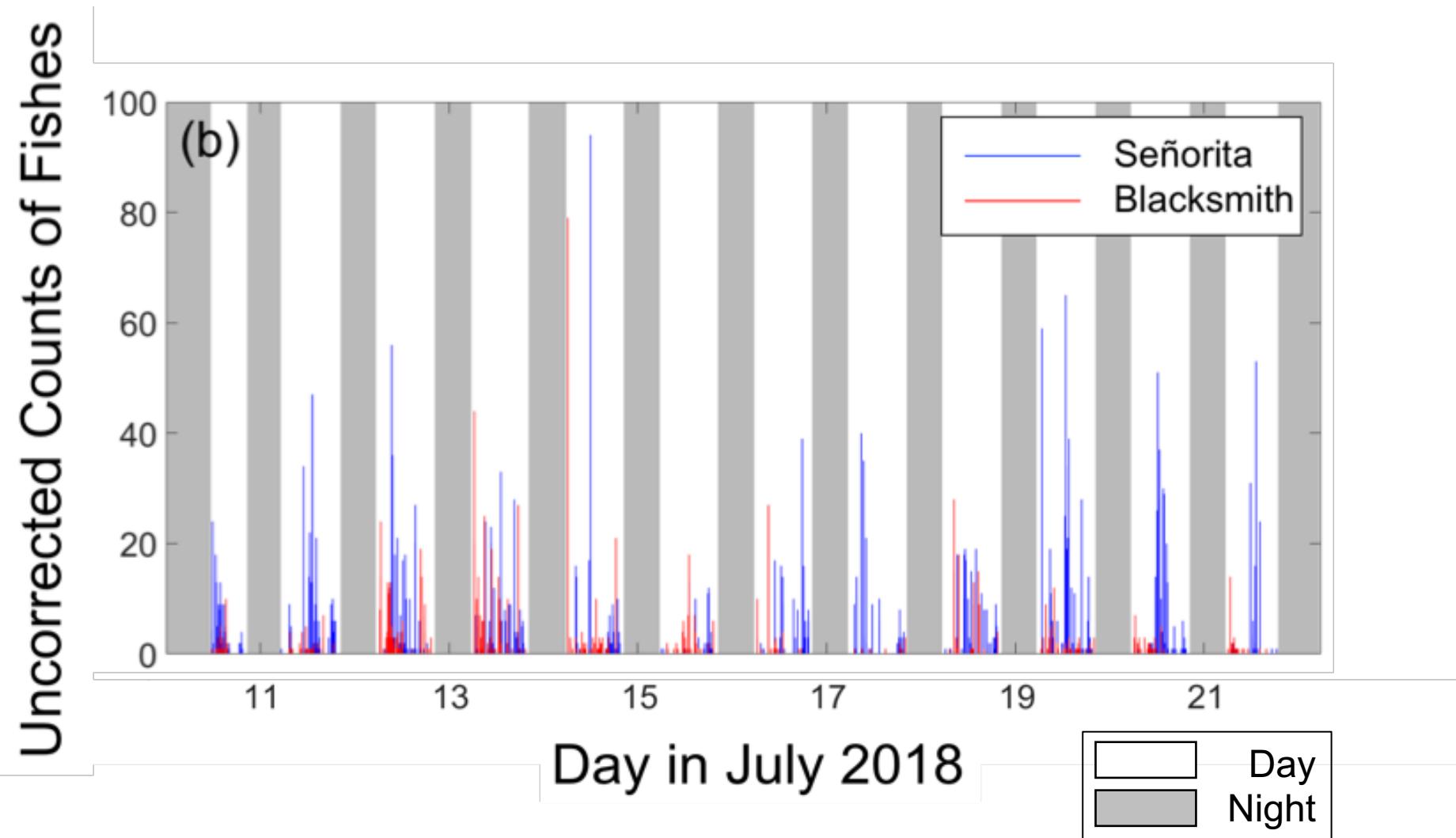


Behavioral Observations Of Fishes

