Structure Portfolio Partitioning

Coastal Navigation Portfolio Management

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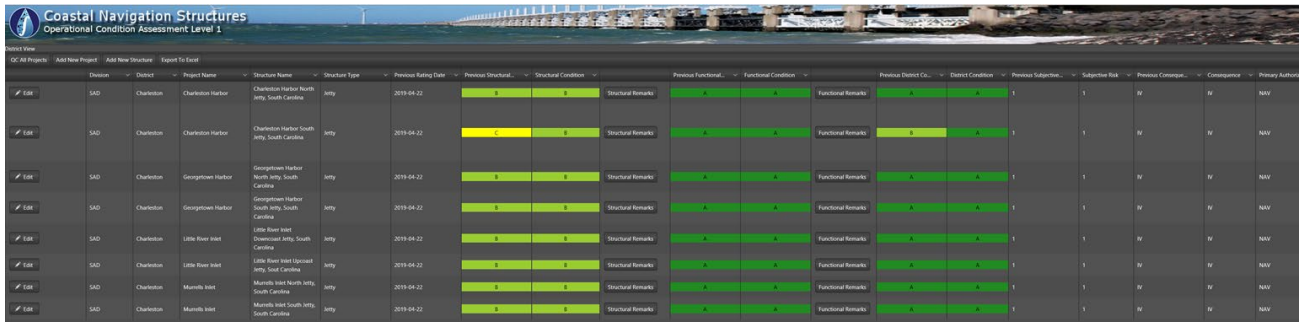
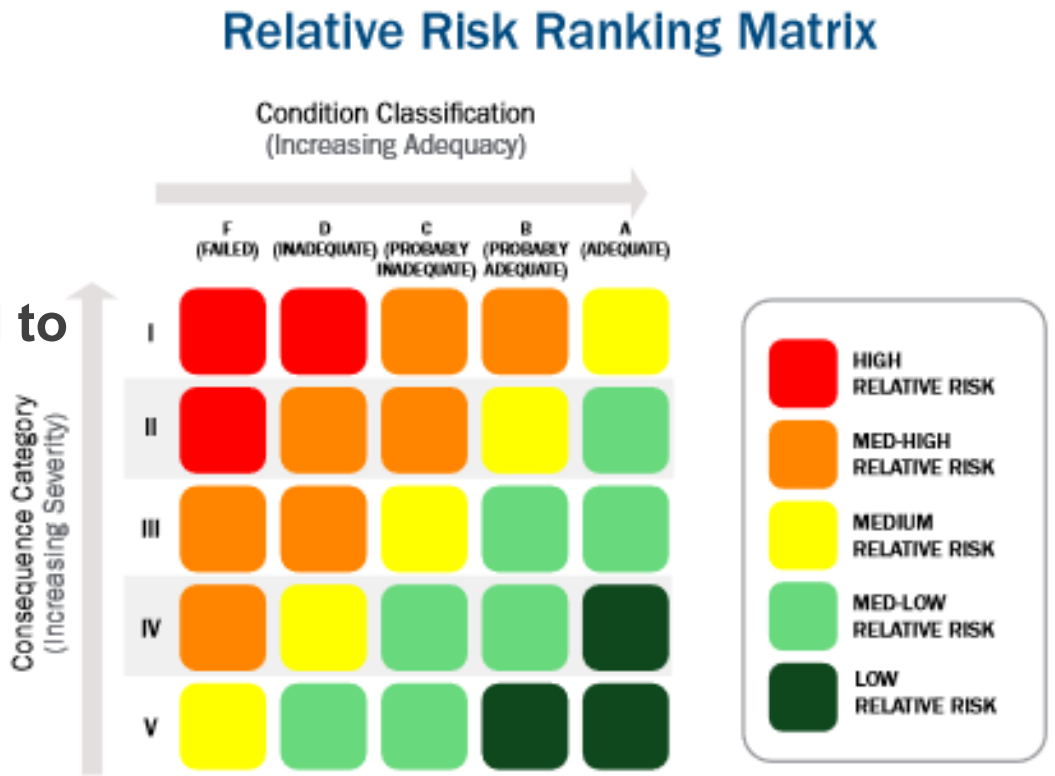
USACE Coastal Structure Portfolio

- **USACE maintains > 1000 coastal structures, most over 50 years old.**
- **Structural and Functional Condition drives maintenance funding (nav) through relative risk ranking.**
- **Functional condition metrics only loosely related to structure functions at present.**





Research Goals

- Augment subjective, qualitative navigation structure performance metric (OCA), and proxy project maintenance prioritization metrics (tonnage, value).
- Cast structure performance in terms of vessel activity for navigation structures.
- Formulate management metrics at “portfolio scale”.

Coastal Navigation Structures Consequence/Economic Impact Category	
Consequence Category	**Consequence Rating Criteria**
I	1. Demonstrated highest economic impact[1] 2. Imminent life safety impact 3. Critical to safe navigation by commercial vessels at High Use Navigation Project (>10 million tons) 4. Critical to safe navigation at DoD Strategic Ports
II	1. Demonstrated High economic impact[1] 2. Probable life safety impact. 3. Probable impacts to subsistence harbors/critical harbors of refuge. 4. High economic loss (5 - 10 million Tons) 5. Alternate modes of transportation exist for Energy Distribution Facilities, but at a higher cost than waterborne transportation
III	1. Demonstrated Moderate economic impact[1] 2. Possible life safety impact. 3. Possible impacts to subsistence harbors/critical harbors of refuge. 4. Moderate economic loss (1 – 5 million Tons)
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[1] Thresholds and basis for economic impact are under development. One measure of economic impact can be demonstrated using rate savings benefit, transportation cost savings, or damages avoided. 2-17-2012

Why this matters…

USACE has awarded contracts valued at ~$47M per year since 2007 on Jetty maintenance, repair, and construction.

