Disentangling coral disease and coral larvae connectivity to inform coral reef restoration in Florida.

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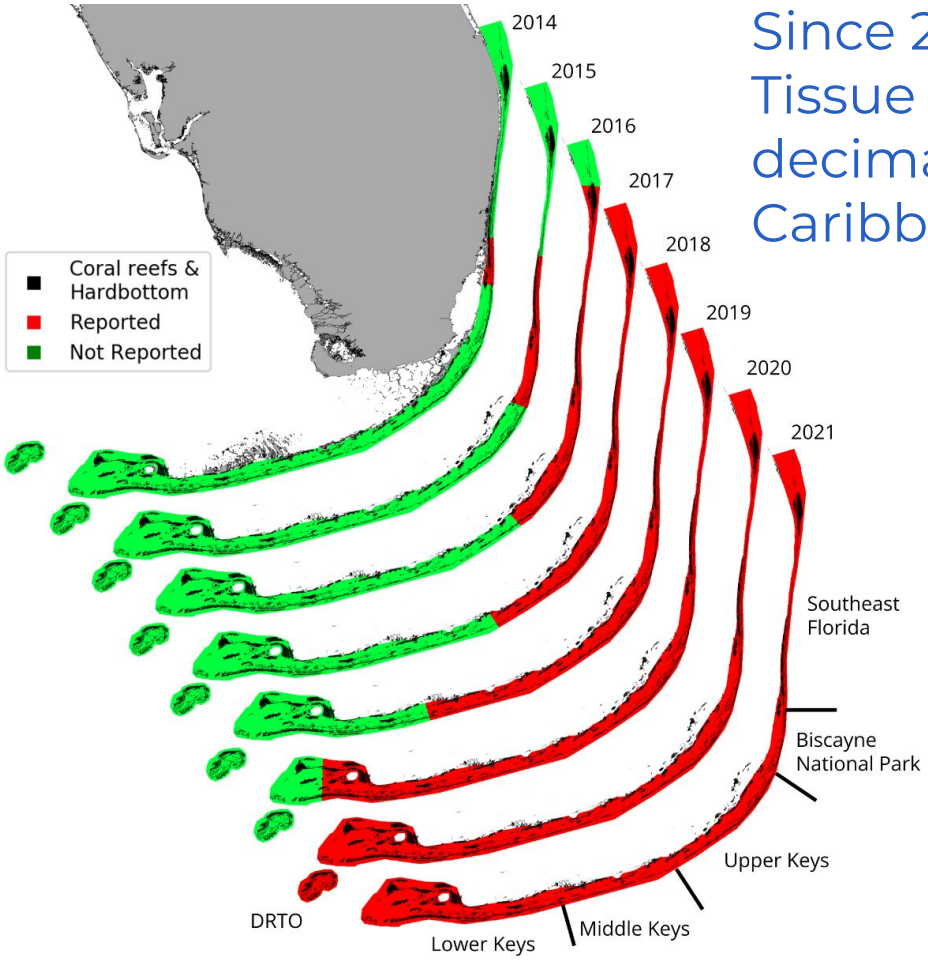


Since 2014, the outbreak of Stony Coral Tissue Loss Disease (SCTLD) has been decimating corals in Florida and the Caribbean

Worst coral disease outbreak **on record**

- At least 22 reef building species affected
- Decline in living coral tissue area of ~60% on impacted reefs.
- Up to a 95% decrease in density of susceptible species on affected reefs

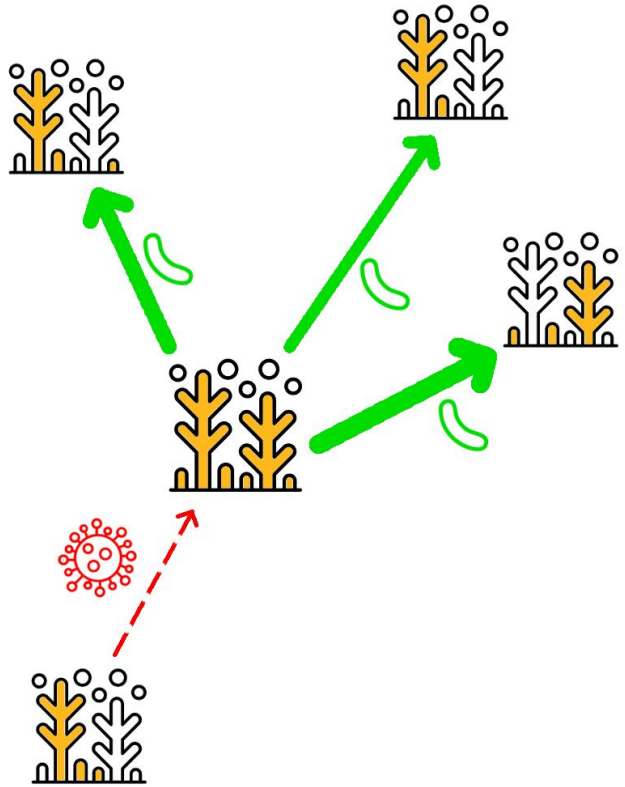
Evidence of **waterborne** disease transmission

It is thus urgent to restore reefs while preventing SCTLD to strike back using **connectivity**

Larval exchanges between reefs promote the resilience of the network

However, ocean transport processes also propagate disease agents between reefs

How can we use connectivity to better understand the propagation of SCTLD and inform coral reef restoration ?

