Oyster model inventory: Identifying critical data and modeling approaches to support oyster reef restoration in U.S. Gulf of Mexico waters

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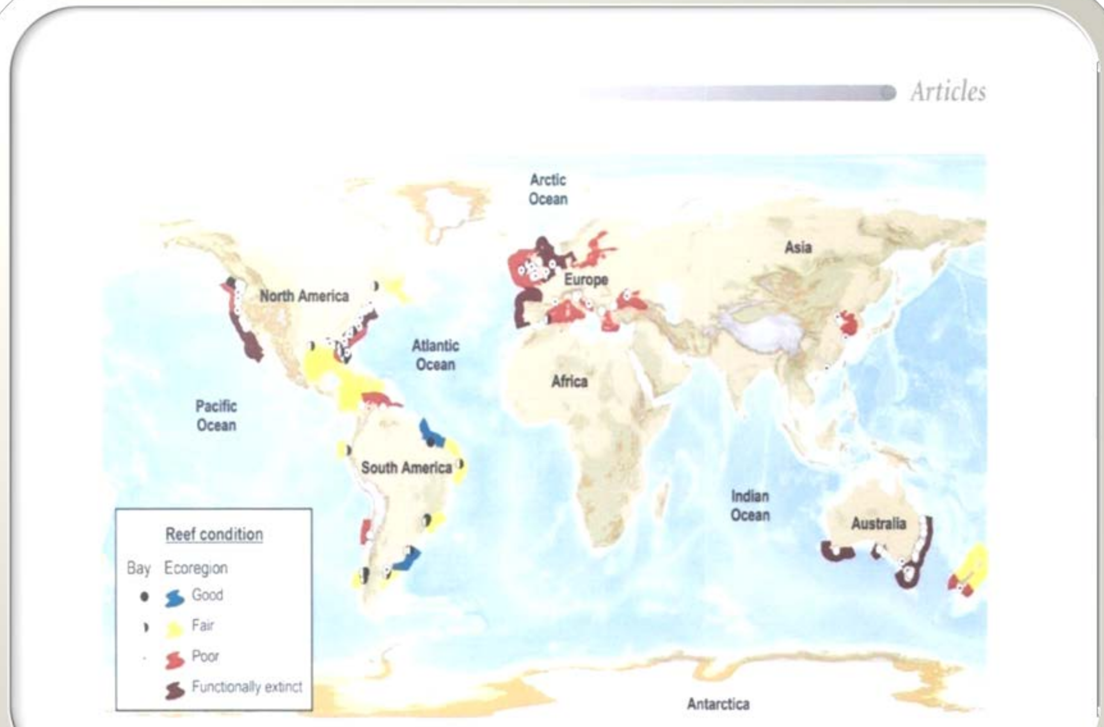
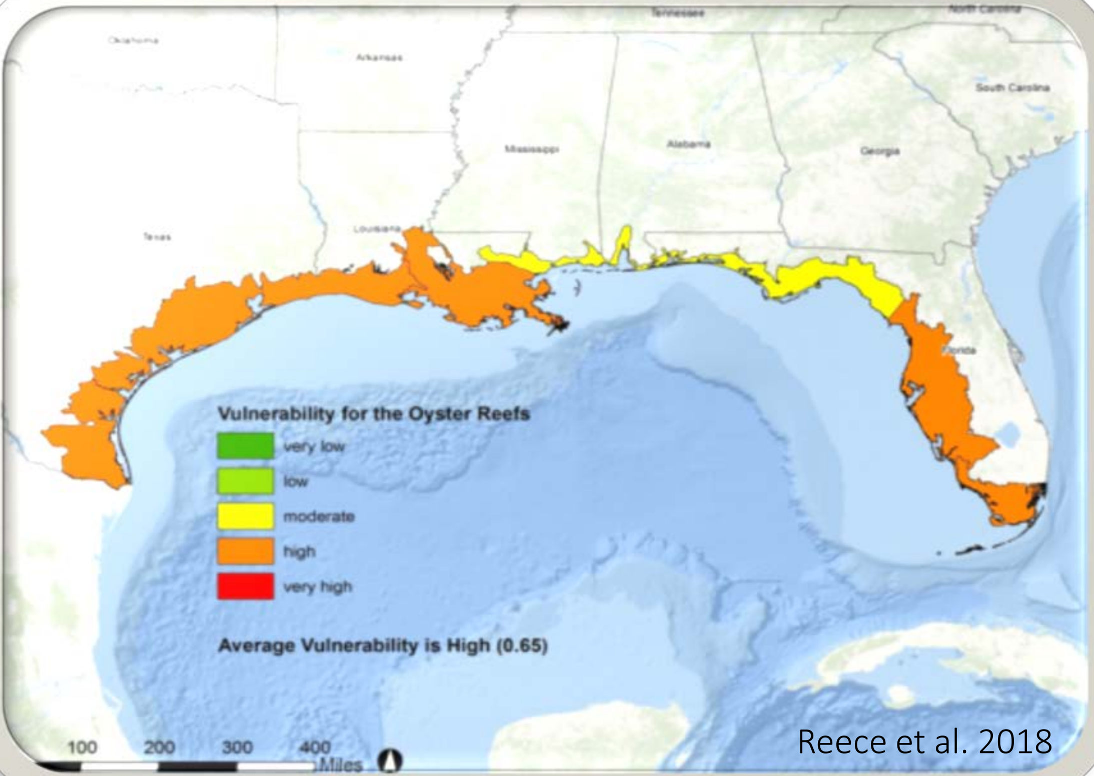
USGS science for a changing world

LSU AgCenter

Shellfish reefs occur globally, but are considered highly vulnerable.