The average maintained HMTF project (~521) costs $~1.9M annually.

There are ~541 HMTF projects that are not maintained.

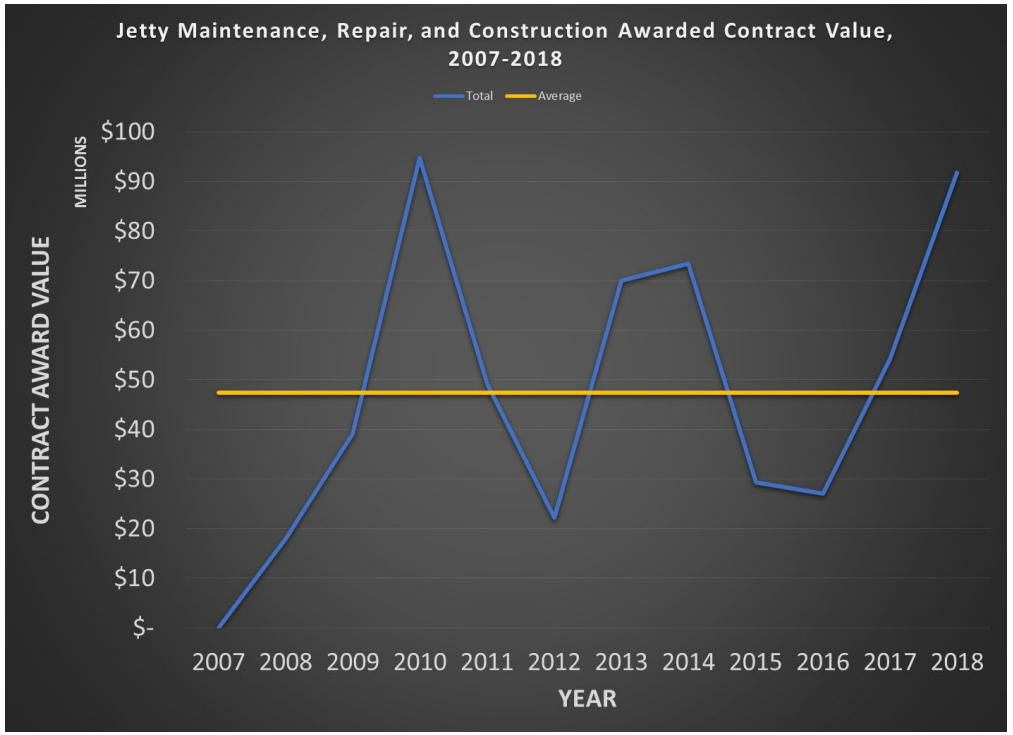
10-year coastal structure expenditure ≈ 24 HMTF projects.

MCR Repair costs ($257M):

- **North Jetty: $79,797,000**
- **South Jetty: $146,884,000**
- **Jetty A: $30,520,000**

Project BCR: 1.1

http://cdm16021.contentdm.oclc.org/utils/getfile/collection/p16021coll7/id/3/filename/4.pdf



MCR Repair Costs ≈ 25% annual USACE dredging budget.

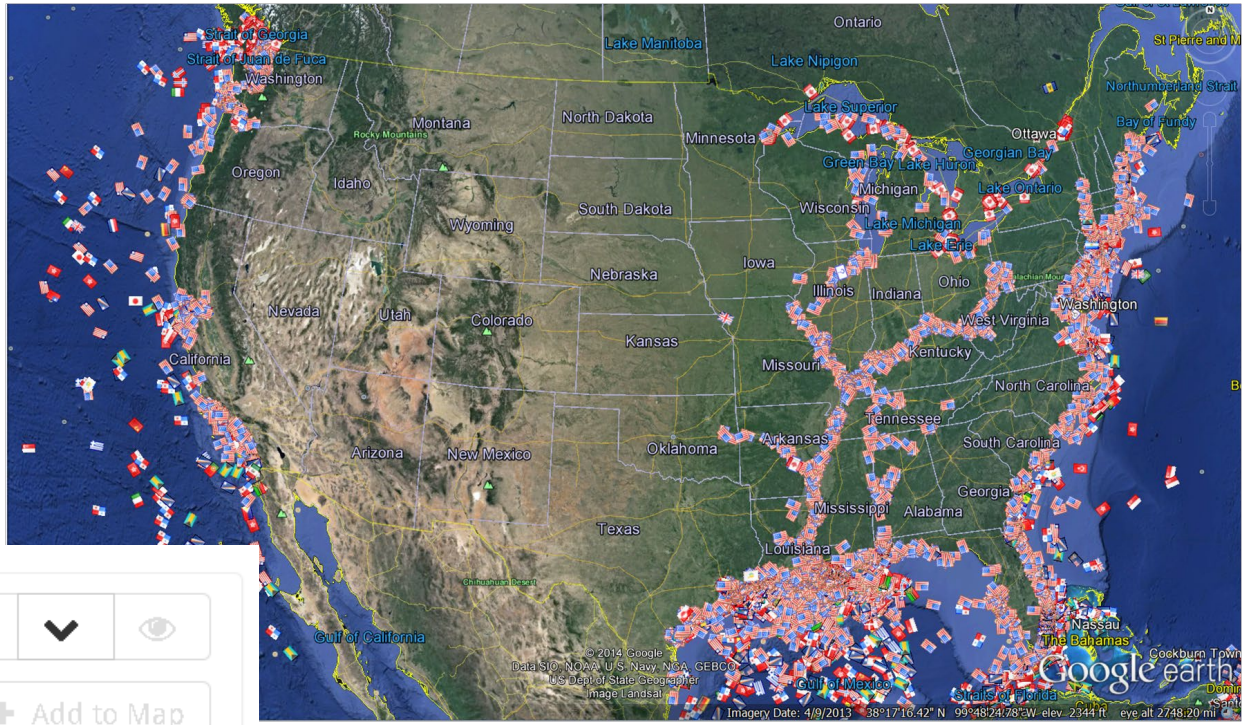
Structure Function Drives Maintenance Funding

