Portfolio-Scale Infrastructure Analysis Using AIS

Brandan Scully, PE, PhD
CIRP CNPM Co-PI, Study Lead

David Young, PhD (CHL)
James Ross, PhD (ITL)
Christina Saltus, GISP (EL)

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US Army Corps of Engineers

COASTAL & HYDRAULICS LABORATORY

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USACE Coastal Structure Portfolio

- **USACE maintains > 1000 coastal structures, most over 50 years old.**

- **USACE has awarded contracts valued at ~$47M per year 2007-2018 on jetty maintenance, repair, and construction.**

- **Annual structure expenditure ($47M) ≈ 24 maintained HMTF projects (~$1.9M average)**

- **Large structures at individual projects have recapitalization costs ≈ 25% annual USACE dredging budget.**

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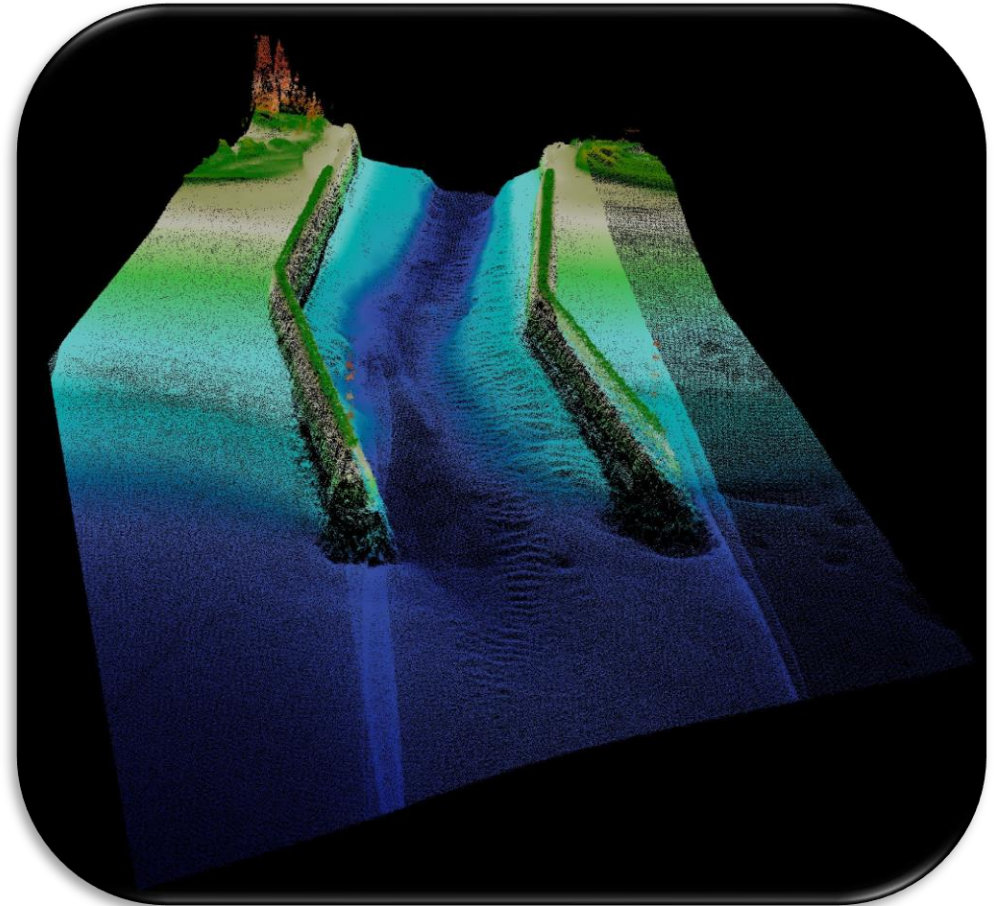
Structure Management: Present

- **Maintenance funds awarded on relative risk basis**

- **Consequence**
  - **Cargo Tonnage**
  - **Cargo Value**
  - **Strategic port impact**
  - **Life safety impact**

