# The economic impact of freshwater inputs to an estuarine fishery

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# Background and purpose

Freshwater inputs affect coastal ecology and productivity

- Salinity, nutrients, temperature

Increasing demand for freshwater, climate change ➔ reduced inputs, increased variability

Little information available on economic impacts

- Temperate estuaries among the most productive ecosystems in the world
- Coastal resources rarely prioritized

# Background and purpose

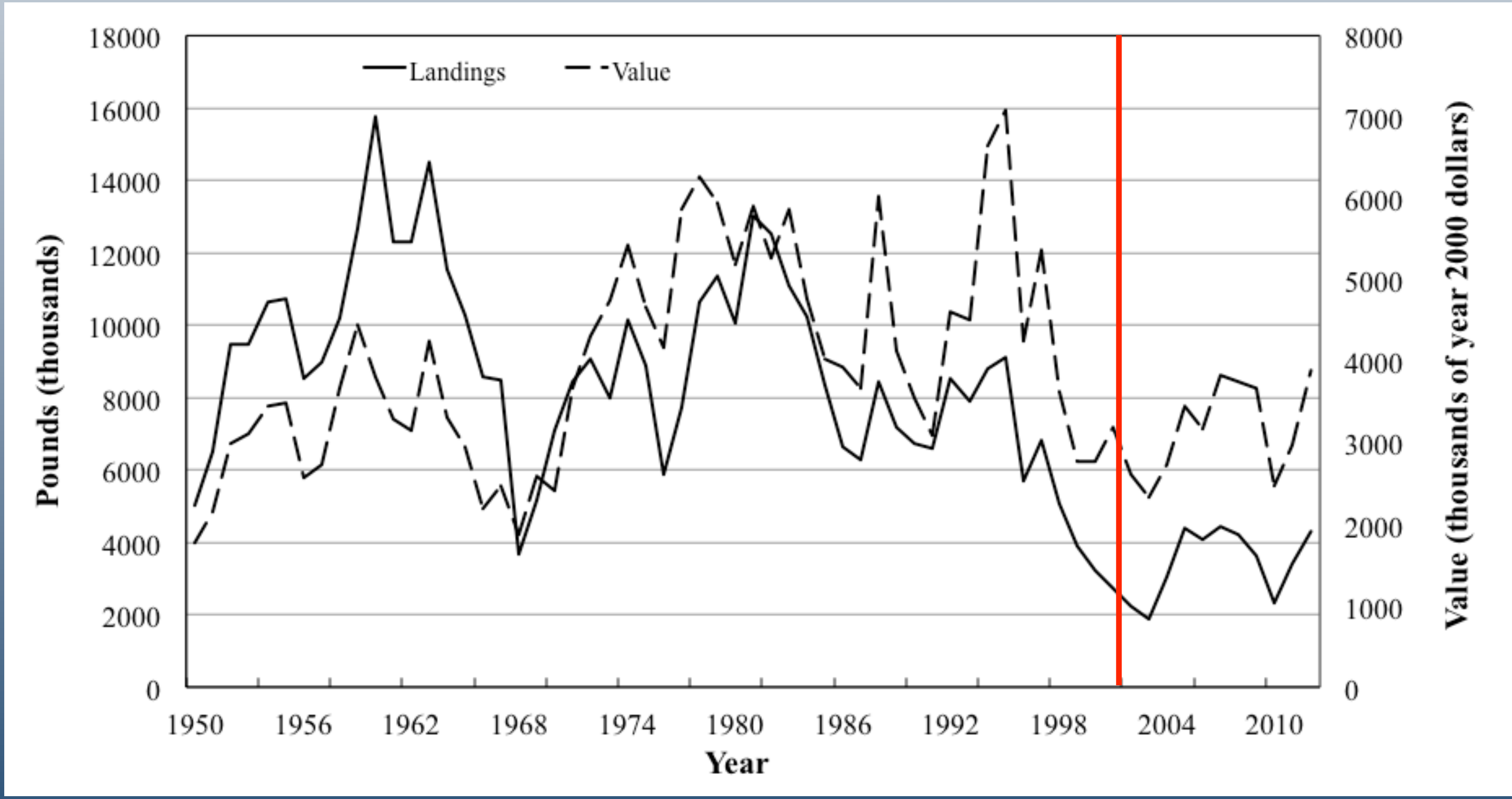
This research: investigate the relationship between freshwater inputs and fishery performance in the Georgia blue crab fishery

