Possible ballast water transfer of lionfish to the eastern Pacific Ocean

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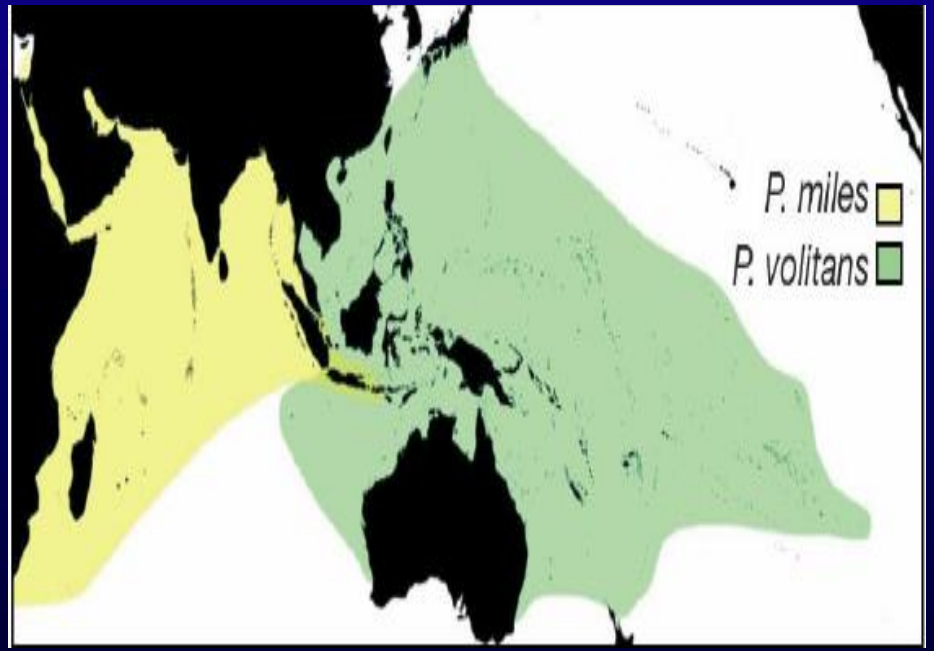
Lionfish

- Two sister species
- Model invasive species:
  - Mature early, broad physiological tolerances, highly fecund, extremely different from predators native to the Atlantic
  - Profound impacts
- Is the eastern Pacific in store for an invasion of similar scale and consequence?



Kulbicki et al. (2012)

Lionfish

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Schofield et al. (2017)

Objectives

- Determine if there's sufficient propagule pressure to warrant concern over an invasion to the eastern Pacific Ocean

- Develop a Species Distribution Model (SDM) to determine risk of establishment if sufficient lionfish propagules are released into the eastern Pacific Ocean

Methods

All National Ballast Information Clearinghouse (NBIC) Records

Ship traffic between 2006-2013

Ships that loaded ballast water from ports in Gulf of Mexico, Caribbean, east USA

Ships transited through Panama Canal

Ballast water discharged untreated on Pacific coast

Methods

- SDM created using physiological tolerances of lionfish in conjunction with available environmental data
    - General Additive Model (GAM) used
    - Lionfish presence points taken from 1985-2015 from USGS
    - Environmental data provided by AquaMaps matched with presence points; 383 unique presence cells
        - Used environmental conditions derived from these points to distinguish between absence and pseudoabsences throughout the invaded range of lionfish in the Atlantic

Methods

- 18 environmental variables (relating to depth, surface and bottom temperatures, salinity)
    - Highly correlated variables removed (12)
- To determine the final model
    - Removed each variable step-wise, and compared the adjusted pseudo-r^2 of the reduced model to the full model
    - Only variables that explained $\geq$1% unique variation were retained
- Sensitivity analysis allowed us to highlight the variables most important to establishment (for each variable, increased the value incrementally while holding all others at the mean)
- GIS used to plot results of the model

Ports in the continental western USA that received discharges of untreated ballast water

