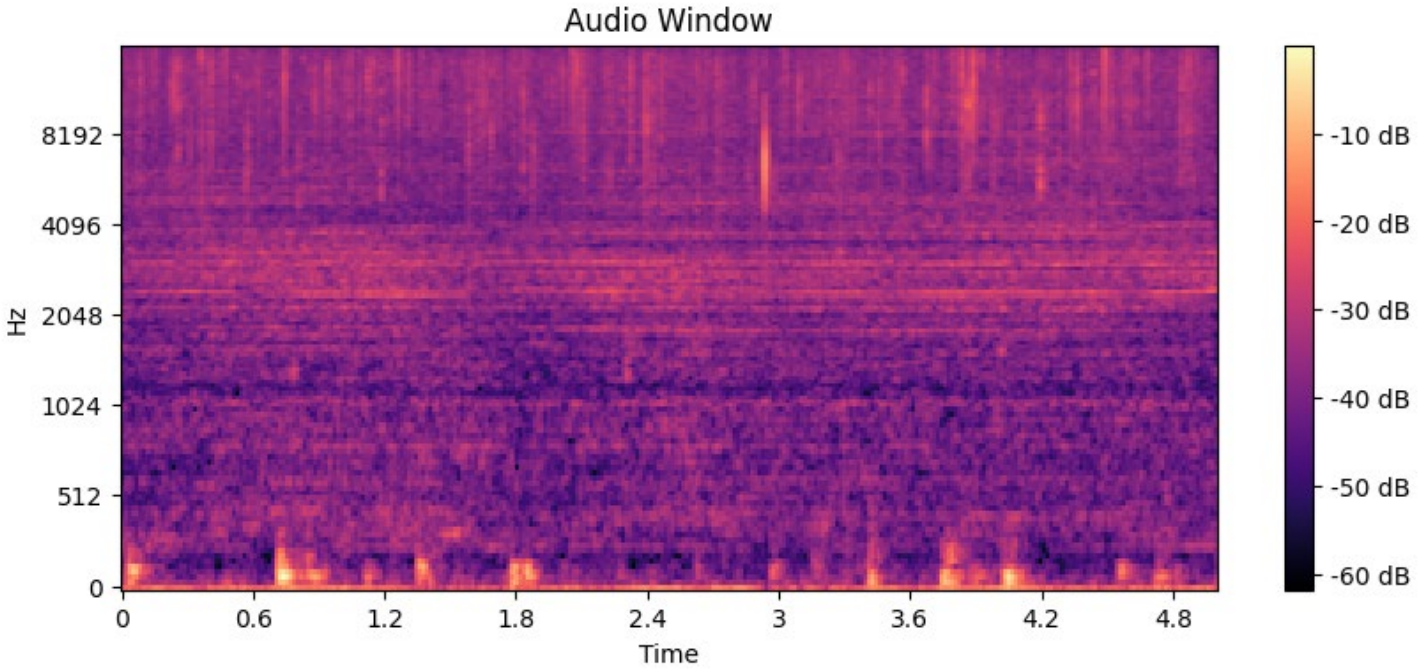
Developing a Machine Learning-Powered Boat Detector for Underwater Acoustic Data

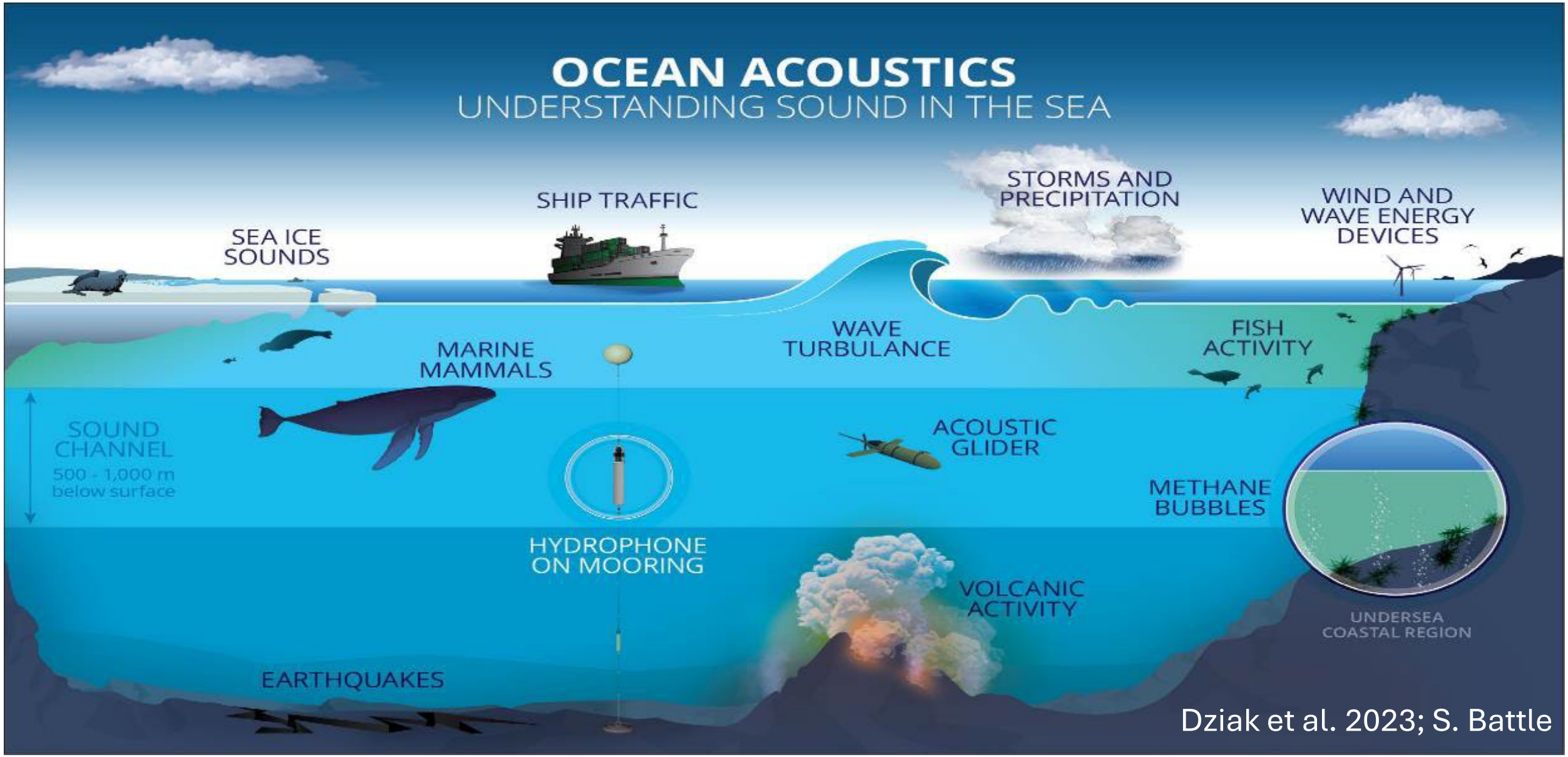
David Kochan, Luke McEachron, Tom Denton, Sarah Burnsed, Joel Bickford, Susan Lowerre-Barbieri

Florida Fish and Wildlife Research Institute, St Petersburg, FL

Research at Google



Passive Acoustic Monitoring: The environment is noisy



Dziak et al. 2023; S. Battle

Passive Acoustic Monitoring: Hear what you can’t see

Passive Acoustic Monitoring: Equipment

- Microphones/hydrophones can be cheaper than cameras
- Reduced power requirements compared to cameras
- Audio files take up less space than photo/video data


Credit: Samuel R.P-J. Ross


https://graysreef.noaa.gov/science/soundscapes.html

Baseline

Dropping a bombshell: Acoustic characterization of blast fishing in Todos os Santos Bay, Brazil, and its implication for marine conservation

Victor Melo-Souza [a], Alexander Gavrilov [b], Marcos R. Rossi-Santos [a]

