



What do Western Atlantic fishes hear? Exploratory studies of U.S. Continental Shelf soundscapes

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BACKGROUND

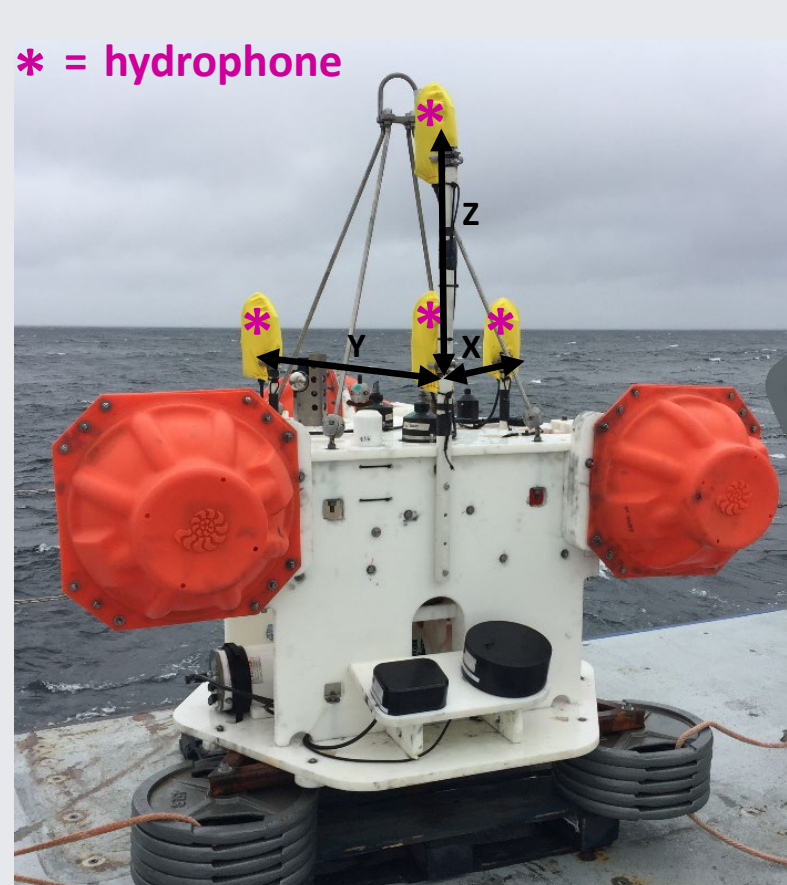
- **Soundscapes** consist of biological, geological, & anthropogenic sounds present in a habitat
- Fish detect and produce sounds for ecological functions (e.g., navigation, communication); anthropogenic sounds (e.g., from vessels) can interfere with fishes' detection of natural sounds¹⁻²
- All sounds consist of two main quantities:
 - **sound pressure (SP)**, heard by mammals & only some fish
 - **particle motion (PM)**, heard by all fish & many invertebrates
- Soundscape studies usually only measure pressure, thus have limited applicability to fish & invertebrates

OBJECTIVES

Assess differences between Gulf of Maine (**GM**) and U.S. Mid and South Atlantic Bight (**MSAB**) soundscapes, including:

1. Temporal variability of sound levels & sound sources
2. Sound pressure vs. particle motion (do they scale predictably?)
3. Sound levels relative to hearing of sound-producing fishes
 - GM: Atlantic cod (*Gadus morhua*)³, hears SP & PM
 - MSAB: Red drum (*Sciaenops ocellatus*)⁴, hears PM, maybe SP