- **Condition**
  - **Structural Condition**
  - **Functional Condition**

Relative Risk Ranking Matrix

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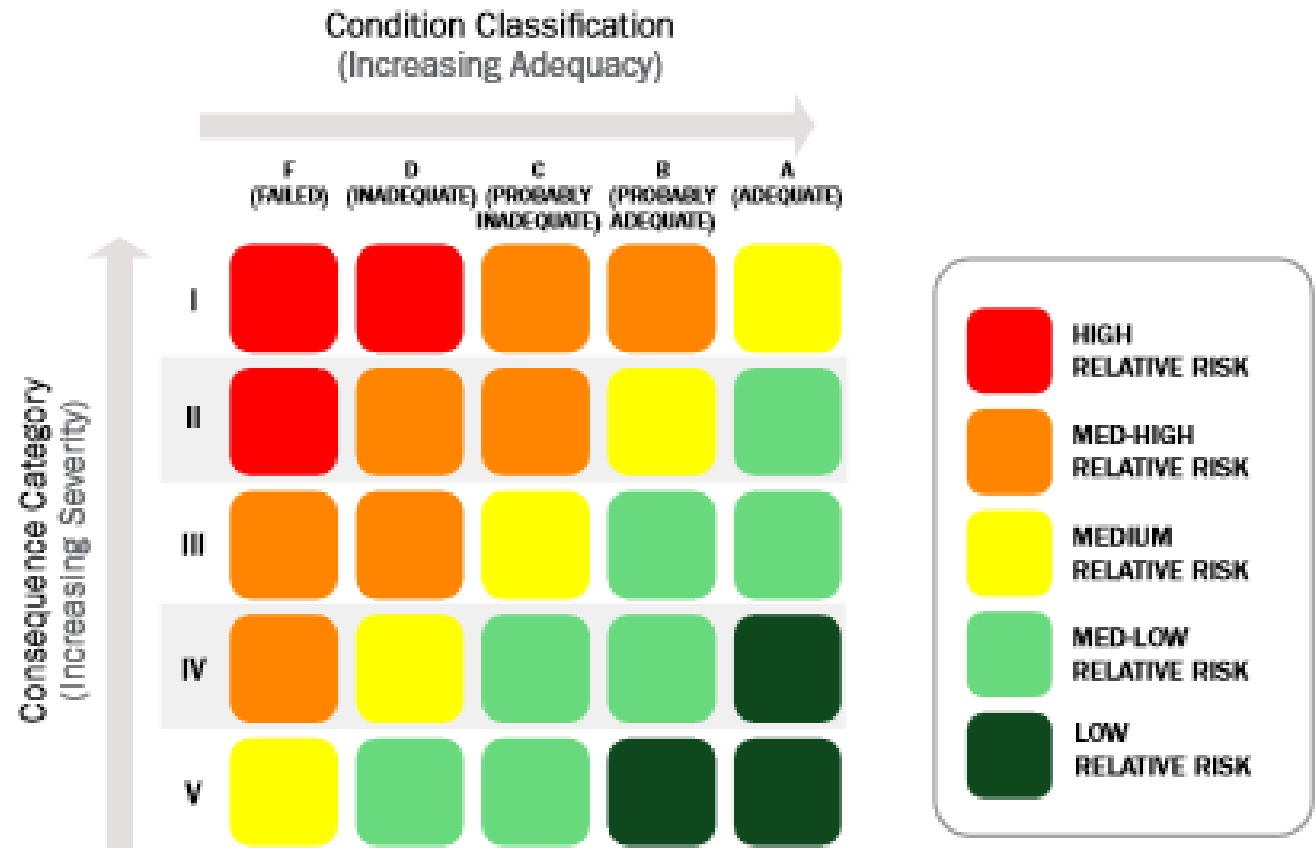
Functional Condition Metrics

- **"Vessel navigability"**
  - **Pilot testimony**
  - **Small-sample instrumented motion studies**
  - **Accident reporting**
- **O&M dredging increases**
  - **Heavy upland rainfall**
  - **Urban Development**
  - **Aeolian transport**
- **Authorized limit availability does not categorically impact vessel ability to transit.**
  - **Some projects don't have design vessels.**
  - **Vessels frequently call at drafts below design vessel draft/authorized channel depth.**
  - **Vessels frequently call at water levels above design water level.**
  - **Vessels sail around shoal areas.**

| Level of Functionality	TABLE F-10 Coastal Navigation Structures Functional Condition Rating (FCR) Table
Full -- A	No notable impact, project performing as designed.
Sufficient – B	(1) Infrequent or periodic limitations on navigability, or (2) minor/periodic increases in dredge quantity
Reduced -- C	(1) Less than 10% of the time, design vessels cannot navigate or operate within authorized limits; (2) O&M dredging requirements in the Entrance and Bar Channel have increased less than 10%, as compared to the long-term average annual rate.
Severely Degraded -- D	(1) 10-20% of the time, design vessels cannot navigate or operate within authorized limits; (2) O&M dredging requirements in the Entrance and Bar Channel have increased 10-20%, as compared to the long-term average annual rate.
Completely Degraded -- F	(1)-20-40% of the time, design vessels cannot navigate or operate within authorized limits; (2) O&M dredging requirements in the Entrance and Bar Channel have 20-40%, as compared to the long-term average annual rate.

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Research Objective, Drivers, and Goals

Advance objective, quantitative, and systems-based approaches to management of the Corps' coastal navigation portfolio of projects.