Active or passive acoustic monitoring? Assessing methods to track anuran communities in tropical savanna wetlands

Isabella Melo [a b 1], Diego Llusia [c d], Rogério Pereira Bastos [a b], Luciana Signorelli [b 1]

Passive acoustic detection of deep-diving beaked whales

Walter M. X. Zimmer; John Harwood; Peter L. Tyack; Mark P. Johnson; Peter T. Madsen

The sound of recovery: Coral reef restoration success is detectable in the soundscape

Timothy A. C. Lamont, Ben Williams, Lucille Chapuis, Mochyudho E. Prasetya, Marie J. Seraphim, Harry R. Harding, Eleanor B. May, Noel Janetski, Jamaluddin Jompa, David J. Smith ... See all authors

Passive acoustic methods of small boat detection, tracking and classification

Publisher: IEEE Cite This PDF

Alexander Pollara ; Alexander Sutin ; Hady Salloum All Authors

OPEN ACCESS

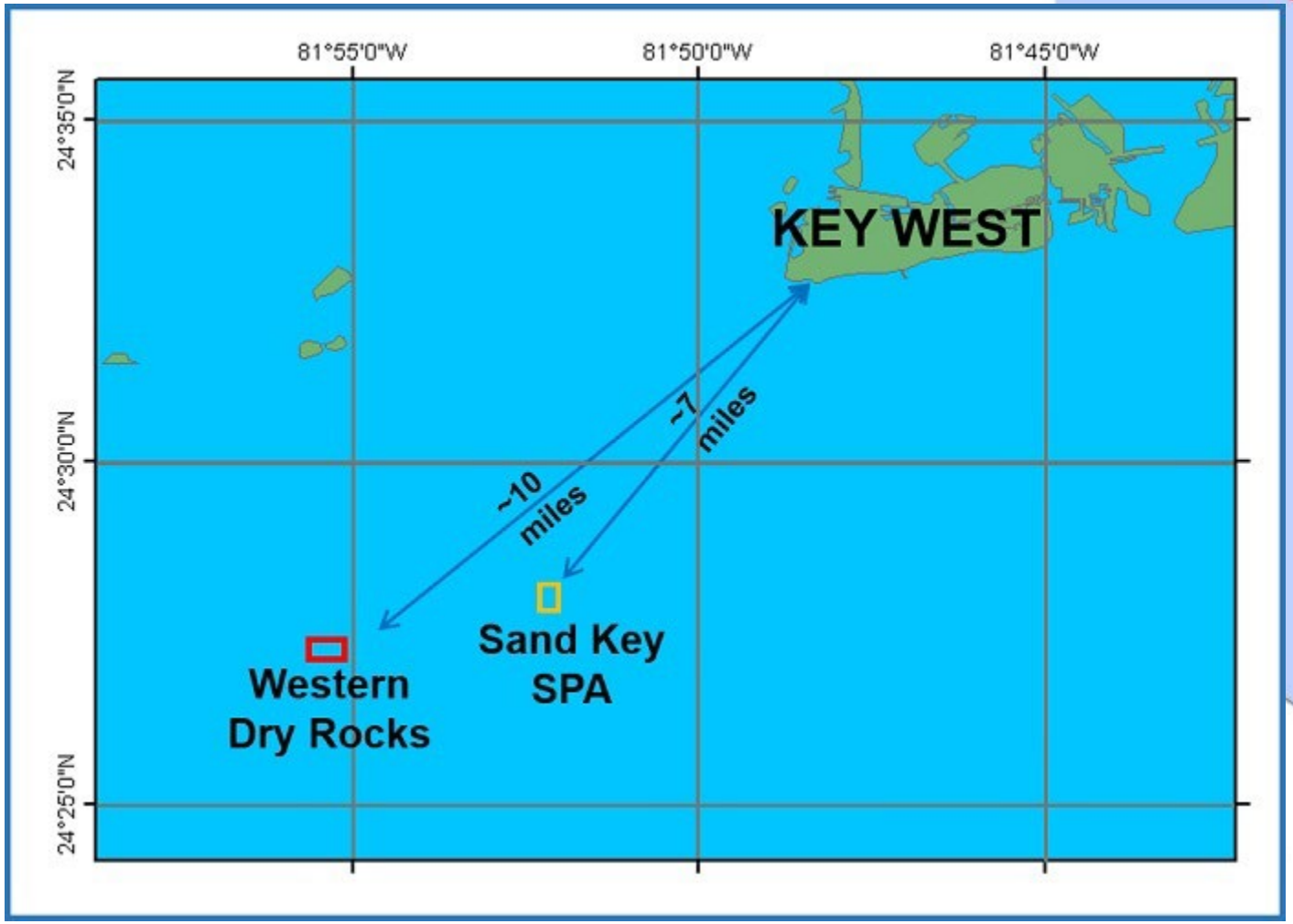
PMEL Passive Acoustics Research: Quantifying the Ocean Soundscape from Whales to Wave Energy

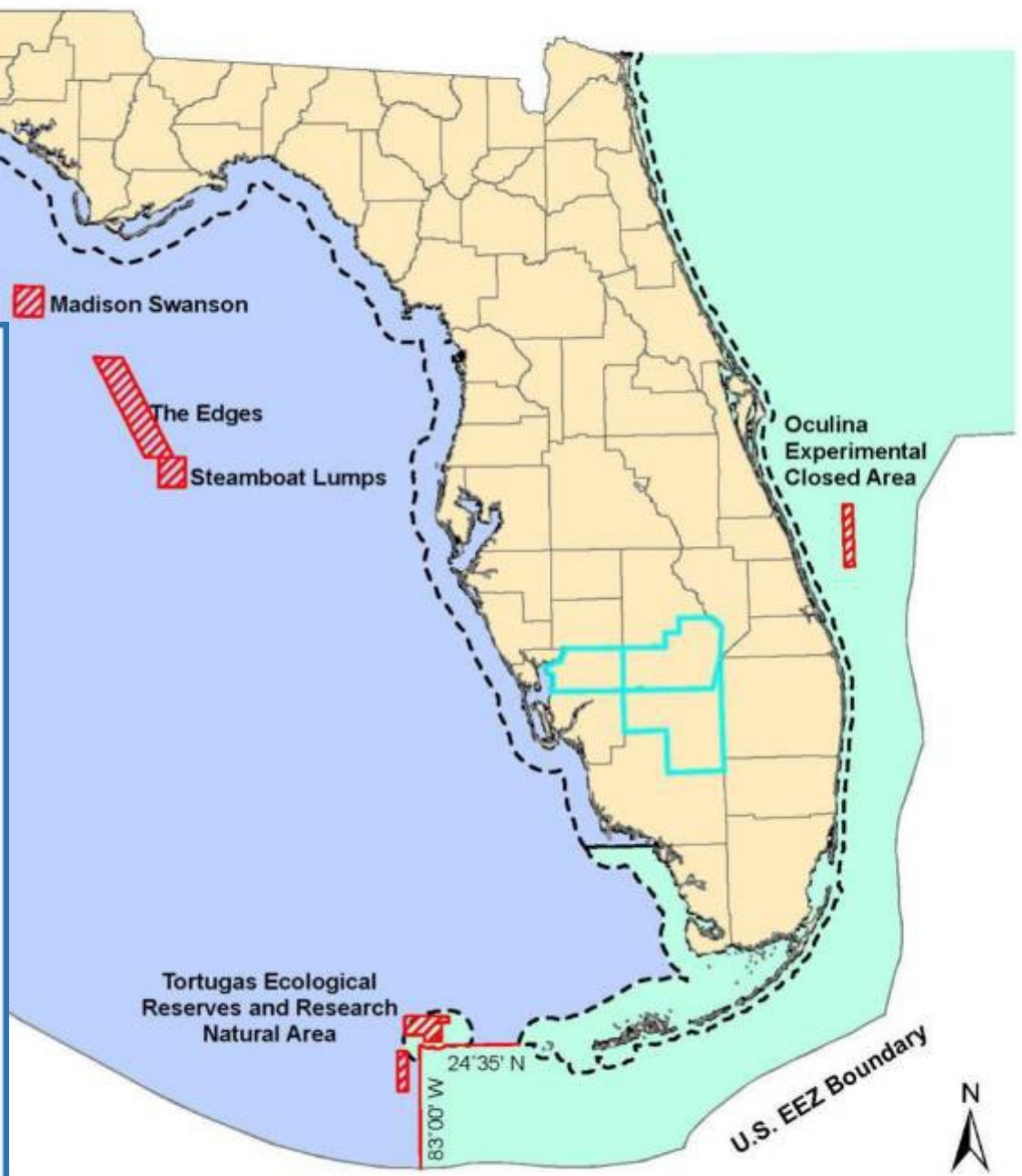
By Robert P. Dziak, Haru Matsumoto, Samara Haver, David K. Mellinger, Lauren Roche, Joseph H. Haxel, Scott Stalin, Christian Meinig, Katie Kohlman, Angie Sremba, Jason Gedamke, Leila Hatch, and Sofie Van Parijs