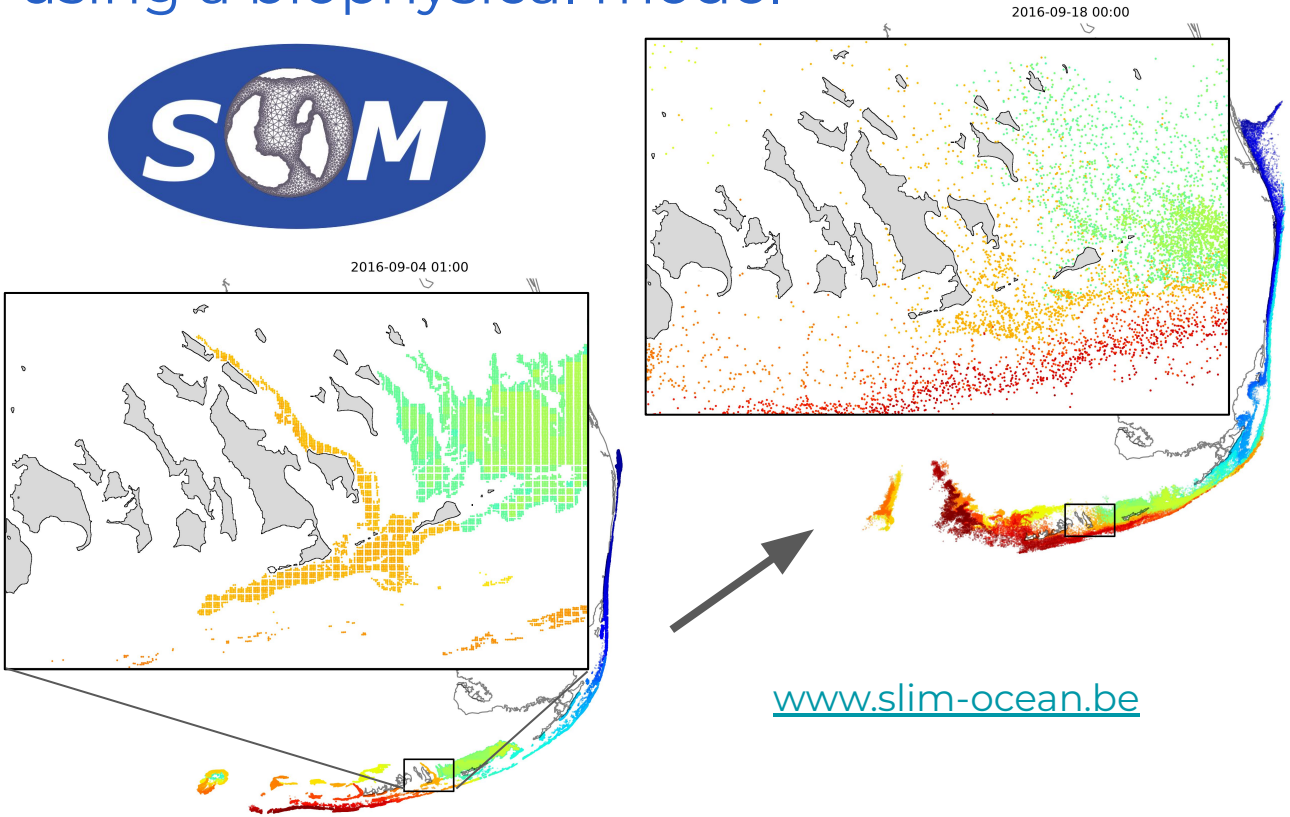


We simulated the transport of coral larvae and disease agents in Florida using a biophysical model

Monthly **connectivity matrices** for **SCTLD** between 2018 and 2021

Connectivity matrices from mass spawning events of

- *A. cervicornis*
- *C. natans*
- *D. cylindrus*
- *O. faveolata*
- *P. strigosa*



