

# Nitrogen-enriched discharges from a highly managed watershed intensify *Karenia brevis* blooms in southwest Florida

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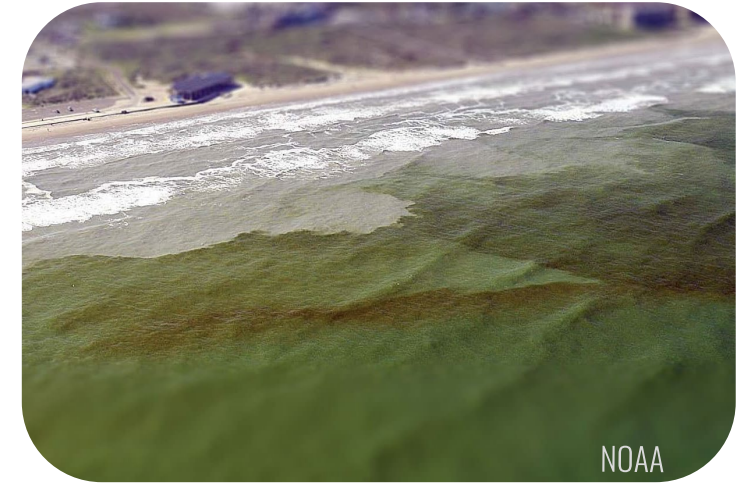
# *Karenia brevis*

The *K. brevis* organism

Impacts of blooms

Mitigation and prevention

Causal drivers





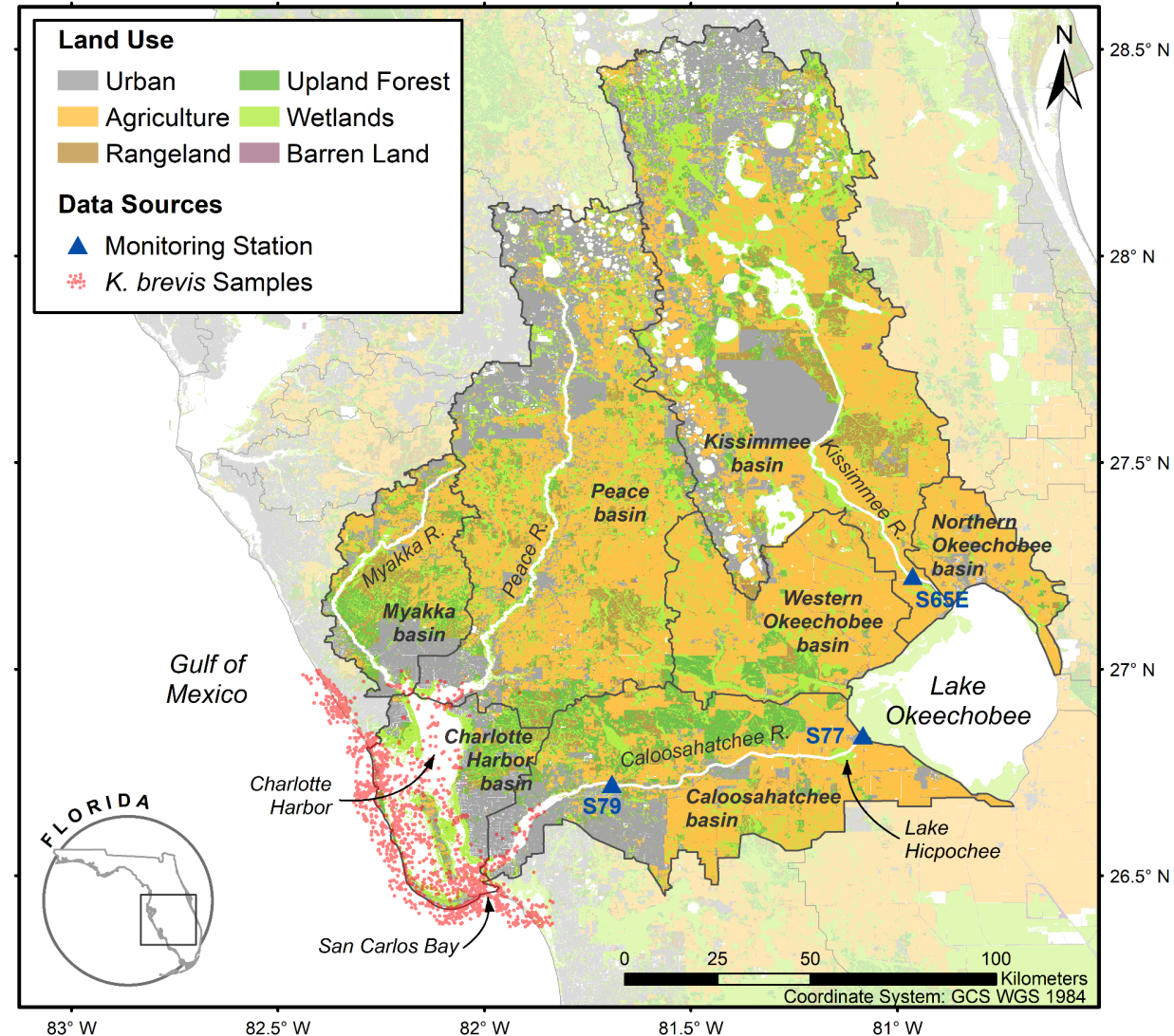
# Does human activity exacerbate *K. brevis* blooms in Florida?