Passive Acoustic Monitoring as a Tool to Investigate the Spatial Distribution of Invasive Alien Species

by José W. Ribeiro, Jr. *, Kristopher Harmon, Gabriel Augusto Leite, Tomaz Nascimento de Melo, Jack LeBien and Marconi Campos-Cerqueira

Marine Protected Areas





Marine Protected Areas: Spawning Aggregations

Western Dry Rocks – closed 4/1 – 7/31
10 miles offshore

Steamboat Lumps – closed year-round
120 miles offshore
Florida Middle Grounds – open seasonally
85 miles offshore
Tarpon Springs – open seasonally
30 miles offshore

Marine Protected Areas: Spawning Aggregations

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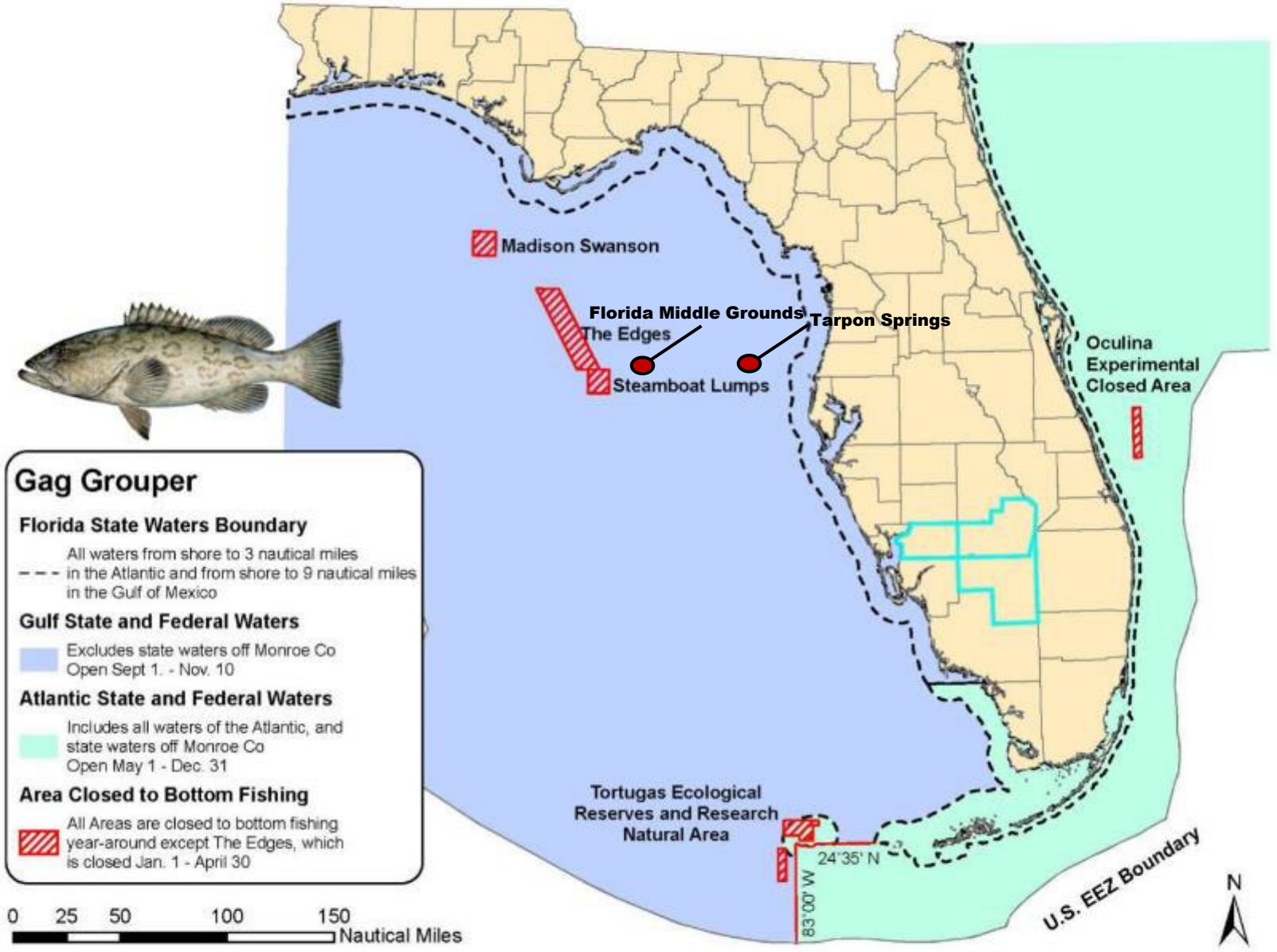
Tarpon Springs – open seasonally
30 miles offshore