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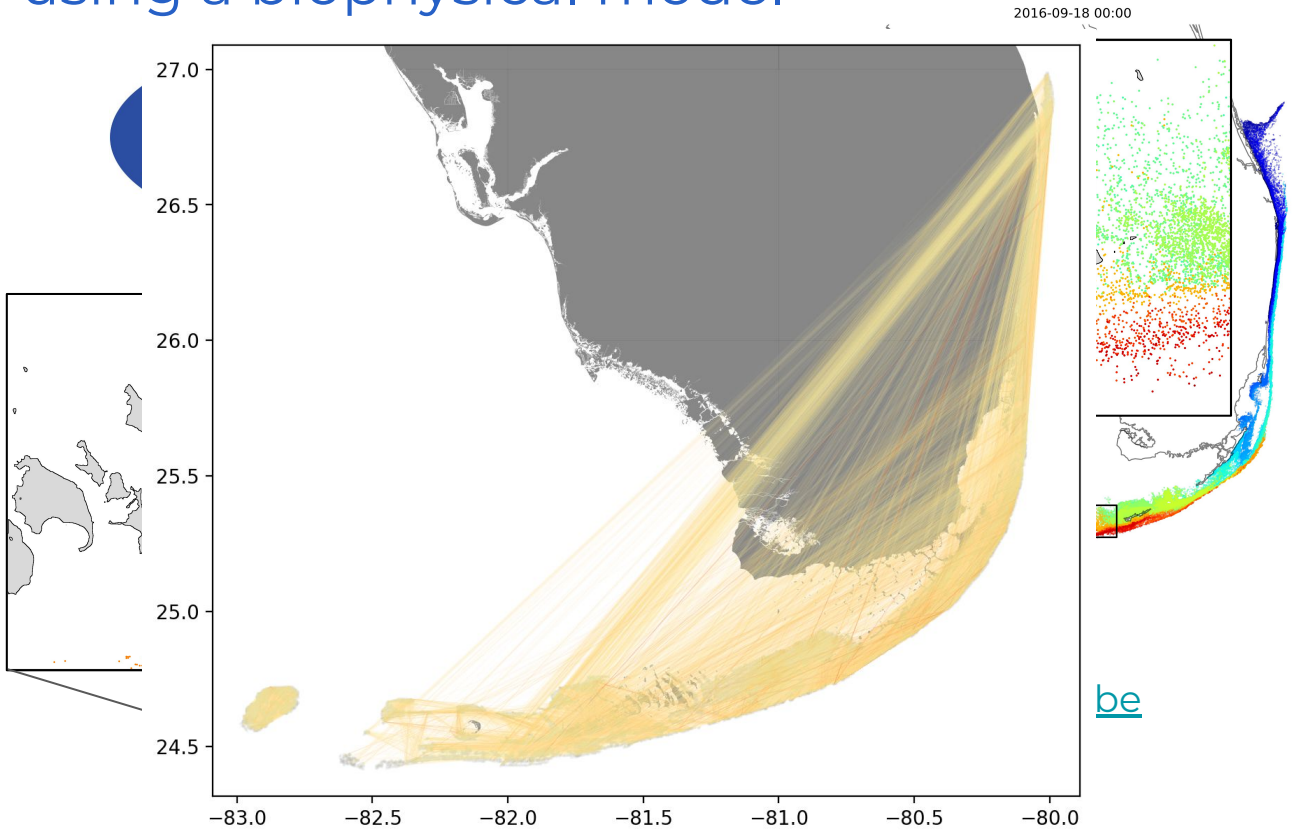

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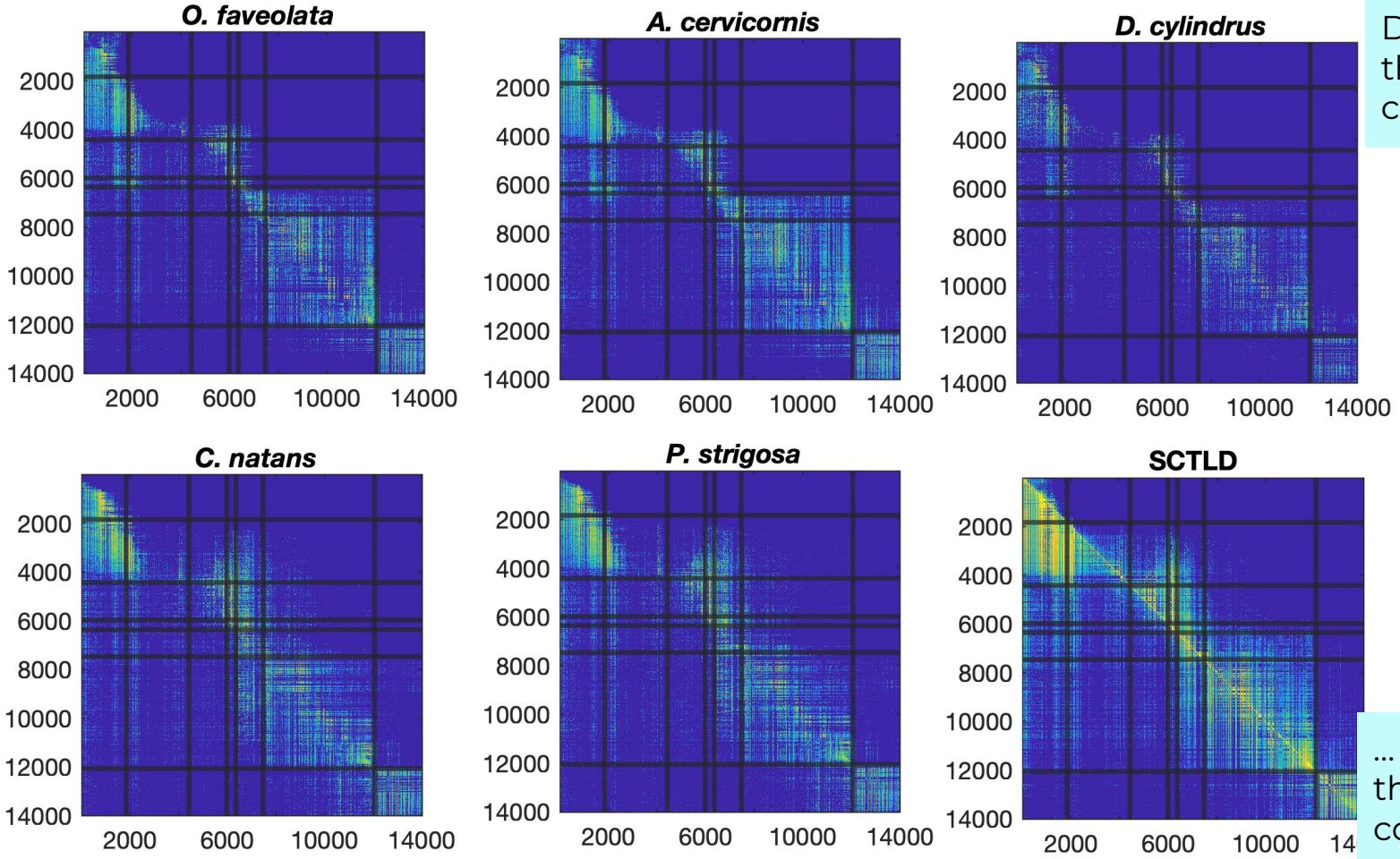