Beck et al. 2011

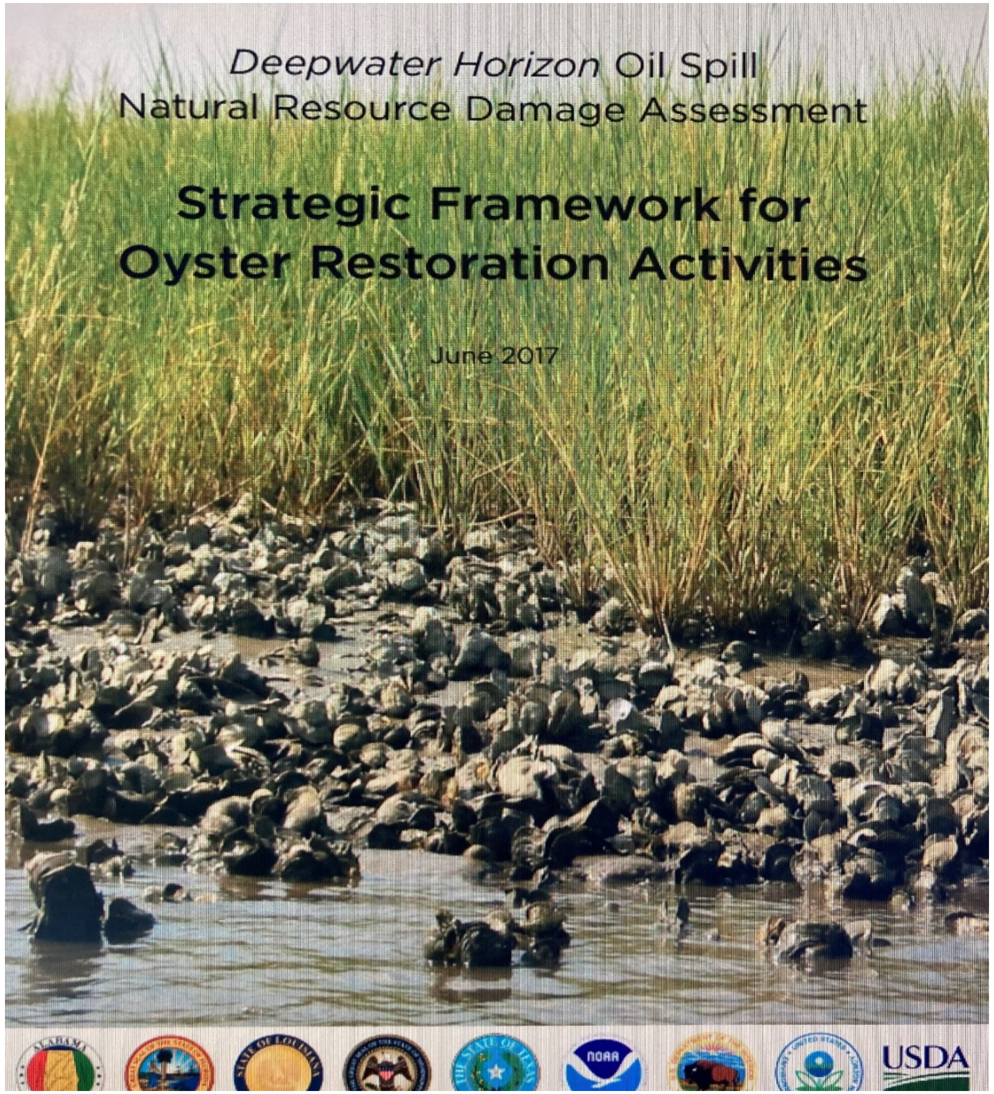


Reece et al. 2018

Increased investment in restoration of oysters for both conservation and harvest across a large spatial area generated broad resource-level goals

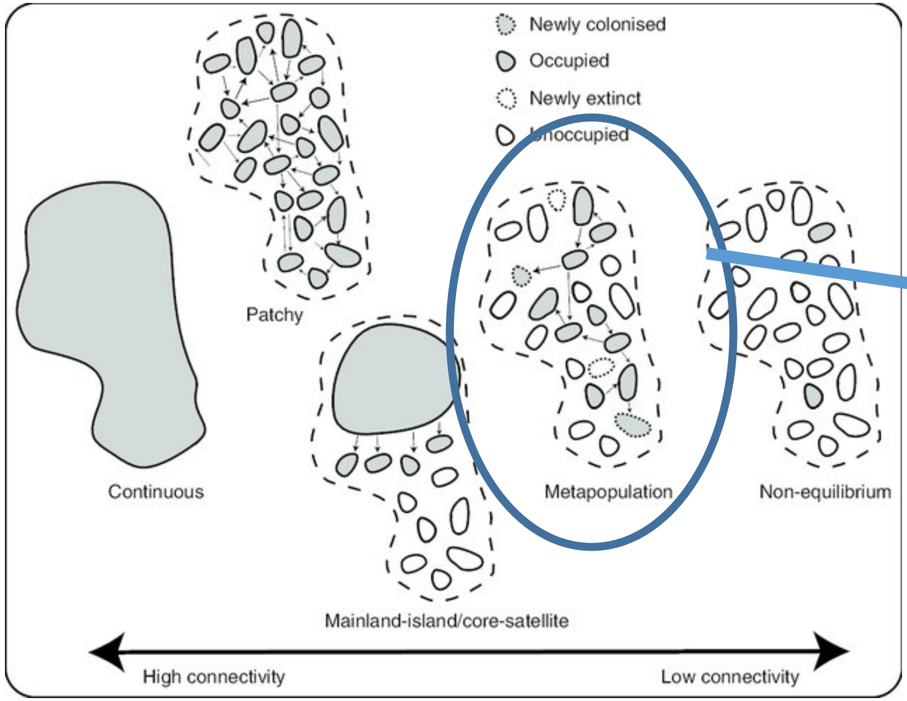
Goals:
1) Restore oyster abundance and spawning stock
2) Restore resilience & diversity

Approaches:
1) Restore or create oyster reefs
2) Develop network of oyster reef spawning reserves

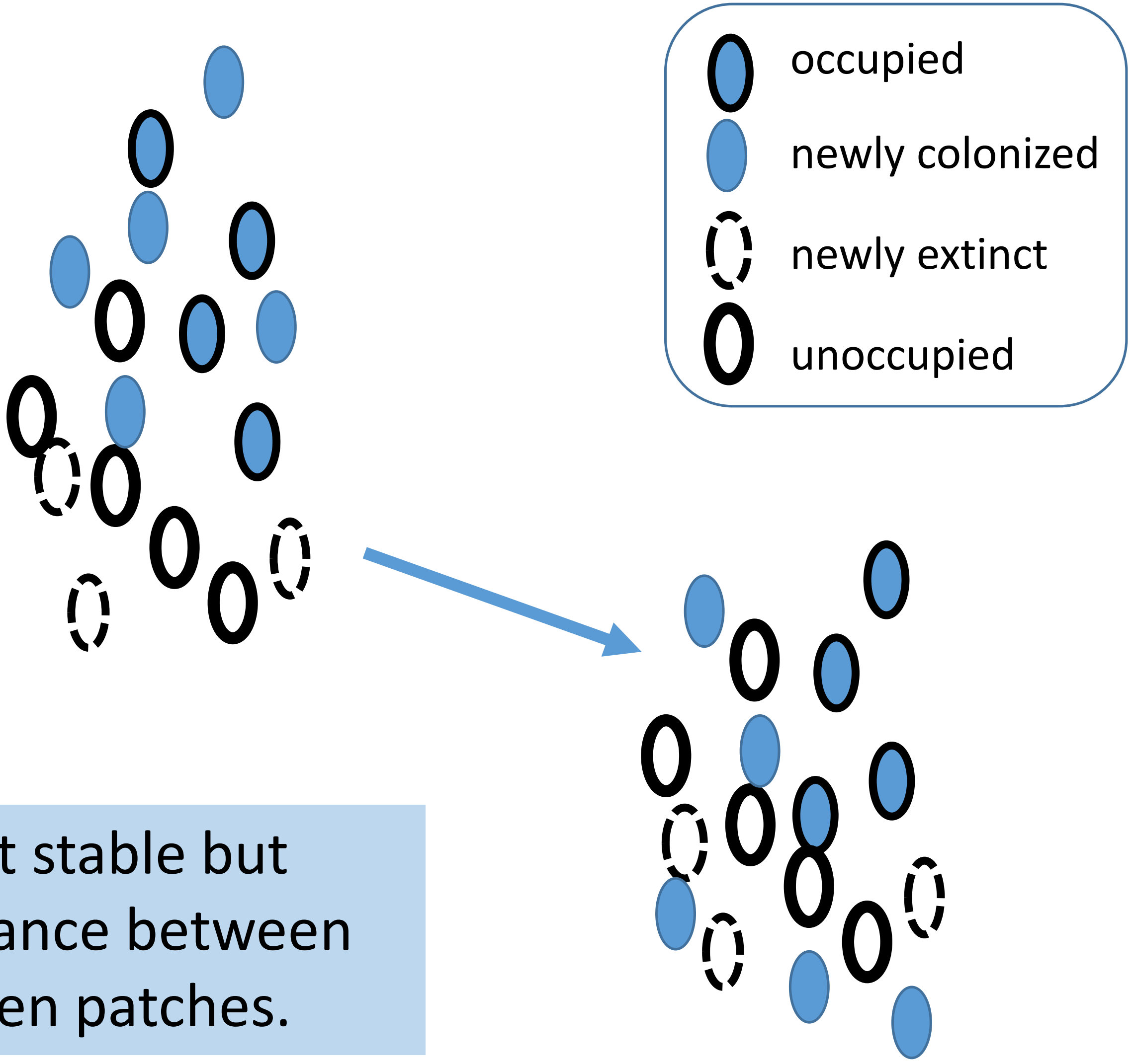


Preliminary Information-Subject to Revision. Not for Citation or Distribution

Oysters live in a habitat made up of patches that are suitable for and accessible to the individuals (i.e., a metapopulation).