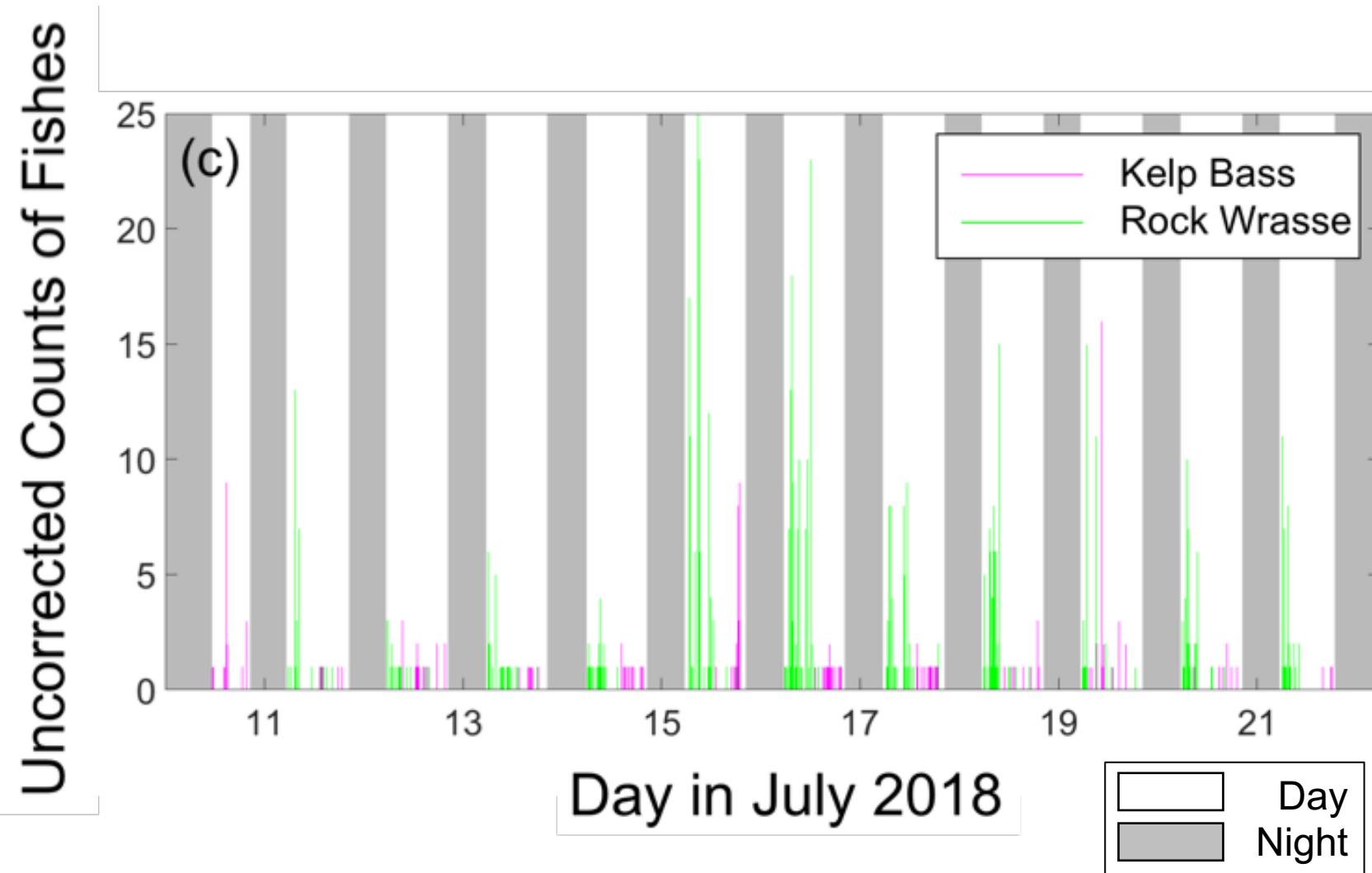
Time Series Of Occurrences Of Fishes



Time Series Of Occurrences Of Fishes