METHODS



Bottom-lander developed by JASCO, with 4 hydrophones covered with flow shields

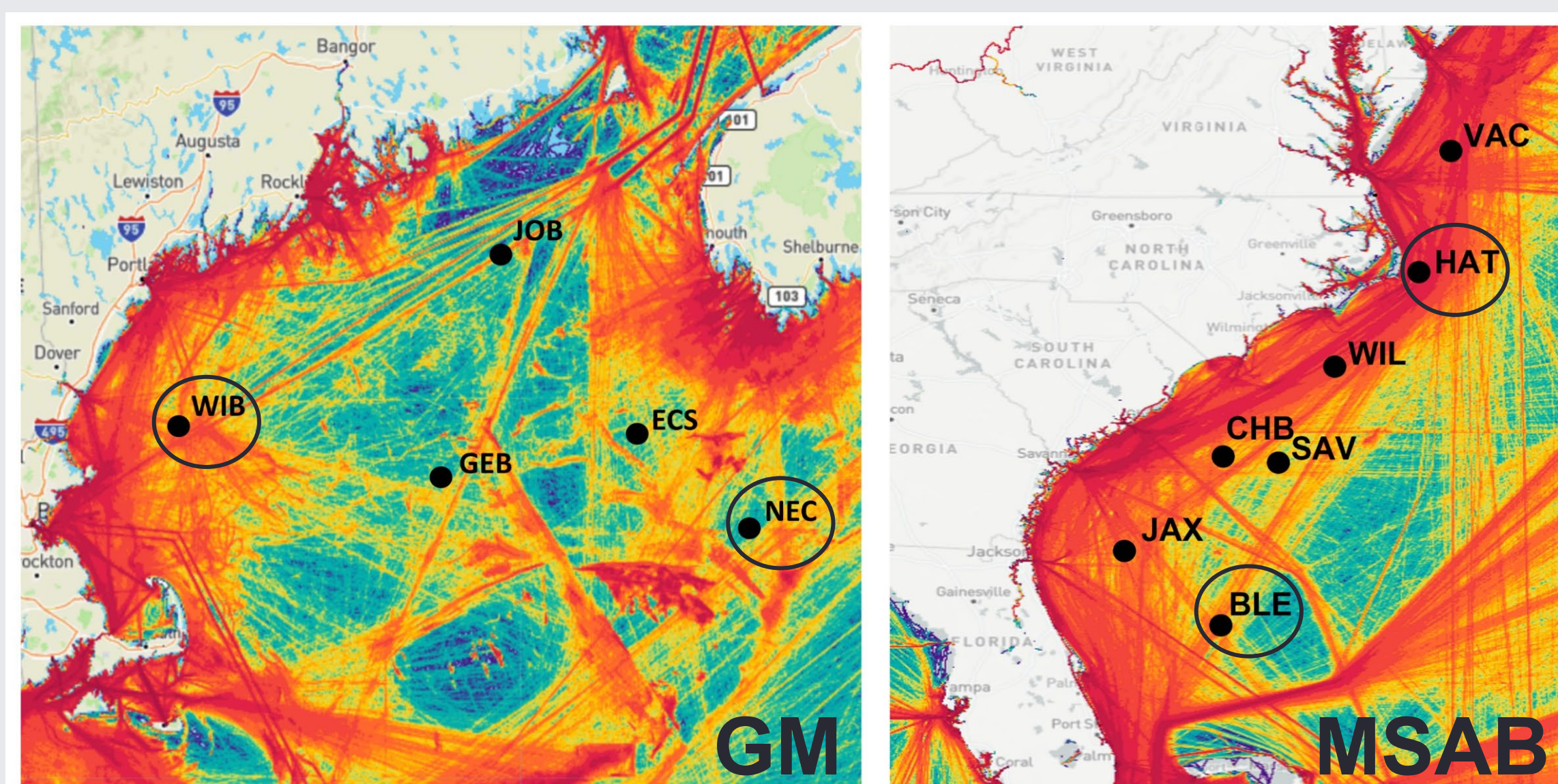
- Landers at 5 GM sites & 6 MSAB sites, with 4 hydrophones (sound pressure sensors)
- Analyzed 1 year of data from each region
- Particle motion (acceleration) measured from difference of pressures (p_1, p_2) along 3 axes (X,Y,Z):

$$a_{measured}(t) = - \frac{(p_2(t) - p_1(t))}{\rho d} \quad d = 0.5 \text{ m} \quad \rho \approx 1025 \text{ kg m}^{-3}$$

- Vector norm calculated to get 3D magnitude
- Far from sound source, seafloor, & surface: **plane wave approximation** assumes predictable scaling between pressure and particle motion:

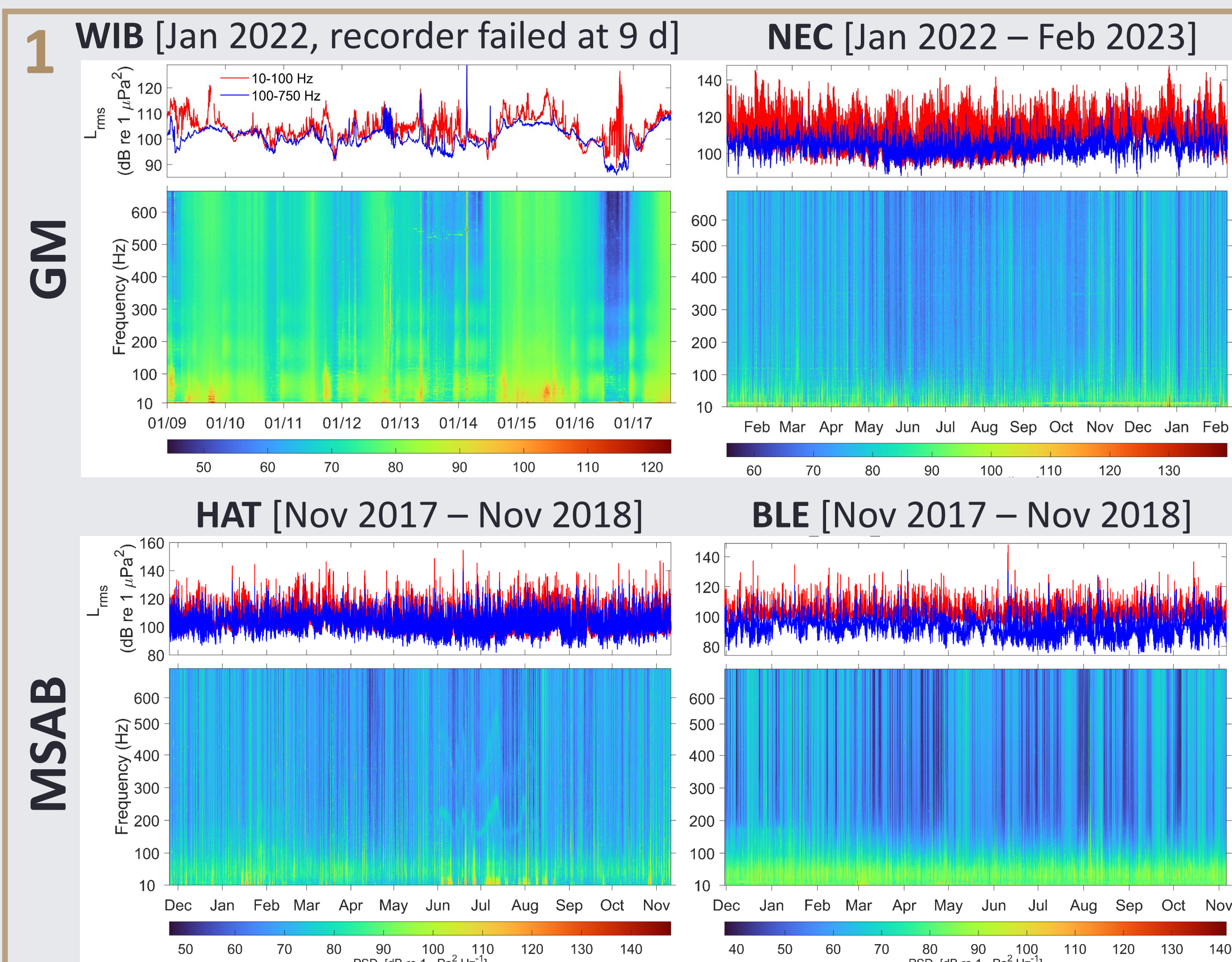
$$u_{pw} = \frac{p}{\rho c} \quad a_{pw} = \frac{du}{dt} \quad u = \text{particle velocity (m s}^{-1}\text{)} \quad c = \text{sound speed} \approx 1500 \text{ m s}^{-2}$$