- **USACE navigation project metrics are insufficient to drive gains in performance of the coastal navigation system.**
  - ***Cargo throughput* is beyond USACE control.**
  - **Channel *controlling depth* is under-informative.**
- **Infrastructure maintenance is assumed but rarely demonstrated to improve vessel performance.**
  - **USACE lacks the ability to measure vessel performance directly.**
  - **Evidence that structure investments benefit users is scarce.**
- **GOALS:**
  - **Augment existing structure performance and project prioritization metrics.**
  - **Cast structure performance in terms of vessel activity for navigation structures.**
 - **Formulate management metrics at "portfolio scale".**

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Automatic Identification System: Game Changer

- **Who uses the waterway**
- **Under what conditions**
- **How they perform**

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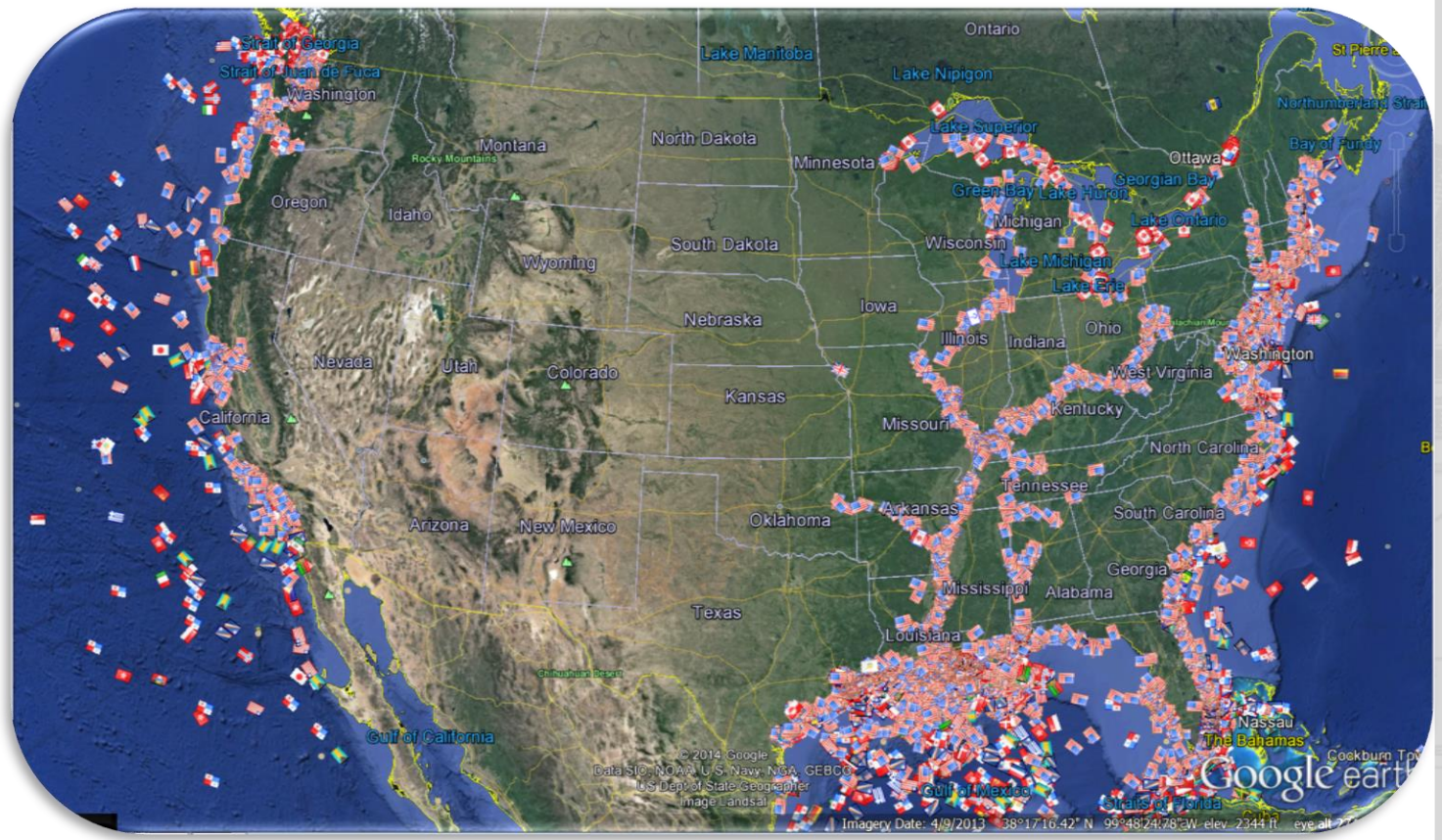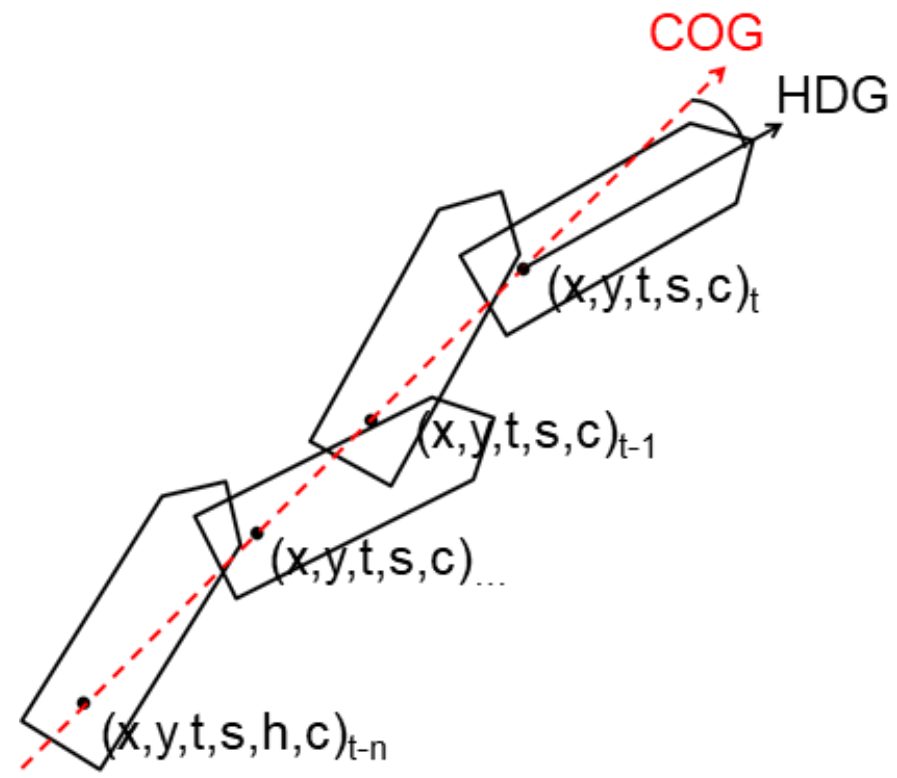
Measuring "Navigability"