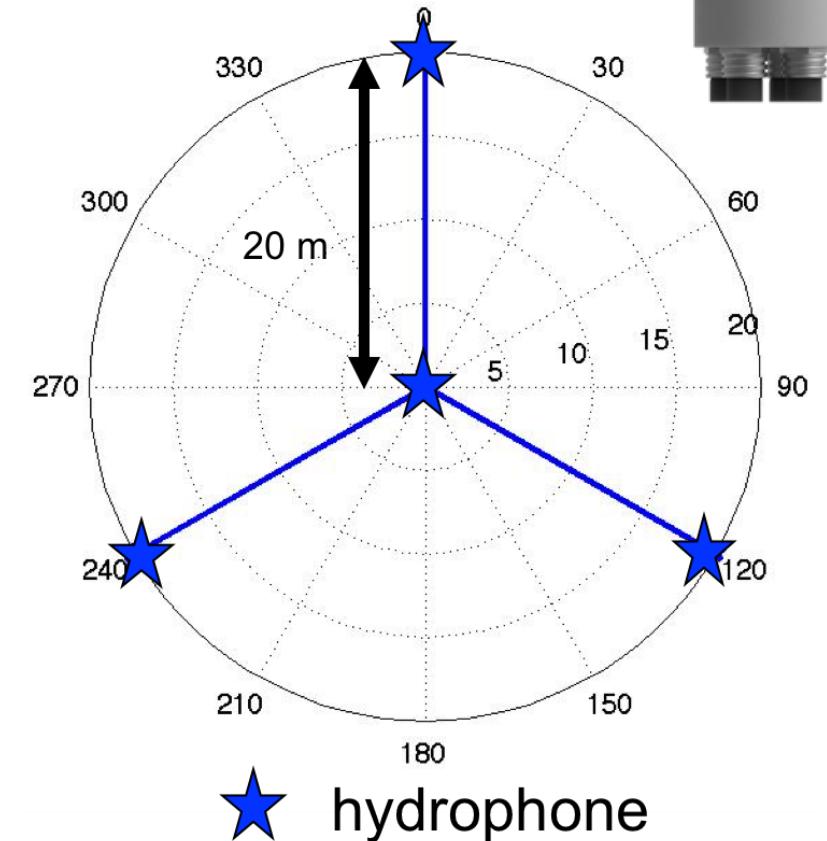
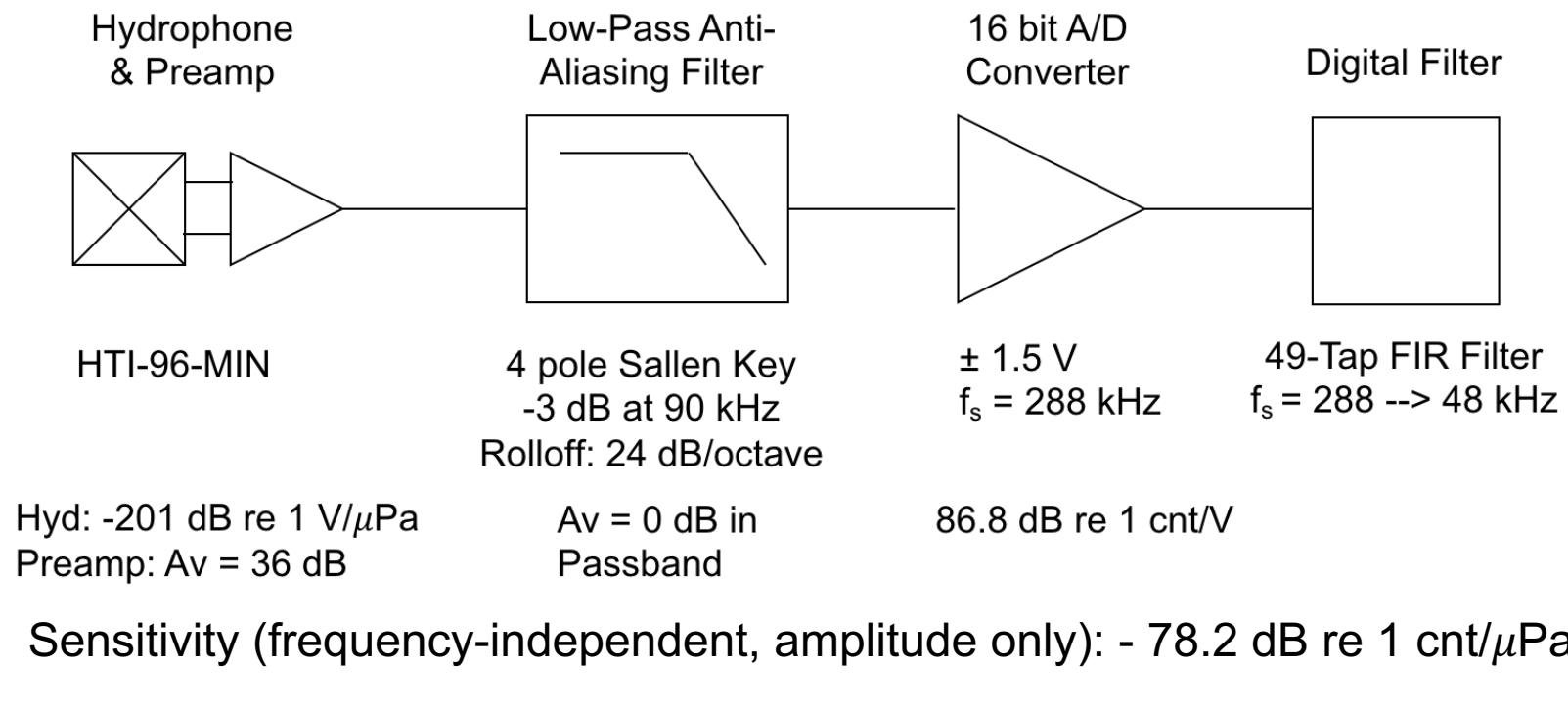