D. cylindrus has the weakest connectivity...

... and SCTLD has the strongest connectivity

We developed a restoration index combining larval and disease connectivities at each reef

Weighted disease in-degree

$$D_i^{in} = k_i^{in,dis} \times \left(\frac{s_i^{in,dis}}{k_i^{in,dis}} \right)^{\alpha^{dis}}$$

$$C_i^{out} = k_i^{out} \times \left(\frac{s_i^{out}}{k_i^{out}} \right)^{\alpha}$$

Weighted larval out-degree

Restoration index

Relative importance of disease risk (susceptibility to disease)

$$R_i = \frac{C_i^{out} - \beta D_i^{in}}{C_{\max}^{out}}$$

number of connections (= degree)

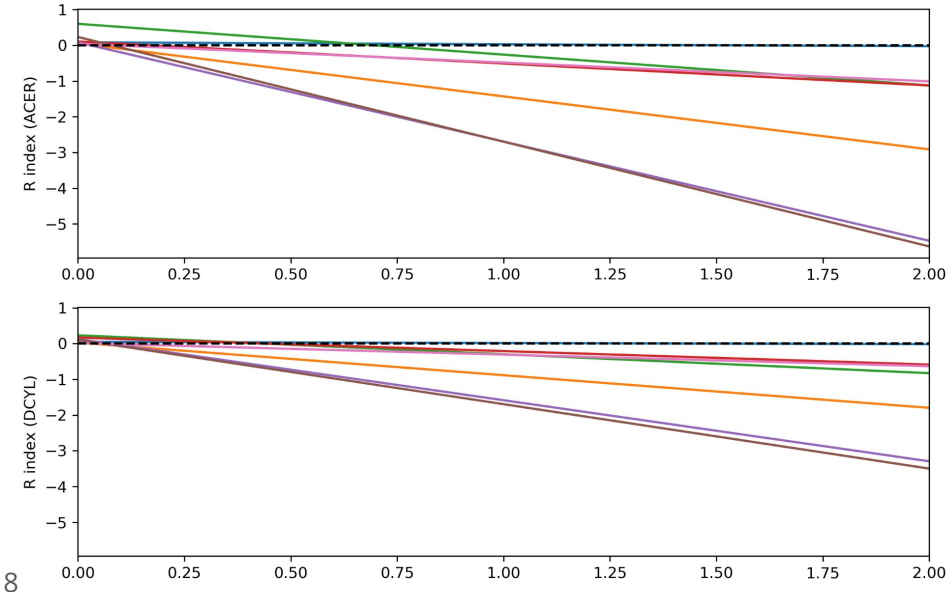
sum of connection weights

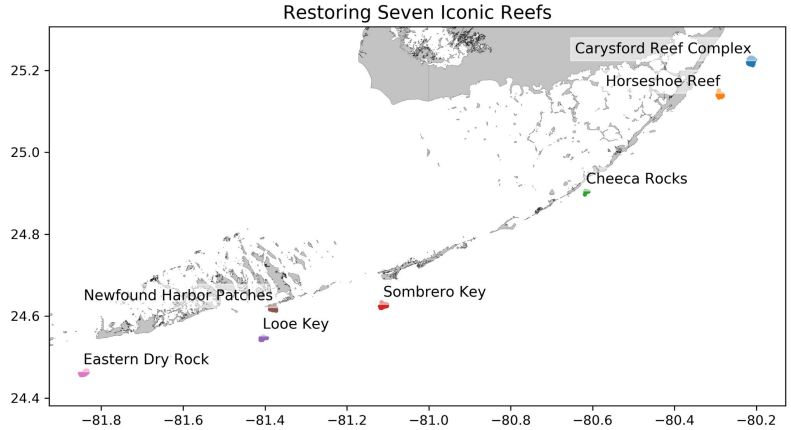
relative importance of degree versus connection weight