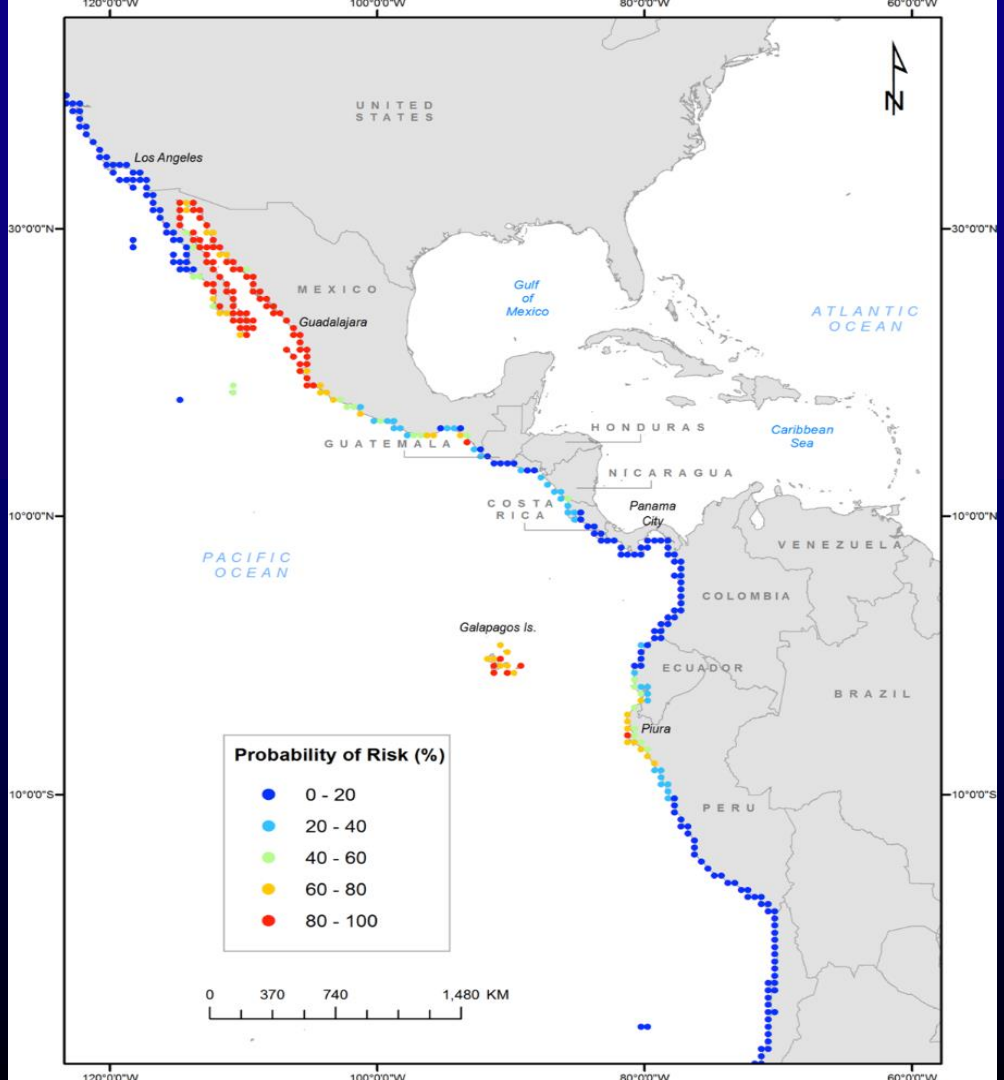
Location	Number of Vessel Trips	Volume Discharged (m^3)	Number of Tanks Discharged
Los Angeles/Long Beach, CA	8	24096	29
Portland, OR	3	3094	5
San Francisco, CA	3	11785	4
Richmond, CA	3	4141	5
Oakland, CA	3	1250	6
Longview, WA	1	706	1
Astoria, OR	1	77	1
Tacoma, WA	1	710	3
Everett, WA	1	182	2
Benicia, CA	1	1366	4
San Diego, CA	1	142	1
Seattle, WA	1	147	2

MacIsaac et al. (2016)

Factors retained and their weightings in SDM to assess potential range of lionfish if introduced to the western USA

Variable	Unique Variance Explained
Area (km^2) less than 20m depth	0.028
Minimum bathymetry (m) negative elevation	0.022
Mean bathymetry (m) negative elevation	0.012
Mean annual SST range (°C)	0.093
Mean annual minimum SST (°C)	0.078
Mean annual SBT (°C)	0.010
Mean annual salinity (‰)	0.034

MacIsaac et al. (2016)



Environmental Suitability of the western USA, plus Central and South America

MacIsaac et al. (2016)

Discussion

- An invasion scenario akin to that experienced on the US east coast is unlikely on the US west coast due to environmental mismatch
- There is still cause for concern of establishment to other regions along the eastern Pacific coast if the species is introduced
    - However, we lack ballast water data for Central and South America

Discussion

- Many aspects of lionfish biology are currently unknown (e.g. physiological tolerances across ontogeny is largely unknown)
    - USGS is reliant on the voluntary submission of records
    - Most records of occurrence are from shallow waters in areas frequented by divers
    - The range of lionfish is currently expanding to deeper, colder waters

- A more complete dataset would lend confidence to these predictions

- In light of potential invasion risk, we advocate for mandatory ballast water transfer of vessels transiting through the Panama Canal from Atlantic to Pacific coasts
    - Gatún Lake
    - Consent by Panama

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