- **Variance in heading-course deviation measures performance gain as vessels transit structures.**

- **10K vessel transits at 3 locations, 3 years**
  - **Mouth of Columbia River**
  - **Freeport Texas**
  - **Savannah Georgia**

- **Typical asset management practice requires observing changes in the metric over time.**

- **Next step is to find a natural experiment – major structure failure or repair – to observe metric before/after.**
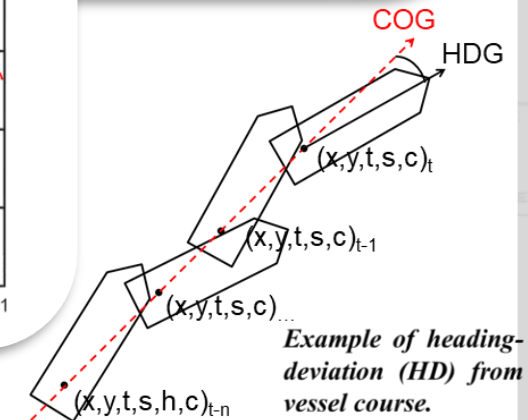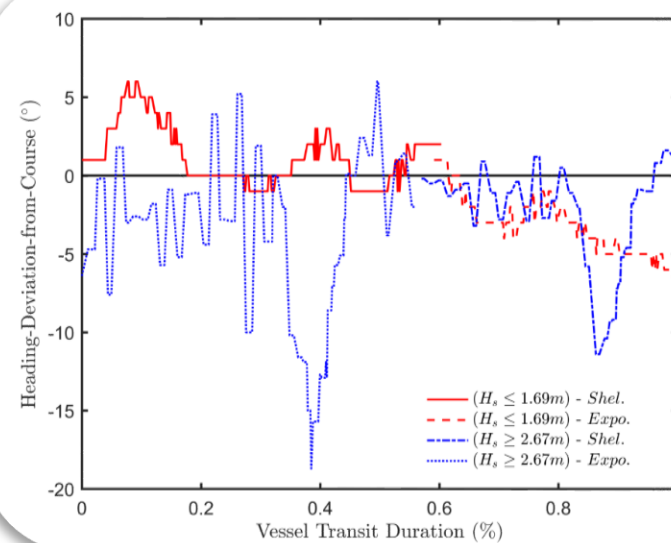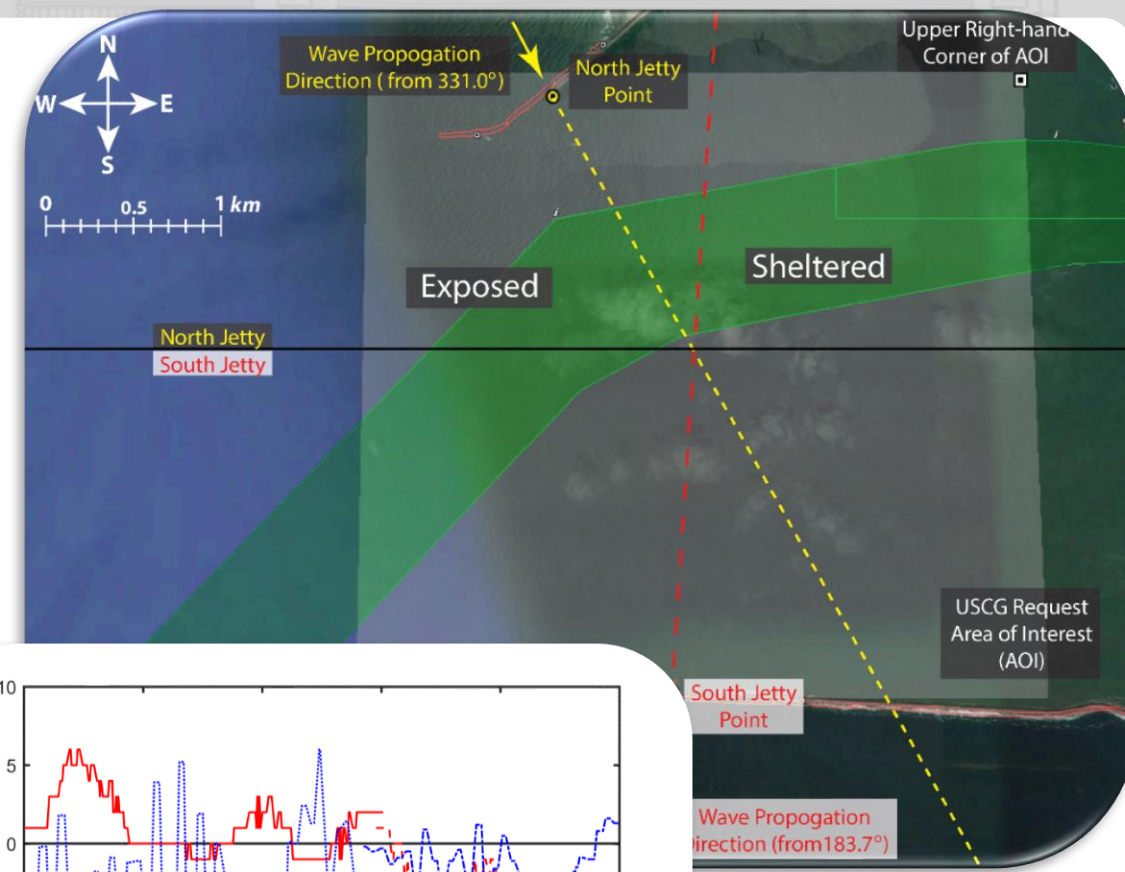
Example of heading-deviation (HD) from vessel course.