Van Nouhuys 2016



Local populations are, on their own, not stable but persist in the long-run because of a balance between local extinction and colonization between patches.

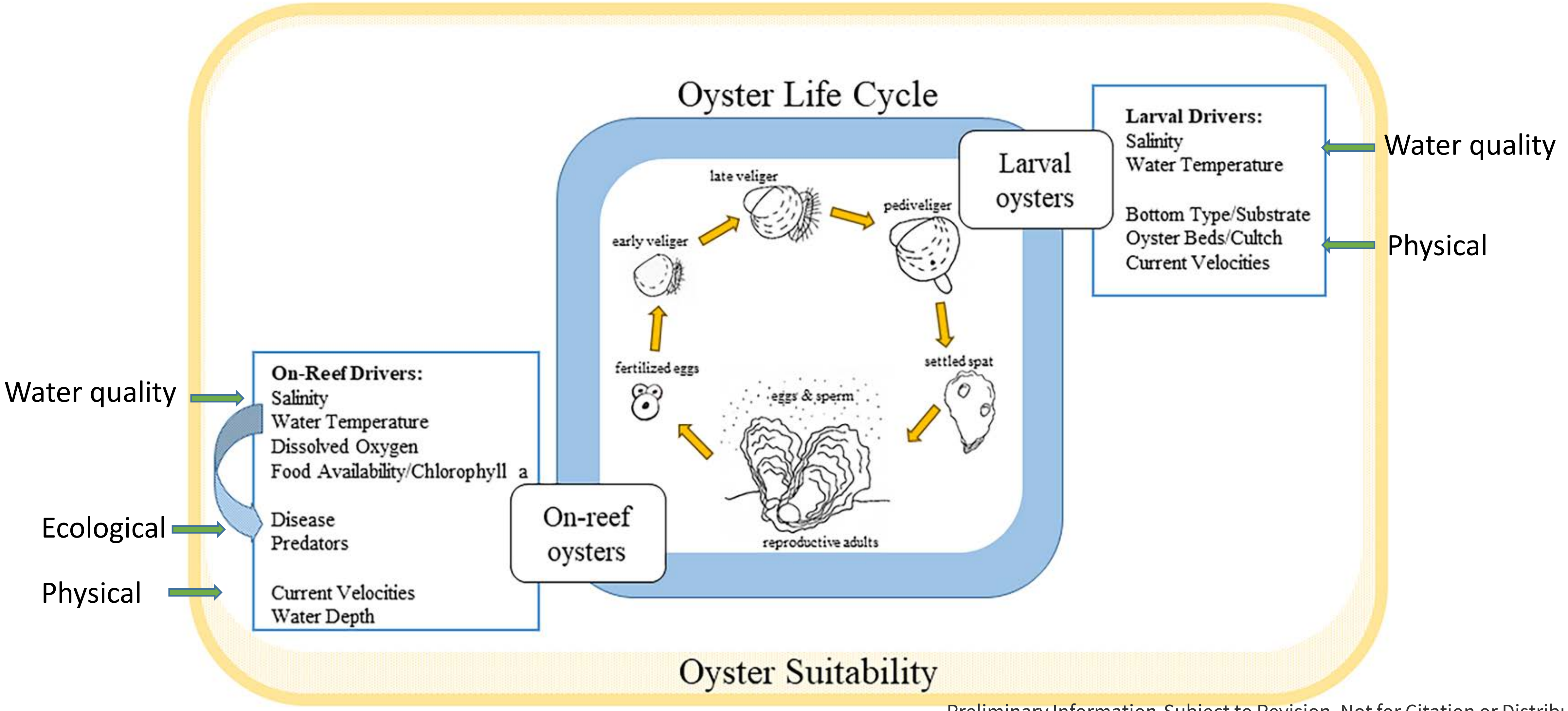
Conservation and restoration science demonstrate connectivity promotes species and conserves ecological functions.

Single reef investments ignore:
- Necessary connectivity
- Dynamic environmental conditions

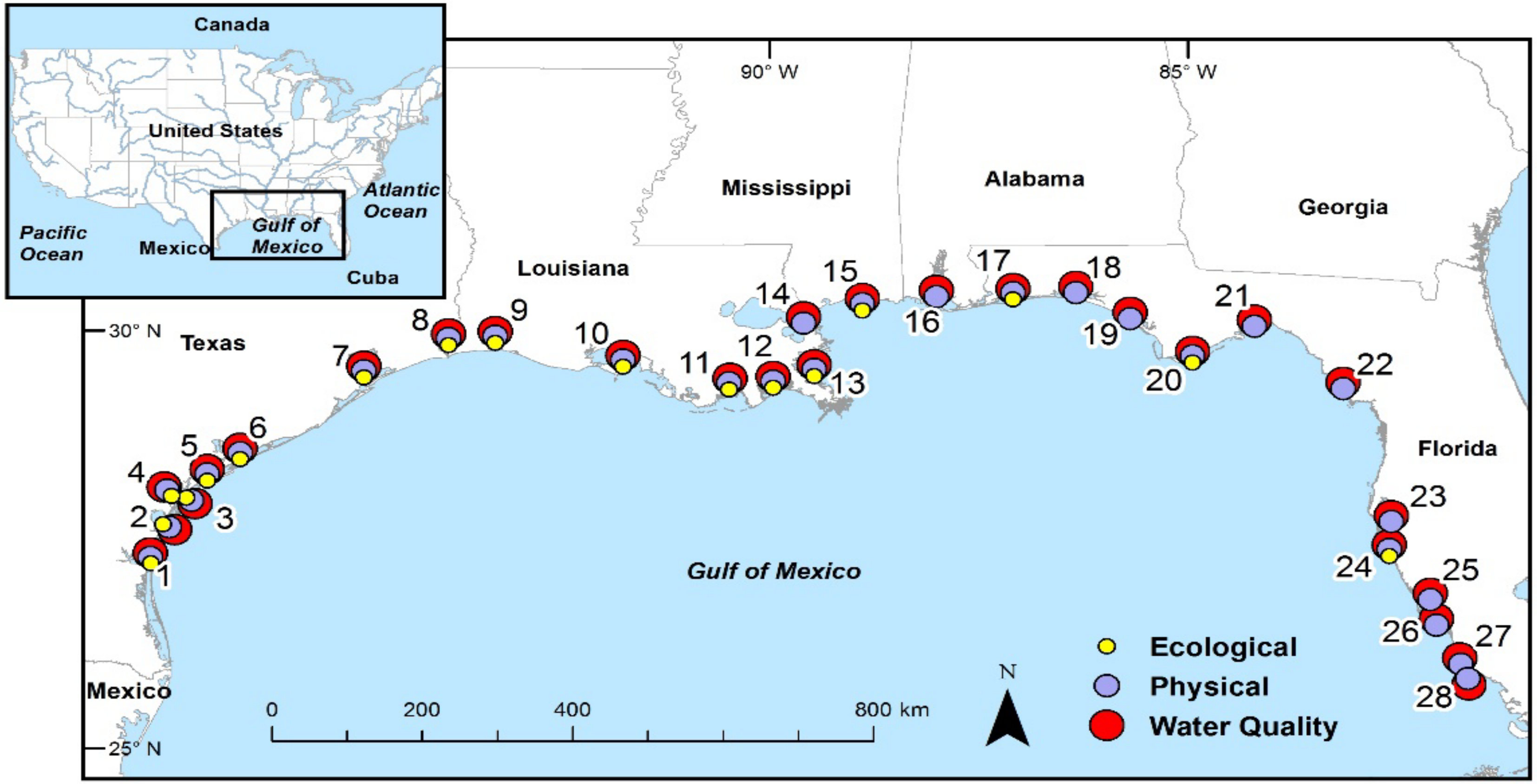
What tools exist to support oyster restoration, that specifically address connectivity of habitats, and shifting environmental conditions?