- Structure functional condition is tied to vessel navigability, O&M dredging increase.
- "**Vessel navigability**" is **anecdotal** or ***was* expensive** to measure directly
- O&M **dredging increases** over background:
  - **marginally related to structure function**
  - **otherwise explained,** e.g. budget increase
- **Authorized limits** relates to width and depth. **Shoals don't preclude safe navigation**
  - Vessels frequently transit with less than design vessel draft
  - Vessels call at water levels above design water level
  - Vessels sail around shoals
- Currently no practice for quantifying the vessel operating functions described in FCR

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.

Marine Cadastre

- Nationwide AIS 1-minute sampling
- Available 2009-2017
- Marinecadastre.gov



2009 - 2017 National AIS at 1 Minute Intervals

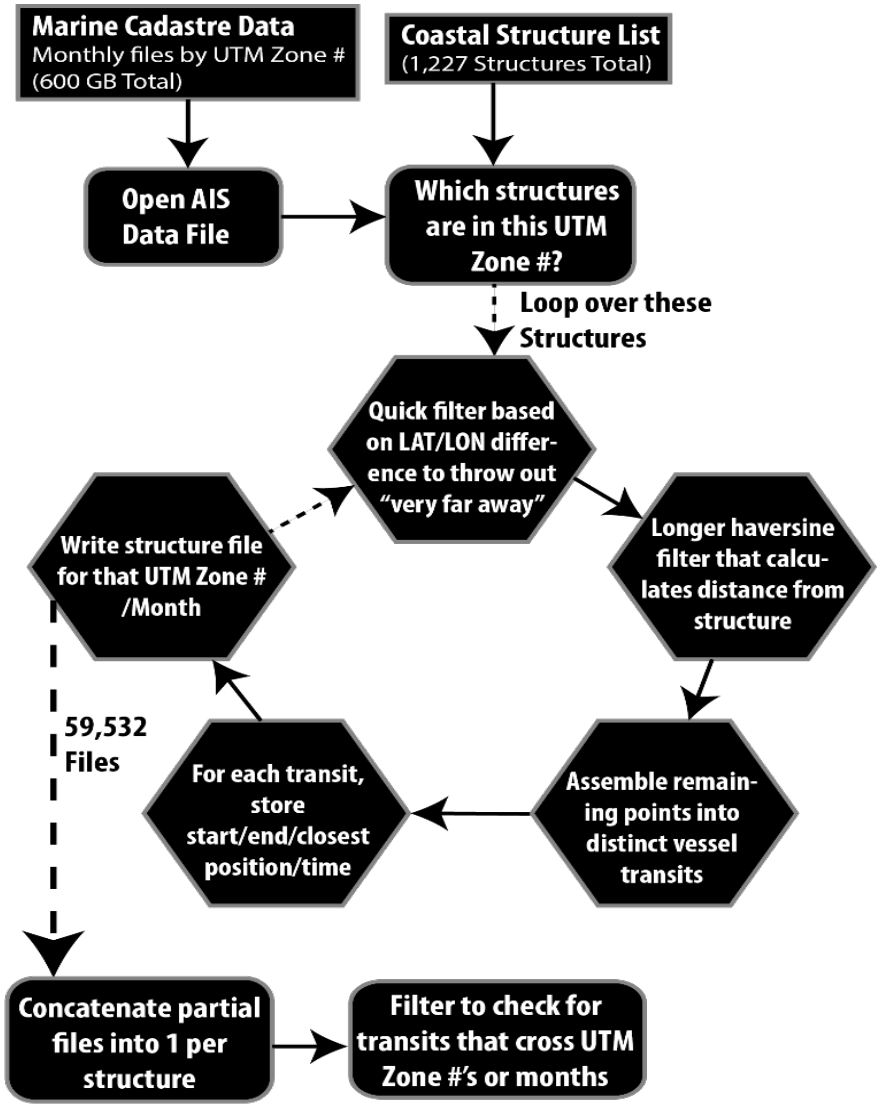
MarineCadastre.gov

Add to Map

Automatic Identification System (AIS) data are information collected by the U.S. Coast Guard to monitor real-time vessel information to improve navigation safety. Data such as ship name, purpose, course, and speed are acquired 24 hours per day primarily in coastal U.S. waters. However, the data sets featured on this website are the 2009 to 2017 archived AIS data sets intended to be used by the ocean planning community to better understand vessel traffic patterns. These data are provided for analysis in desktop GIS software. For more information, visit the Nationwide Automatic Identification System website.