"pw" = plane wave approximation

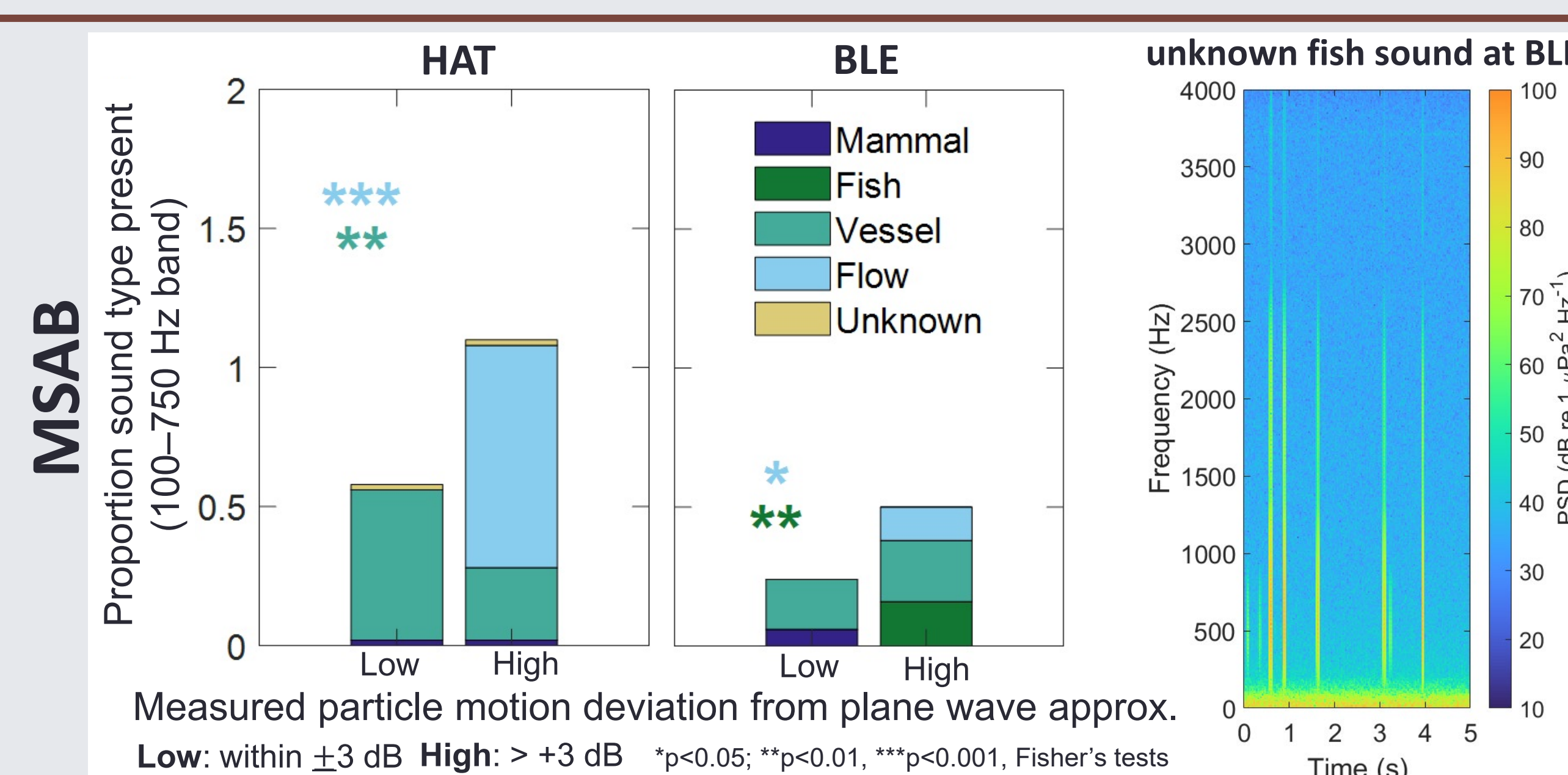