Objective: To inventory available environmental data and relevant models useful to support oyster restoration and conservation decision making in waters of the U.S. Gulf of Mexico.

Understanding the oyster life cycle provides critical information to inform restoration, habitat needs, and scale for restoration.

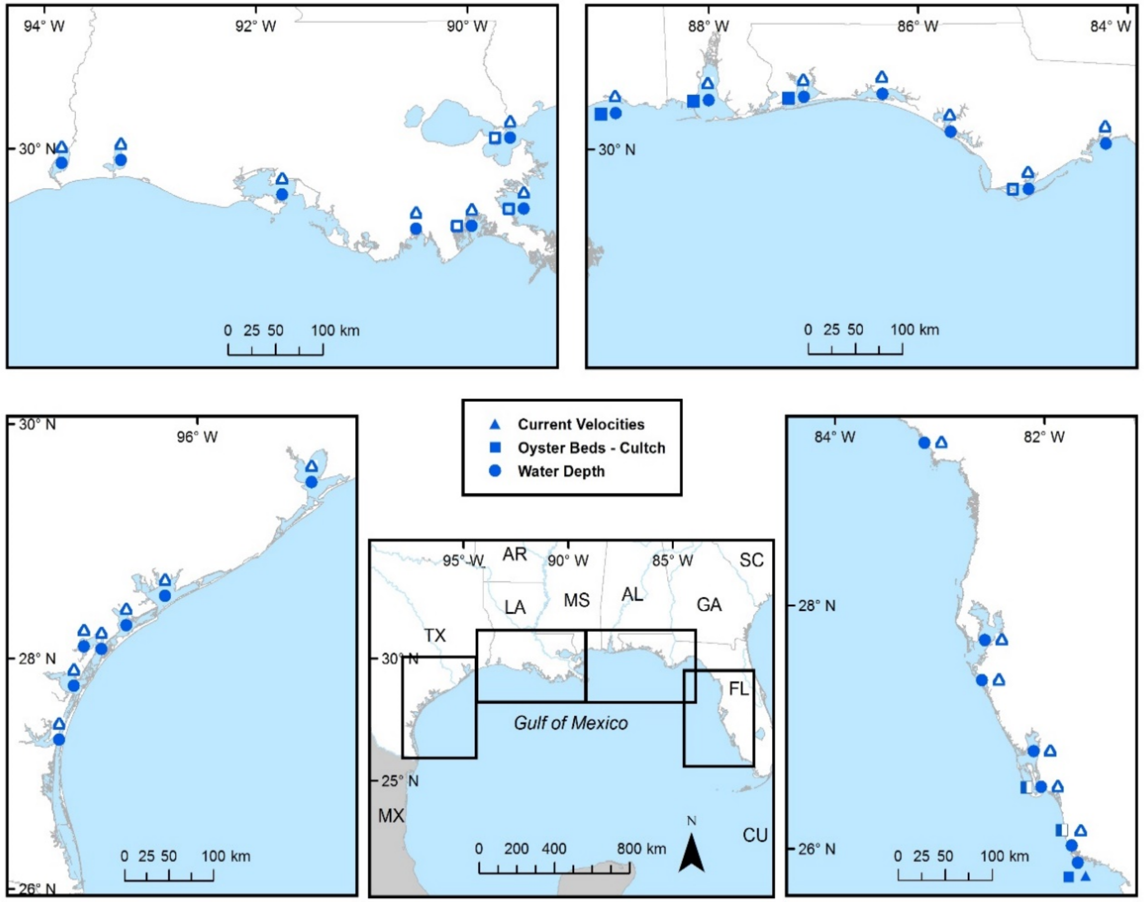


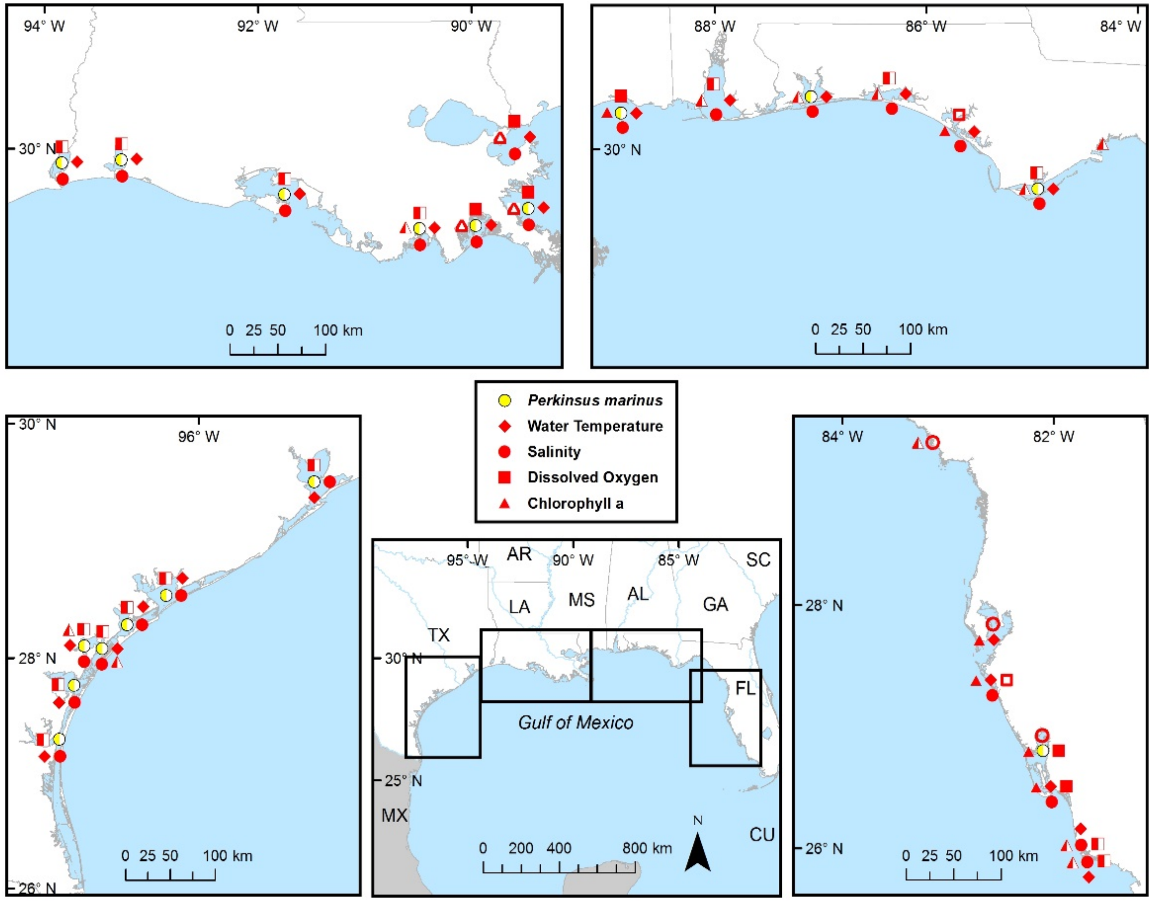
Environmental data driving the oyster life cycle includes water quality, physical and ecological data (discrete, modeled).