**Anthropogenic intensification is physically plausible**

(Turner et al. 2006; Heil et al. 2014)

**But correlation tests have yielded mixed results**

(Dixon & Steidinger 2002; Dixon et al. 2014)



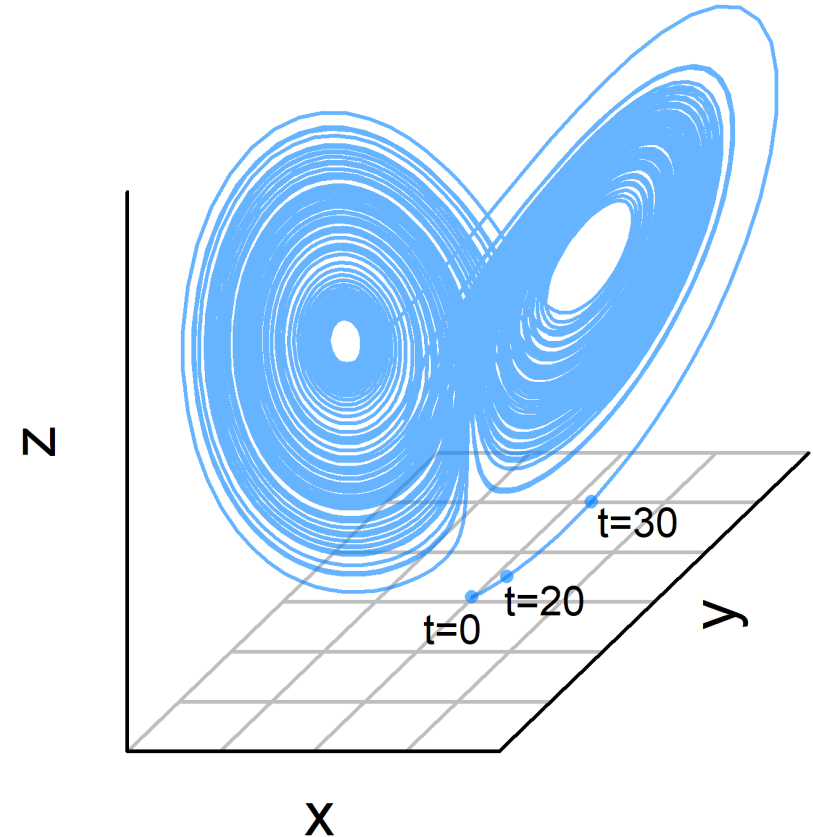
# Correlation and causality

**Correlation tests are unreliable in complex, open systems**

- **Correlation  $\neq$  causality**
- **No correlation  $\neq$  no causality**

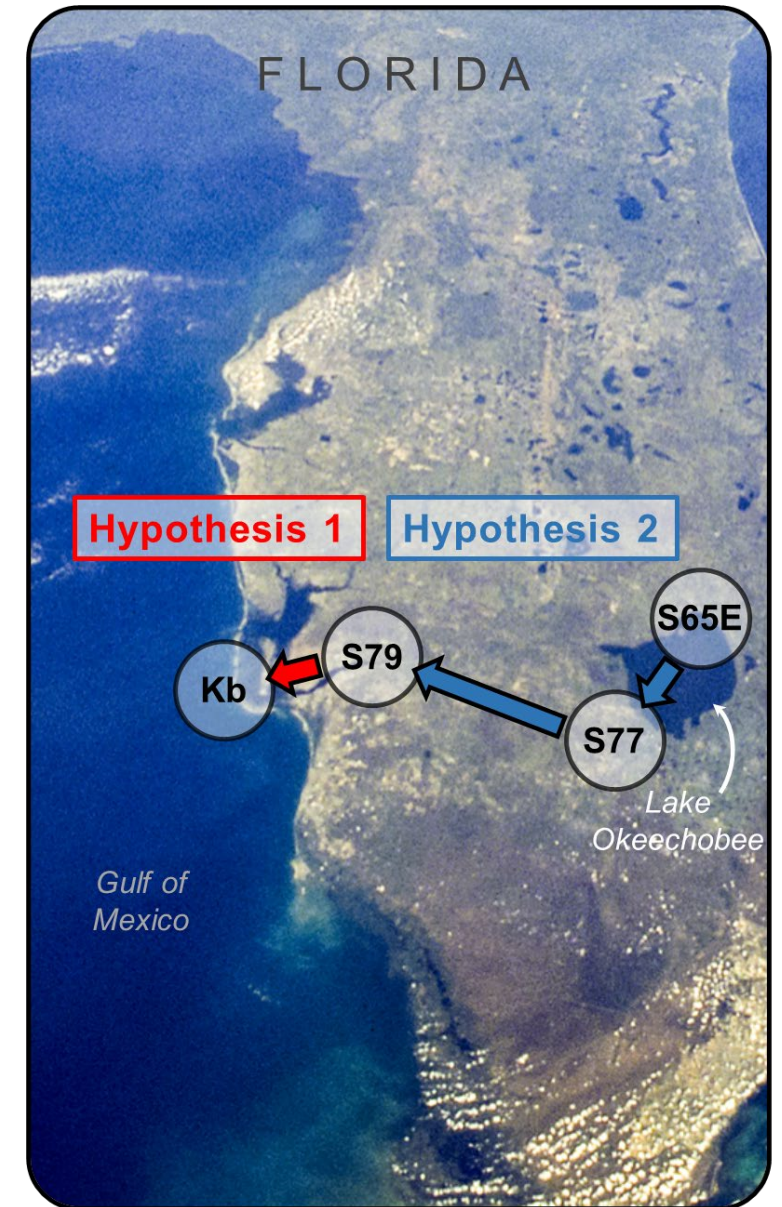
**Phase space**

- **Manifolds encode the rules governing causal interactions**
- **Analysis of manifolds respects state dependence**



# Hypotheses

1. Nutrient-enriched discharges from the Caloosahatchee River (S79) intensify *K. brevis* blooms (Kb) near Charlotte Harbor
2. This influence extends upstream to Lake Okeechobee (S77) and the Kissimmee basin (S65E)