Distributed AIS-derived Inlet Structure Metrics

- Metrics are easy:
  - Vessel transit count
  - Number of unique vessels
  - Transits/unique vessel
  - Vessel closest point of approach
  - Seasonal time-series decomposition
  - Information Entropy
- Portfolio scale analysis requires parallel approach
  - Historical vessel data (~600GB)
  - Structure portfolio (~1,200 structures)

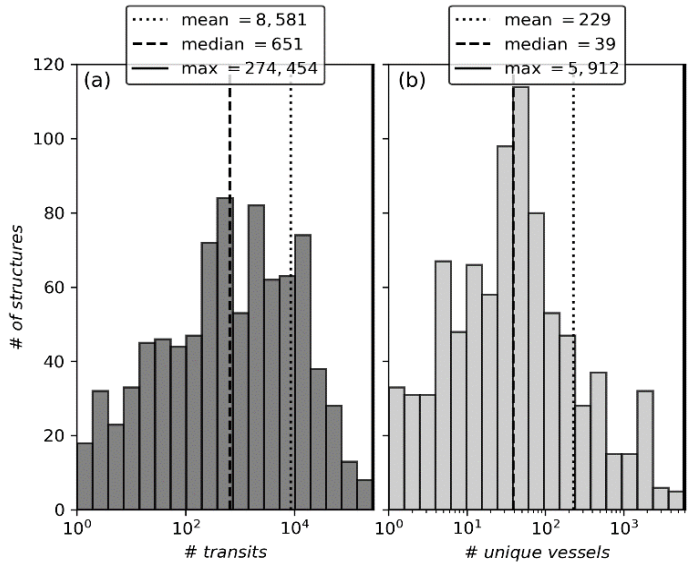


Results

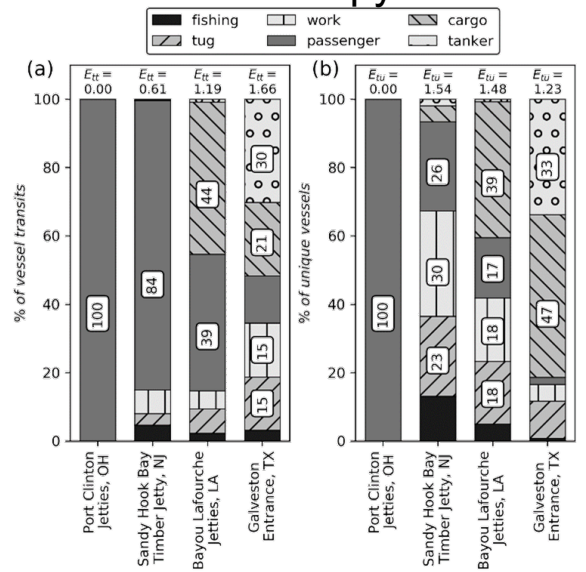
- We considered:
  - 6 years of data (2009-2014)
  - 865 navigation structures
  - 8M vessel transits (+ i.d.)

Ship and Cargo Type Code	Description
30	Fishing
31, 32	Towing (ahead or alongside, astern)
52	Tugs or workboats
6X*+	Passenger ships ≥ 100 gross tons
7X*	Cargo (freight) ships or integrated tub barge (ITB) vessels
8X*	Tankers or integrated tug tank barge vessels
* where X indicates digits 0-9, representing all vessels in this class.	
+ passenger vessels ≤ 100 gross tons and high speed craft coded as 4X were excluded	