1. Laguna Madre/Baffin Bay
2. Corpus Christi Bay
3. Aransas Bay
4. Copano Bay
5. San Antonio Bay
6. Matagorda Bay
7. Galveston Bay
8. Sabine Lake
9. Calcasieu Lake
10. Vermilion/Atchafalaya Basin
11. Terrebonne Basin
12. Barataria Basin
13. Breton Sound
14. Pontchartrain Basin
15. Mississippi Sound
16. Mobile Bay
17. Pensacola Bay
18. Choctawhatchee Bay
19. St Andrew Bay
20. Apalachicola Bay
21. Apalachee Bay
22. Suwannee River
23. Tampa Bay
24. Sarasota Bay
25. Charlotte Harbor
26. Caloosahatchee River Estuary
27. Rookery Bay
28. North Ten Thousand Islands

Accounting of what parameters are available by estuary, identifying discrete data collections, and modeled data outputs.



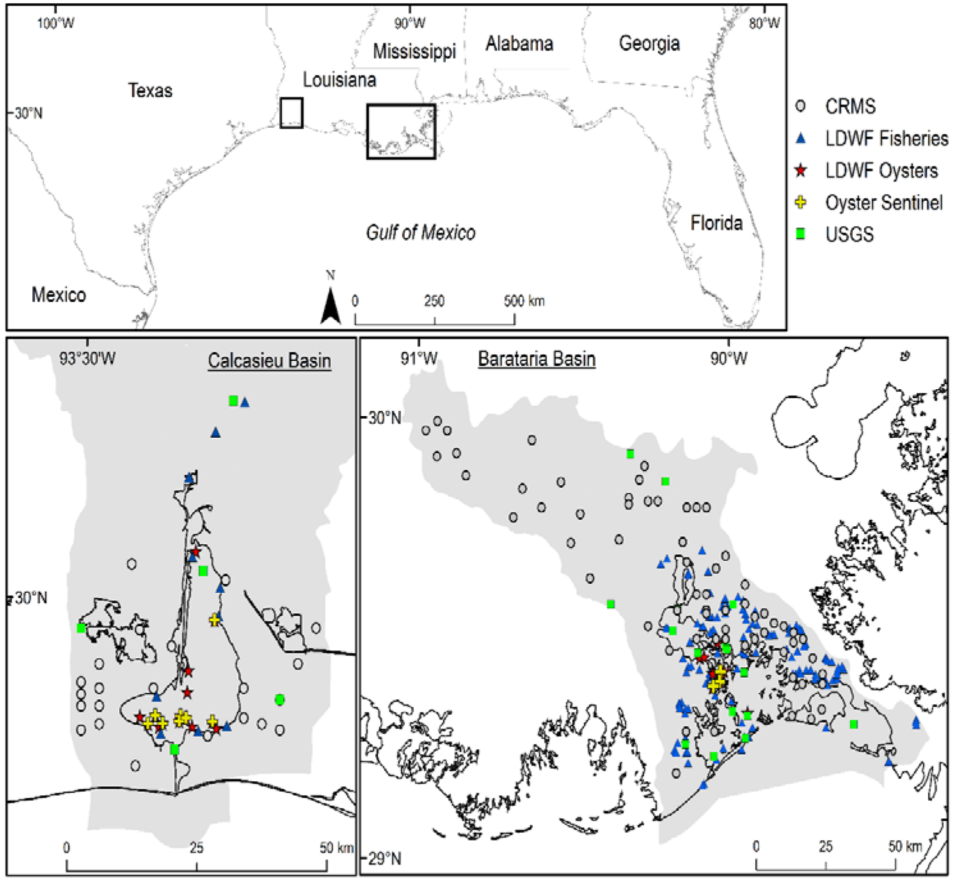


open symbol = modeled data; half-filled symbol = discrete data; solid symbol = modeled and discrete data

Existing programs and work provide a range of available data to drive oyster models.

- Significant variability in temporal and spatial coverage across estuaries impact:
  - Appropriate resolution to develop models for management purposes
  - Limit calibration and validation of models

- Hydrodynamic and water quality models built by private industry could limit availability or integration into research and management



Coordinated, spatially distributed continuous data recorders and long-term monitoring programs could inform models useful for site selection for restoration of reef networks.

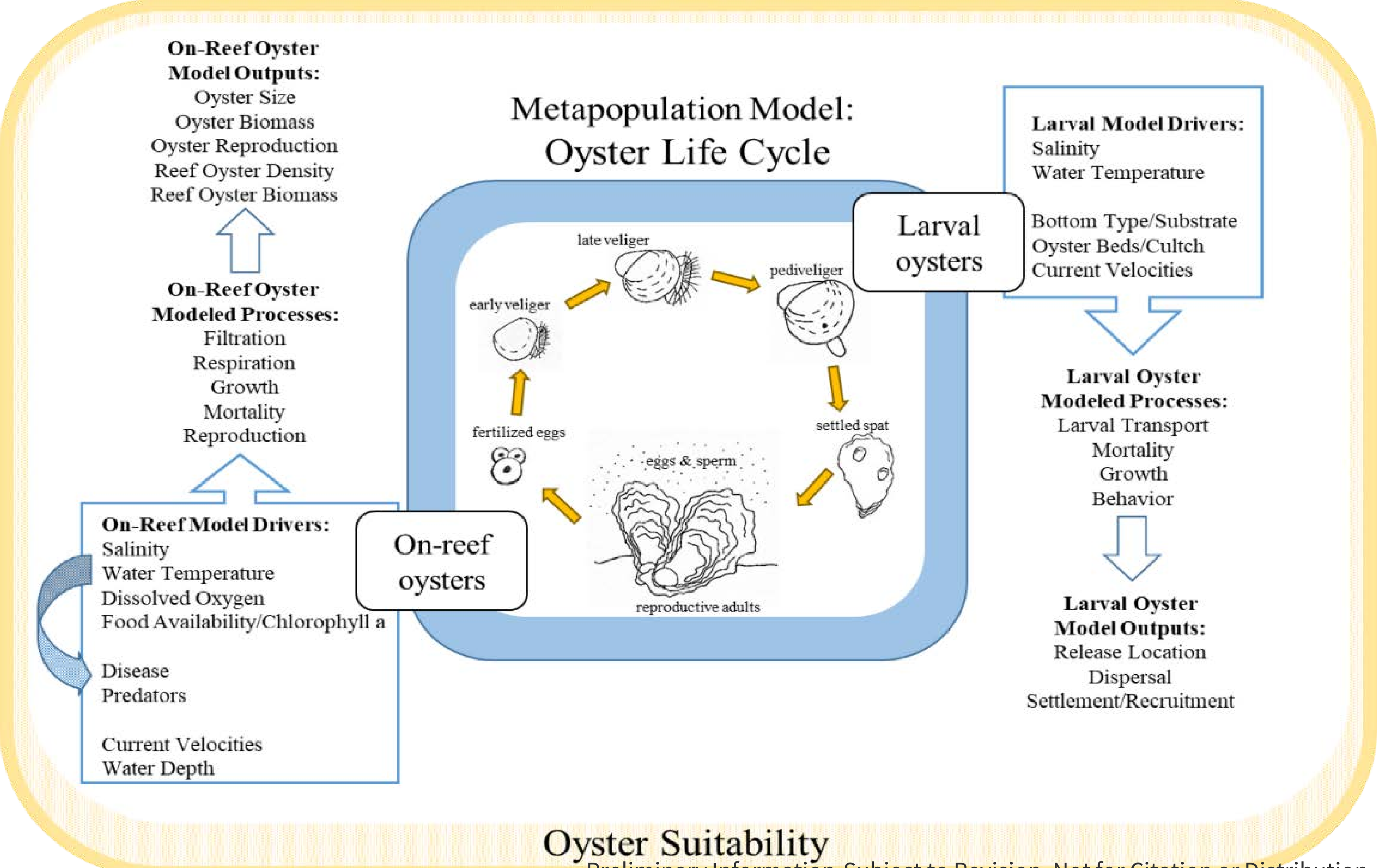
Oyster models capture different aspects of the oyster life cycle, including the connectivity of populations.