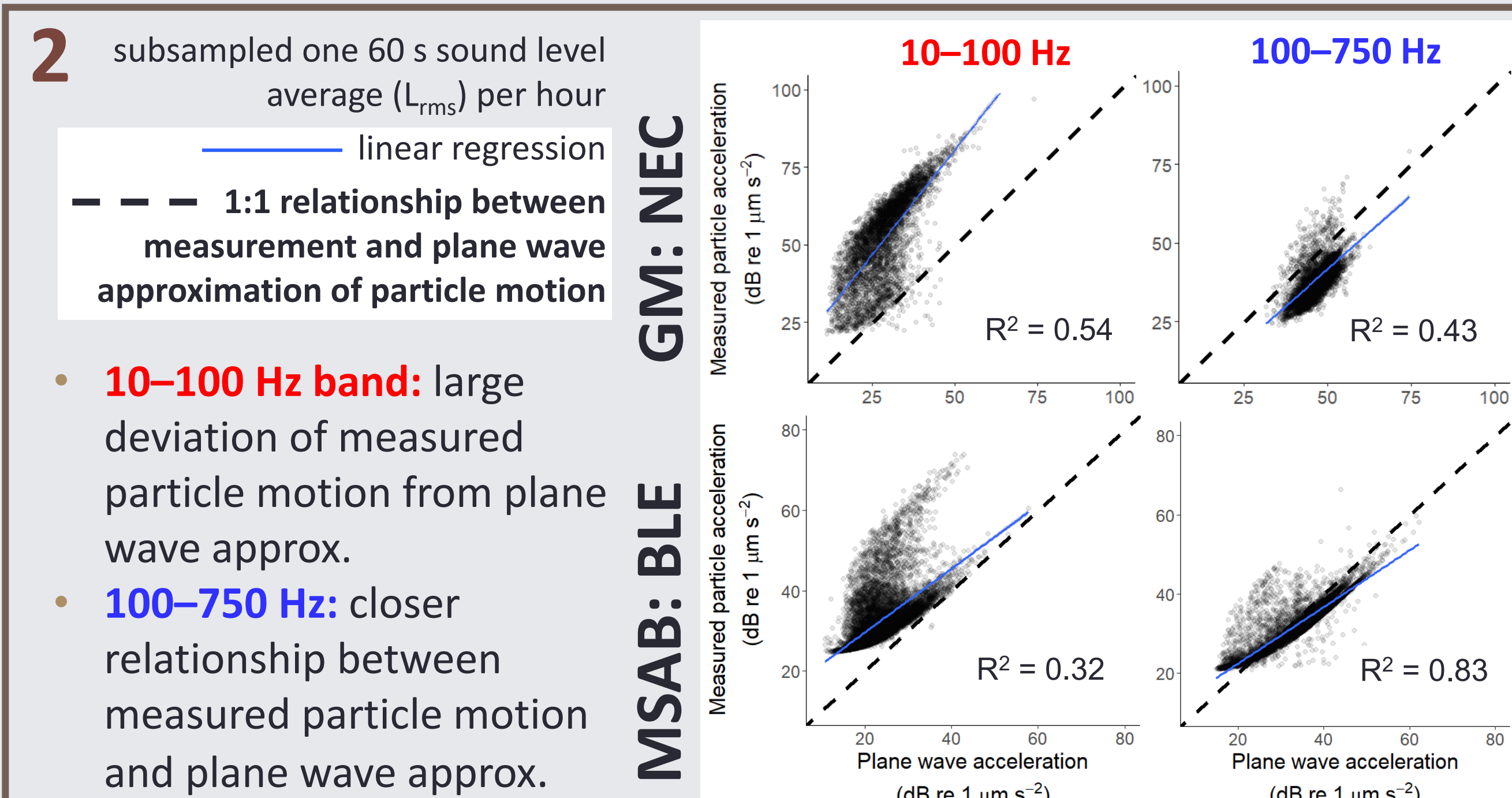