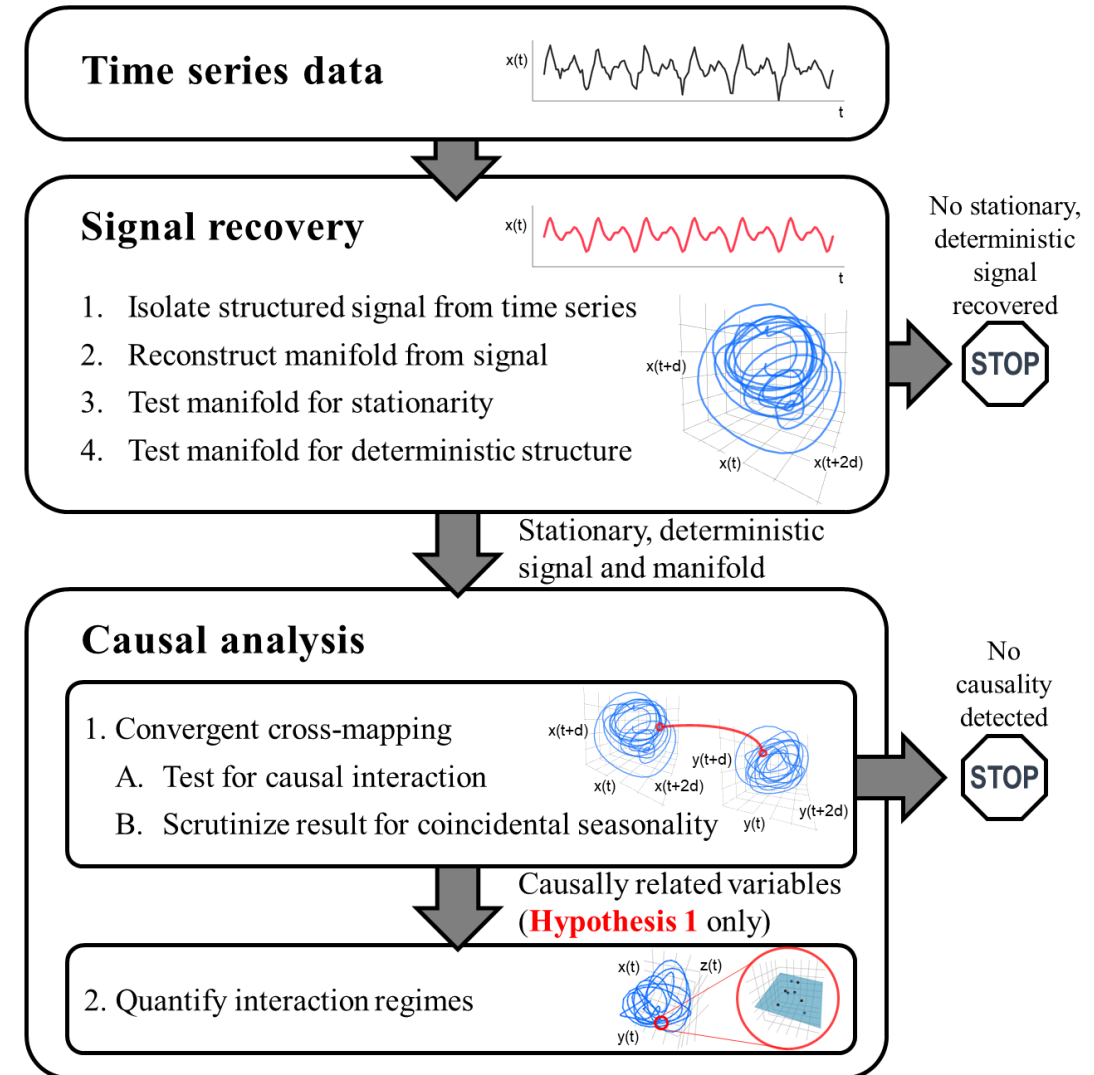
# Methods

1. Recover *signals* representing systematic patterns of behavior

Systematic behavior implies systematic causal interactions

2. Causal analysis identifies causally related variables and quantifies their interaction regimes over time

## Workflow



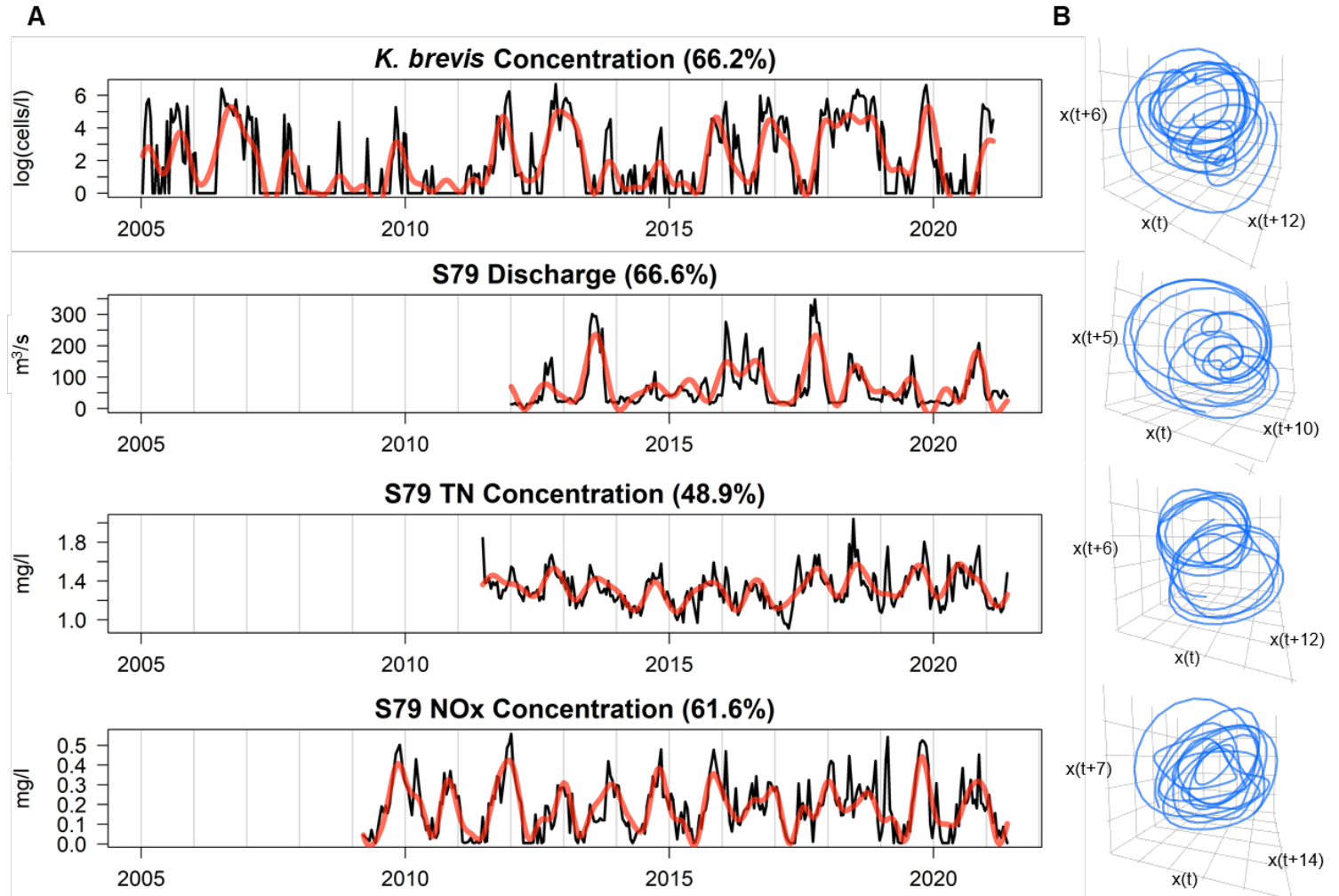