Time Series Of Occurrences Of Fishes

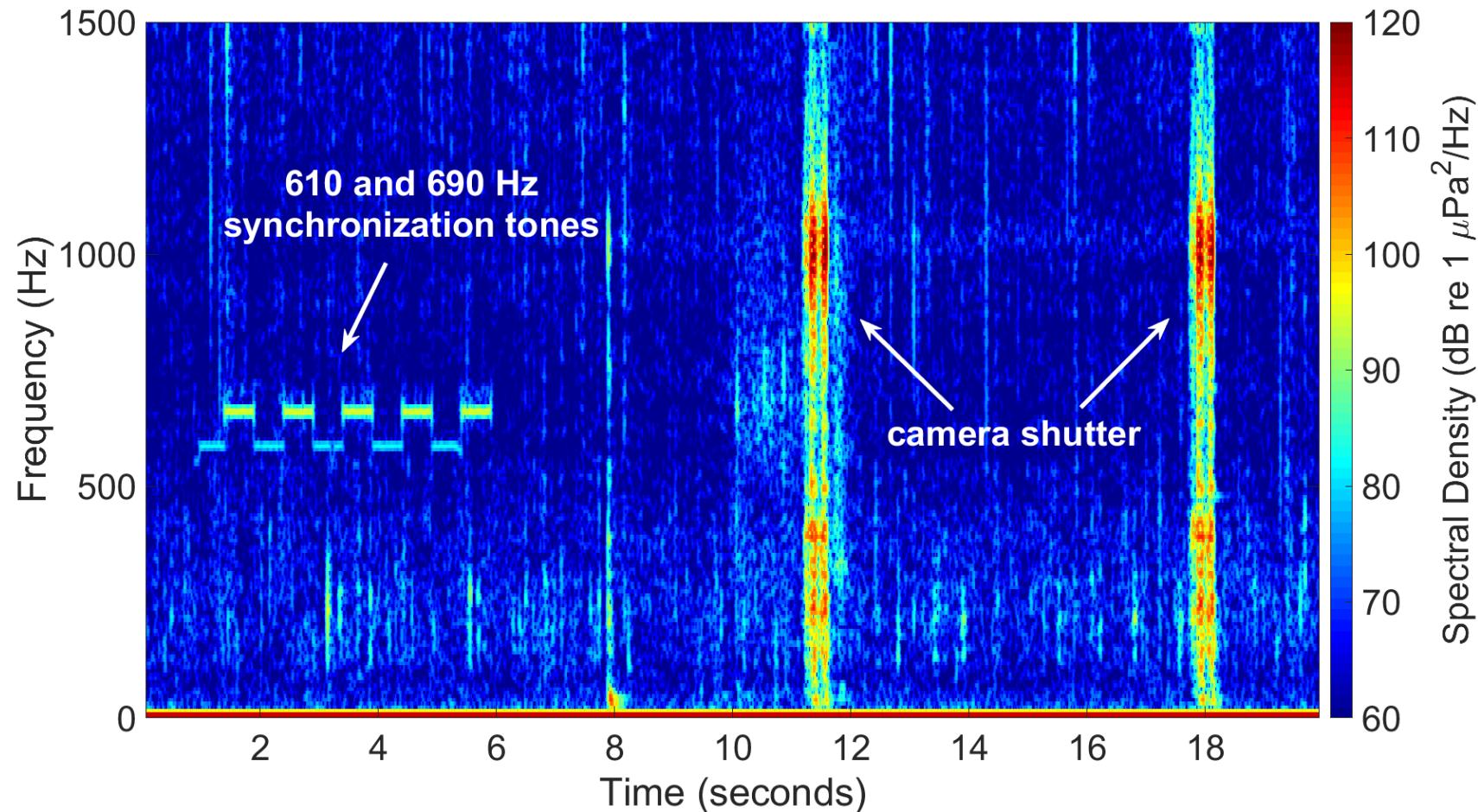


Passive Acoustic System

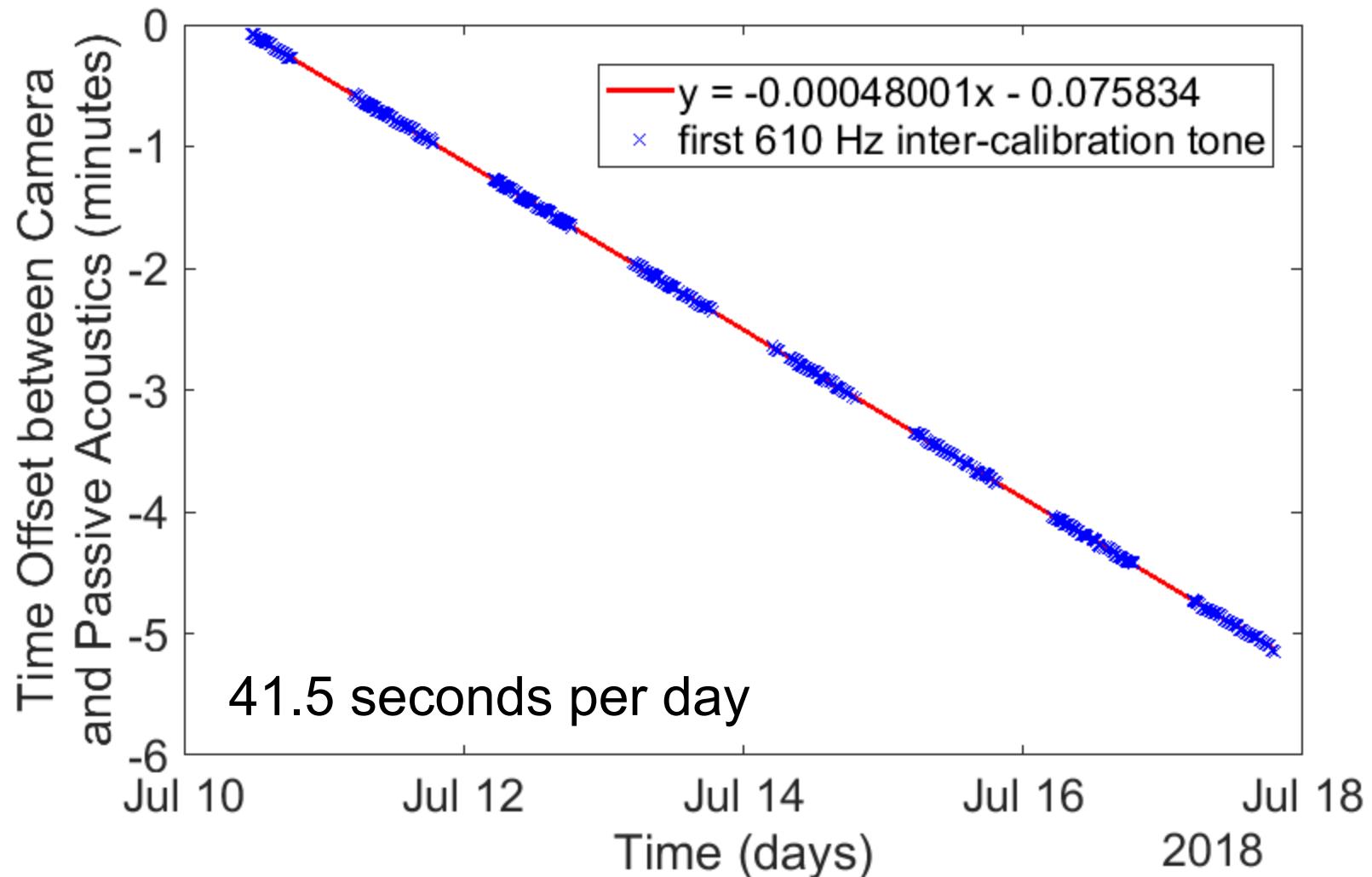
SoundTrap ST4300 256 GB acoustic recorder



