

#### Aquatic Invasive Species and Shipping-Modeling Risk



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# **Aquatic Nuisance Species**

Aquatic Nuisance Species can cost millions of dollars in mitigation and management every year



Lionfish (Pterois volitans)

Successful Invader needs 3 things:

- Rapid growth and reproduction
- Adaptability
- No predators



Zebra mussel (Dreissena polymorpha)



#### **Marine Nuisance Species Patterns**



#### **Aquatic Nuisance Species Costs**



Cuthburt et al 2021

### **USACE** Costs

#### Figure 1. USACE Estimated Spending on Nuisance Species Efforts by Response Activity, FY2022



**Source:** CRS, using FY2022 National Invasive Species Council Crosscut Budget, at https://www.doi.gov/invasivespecies/crosscut-budget.



### **Invasion Vectors**



Invaders spread beyond regional range:

- In Ships
- On Ships
- Aquaculture/Aquarium Trade
- Intentionally

(New Scientist, Illustration: Andrzej Krauze)

### **Review of Current Ecological Models**



### **Research Questions**

- What is the potential impact of commercial ships and recreational vessels on aquatic invasion risk?
- How do the patterns of commercial ships and recreational vessels differ in space and time?
- How does this potential impact differ across species?



# **Model Framework**

- What is the potential impact of commercial ships and recreational vessels on aquatic invasion risk?
- How do the patterns of commercial ships and recreational vessels differ in space and time?
- And does this potential impact differ across species?



This project focuses on **developing a model that couples Automatic Information System** (AIS) data describing global ship movement with species distribution models to identify high-risk areas for marine bioinvasion.

### **Conceptual Model Framework**



Environment

Habitat Suitability or Matching (seasonal and locational components)

# Model Development: Environmental Data

- 6 Major commercial ports and various recreational zones
- 10 non-native marine species identified to include in model
  - Five phyla (tunicate, bivalves, polycheate, crustaceans, hydrozoans)
  - Multiple functional groups (mobile, sessile, burrowing, planktonic, filter feeders, predators
- Environmental drivers and thresholds identified for each species (NEMESIS Database)
  - Water Temperature
  - Salinity
- Habitat suitability curves derived for each species and environmental parameters

#### **Target Ports**



#### Environment

Habitat Suitability or Matching (seasonal and locational components)

### **Model Development: Environmental Data**

Water Quality data acquired for all FL coastal counties (STORET data warehouse, FL DEP)





Average of Temp (deg C)
Mussel Perna viridis (Asian Green Mussel)
Hydrozoan Blackfordia virginica

• Barnacle Megabalanus coccopoma (Titan Acorn Barnacle)

Amphipod Caprella scaura
Bivalve Teredo navalis (Naval Shipworm)
Crab Eriocheir sinensis (Chinese mitten crab)
Polychaete Ficopomatus enigmaticus

#### Environment

Habitat Suitability or Matching (seasonal and locational components)

# **Model Development: Habitat Suitability**









#### Habitat Suitability or Matching (seasonal and locational components) Species Salinity Thresholds 70 60 58 55 50 45 40 40 40 40 38 38 35 35 32 32 30 30 29 28.75 28.5 26 25 22.75 20 20 18.5 18 17.5 17.5 10 7.5 6 5 2 2 0 Charybdis helleri Eriocheir sinensis Styela plicata Caprella scaura Perna viridis Teredo navalis Turritopsis Blackfordia Megabalanus Ficopomatus (Pleated dohrnii (Amphipod) (Asian Green (Naval virginica (Swimming (Chinese mitten enigmaticus coccopoma (Immortal Tunicate) (Black Sea (Australian Mussel) Shipworm) Crab) crab) (Titan Acorn Jellyfish) Jellyfish) Barnacle) tubeworm) Salinity Estimated Average Min Salinity Max Salinity

#### Environment

# Model Development: Biological Thresholds

Vectors/Propagule

Recreational Shipping

Pressure

Commercial Shipping

# Model Development: Vectors of Invasion

 AIS – Automatic Identification System is a shipboard broadcast system that acts like a transponder

Automatic Identification System (AIS)





Abbreviations used in map: NAIS = Nationwide Automatic Identification System; ACOE = Army Corps of Engineers; PSS = Primary Shoreside (USCG) ; MXAK = Marine Exchange of Alaska; VTS = Vessel Traffic Service; SLSDC = St. Lawrence Seaway Development Corporation. Credit: USCG



# Model Development: AIS Data

Customs data and AIS data used in combination to determine route patterns of commercial and recreational vessels in and around FL Used to develop weighting and connectivity distributions



AIS Signal density plot of Pleasure Craft vessels that were identified in the Sarasota FL region (orange box) in 2020 and then tracked for 1-month.