Large restoration index = **good supplier** of **larvae** and **poor sink** of **disease** agents

The restoration index R was used to assess the susceptibility of restored reefs to disease

Seven iconic reefs selected for restoration in the Florida Keys based on their ecological services, connectivity and genetic complexity

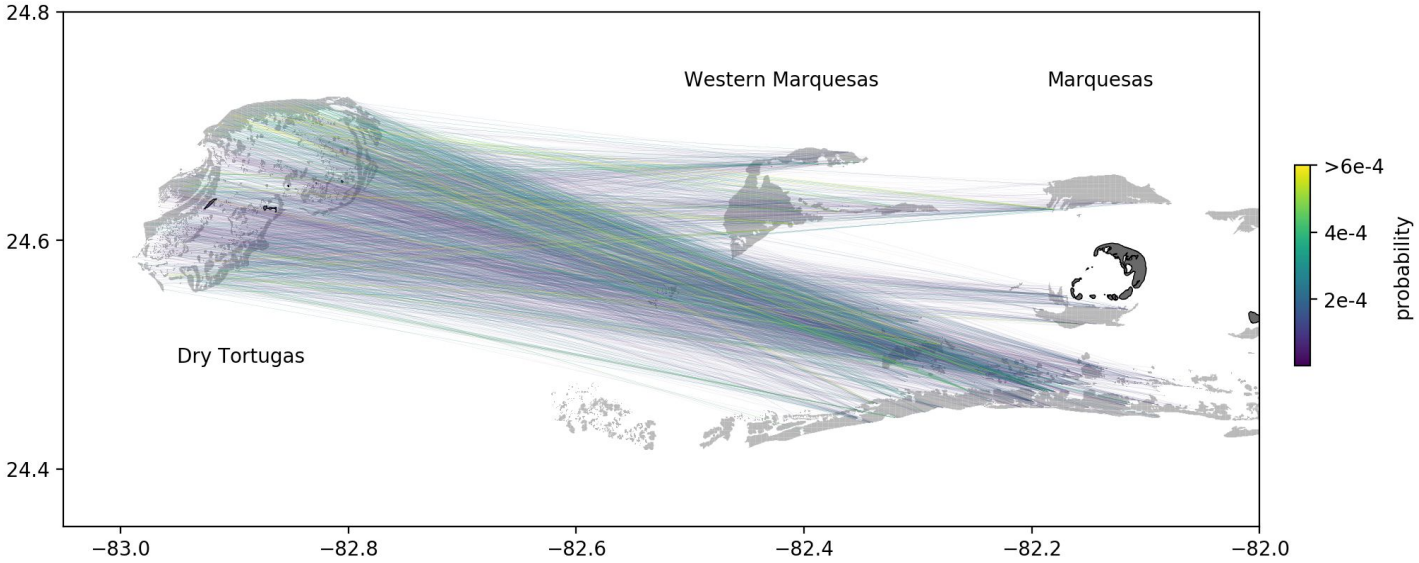




Our results suggest that:

- Carysford Reef and Cheecah Rocks are more protected against disease ($R > 0$ when $\beta < 0.4$)
- Horseshoe Reef and Looe Key are more susceptible to disease ($R < 0$ when $\beta < 0.1$)