# Results: Signal recovery (Kb & S79)

**Signals** represent systematic patterns of behavior

Seasonality

Other S79 variables

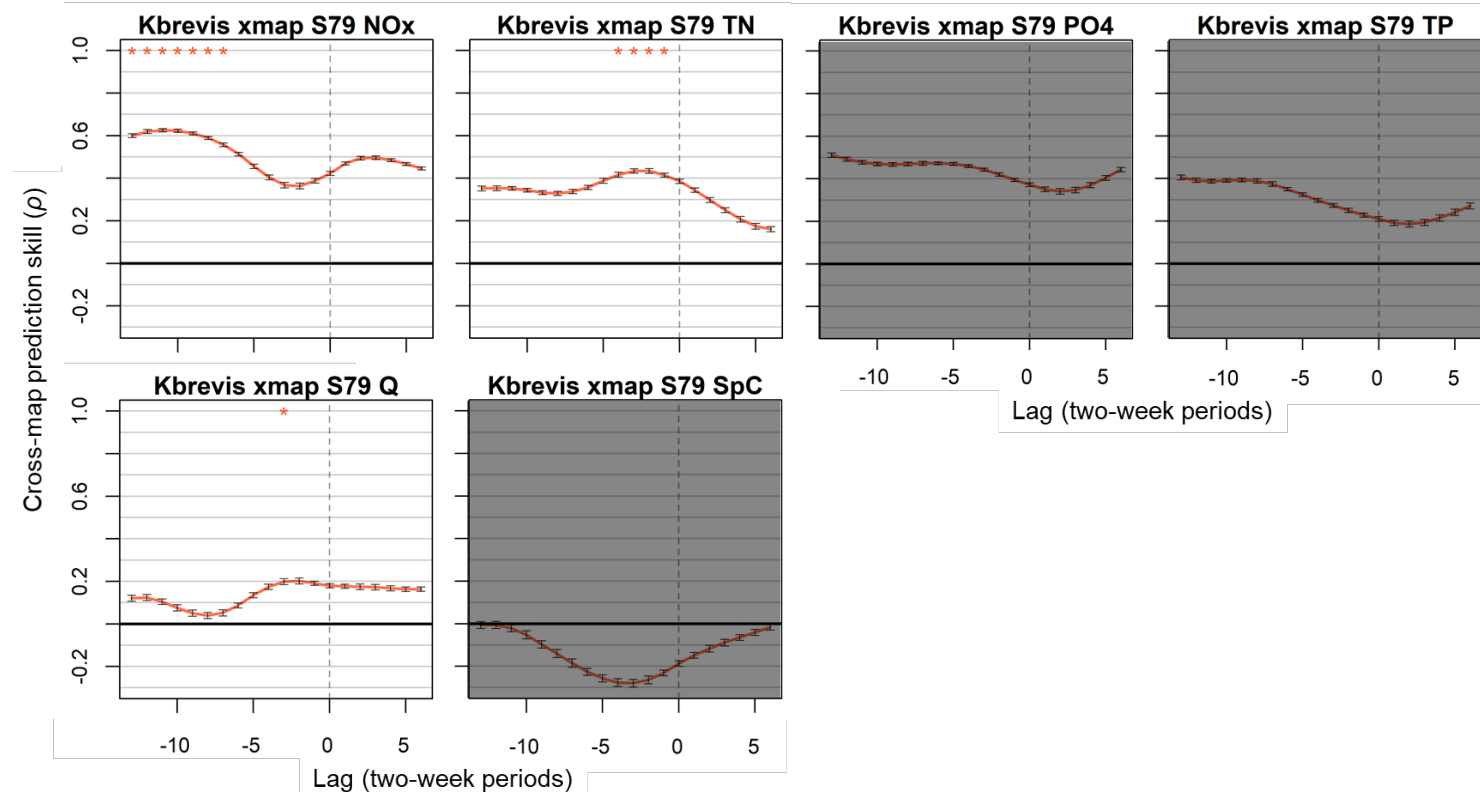


# Results: Causal relationships (Kb & S79)

Caloosahatchee River discharge and nitrogen concentration dynamics systematically influence *K. brevis* bloom dynamics