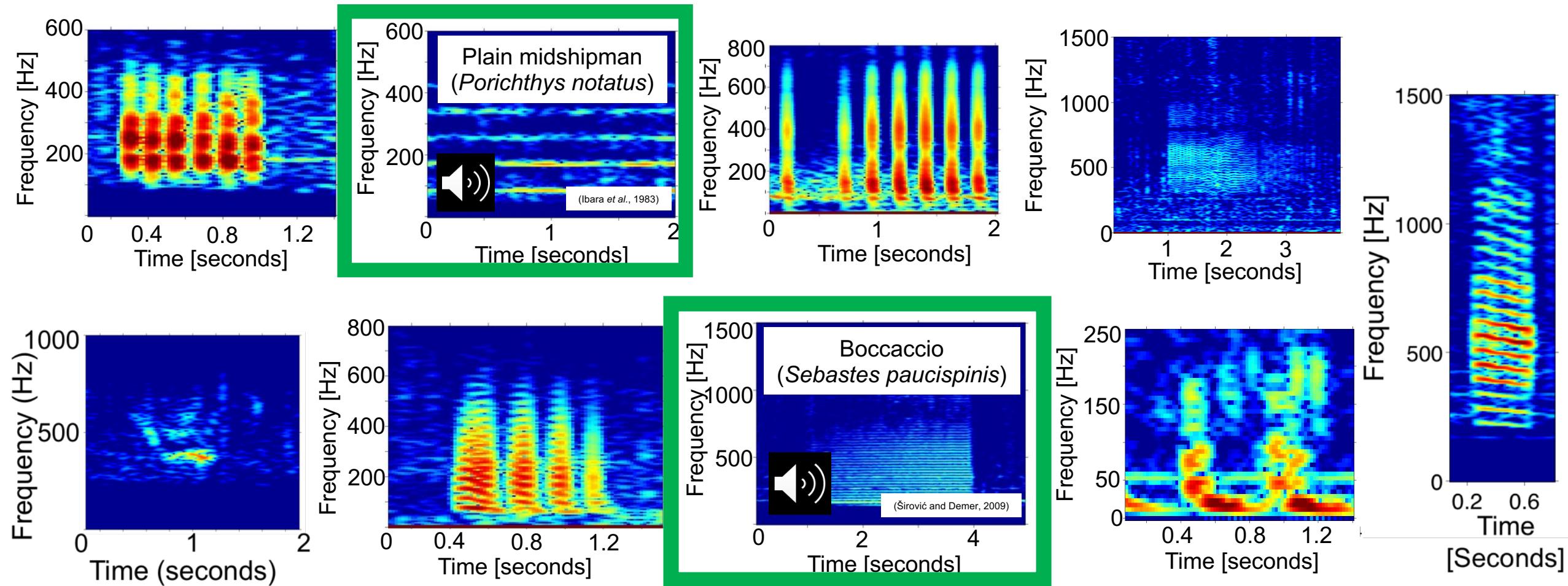
Time Synchronization of Optical Imaging and Passive Acoustic System