Suitability Models

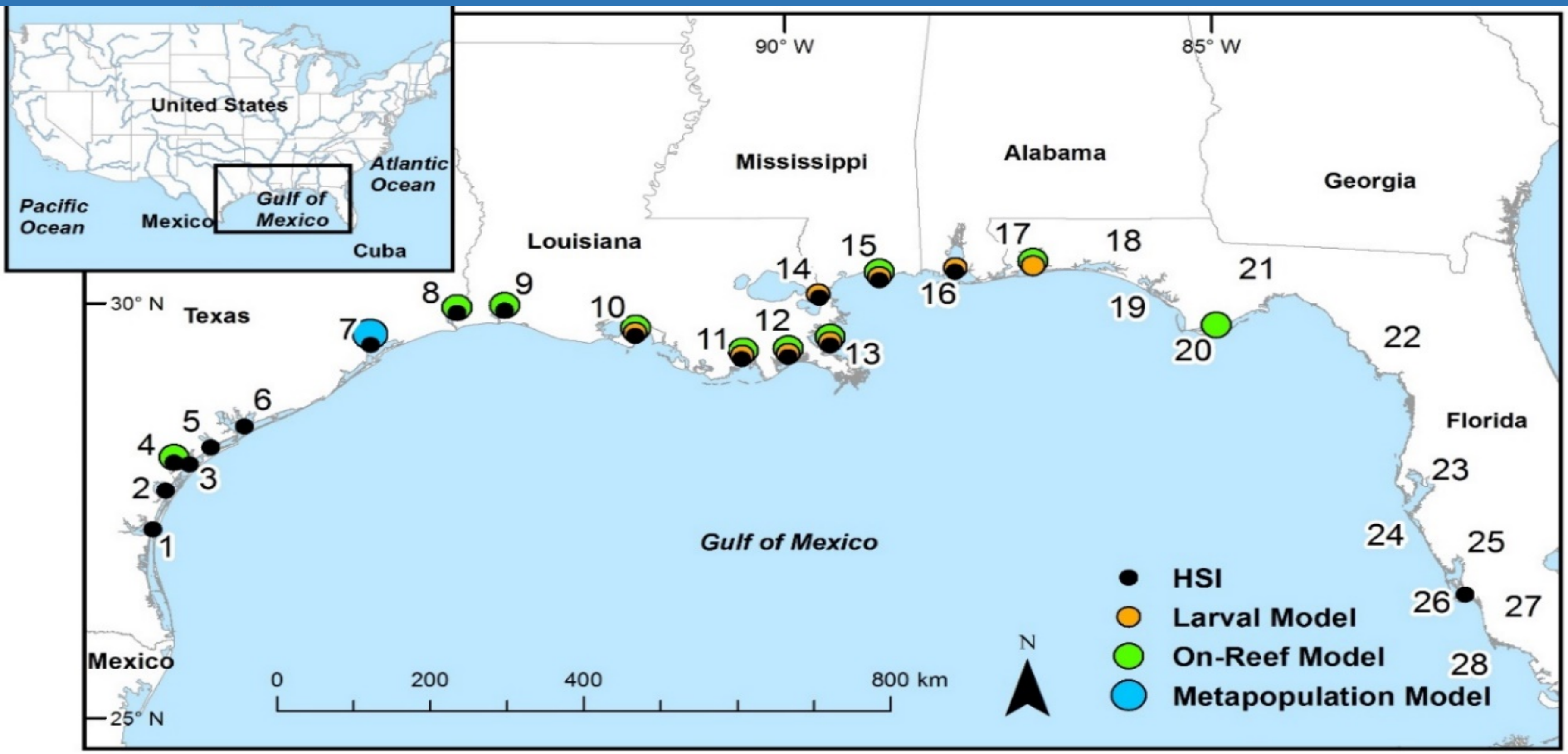
On-reef Oyster Models

Larval Models

Metapopulation Models



Oyster models are inventoried by approach and estuary.



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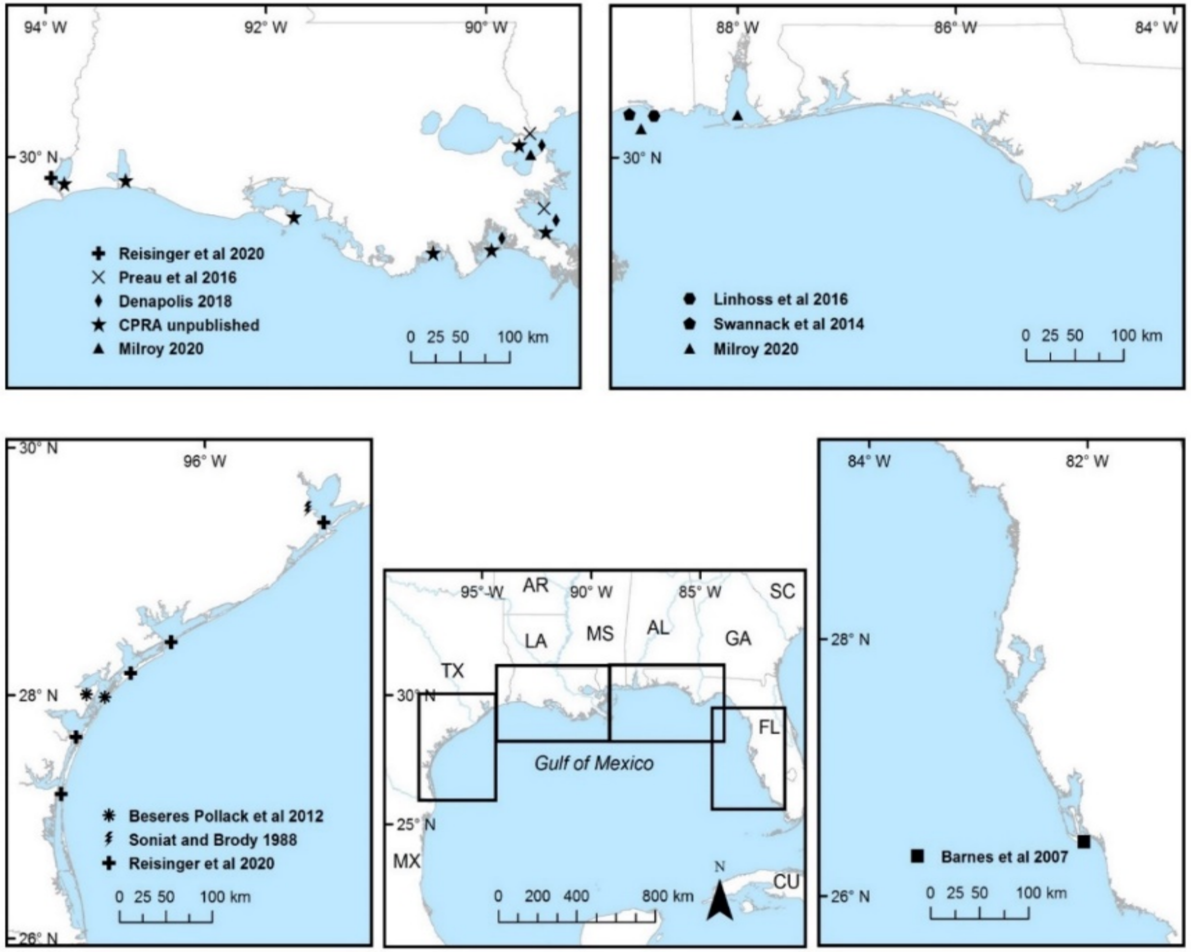
Database of oyster models