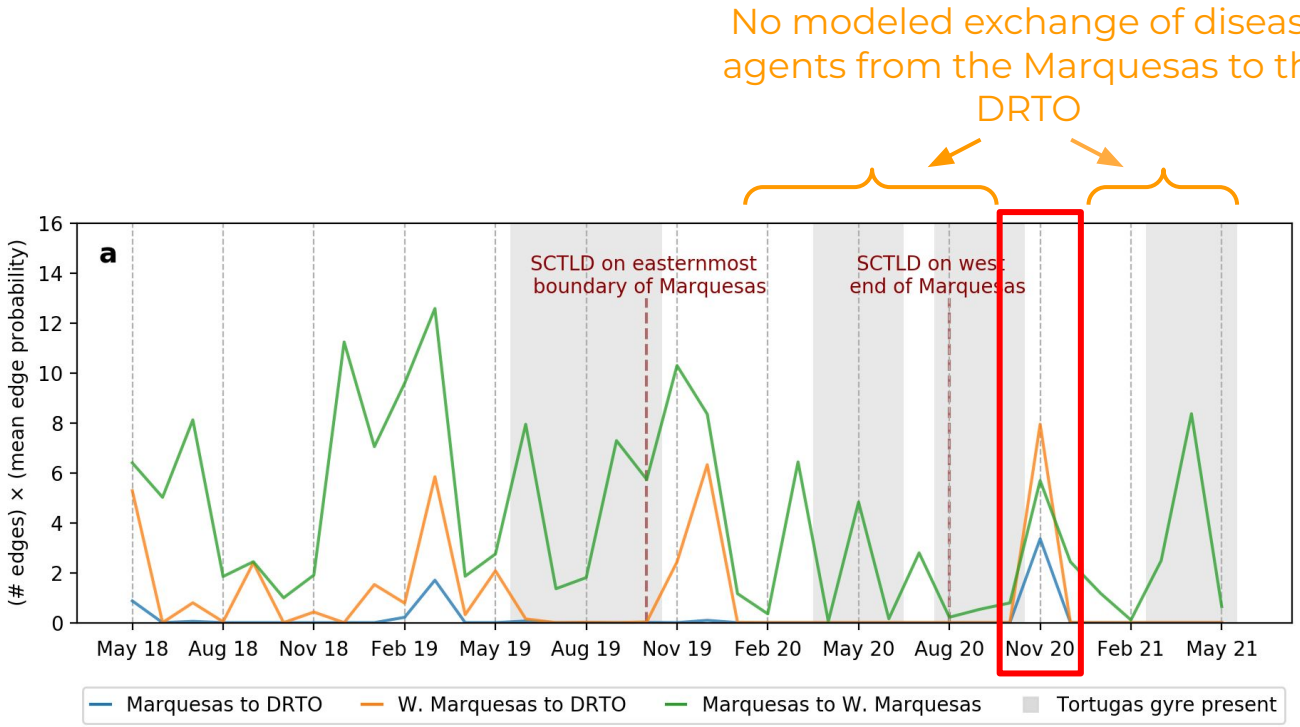
Furthermore, we studied the timing of the propagation of SCTLD in Florida using disease connectivity networks



We analyzed the temporal evolution of the number of hydrodynamic-predicted connections between the **Marquesas** and the **Dry Tortugas (DRTO)** in the disease network as well as their strength

Our results suggested that disease agents probably reached the Dry Tortugas in November 2020

Our results indicate that the connectivity between the Marquesas and the Dry Tortugas is strongly impacted by the local eddy activity