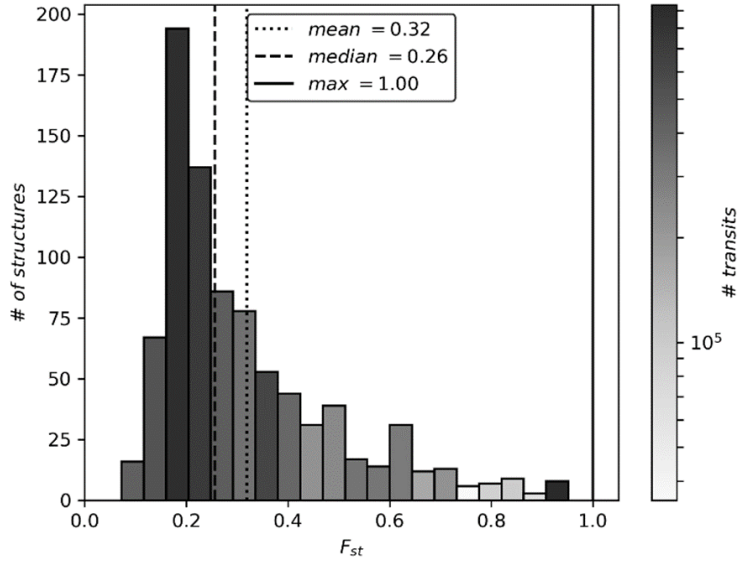
Traffic volume & unique users



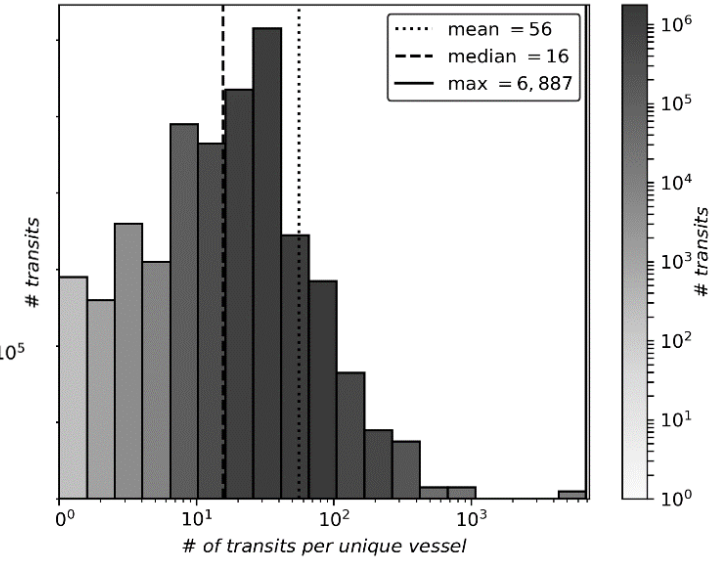
Traffic entropy



Seasonality



User intensity



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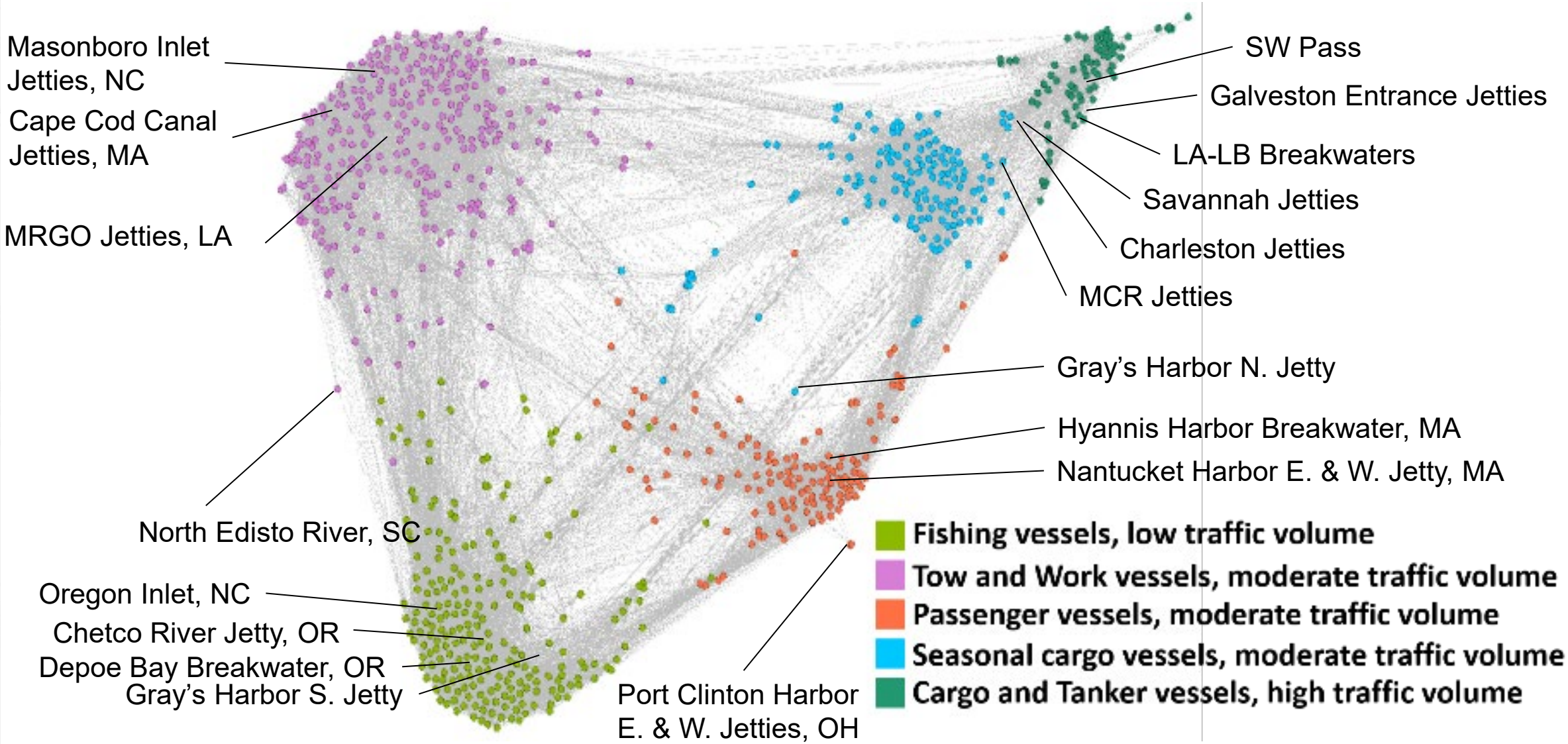
Clustering Structures: Management Cohorts