Model Approach /Part of Oyster Life Cycle	Reference	Location	Model Description and Objective	Model Input Variables	Timeframe and Sources for Input Data in Modeling Study	Modeled Processes	Model Output Variables	Spatial Description	Temporal Description	Oyster Model Calibration/Validation	Coupled Model Calibration/ Validation	Applicability for Siting Broodstock Oyster Reefs	Model Accessibility and Ease of Use
Habitat Suitability Index Models													
Habitat Suitability Index	Cake 1983	Northern Gulf of Mexico (nGoM)	Discrete HSI model for larval settlement and post-settlement spat, seed and sack life stages on reefs constructed from the literature and developed to apply with field data collections in nGoM estuaries. Seminal work.	Oyster Density Predator (Density) Disease (Perkinsus marinus intensity) Salinity Bottom Type/Substrate Oyster beds/cultch	None. This was the seminal study providing a hypothesis of species-habitat relations.	Suitability functions from 0 to 1	Oyster Habitat Suitability (larval settlement) Oyster Habitat Suitability (on-reef oysters)	None - original discrete oyster HSI model proposed for field validation across all of the nGoM	Single HSI score for specific location based on seasonal, annual and/or long-term data	None for this original HSI publication, but used for many of the below cited, validated models.	Not applicable	Provides easy to use means to assess suitability of habitat for oysters at specific locations. Ability to examine suitability for predicted future conditions easy.	Easy to construct and communicate. Most recent HSIs have been adapted from Cake 1983 and Soniat and Brody 1988

HSI models describe the suitability of a location to support oysters.



PROS

- Widely available
- Flexible
- Easy to spatialize

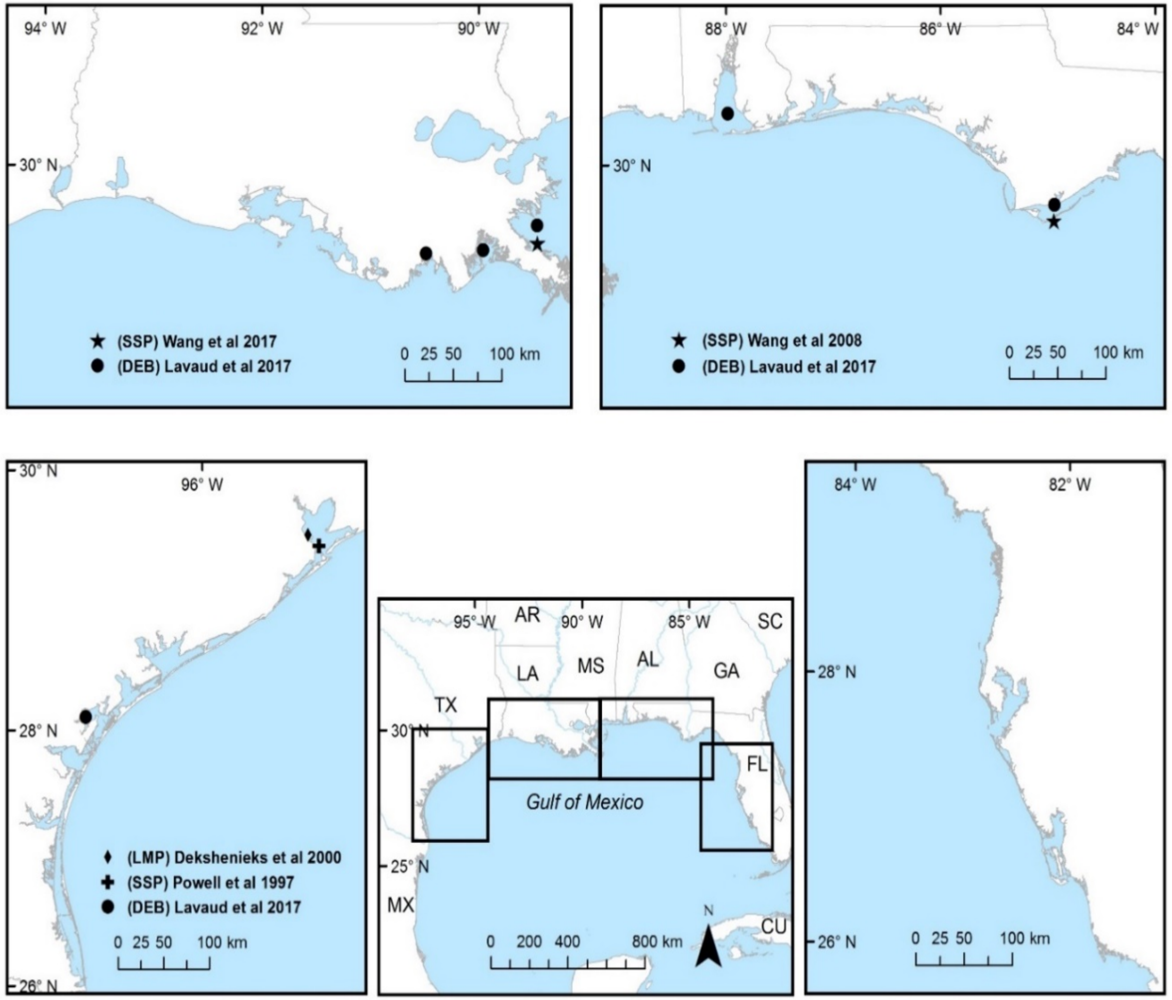
CONS

- Lack accuracy due to broad thresholds and tolerances
- Lack of larval suitability to assess connections
- Don’t handle complex interactive effects well

NEXT STEPS, CHALLENGES

- Develop spatial platform
- Invest in larval suitability habitat investigations to add connectivity component (see Milroy 2020)
- Include all variables via stakeholder needs with flexible parameters and ability to turn on/off

On-reef oyster models represent on-reef (sessile) oyster population vital rates.



PROS

- Detailed predictions of on-reef oyster growth, survival and reproduction
- Can be scaled to individual oyster, population or reef levels, and predict production
- Transferable with local data