Causality, not just coincidence

Time delays



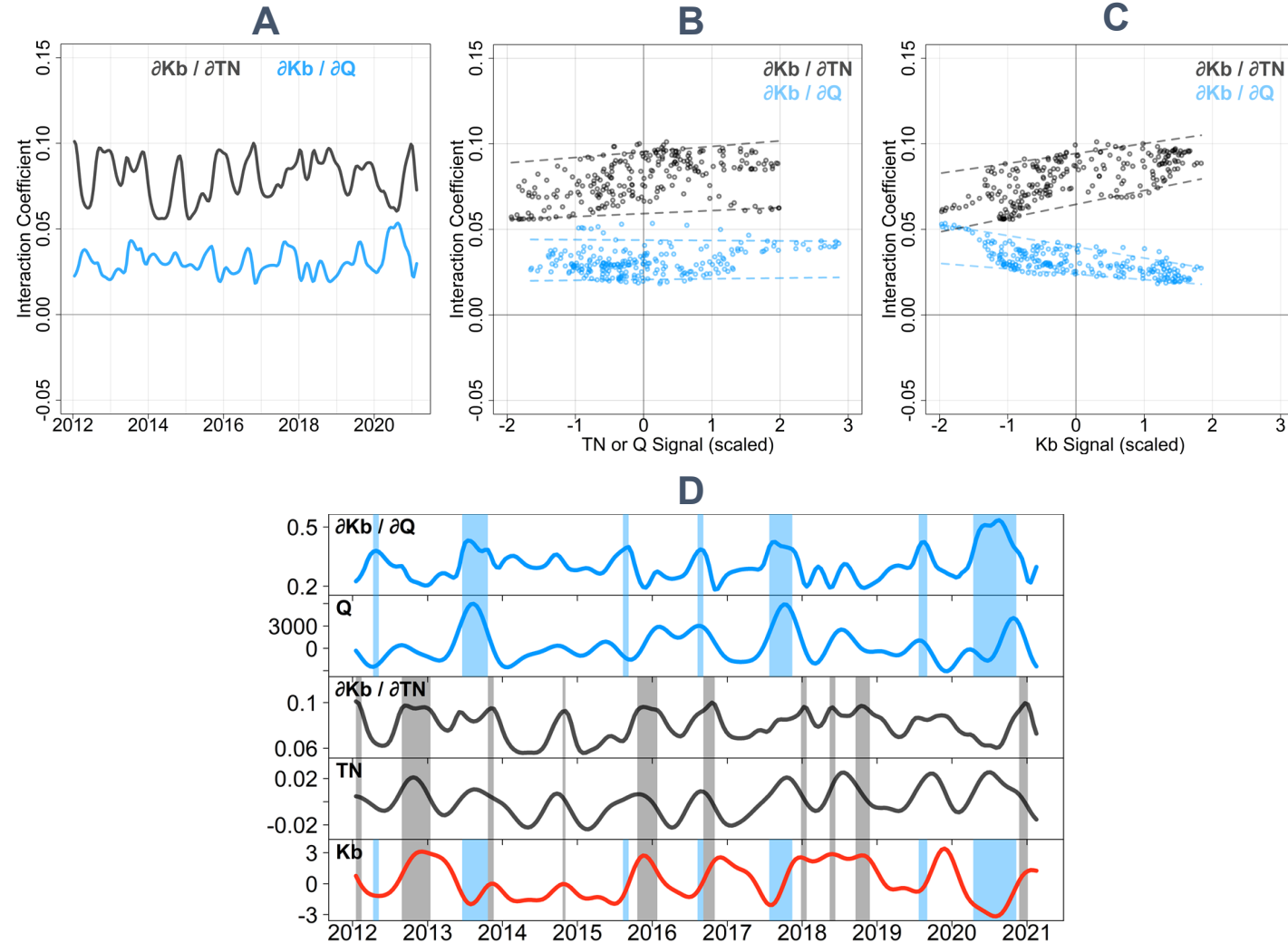


# Results: Interaction regimes (Kb & S79)

Caloosahatchee River discharges and nitrogen persistently intensify *K. brevis* blooms