Study sites (black dots) overlaid on vessel density maps in the Gulf of Maine (left) and U.S. Mid and South Atlantic Bight (right). Circled sites were selected for cross-region comparisons [maps from marinetransport.com, 2021 data]. **Depths:** WIB 140 m; NEC 236 m; HAT 295 m; BLE 870 m

RESULTS

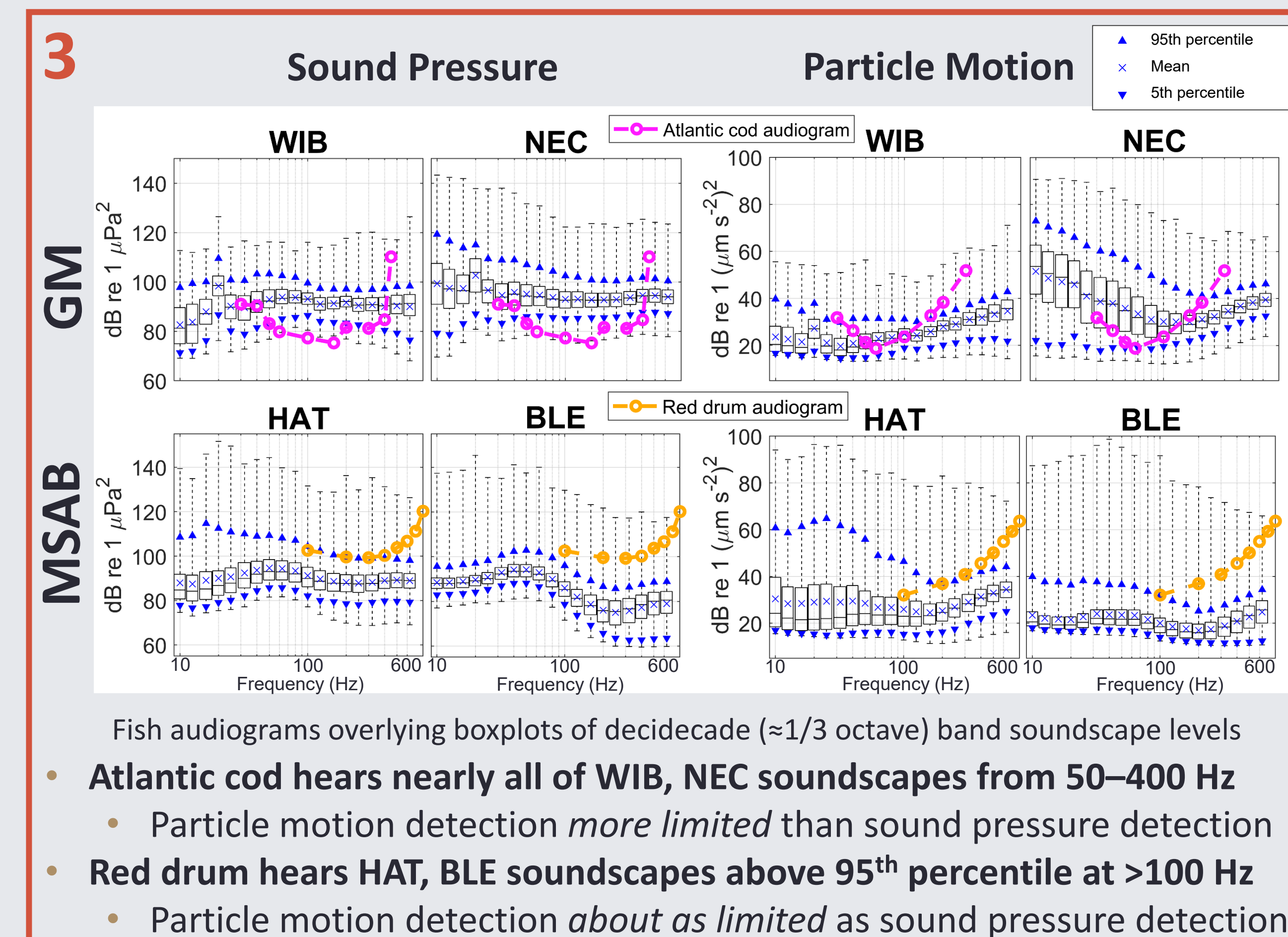


- **Main contributing sound sources across regions:** wind (>100 Hz), vessels (mostly <350 Hz), large whales (20–600 Hz) current flow (<100 Hz)
- Temporal trends similar for pressure (above) & particle motion (not shown)



- **Sources with strong particle motion relative to sound pressure: fish sounds at BLE, current (hydrodynamic) flow at all MSAB sites**
- Sources with similar particle motion & sound pressure: vessels, mammals
- Similar analyses underway for GM, including search for fish sounds

RESULTS CONTINUED



- **Atlantic cod hears nearly all of WIB, NEC soundscapes from 50–400 Hz**
 - Particle motion detection *more limited* than sound pressure detection
- **Red drum hears HAT, BLE soundscapes above 95th percentile at >100 Hz**
 - Particle motion detection *about as limited* as sound pressure detection

CONCLUSIONS

1. **MSAB & GM:** sound pressure & particle motion similarly show temporal trends in major sound sources
 - Both regions have seasonal wind-influenced sound levels (higher in winter), temporal variation of vessel and marine mammal sounds are site-specific
2. **MSAB:** Fish sounds at BLE (> 100 Hz) had high particle motion, sound pressure alone would underpredict sound levels; relevant to near-field fish communication
 - **MSAB & GM:** current (hydrodynamic) flow (< 100 Hz) led to high particle motion: non-acoustic, but relevant cue for fish
3. Better sound pressure sensitivity of Atlantic cod compared to red drum allows detection of much greater portion of soundscapes (down to lower sound levels)

NEXT STEPS

- Expand soundscape analyses to all sites
- Search for fish sounds (acoustic presence) at Gulf of Maine sites
- Parse vessel sounds from natural soundscape, model masking effects of vessel sounds on cod (done for red drum in MSAB in related study²)

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