- Feature vectors defined with relevant performance metrics (20)
- Each structure gets a score ($-1 \leq x \leq 1$) for each performance metric
- Feature vectors are compared for similarity
  - Pearson Correlation (865 x 865 dense matrix)
- r-neighborhood (90^{th} %) pruning of affinity scores
  - (865 x 865 sparse binary matrix)
  - No management interpretation for negative correlation.
- Structures are clustered into management groups
  - Label Propagation Community Detection Algorithm, Cordasco, G., & Gargano, L. 2010

Feature Vectors: The Original 20

- r2Cnts – The coefficient of determination for overall fit of the time series decomposition model of vessel traffic at each structure based on the total number of observed vessel transits.
- FsCnts – The coefficient of determination for the seasonal component of the time series decomposition model of vessel traffic at each structure based on the total number of observed vessel transits, F_{st}
- r2Unq – The coefficient of determination for overall fit of the time series decomposition model of vessel traffic at each structure based on the total number of unique vessels observed.
- FsUnq – The coefficient of determination for the seasonal component of the time series decomposition model of vessel traffic at each structure based on the total number of unique vessels observed.
- unq – The total number of unique vessels observed at each structure.
- count – The total number of individual transits observed at each structure.
- trips_per_unq – The average number of individual transits observed for unique vessels at each structure.
- ~~avg_dist – For each structure coordinate pair, x is the distance between the coordinates and the AIS broadcast location nearest the structure for each observed transit within the search radius. Avg_dist, $\bar{x}$, is the average of these CPA distances for each structure.~~
- fish_% – The fraction of the total number of observed vessel transits at each structure with ship and cargo type code 30.
- fishUnq_% – The fraction of the total number of unique vessels observed at each structure with ship and cargo type code 30.
- tow_% – The fraction of the total number of observed vessel transits at each structure with ship and cargo type code 31 or 32.
- towUnq% – The fraction of the total number of unique vessels observed at each structure with ship and cargo type code 31 or 32.
- work_% – The fraction of the total number of observed vessel transits at each structure with ship and cargo type code 52.
- workUnq_% – The fraction of the total number of unique vessels observed at each structure with ship and cargo type code 52.
- passenger_% – The fraction of the total number of observed vessel transits at each structure with ship and cargo type code 60 through 69.
- passengerUnq_% – The fraction of the total number of unique vessels observed at each structure with ship and cargo type code 60 through 69.
- cargo_% – The fraction of the total number of observed vessel transits at each structure with ship and cargo type code 70 through 79.
- cargoUnq_% – The fraction of the total number of unique vessels observed at each structure with ship and cargo type code 70 through 79.
- tanker% – The fraction of the total number of observed vessel transits at each structure with ship and cargo type code 80 through 89.
- tankerUnq_% – The fraction of the total number of unique vessels observed at each structure with ship and cargo type code 80 through 89.

Detected Communities



Update: Additional Metrics

- Type
  - Dictates service benefit
  - Multiple partially overlapping lists (!)
- Structural condition
- Vessel-Wave correlation
  - Captures structure service
- *Volume trend*

Barrier	1
Beach Hammock	1
Breakwater	453
Bulkhead	8
Dike	62
Disposal Facility	1
Embankment	1
Groin	33
Jetty	301
Mound	4
N/A	9
Pier	109
Revetment	46
Revetted Mole	9
Rock Blanket	1
Seawall	16
Shore Protection	2
Sill	2
Training Wall	3
Wave Absorber	8