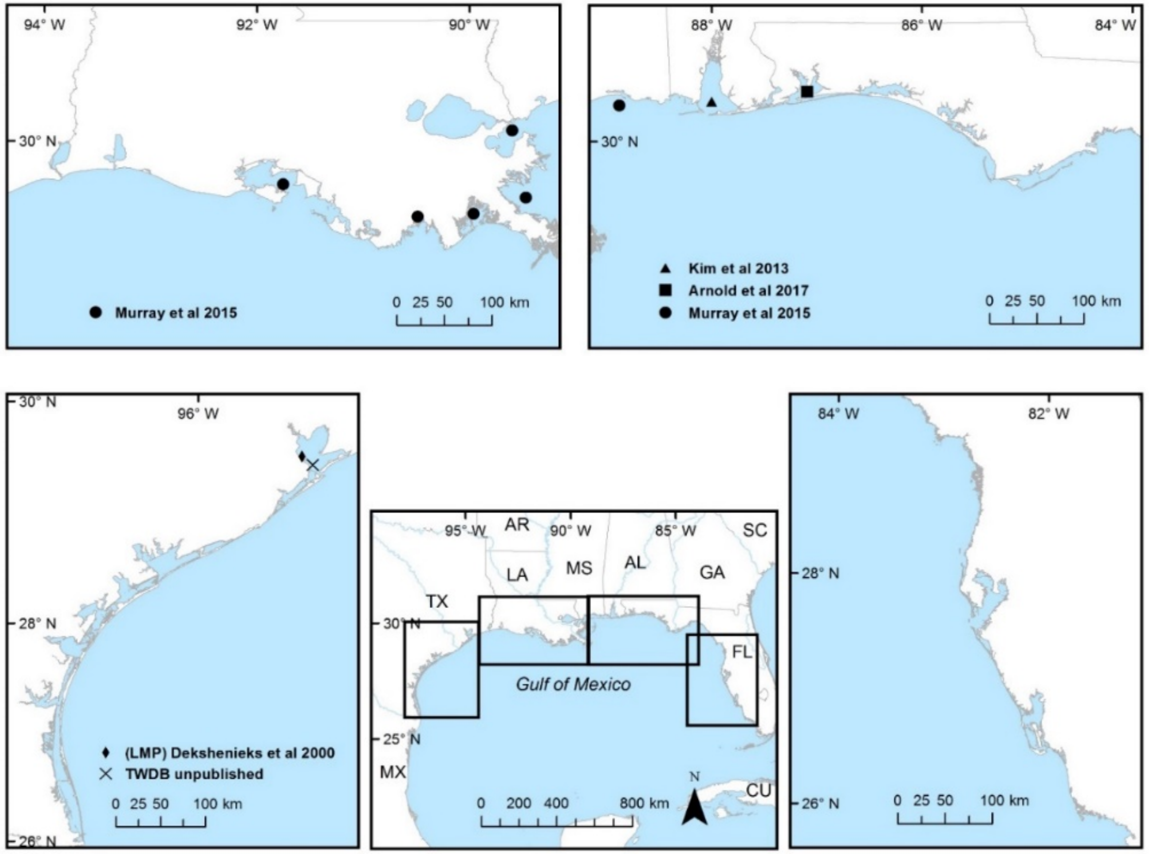
CONS

- Validation and calibration depends on local field data for oyster populations
- Fails to incorporate recruitment, thus lacks ability to examine reefs over multiple years

NEXT STEPS, CHALLENGES

- Develop single mechanistic model for GoM populations with estuary specific data to provide a powerful tool
- Integrate or develop reef/habitat maintenance component

Larval transport models provide information to support site selection related to recruitment and reef connectivity.



PROS

- Demonstrates reef connectivity
- Can be driven by local hydrodynamic models

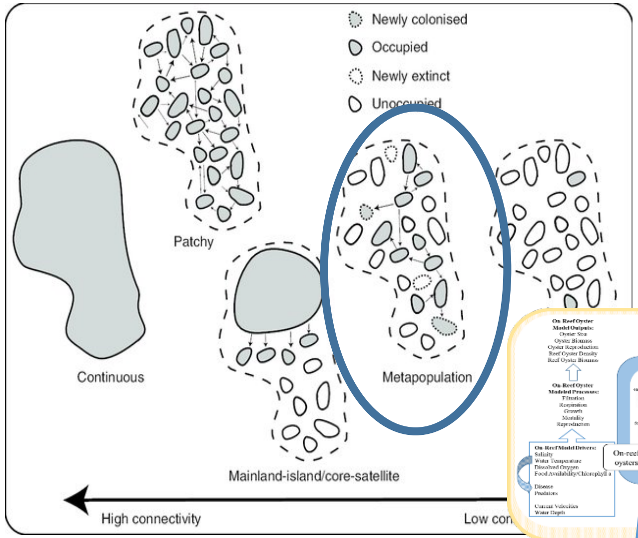
CONS

- Limited data on larval tolerance and survival to changes in environment.
- Limited understanding of larval behavior
- Dependent on fine-scale hydrodynamic models

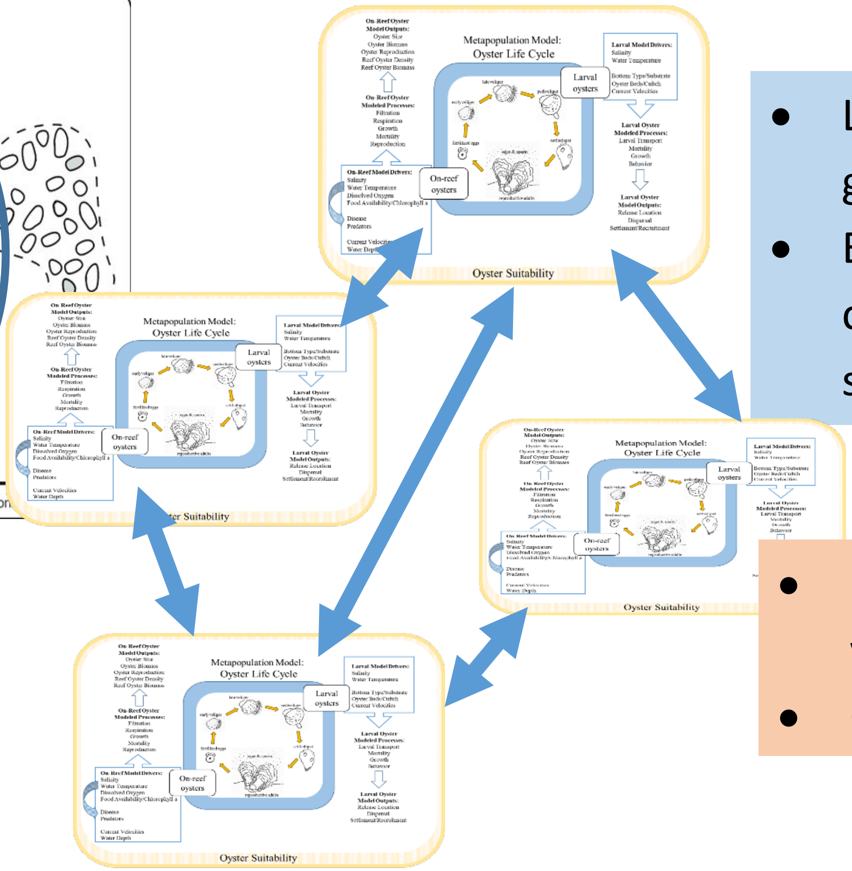
NEXT STEPS, CHALLENGES

- Investment in larval tolerance and thresholds for survival
- Investment in larval behavior studies
- Requires availability of fine-scale hydrodynamic models across areas of interest
- Current development of new approach using a suitability index for larvae may provide valuable tool

Metapopulation approach (coupled larval transport and on-reef oyster models) informs goals of enhanced connectivity and accounts for dynamic conditions.



Van Nouhuys 2016



PROS

- Links larval movement with reef recruitment, and on-reef growth and reproduction
- Enables multi-generation analyses, assessments of connectivity of reefs, identification of broodstock or sanctuary locations

CONS

- Extensive effort and data to construct, test, calibrate and validate model
- Only one example currently

NEXT STEPS, CHALLENGES

- Approach could help move from single reef focused management to management of a network of reefs
- Metapopulation models could help inform site selection for restored reefs

Final thoughts on steps to inform restoration and conservation of oyster resources across the U.S. Gulf of Mexico waters.

- Development of a general geospatial HSI modeling framework could be applied consistently across estuaries
  - Guide restoration practitioners in determining suitable habitat based on available data
  - Requires development of larval suitability and larval input and output components to inform reef connectivity
- Coupled larval transport and on-reef metapopulation model requiring only estuarine specific calibration for local oyster populations and hydrodynamic models
  - Provides greatest detail and level of understanding, but requires significant up-front investment
  - Likely less accessible, more data-intensive, and requires some expertise to use
- Development of single modeling platforms provide flexible tools that are adaptable to any estuary
- Useful to examine different scenarios and outcomes within one estuary, but also to compare across estuaries and region

La Peyre MK, Marshall DA, Sable S. 2020. Oyster model inventory: Identifying critical data and modeling approaches to support restoration of oyster reefs in U.S. Gulf of Mexico waters. Coming soon!

- Provides spatial layers indicating data and models available by estuary
- Provides database documenting existing and published relevant eastern oyster models
- Provides database documenting existing discrete and modeled water quality, physical and ecological data driving oyster models
- Summary report of the eastern oyster life cycle, drivers, and models.