Monitoring Marine Protected Areas

Gag Grouper Season

- 2022: 6 months
- 2023: 6 weeks
- 2024: 2 weeks
- 2025: 2 weeks



3 Sites x 12 Hours/Day x 365 Days/Year x 4 years = **52,560** hours of audio

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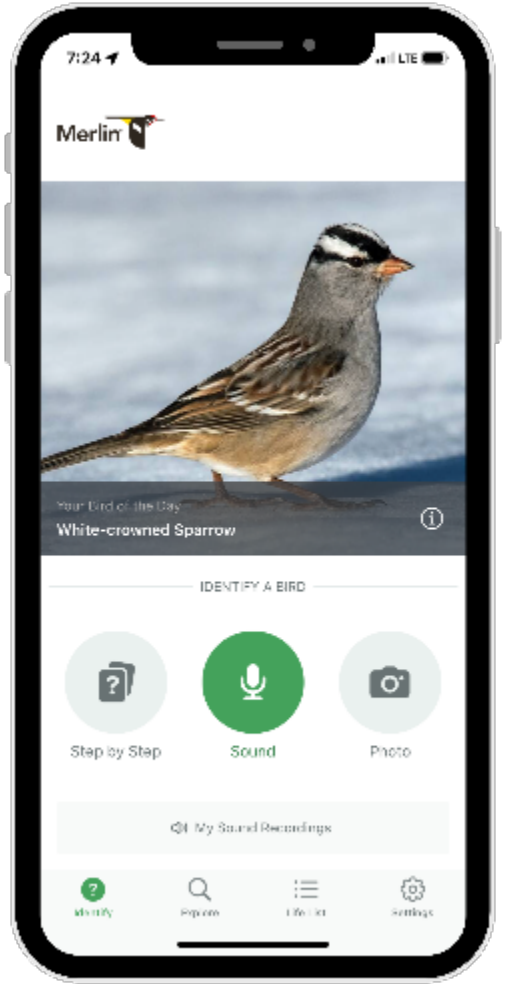
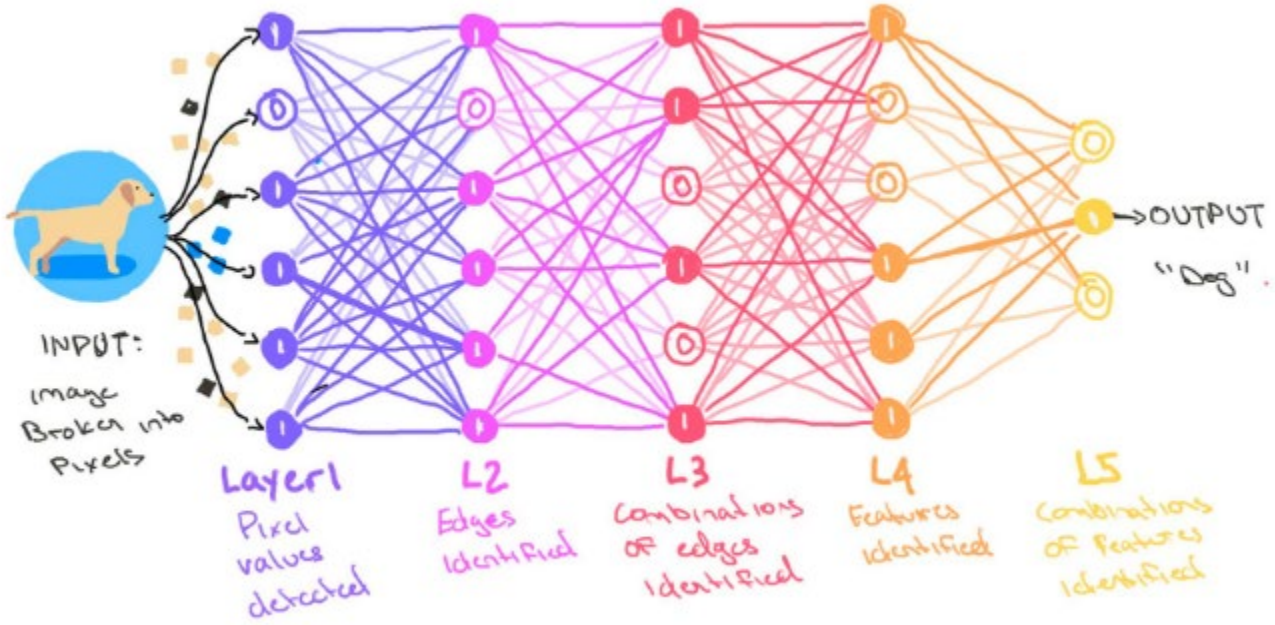


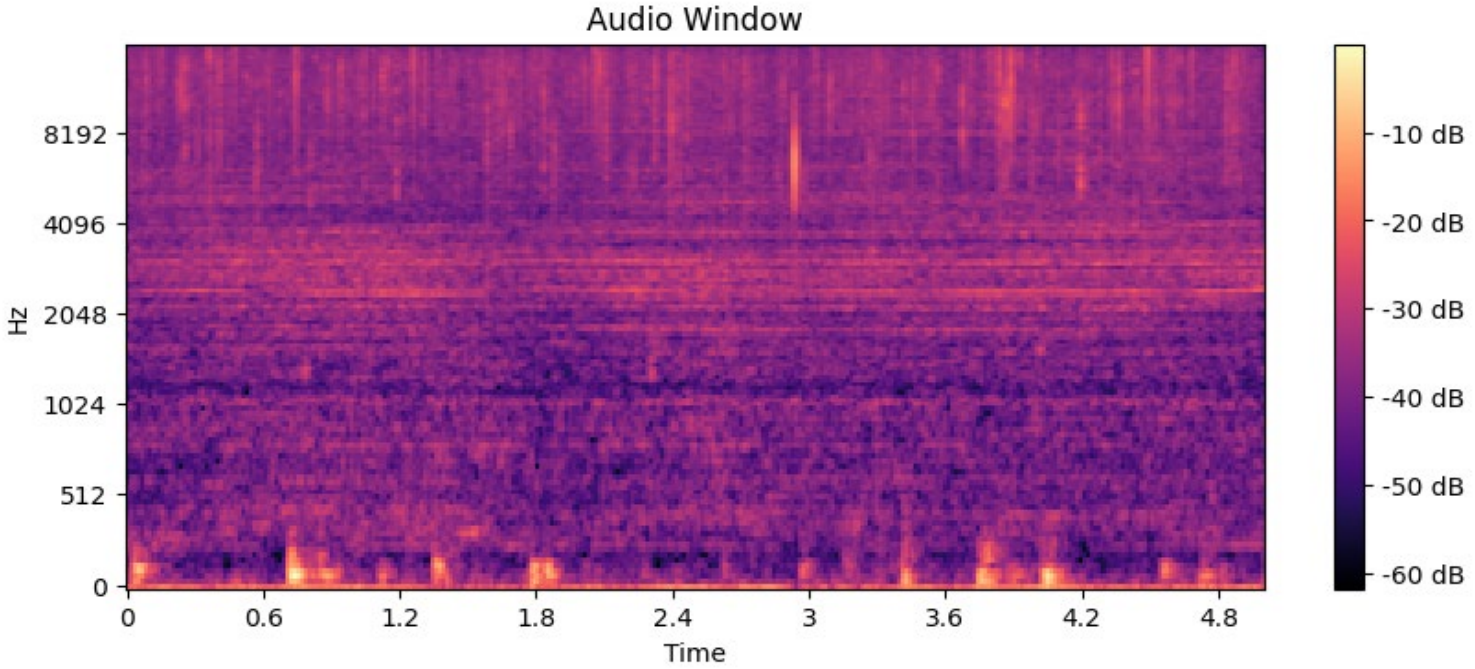
Machine Learning & Artificial Intelligence

- Convert audio to image
- Identify and classify features within image
- Find patterns within features
- Use statistical analyses to match patterns and features to classes

- It's all math and stats!



https://www.notablecap.com/blog/the-anatomy-of-a-neural-network



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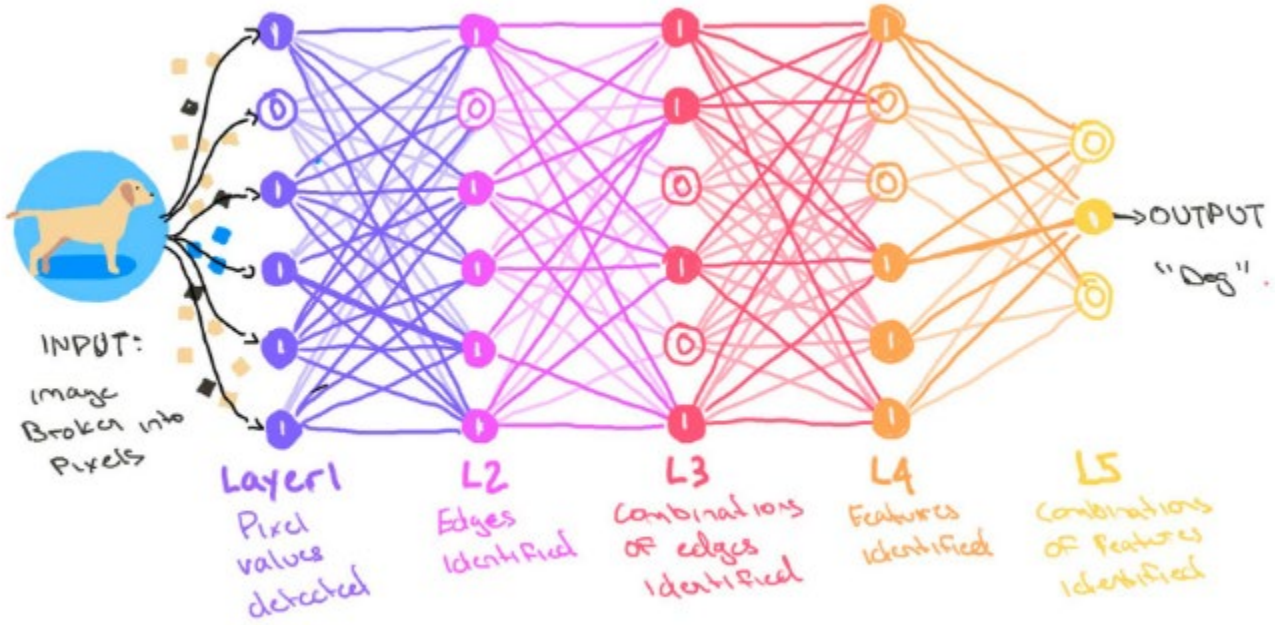