Time Synchronization of Optical Imaging and Passive Acoustic System

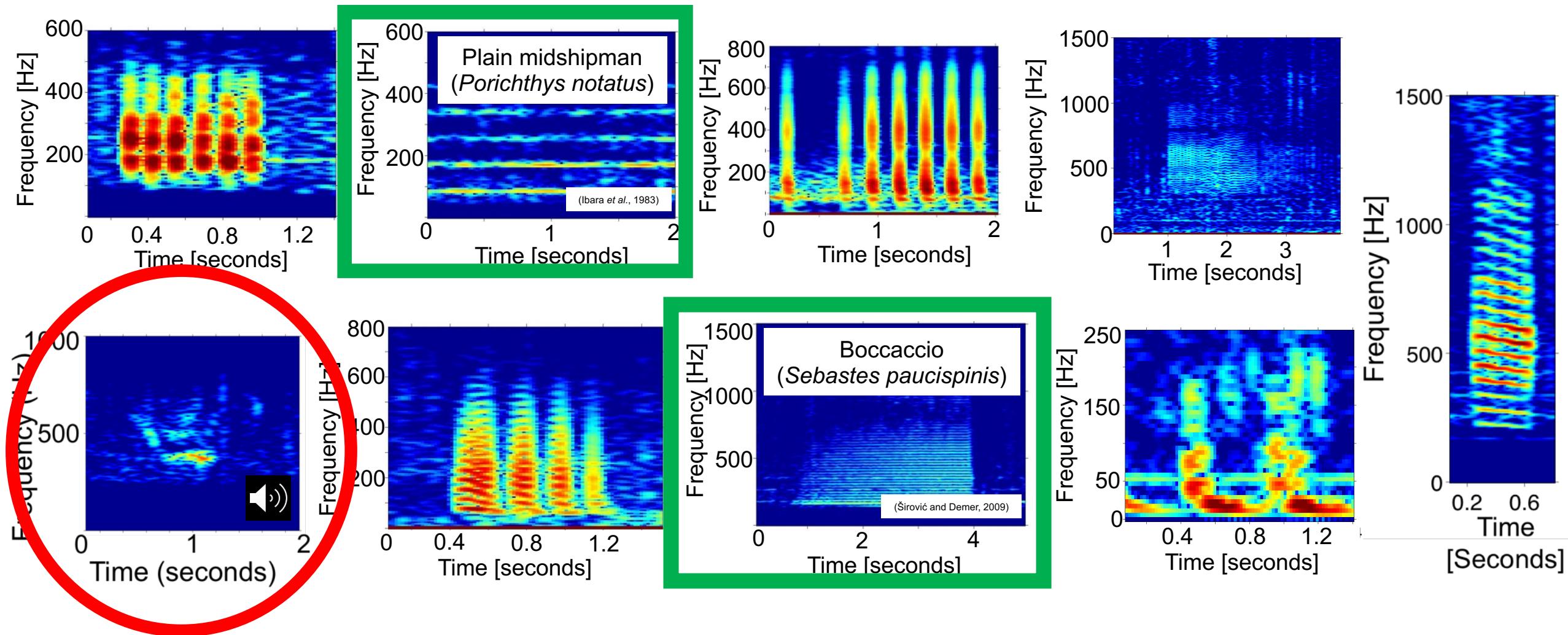


Diversity of Fish-Like Sounds



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

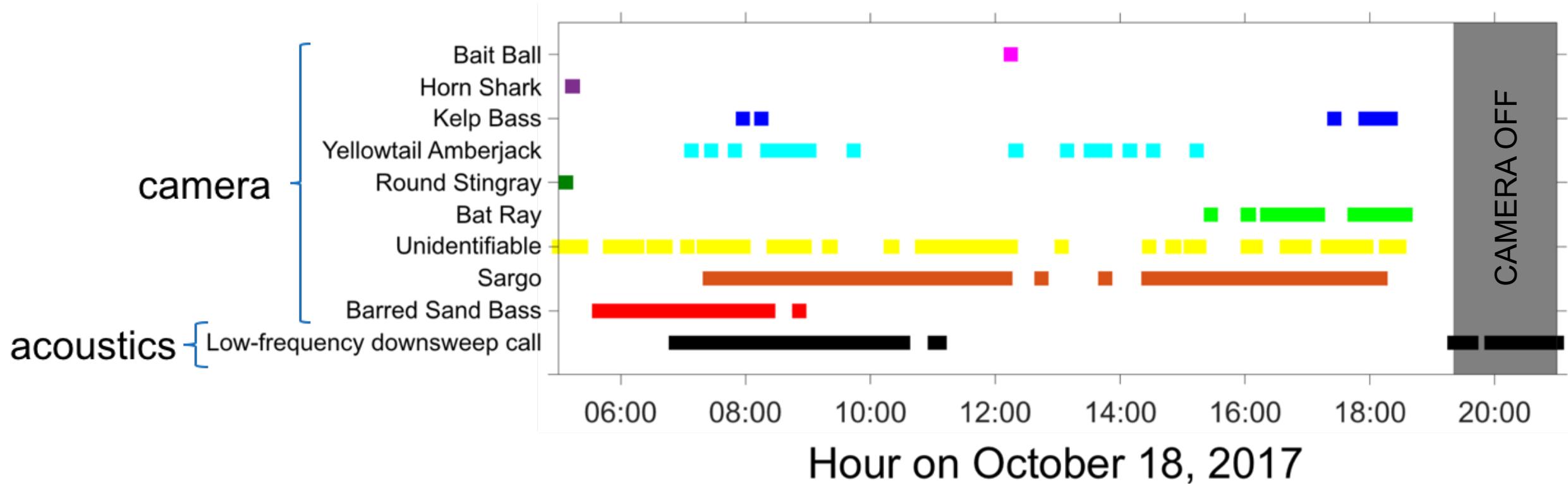


Kaiser-Bessel window with $\alpha = 2.5 w$, $F_s = 4 \text{ kHz}$, NFFT = 512, overlap = 90%; band pass filter = 400-800 Hz.