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Spinoff Insight – Vessel Operating Conditions

- **Vessels transit under relatively calm conditions**
- **A "big wave" relative to a vessel is a small wave relative to a structure**
- *How well must structures be maintained to benefit users?*
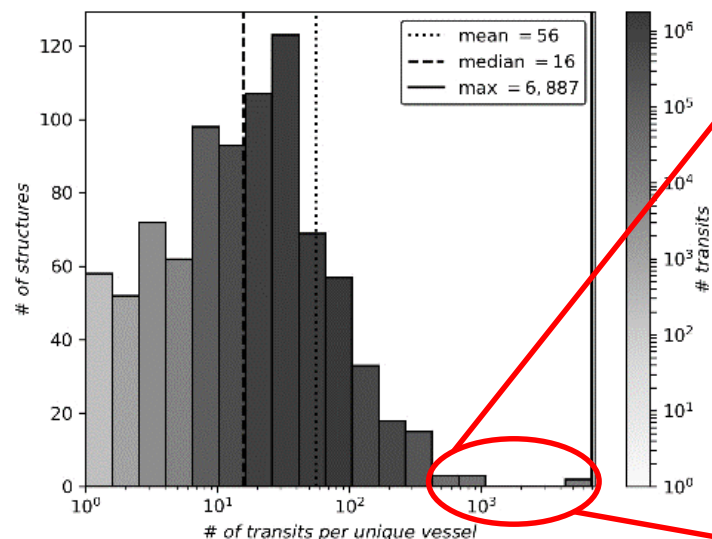
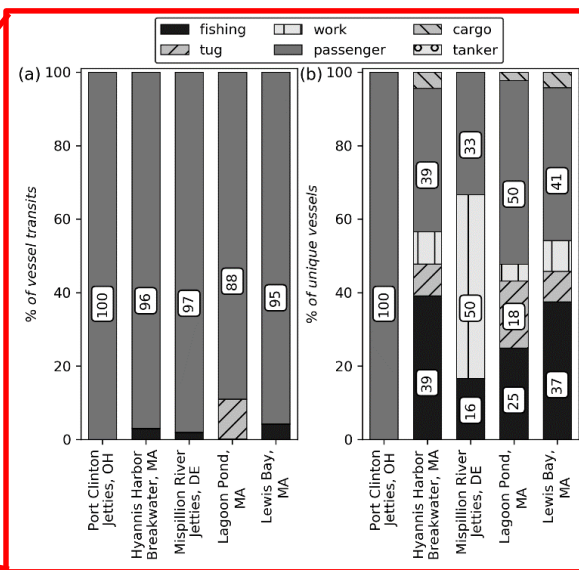**Wave heights during vessel transits, 2012-2014**
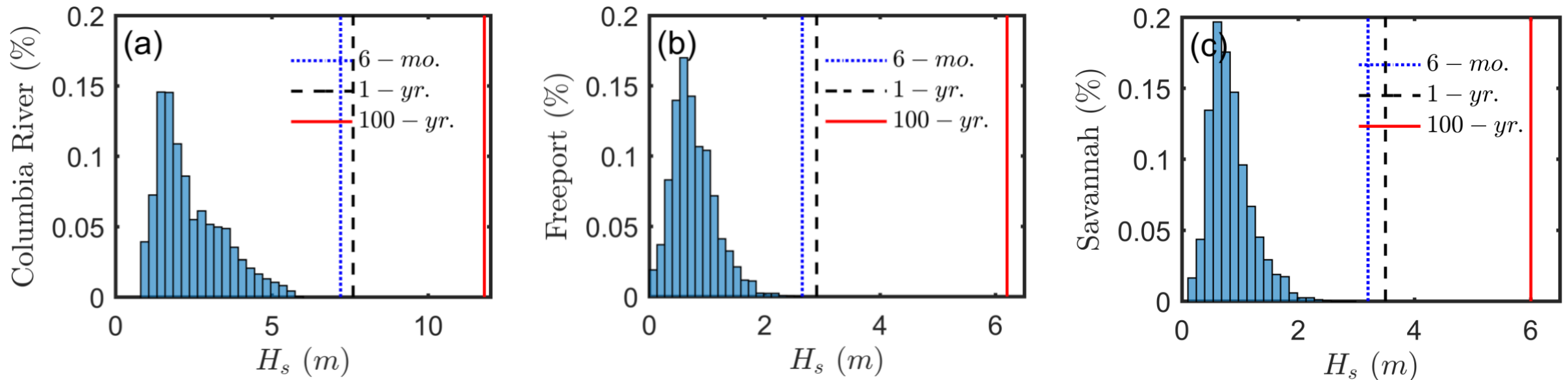
Understanding Structure "Users"