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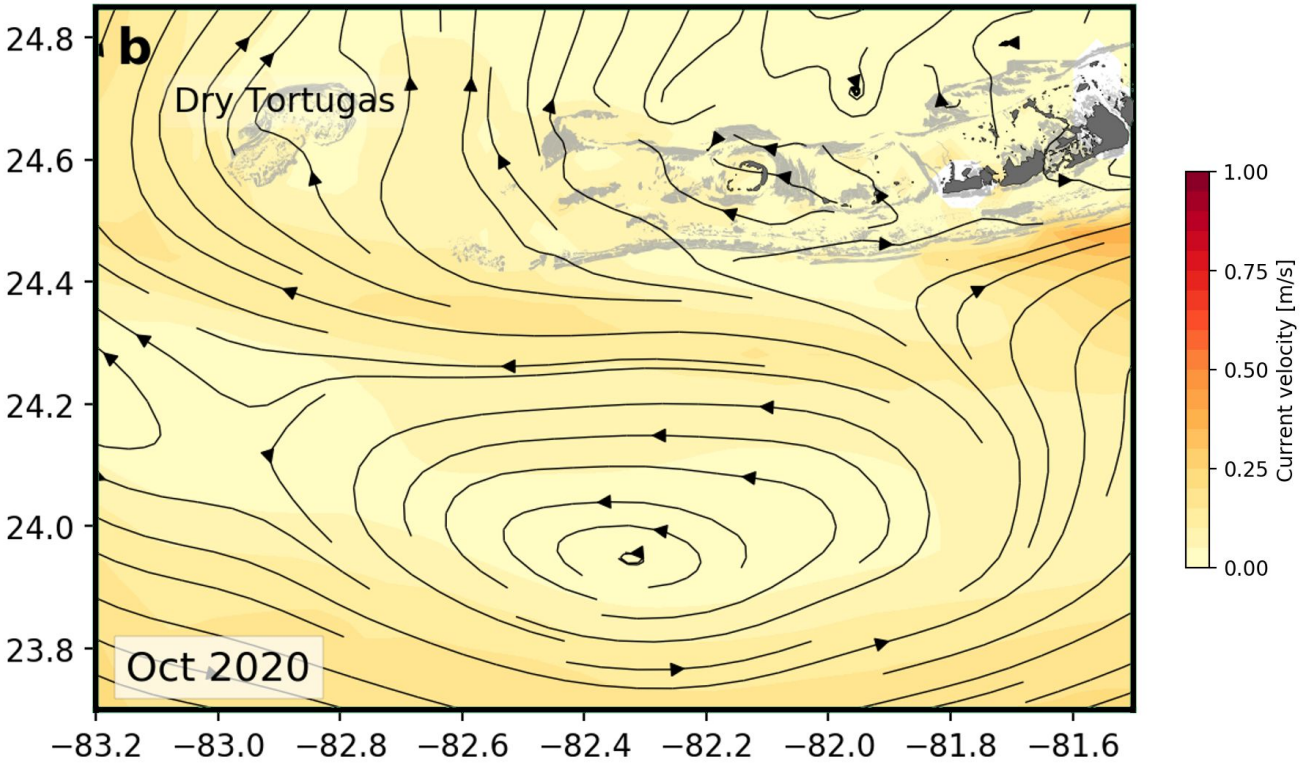
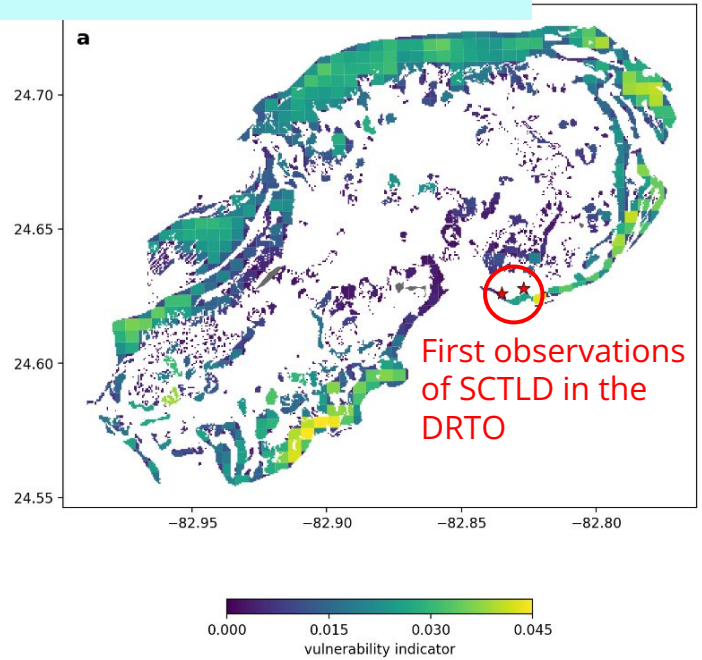
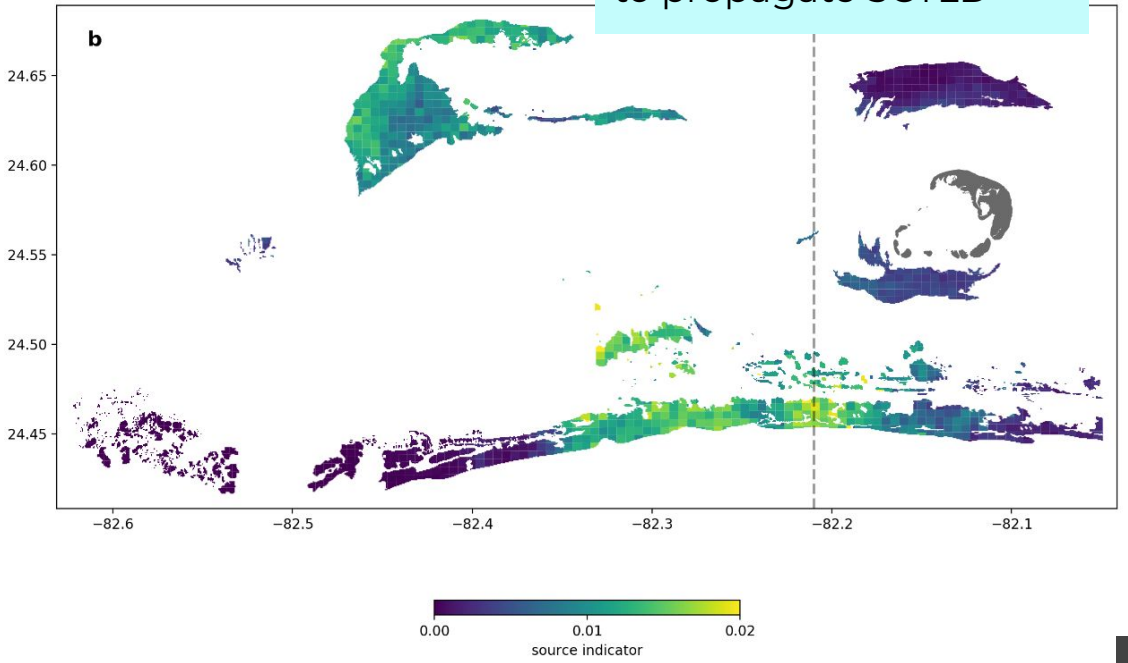


By summing the strengths of all incoming and outcoming connections, we identified the regions most likely to initiate the propagation of SCTLD to the DRTO