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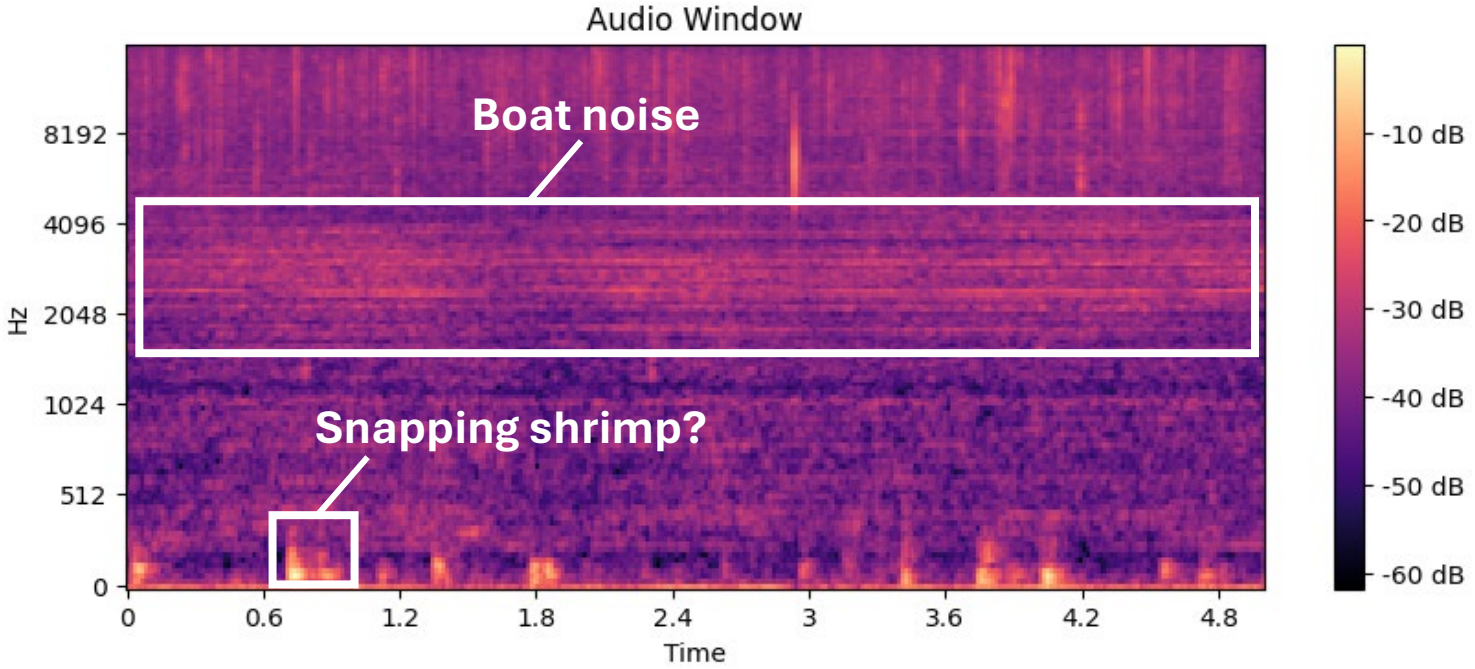
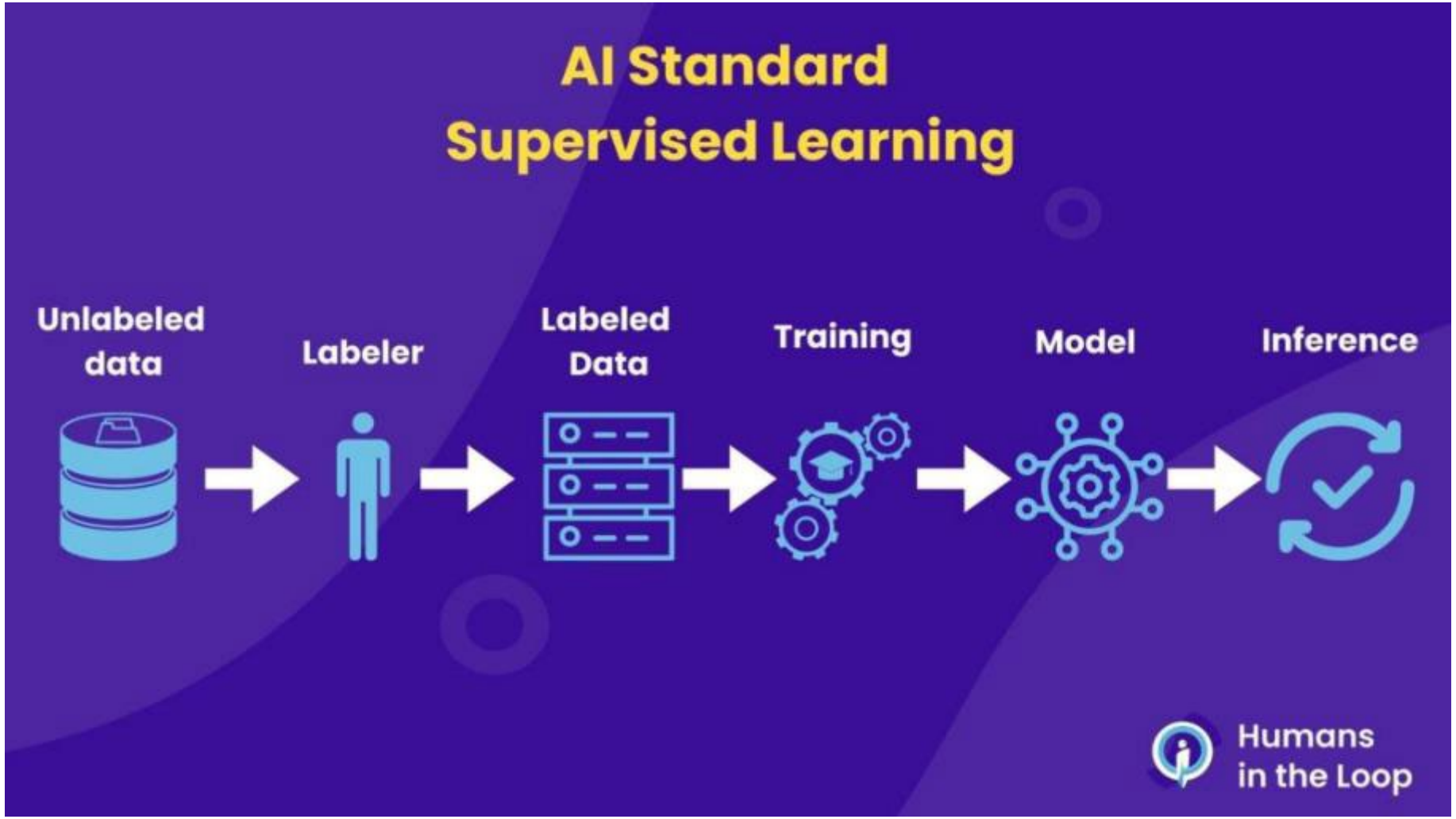