Under what conditions?
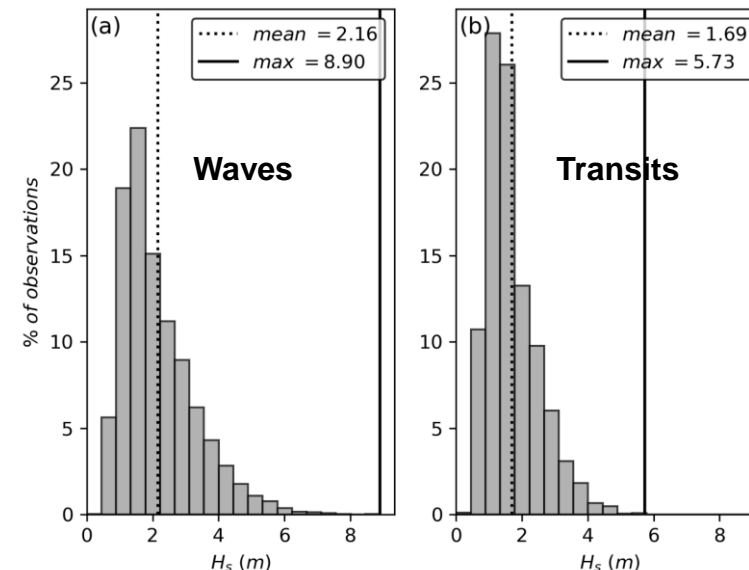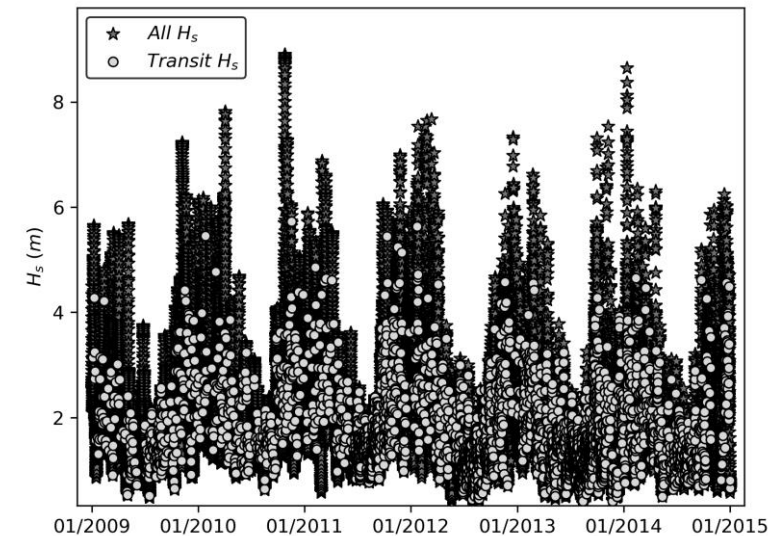
- **Measurable ∩ Meaningful**
  - **Number and type of vessels**
  - **Number of transits**
  - **User & Type intensity**
  - **Timing of transits, seasonality**
  - *Use trends*

Who uses it and how much?

Waves

Transits

How do we find interesting structures?