Reefs most likely to get affected on eastern DRTO

Reefs of the southern Marquesas most likely to propagate SCTLD



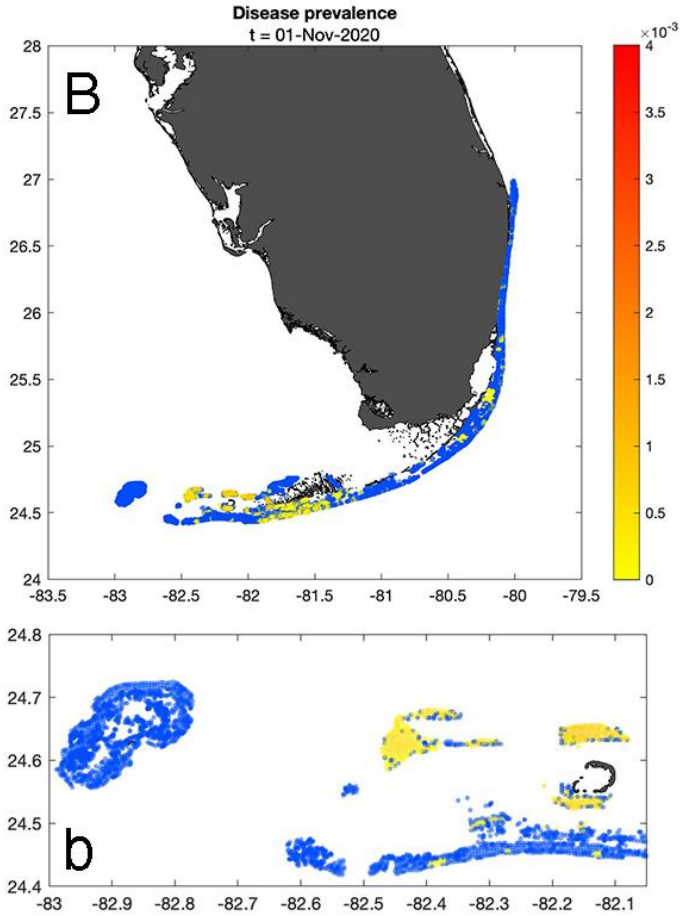


We developed a connectivity-based epidemiological model to reproduce the observed spread of the disease

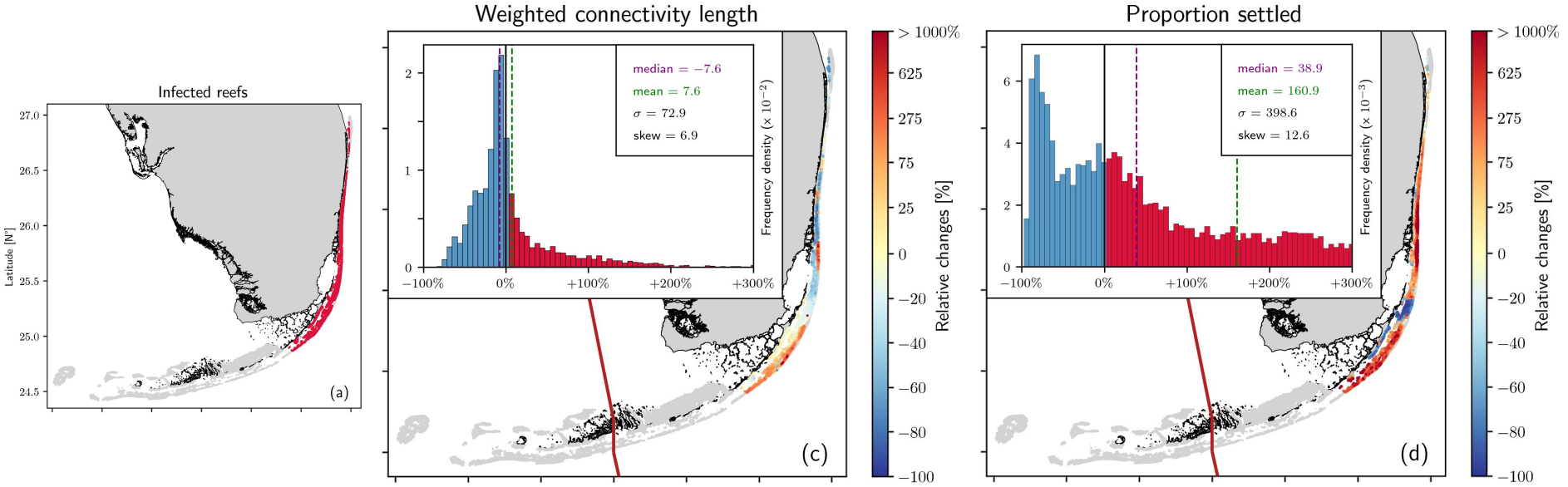
3 degrees of **susceptibility** to the disease were considered for the different coral species:

- Low
- Medium
- High

with different disease **transmission** and **mortality** rates in the model



Work In Progress: Can we use disease connectivity to evaluate the impact of Hurricane Irma on the propagation of SCTLD ?



Under the effect of the hurricane, a **larger fraction** of disease agents released near the disease front reached reefs located **further** away

In brief

We used a high resolution **biophysical model** to evaluate both **larval** and **disease connectivities** in Florida

Combining these connectivities, we identified reefs that are both **good sources of larvae** and **poor sinks of disease agents** and are thus **good candidates for restoration**

Hydrodynamic-predicted disease network can help to **understand** the **timing of the propagation** of the disease throughout Florida and the **impact of hurricanes**