Color represents spectral density (dB re 1 $\mu\text{Pa}^2/\text{Hz}$).

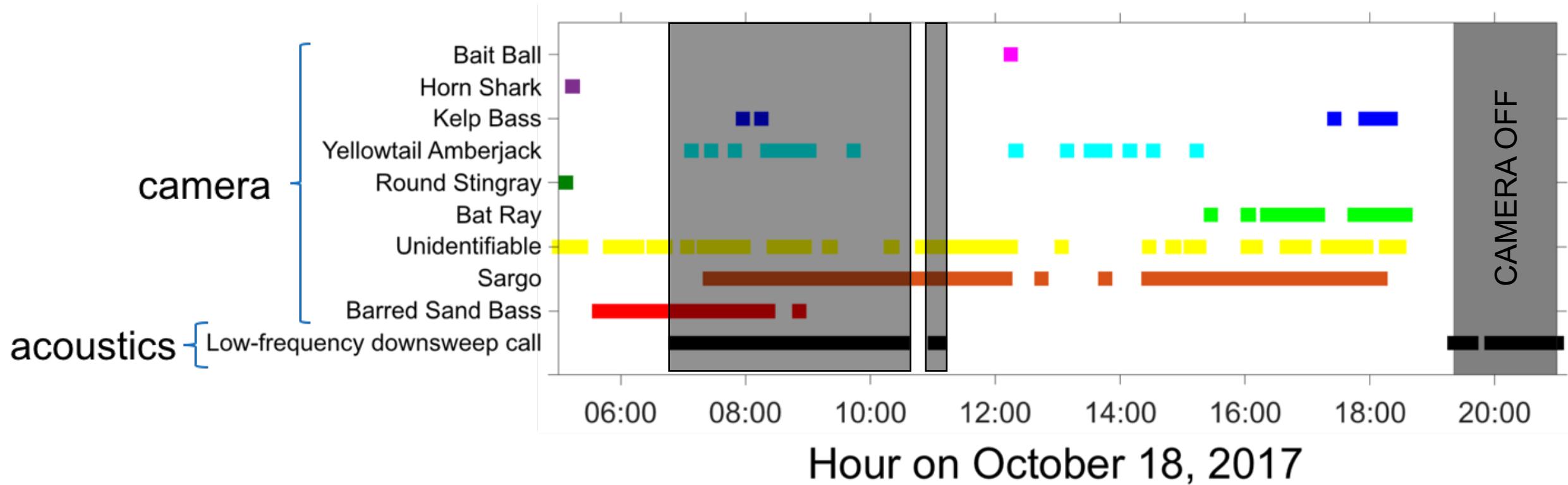
Occurrences of low-frequency downsweep call in acoustic data and fish in images



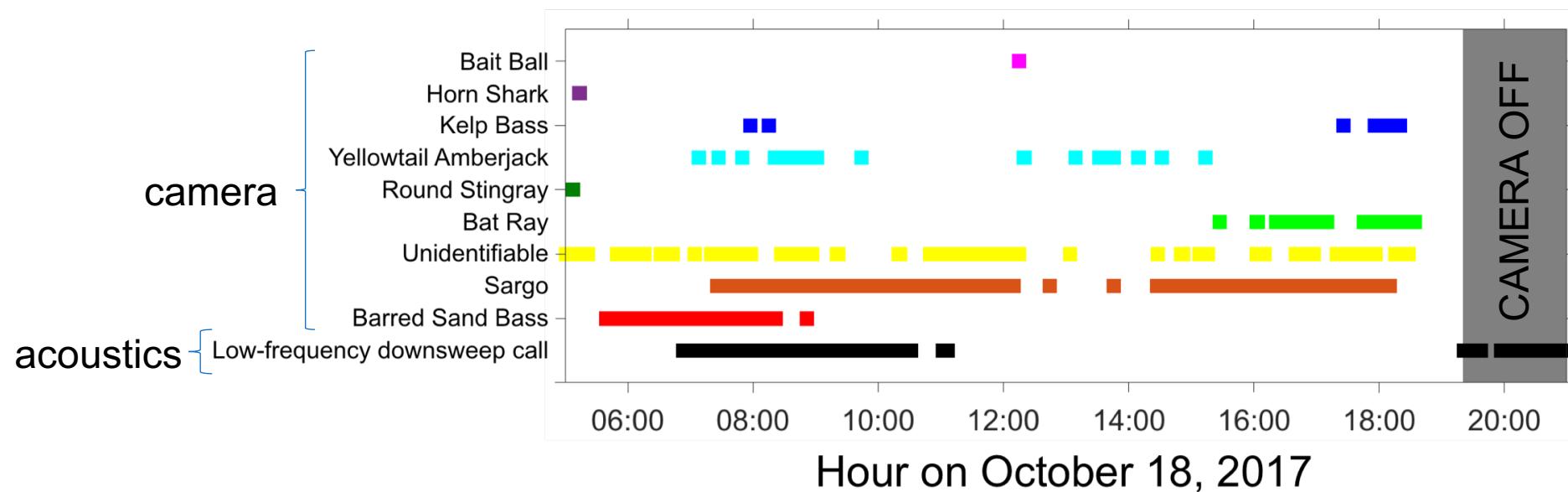
Occurrences of low-frequency downsweep call in acoustic data and fish in images