Traditional ML & AI Models

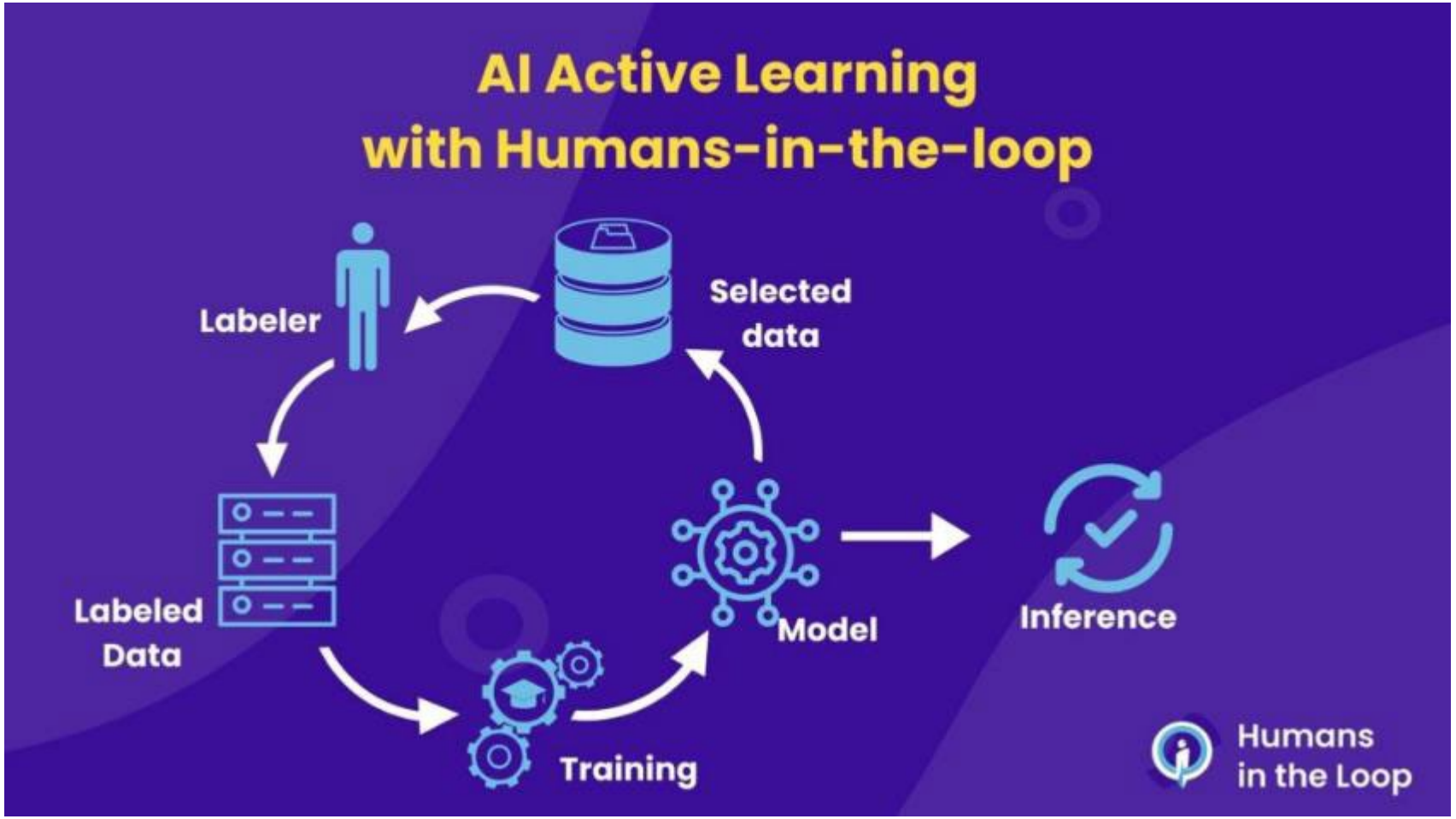
- Need human to label massive amounts of data
- Significant time to train the model
- If model underperforms, guess what else to label to improve model



Agile Modeling with transfer learning

- Start with pre-trained model
- Requires much less training data
- Pre-process data

1. Search dataset to build up training set
2. Search dataset for confusing examples
3. Re-train model and restart the loop

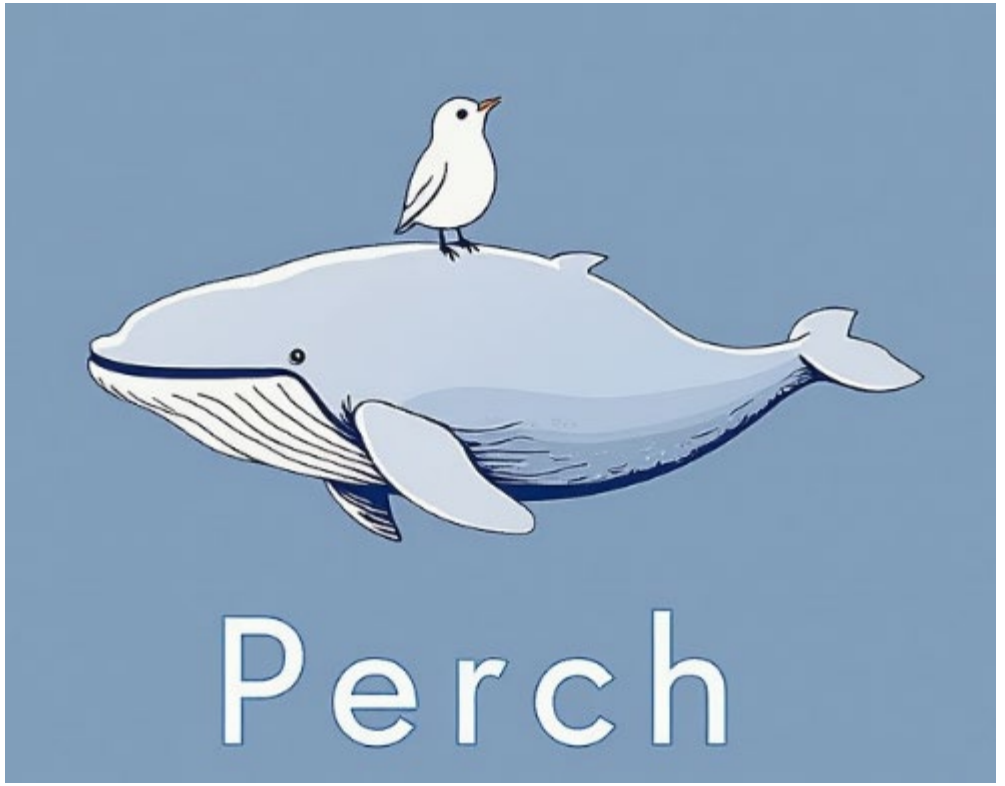


Perch model to boat detector: Perch

Google Research

Trained on the Xeno-Canto bird recording dataset

- Global
- >10,000 species
- 685,000 5s audio segments
- 74-92% accuracy



Article | Open access | Published: 18 December 2023

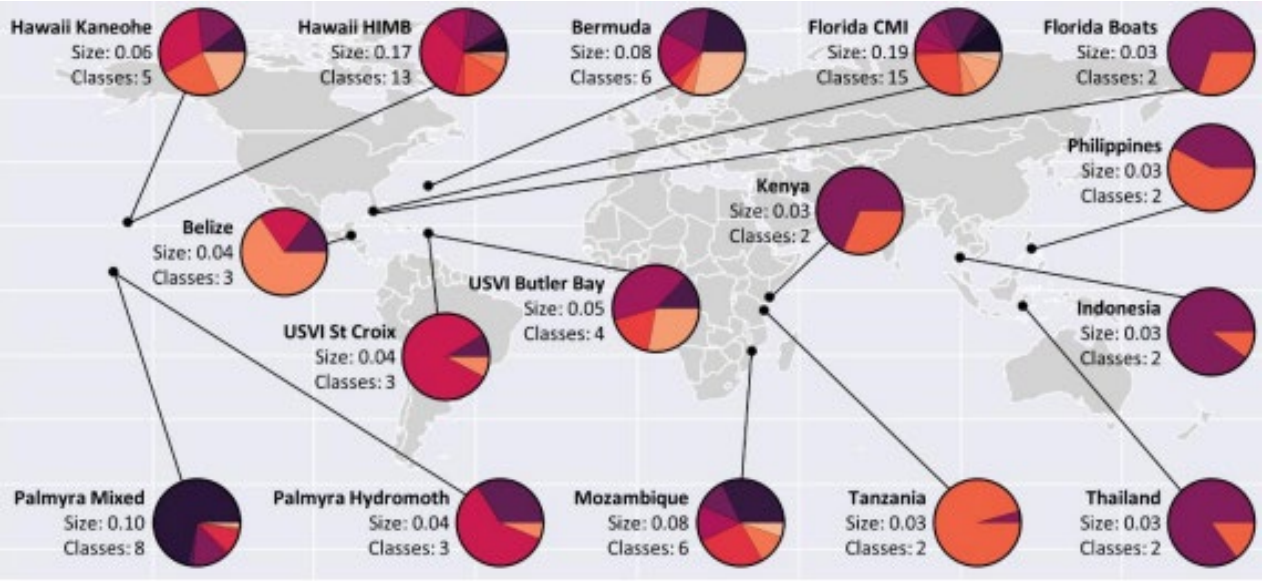
Global birdsong embeddings enable superior transfer learning for bioacoustic classification