- **Information Entropy**
  - **Entropy = $\sum [P(k) * ln(P(k))]$**
  - **Maximum entropy: Even distribution across categories**
  - **Minimum entropy: Distribution focused in fewer categories**
- **Average trip per user = Total/Unique**
  - **Indicates frequent trips relative to the user base**

Increasing Entropy

Increasing Trips/User

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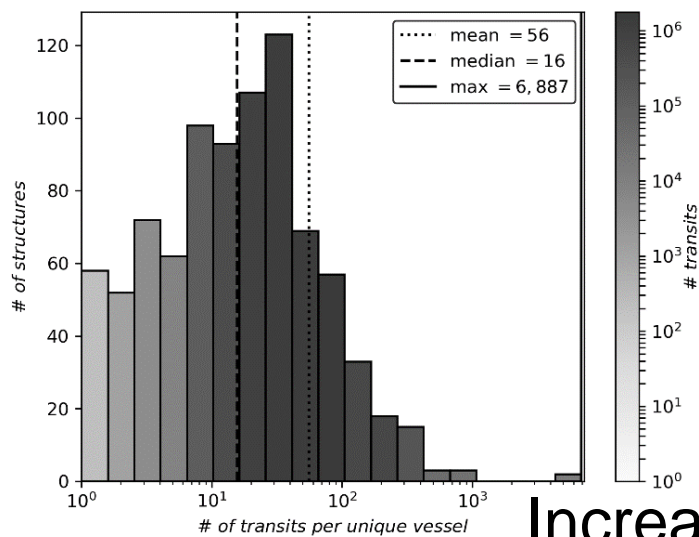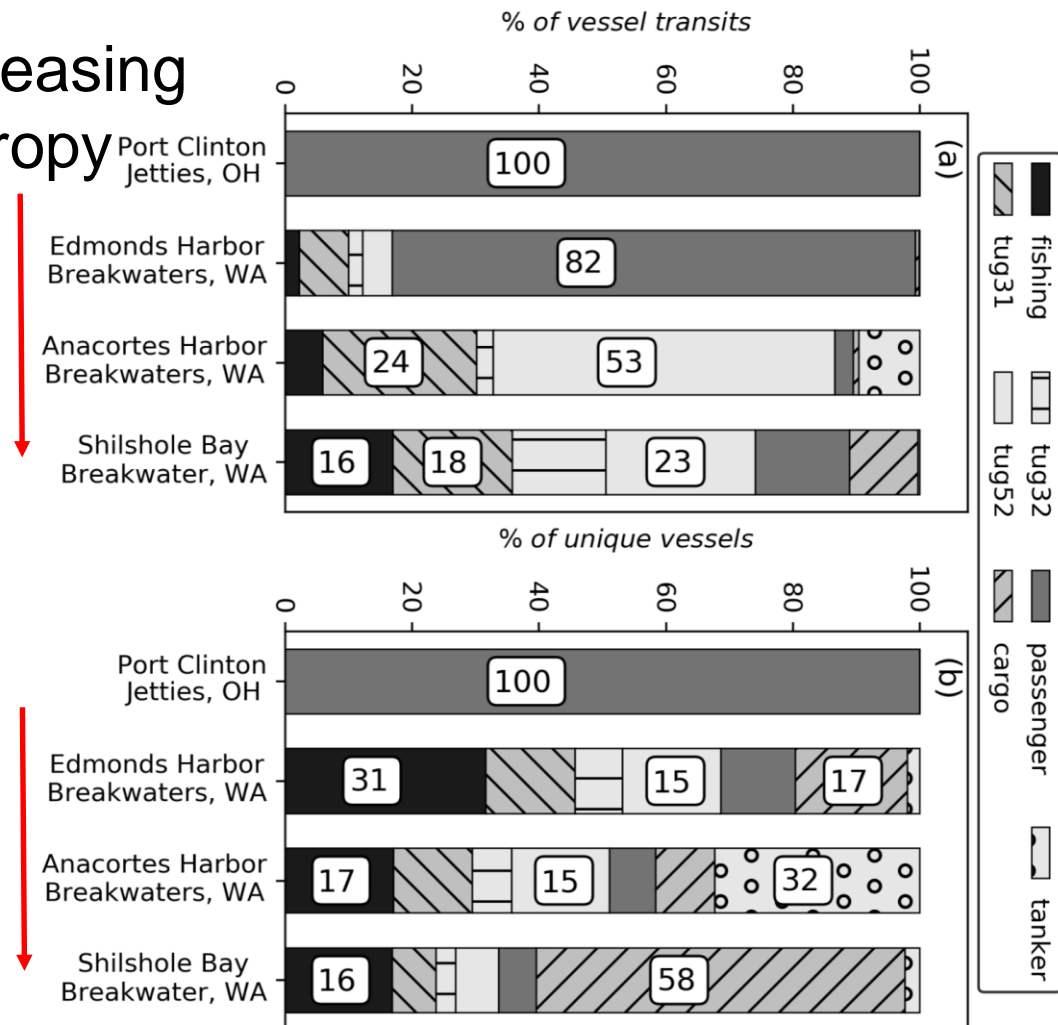
Seasonality

- **Negative correlation of user activity & structure loading: low potential for sheltering service.**
- **Seasonality may result in different maintenance requirements (ice).**