The strengths of these effects are sensitive to *K. brevis* levels

- Discharge most influential during blooms' early stages
- TN most influential during growth/maintenance stages

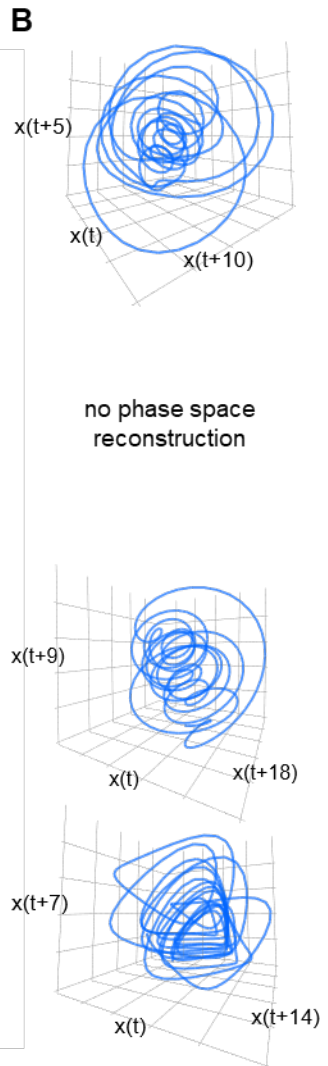
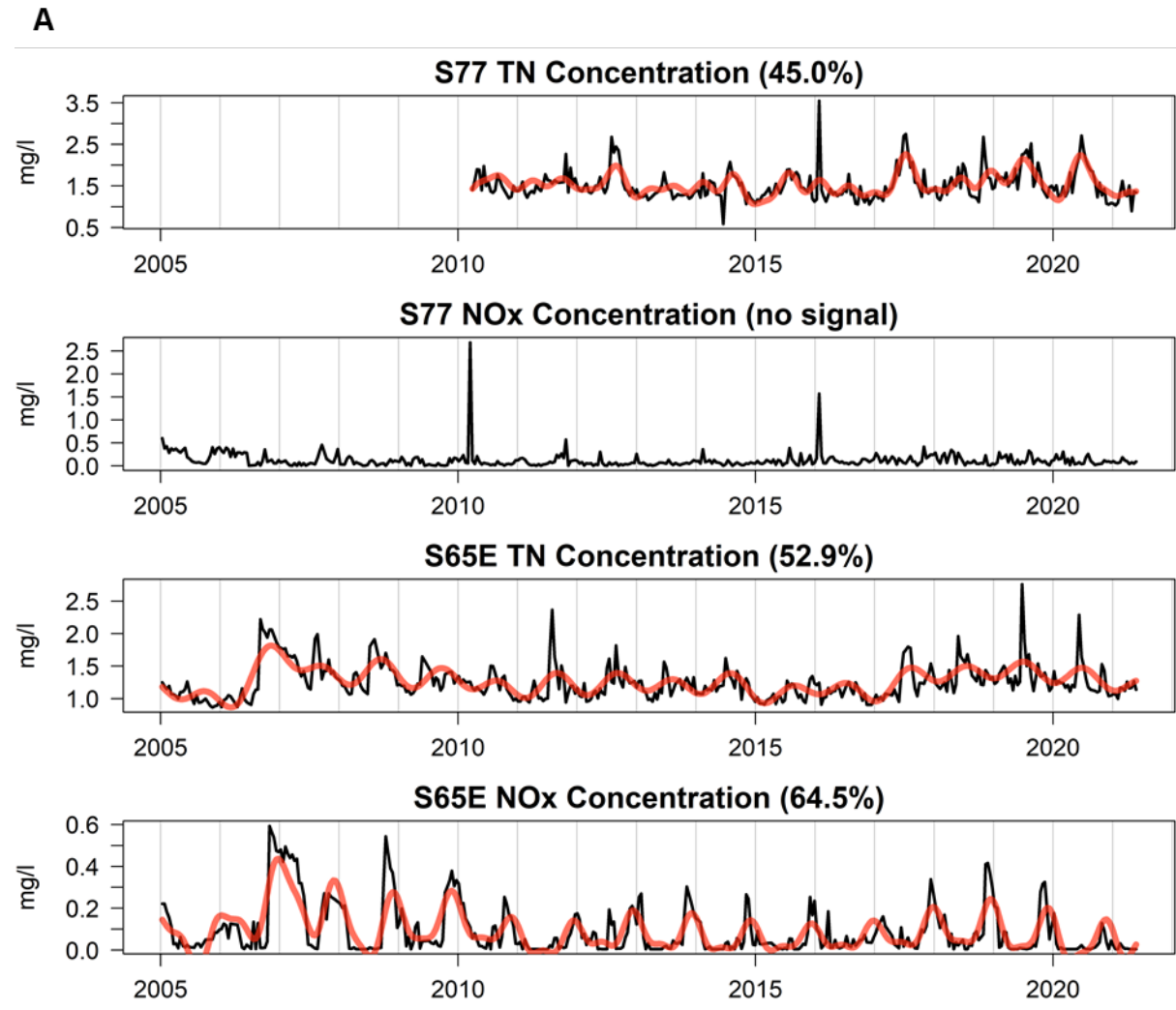