Burooj Ghani, Tom Denton, Stefan Kahl & Holger Klinck

Scientific Reports **13**, Article number: 22876 (2023) | Cite this article

Perch model to boat detector: SurfPerch

- Transfer learning from Perch with underwater data
- 16 datasets from 12 countries
- 36 classes known and unknown sources
- Better model for underwater sounds than Perch and generic models



Leveraging tropical reef, bird and unrelated sounds for superior transfer learning in marine bioacoustics

Ben Williams[abc], Bart van Merriënboer[b], Vincent Dumoulin[b], Jenny Hamer[b], Eleni Triantafillou[b], Abram B. Fleishman[d], Matthew McKown[d], Jill E. Munger[de], Aaron N. Rice[fg], Ashlee Lillis[h], Clemency E. White[ij], Catherine A. D. Hobbs[ij], Tries B. Razak[k], Kate E. Jones[a], Tom Denton[l]

Perch model to boat detector: Florida Boat Detector

- Transfer learning from SurfPerch
- 3 Gulf sites + 1 Keys dataset (soon!)
- 2 classes: **Boat** and **No Boat**
  - **No Boat** = background noise
- 4600 labeled examples of each
- Haven’t harnessed agile learning much yet
- Increased accuracy from 79-82% to 85-90%
- 5 second snippets – very adaptable
- *Can’t count boats, just presence or absence*

Florida Boat Detector in action

Project Questions:

1. Fishing season effect
   - H: Fishing as indicated by boat noise increases with gag season
   - **Boat noise before, during, and after season at 3 sites**
2. MPA and poaching
   - H: Poaching as indicated by boat noise increases with gag season
   - **Boat noise in open season and closed season at SBL (MPA)**
3. Nearshore fishing effort in July
   - H: Fishing as indicated by boat noise is higher in July with gag season
   - **Boat noise in July in 2022 (open) and 2023/2024 (closed)**

Florida Boat Detector in action

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Preliminary Model Metrics

- 123,920 annotated 5-second snippets
  - >90% Tarpon Springs
  - ~9000 used for training
- Setting a 75% confidence threshold for boat noise
- 91.52% **matching** annotations
- 2.26% **false positives** - expecting no boat, got boat
  - This is GREAT!
- 6.21% **false negatives** - expecting boat, got no boat
  - This is NOT great

Results – Fishing Season Effect: Tarpon Springs 2024

Hypothesis:

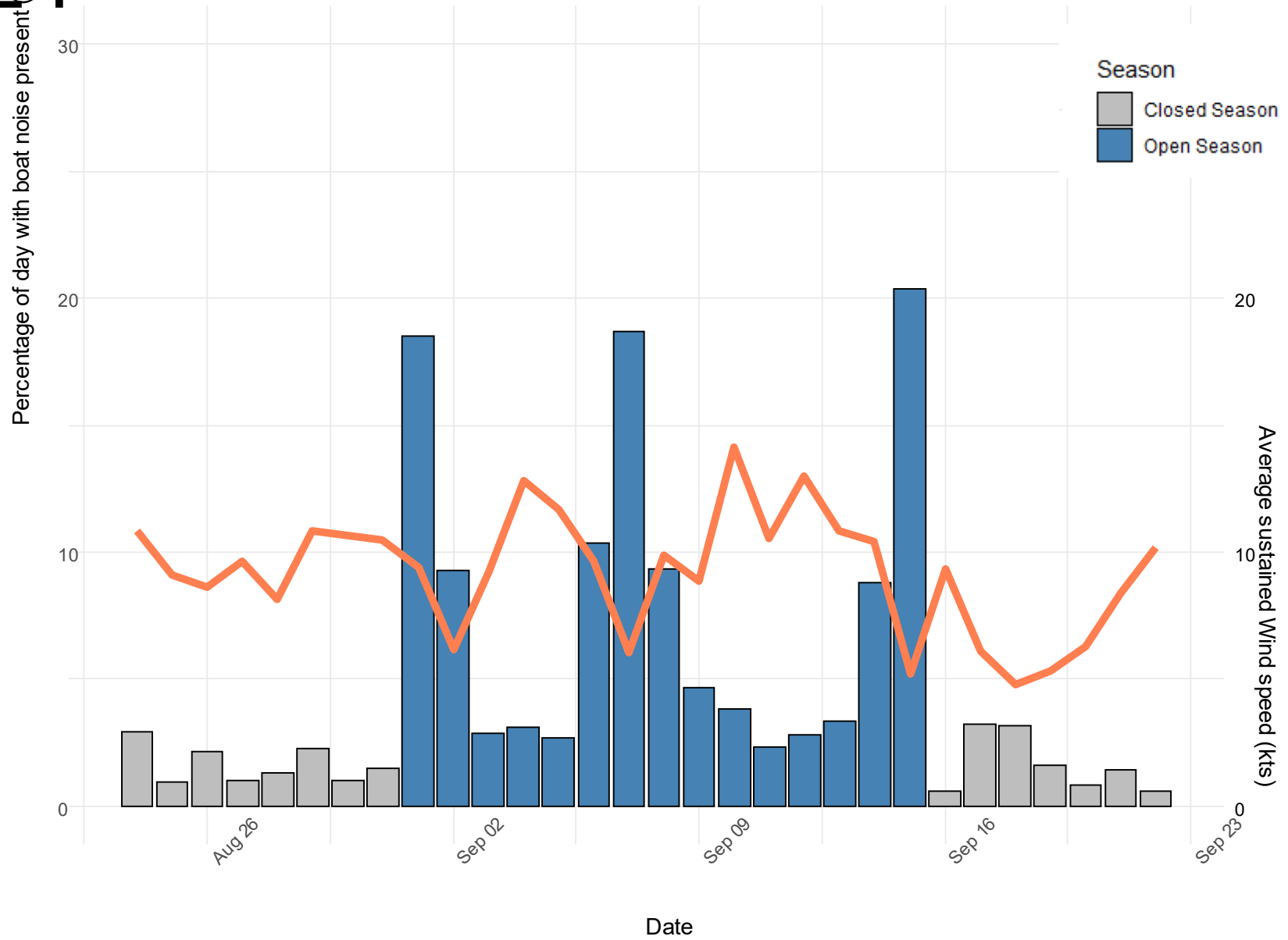
Fishing as indicated by boat noise **increases** during open gag season

Results:

Increased boat noise

Weekend spikes

⬇ Wind ⬆ Boats



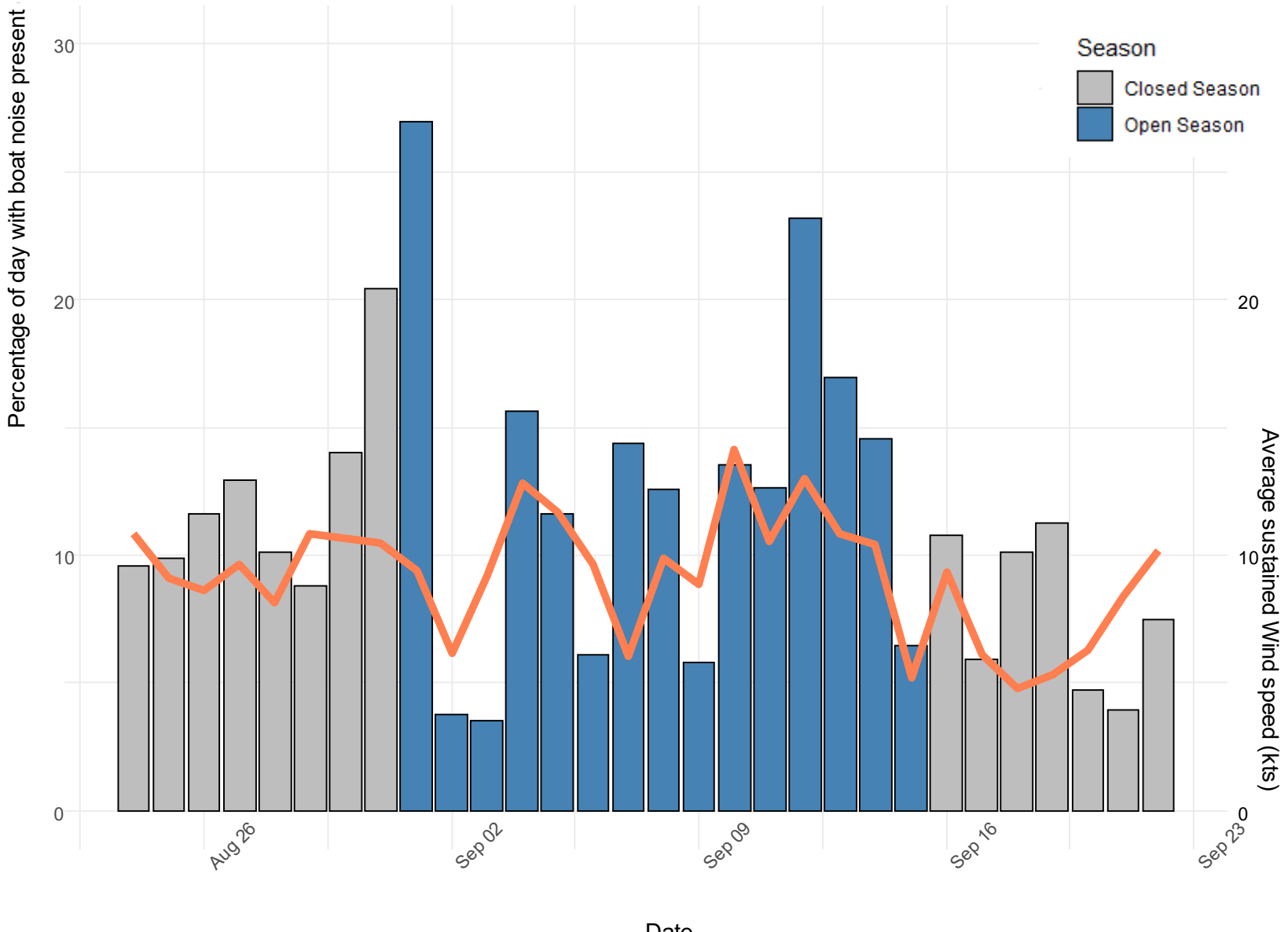
Results – Fishing Season Effect: Florida Middle Grounds 2024

Hypothesis:

- **Fishing** as indicated by boat noise **increases** during open gag season

Results:

- No difference, weekend patterns visible
- Wind increases boat noise



Results – Fishing Season Effect: Steamboat Lumps 2024

Hypothesis:

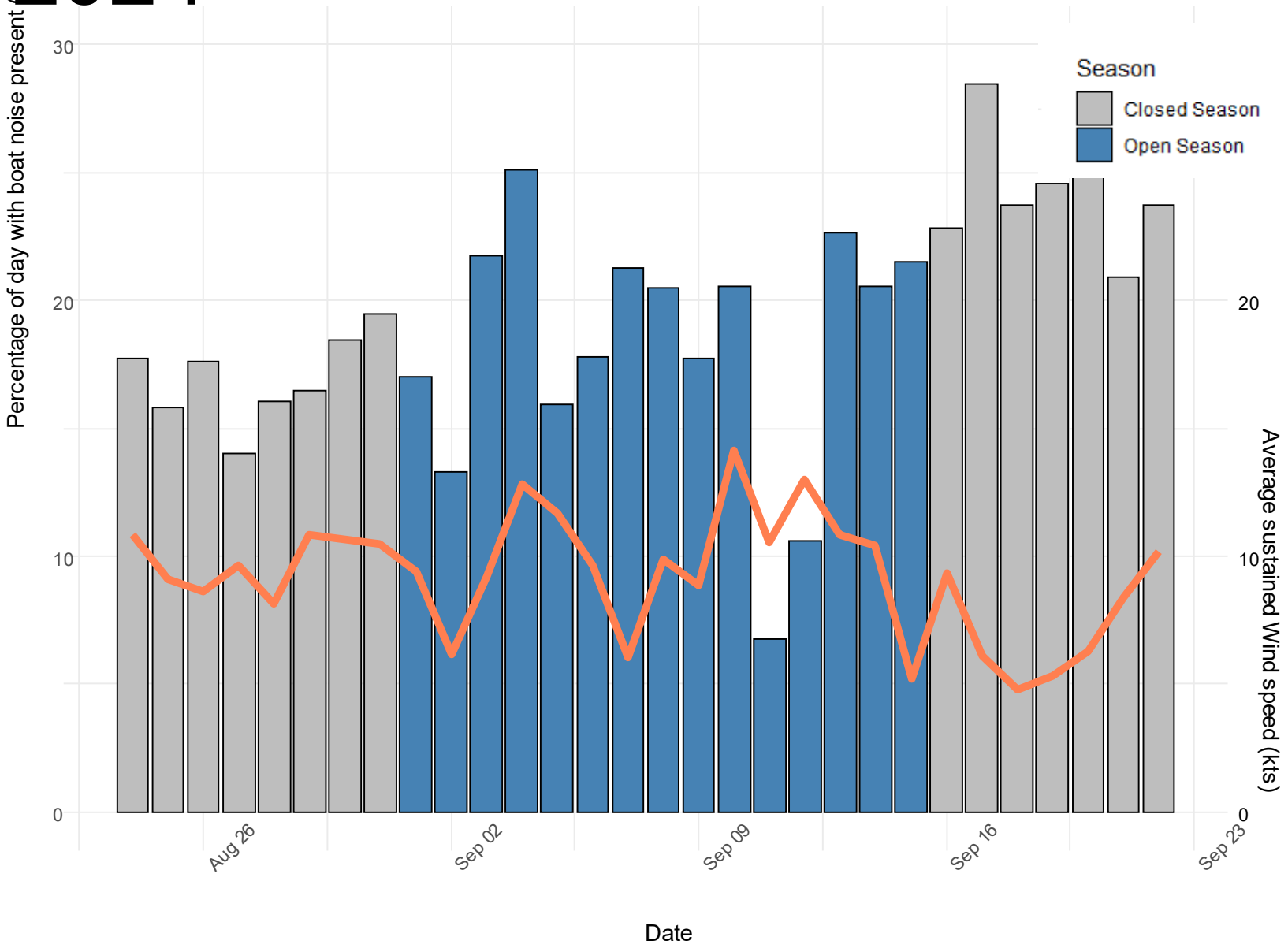
- **Fishing** as indicated by boat noise **increases** during open gag season

Results:

- No difference

Issues:

- Model training needs more SBL data



Florida Boat Detector in the future

- Focus on fixing confusion between boat noise and strong wind/waves
- Add more training data within each domain using agile modeling
- Perch v2 – even better with underwater data
- Add in more boat noise from around Florida
- Operationalize the model with user friendly interface, interactive tool