Port Clinton Harbor East Jetty, OH
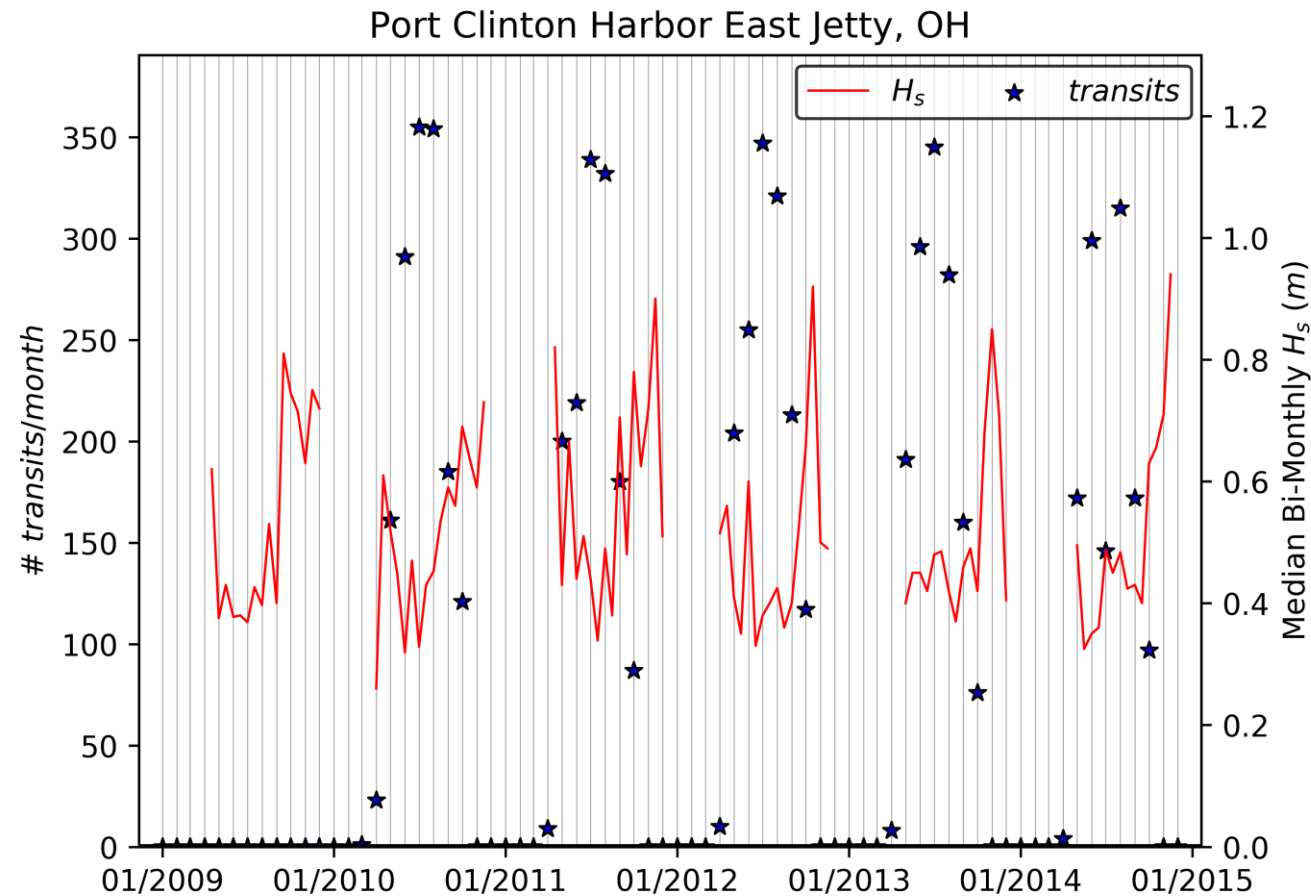
Clustering Structures: Management Cohorts

- **Each structure gets a score (standardized) for each performance metric**

- **Structures are compared for similarity**

- **Strongest similarity scores are retained**

- **Structures are clustered into management groups**

- **Group management drives mission outcomes**

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Detected Communities

Masonboro Inlet Jetties, NC

Cape Cod Canal Jetties, MA

MRGO Jetties, LA

SW Pass

Galveston Entrance Jetties

LA-LB Breakwaters

Savannah Jetties

Charleston Jetties

MCR Jetties

Gray's Harbor N. Jetty

Hyannis Harbor Breakwater, MA

Nantucket Harbor E. & W. Jetty, MA

North Edisto River, SC

Oregon Inlet, NC

Chetco River Jetty, OR

Depoe Bay Breakwater, OR

Gray's Harbor S. Jetty

Port Clinton Harbor E. & W. Jetties, OH

■ Fishing vessels, low traffic volume
■ Tow and Work vessels, moderate traffic volume
■ Passenger vessels, moderate traffic volume
■ Seasonal cargo vessels, moderate traffic volume
■ Cargo and Tanker vessels, high traffic volume

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Conclusions & Next Steps

- **AIS-derived traffic metrics:**
  - quantitatively relate portfolio assets (structures) to use (vessels)
  - facilitate rational allocation of scarce operating funds
  - shorten the information delay over traditional metrics

- **Feature vectors must capture what's important. We'll explore:**
  - Wave loading / design height
  - Dredge cost / repair cost index
  - Traffic volume - wave loading correlation
  - Current management flags – harbor of refuge, subsistence harbor, strategic port, etc.
  - Remove low gain metrics

- **Community detection facilitates group-wise management**

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Brandan Scully, PE, PhD
Brandan.m.scully@usace.army.mil
Phone: (843) 329-8168