Heatmap of vessel traffic inside our regional "watch areas" with minimum (blue tones) at 100 position reports, and max (white) at 5,000+ reports for 2020.



Segmented FL into different "watch areas" to understand movements happening within the state.

Allows us to look at connectivity within specific watch areas.

Approach was to not treat all of FL as one singular area since there are key differences within spatial resolution.

### **Model Development:** Quantifying Shared Vessel Traffic



#### Vectors/Propagule Pressure

#### Commercial Shipping

Recreational Shipping

#### **Model Development:** Quantifying Connectivity

Foreign Vessels inbound to Florida

**Outbound Recreational Vessels within Florida** 

Miami: 16,168		Miami T37: 7,786
Tropical Atlantic: 53,644		Port Everglades T37: 6,076
	Port Everglades: 22,348	Palm Beach T37: 1,029
		St, Lucie Inlet T37: 304
	Palm Beach: 7,560	Fernandina Beach T37: 706
	Fernandina Beach: 719	Canaveral T37: 711
Temperate Northern Atlantic: 14,624	Canaveral: 6,029	
	Key West: 1,968	Key West T37: 1,185 -
		Port Manatee T37: 39
Tropical Eastern Pacific: 2,060	Jacksonville: 9,410	Jacksonville T37: 264
Eastern Indo-Pacific: 14 -	Pensacola: 533	Pensacola T37: 698 -
Temperate Southern Africa: 12	Panama City: 1,497	Panama City T37: 78
Temperate Northern Pacific: 815	Tampa: 5,193	Tampa T37: 775
→ Western Indo-Pacific: 32 - Temperate South America: 425	Port Manatee: 1,275 -	

# Model Approach

Probability species of interest Disturbance associated with vessel route (ensures that the invasion risks between two closely Future Change *located ports are negligible)* (climate, sea-level rise, extreme events) **Vectors/Propagule Environment** Probability of introduction Pressure (survival on route, in and on vessel) **Operations** Habitat Suitability Activity Commercial or Matching Shipping Probability of establishment (seasonal and locational components) (donor and recipient port matching and HSI) Recreational Shipping Calculation of invasion risk based on probability of introduction and **Biofouling Invasion** establishment Risk Reminiscent of Seebens et al. 2013

# **Model Components**

# Probability of association



# **Model Components**



# **Model Components**

#### Probability of establishment



#### Model Results Tampa, Charybdis hellerii



Month

#### Model Results Tampa, *Megabalanus coccopoma*







Jaxshells.org



#### **Model Results Tampa - Drivers**

Month



Taylor-Dixie-Levy-Citrus County TampaArea Walton-Okaloosa-Santa Rose County TampaArea

#### **Recreational Vessels Entering Tampa**



#### Commercial Vessels Entering Tampa



#### Model Results Tampa - Drivers





#### Model Results Tampa - Drivers



# Summary

- 2 species show different monthly patterns of Expected Invasion Risk, both are influenced more by commercial traffic than recreational traffic
- Vectors seem to be drivers for crab
- Habitat suitability seems to be driver for barnacle
- But this is only one site!
- Variation in environmental conditions as well as traffic patterns will highlight complexity
- More target ports, more species results to evaluate

# Summary

Overall goal is to identify high-risk areas for marine bioinvasion to inform planning, operations and mitigation strategies.

- ✓ Performed extensive literature review and data mining
- ✓ Created conceptual model
- ✓ Identified probability equations and data components
- ✓ Developed parameterized model
- Next Steps...
  - Evaluate additional results
  - Scenario analysis
  - Include dredging maintenance/operations activity and future environmental change



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# Questions & Discussion

Thank you for your attention!



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