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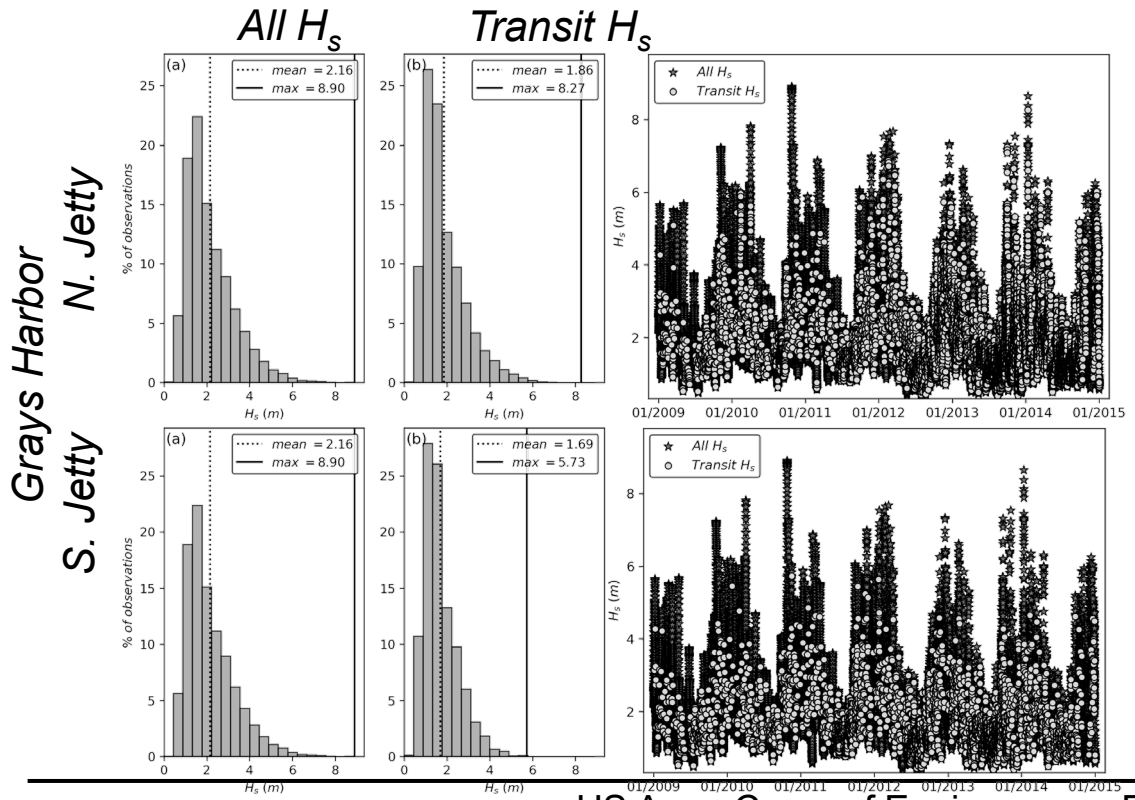
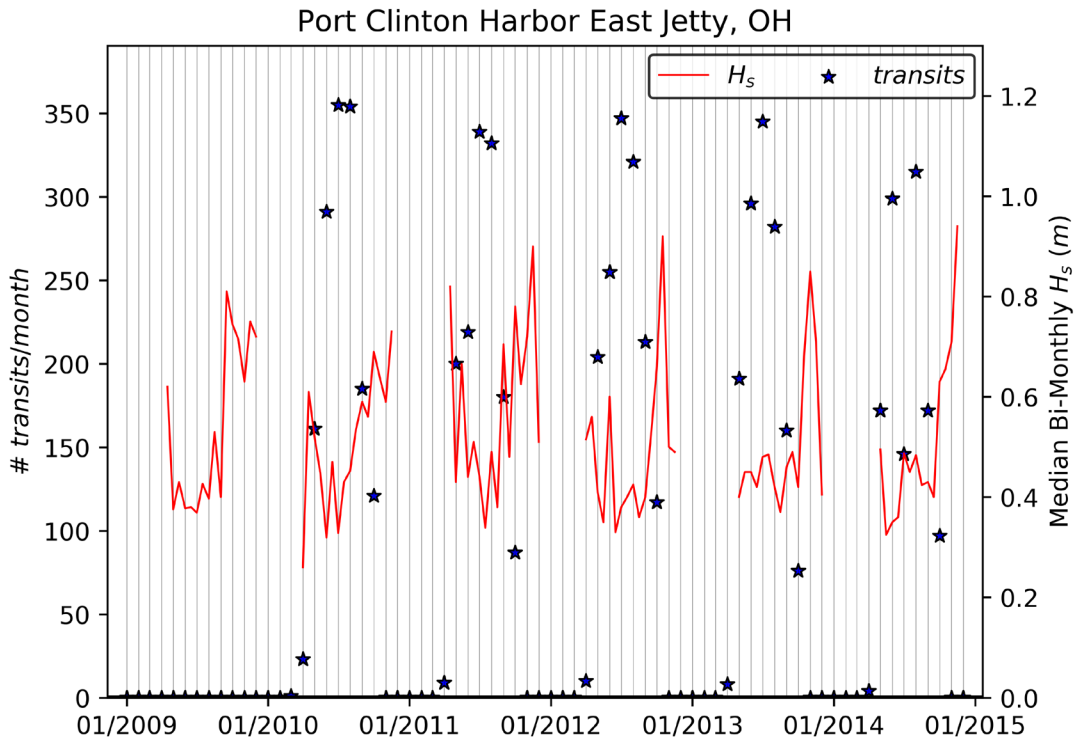
Project Name	Structure Name	Structure Ty...	Previous Rati...	Previous Structural...	Structural Condition		Previous Functional...	Functional Condition		Previous District Co...	District Condition	Previous Subjective...	Subjective Risk	Previous Conseque...	Consequence	Primary Auth
Pultneyville Harbor, NY	East Pier	Jetty	2020-05-22	B	F	Structural Remarks	B	B	Functional Remarks	B	D	2	2	IV	IV	JAV

Coupling Vessel Activity with Wave Data

- **The timing and distribution of vessel transits can be viewed in context with wave activity.**
  - **Negative correlation of user activity & structure loading: low potential for sheltering service.**
  - **Structures may demonstrate different traffic signatures when subject to identical wave conditions.**