Occurrences of low-frequency downsweep call in acoustic data and fish in images



Species-Sound Association



Observed: # of calls within ± 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

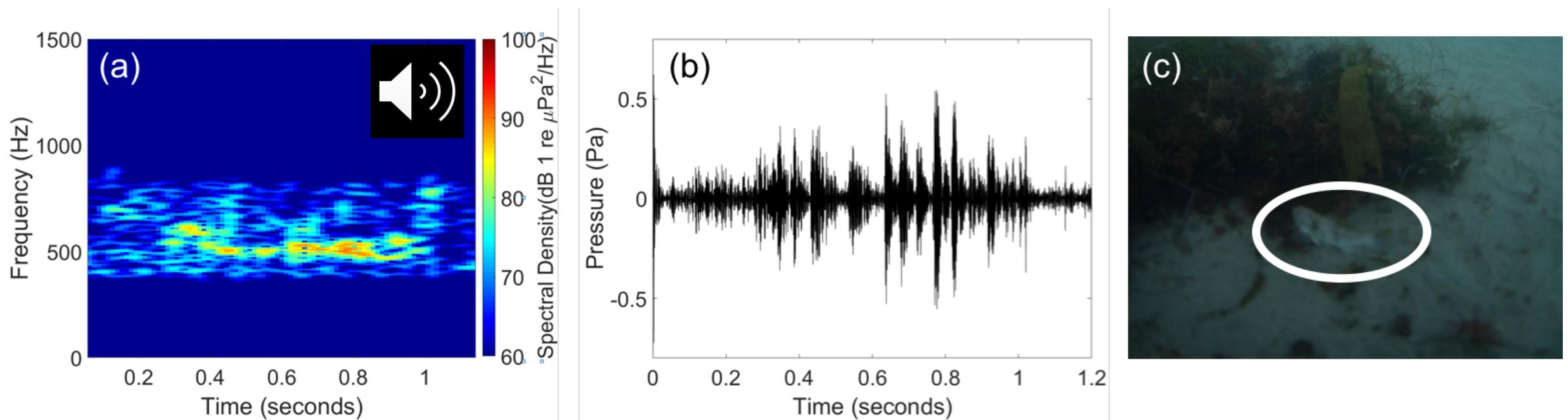


Post-hoc tests: Exact binomial test for each category vs. sum of all other categories with Bonferroni correction

$$\alpha = 0.005$$

p-value = 0.0003 for Barred Sand Bass
p-value > α for all other fish

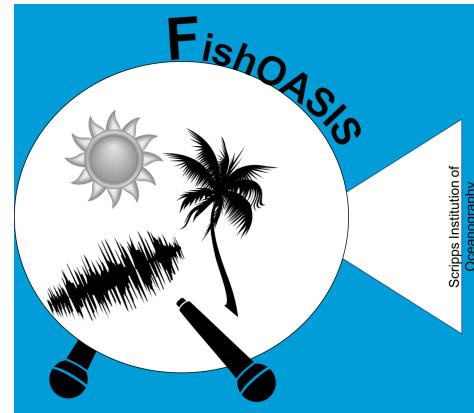
Barred sand bass (*Paralabrax nebulifer*)



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 $\mu\text{Pa}^2/\text{Hz}$).

Capabilities of FishOASIS

- deployment length of 14 days when recording acoustic data continuously and capturing 24 images, every 12 minutes for 16 hrs
- optically identify species of fish in poor light conditions (i.e., before and after sunset) without artificial light
- make fish behavioral observations and time series of fish presence/absence
- time synchronization of the camera and passive acoustic systems to account for passive acoustic system clock drift to enable species-sound associations
- user-defined sampling protocol



Cost of FishOASIS

- optical imaging system: approx. \$4,350 (\$2,335 for Sony a7s II camera) (USD in 2017)
- passive acoustic system: \$7,905 (USD in 2017)

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Thank you!



Questions?