# Results: Upstream signals (S77 & S65E)

Nitrogen dynamics at  
Lake Okeechobee (S77) and  
Kissimmee basin (S65E)

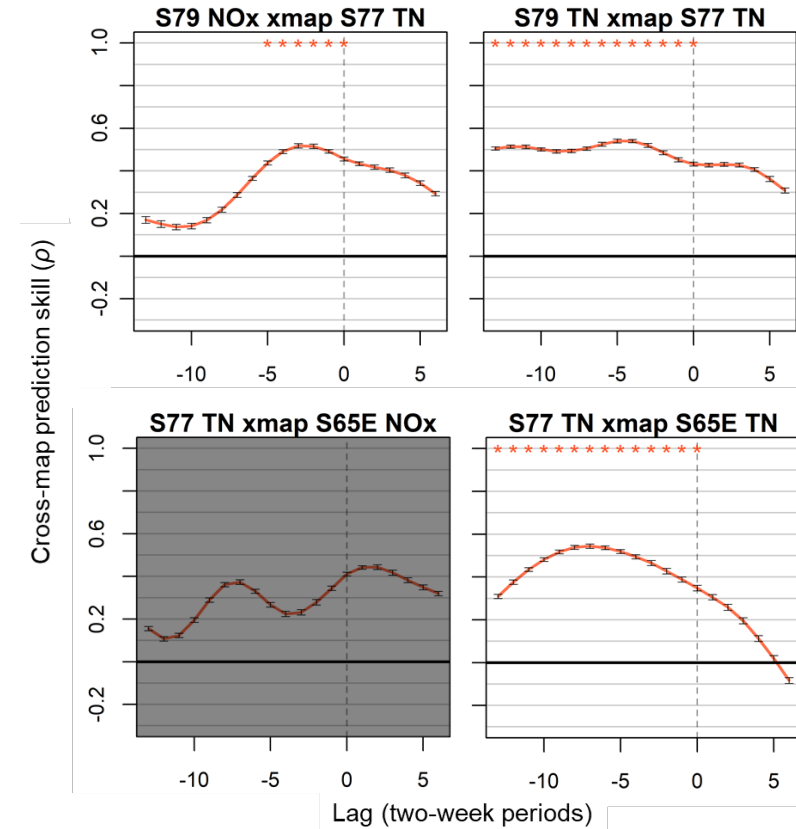
No S77 NOx signal

Seasonality



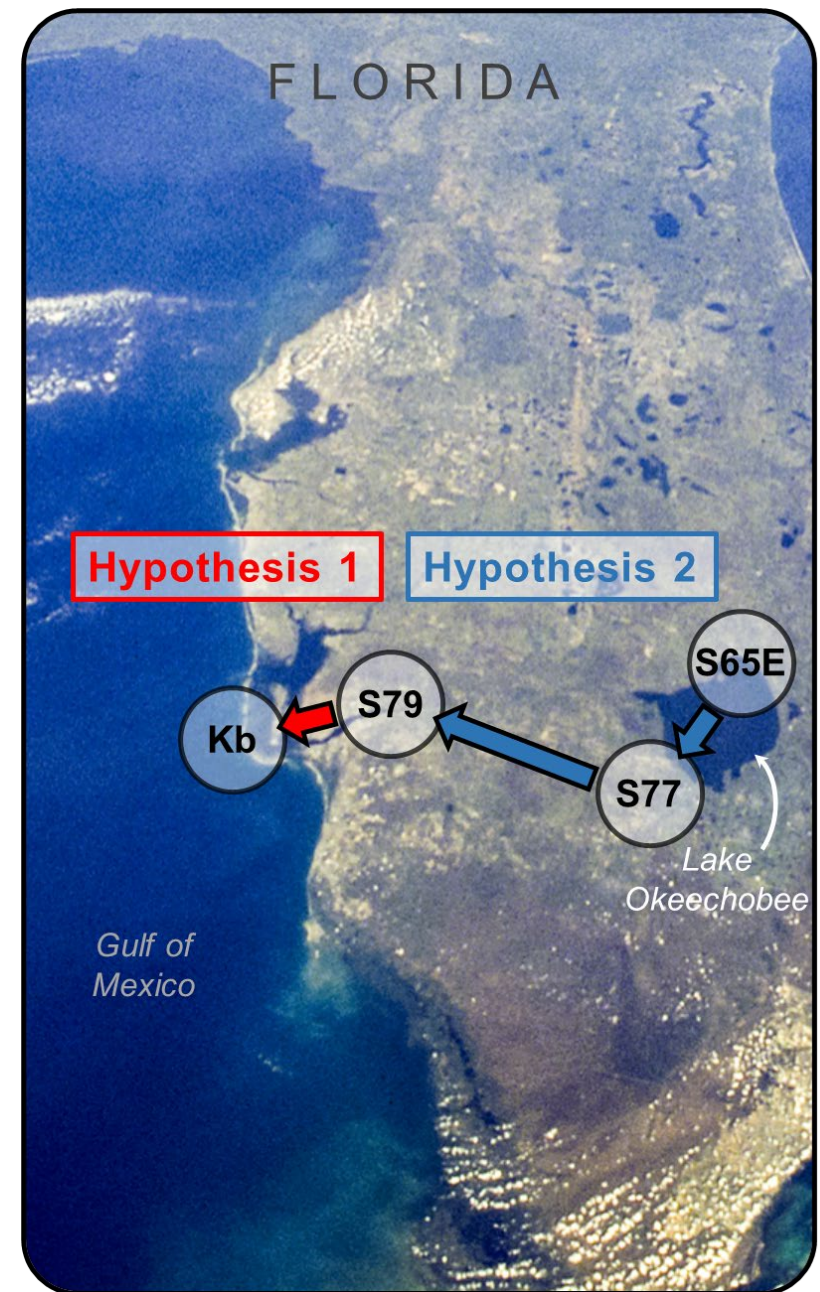
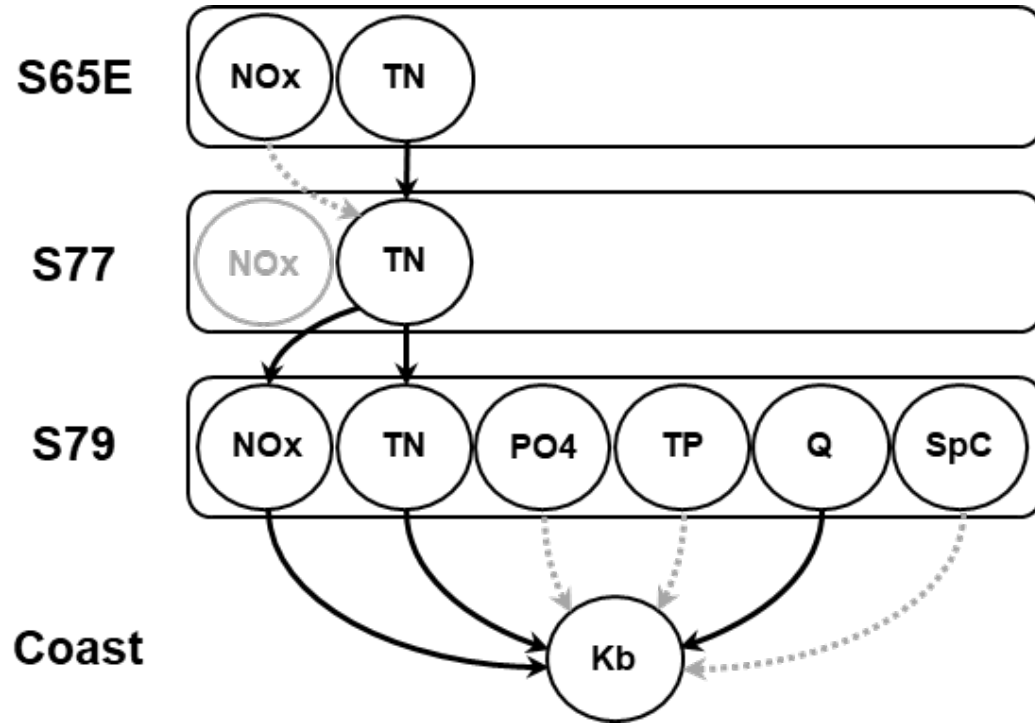
# Results: Upstream causal relationships (S77 & S65E)

Influence of nitrogen inputs on *K. brevis* blooms can be traced upstream to Lake Okeechobee (S77) and the Kissimmee basin (S65E)





# Results: Summary



# Takeaways

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- **Correlations don't tell us the whole story about anthropogenic forcing**
- **There is empirical evidence of anthropogenic intensification of coastal *K. brevis* blooms near Charlotte Harbor**
- **Mitigating blooms will likely require watershed-scale interventions, modifications to Lake Okeechobee discharge protocols, and holistic investigations of interactions among anthropogenic and natural processes driving blooms**

# Contact

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## UF Center for Coastal Solutions