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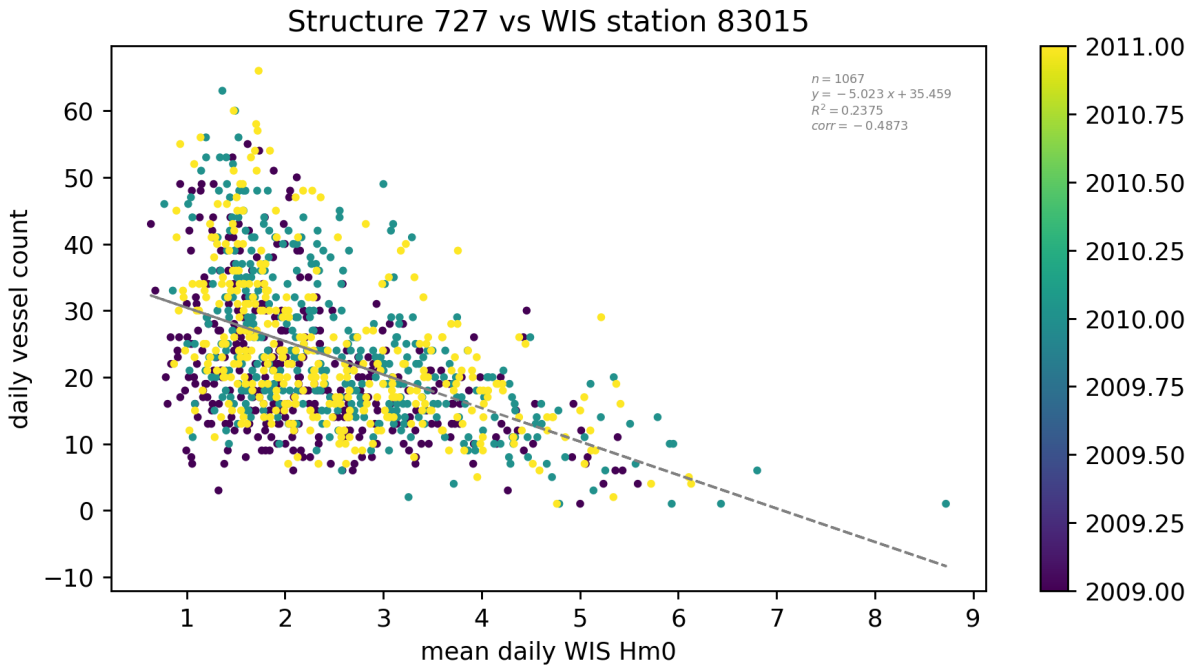

A	B	C	D
Description	snum	WIS station	correlation WIS
Baptiste Collette Bayou East Jetty	2	73139	-0.27820897
Baptiste Collette Bayou West Jetty	3	73139	-0.277757485
South Pass East Jetty Longitudinal Dike	30	73137	-0.012735862
SW Pass East Jetty	31	73137	-0.019324071
South Pass Inner East Jetty	32	73137	-0.031206529
SW Pass West Jetty	33	73137	-0.018316134
Portland Harbor North (Inner Harbor) Breakwater, Maine	624	63035	-0.085106344
Portland Harbor South (spring Point) Breakwater, Maine	625	63035	-0.085916496
Columbia River at Mouth Jetty "A", Oregon and Washington	727	83015	-0.487313729
Columbia River at Mouth North Jetty, Oregon and Washington	728	83015	-0.47429092
Columbia River at Mouth South Jetty, Oregon and Washington	729	83015	-0.479650368
Columbia River (mouth), Oregon and Washington	773	83015	-0.44959145
Gray's Harbor North Jetty, Washington	778	83010	-0.204663677
Gray's Harbor South Jetty, Washington	779	83010	-0.043840772
Savannah Harbor Cockspur Jetty, South Carolina	1001	63368	-0.025940392
Savannah Harbor Oyster Bed Jetty, Sout Carolina	1002	63368	-0.027685125
LA-LB Harbors Long Beach Breakwater, California	1064	84109	0.026471469
LA-LB Harbors Middle Breakwater, California	1065	84106	-0.09023035
LA-LB Harbors San Pedro Breakwater, California	1066	84106	-0.008646869
Brazos River, Texas	1181	73019	-0.166170353
Sabine Pass East Jetty, Texas	1222	73091	-0.115559233
Sabine Pass West Jetty, Texas	1223	73091	-0.122042883

Update Summary

- Growing the Team
  - Candice Hall, Charlene Sylvester, Nathan Mays
- List validation
  - Multiple coastal structure datasets.
- New metric development
  - Type
  - Condition
  - Vessel-wave correlation
    - Linking datasets takes time
- Workflow automation
- Visualization
  - Partnered with College of Charleston
  - Translating student effort

Internal Viewer

Now Automated!

Conclusions

- AIS-derived traffic metrics quantitatively relate portfolio assets (structures) to use (vessels)
- Feature vectors can be customized to describe relevant metrics. We could add:
  - Wave loading/design height
  - Historical maintenance cost or effort
  - Transit vs. wave height timing coincidence
- AIS-derived metrics facilitate rational allocation of scarce operating funds
- Community detection can facilitate group-wise management
- Parallel computing approach facilitates “portfolio scale” analysis
- Development of parallel computing capability in this space strategically positions CIRP within the vessel computational analysis space
- Next steps, i.e computation of 4-d vessel clearance, builds on this work.

Benefits

- **Working at scale strategically positions CNPM to explore other AIS-derived portfolio-wide metrics**
  - **4-D around-ship clearance – FY 19 goal**
  - **Vessel-based infrastructure classification**
  - **Large scale quantification of navigation risk**
- **A variety of alternative datasets can be swapped in for structure dataset**
  - **Ports**
  - **Habitat**
  - **Population centers**
- **Nationwide answers – navigation projects don't exist in a vacuum.**

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