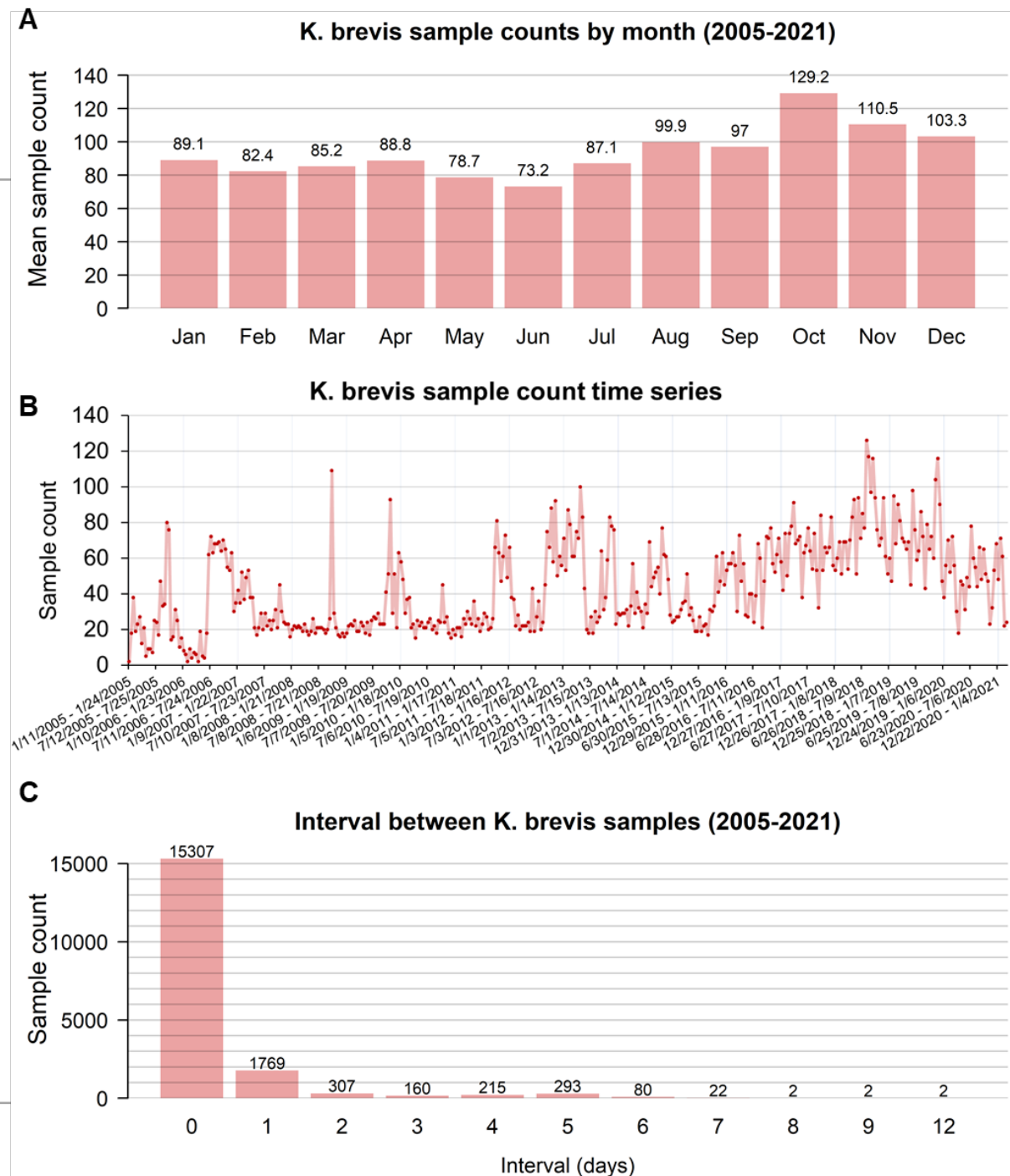
<https://ccs.eng.ufl.edu/>



# Bias in the *K. brevis* data

Event-based sampling introduces bias: Seasonal sampling effort may create a false seasonal signal.

- A. Overall, sampling effort was higher from Oct – Dec.
- B. Sample counts per 2-week bin. The seasonal component was weak: Interannual differences more important than intra-annual differences.
- C. Spatiotemporal coverage was good.
  - Typical sample frequencies:  $\geq 1$  per day.
  - Within each 2-week bin, sample locations were typically distributed throughout the study area with several routine monitoring locations (Video)



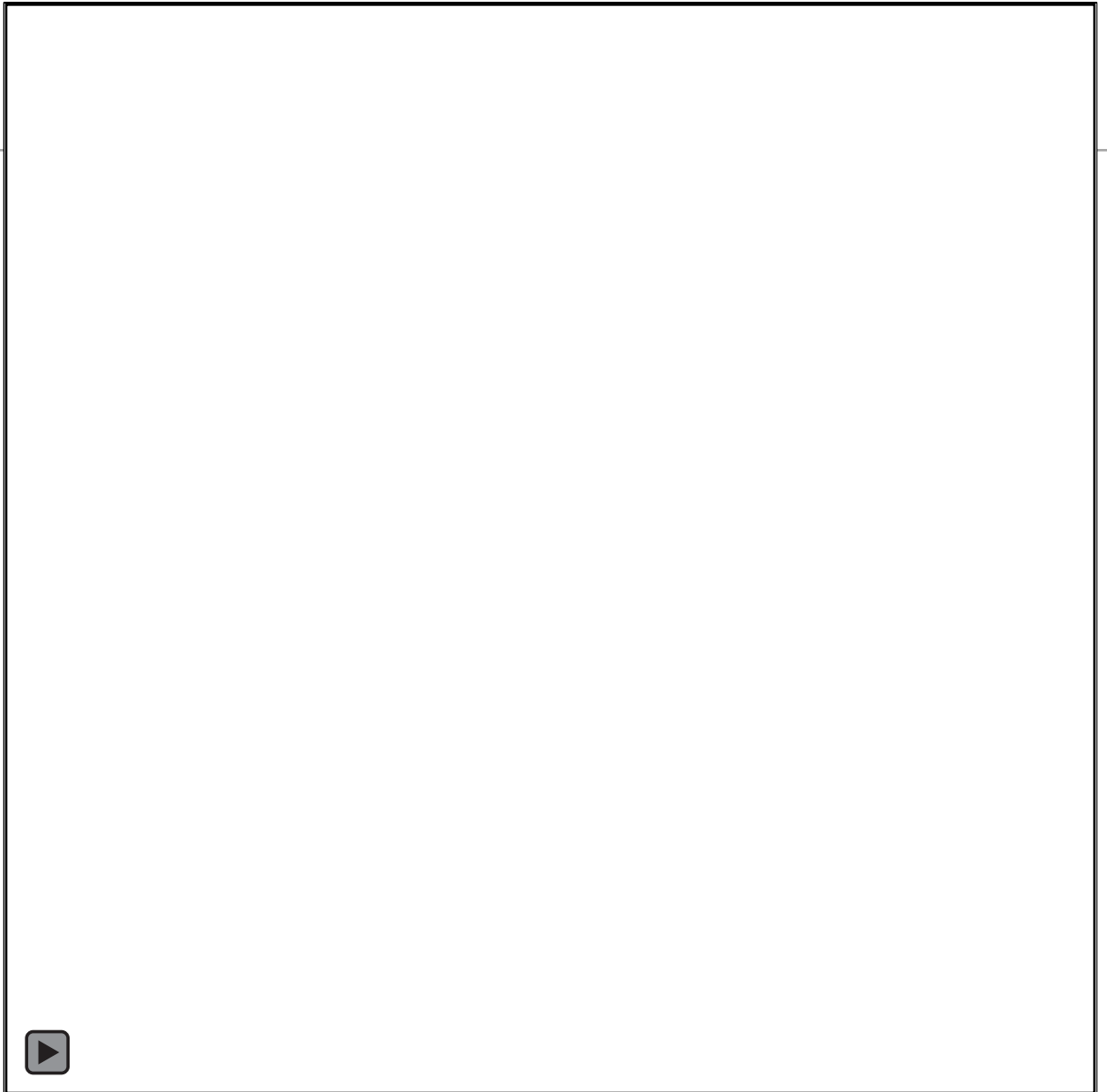
# *K. brevis* data

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Data source: NOAA HABSOS

Data aggregation

- 14-day bins
- Arithmetic mean



# Phase space and causal inference

- Interacting variables share information such that *system dynamics (a)* can be reconstructed from the dynamics of a single variable
- Correspondence between two *phase space reconstructions (b) and (c)* implies a causal relationship
- Analogy: Two shadows cast by the same object