Blue crab (*Callinectes sapidus*)

- Second to shrimp in value to GA
- Coastal estuaries, small vessels, effectively open-access
- Depend on moderate salinity in numerous ways (spawning, recruitment, juvenile/adult mortality)
- Significant fishery declines over past 20 years, linked to drought/elevated salinity

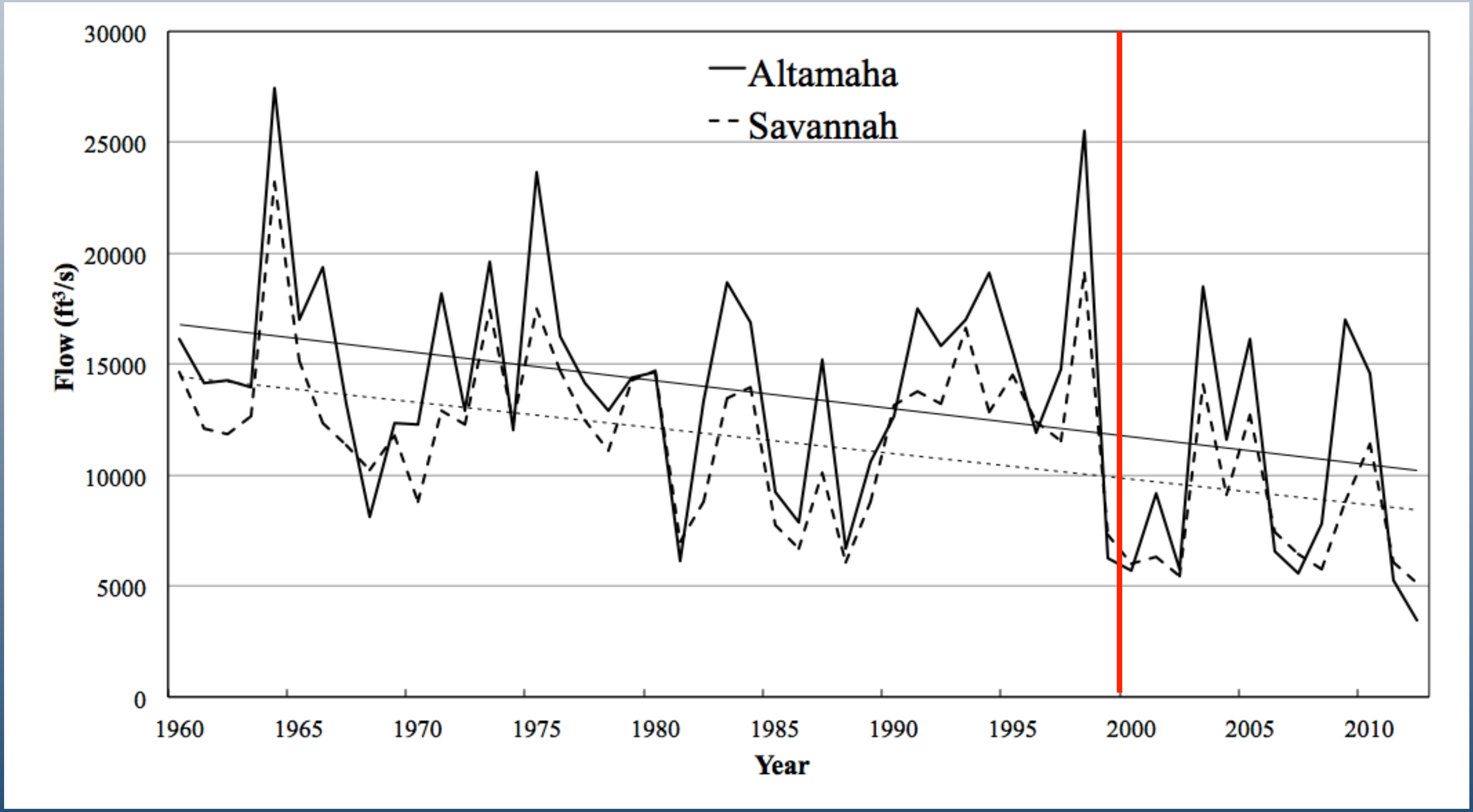
# Background and purpose

Despite significant declines since mid-1990s, increasing demand has kept participation relatively high



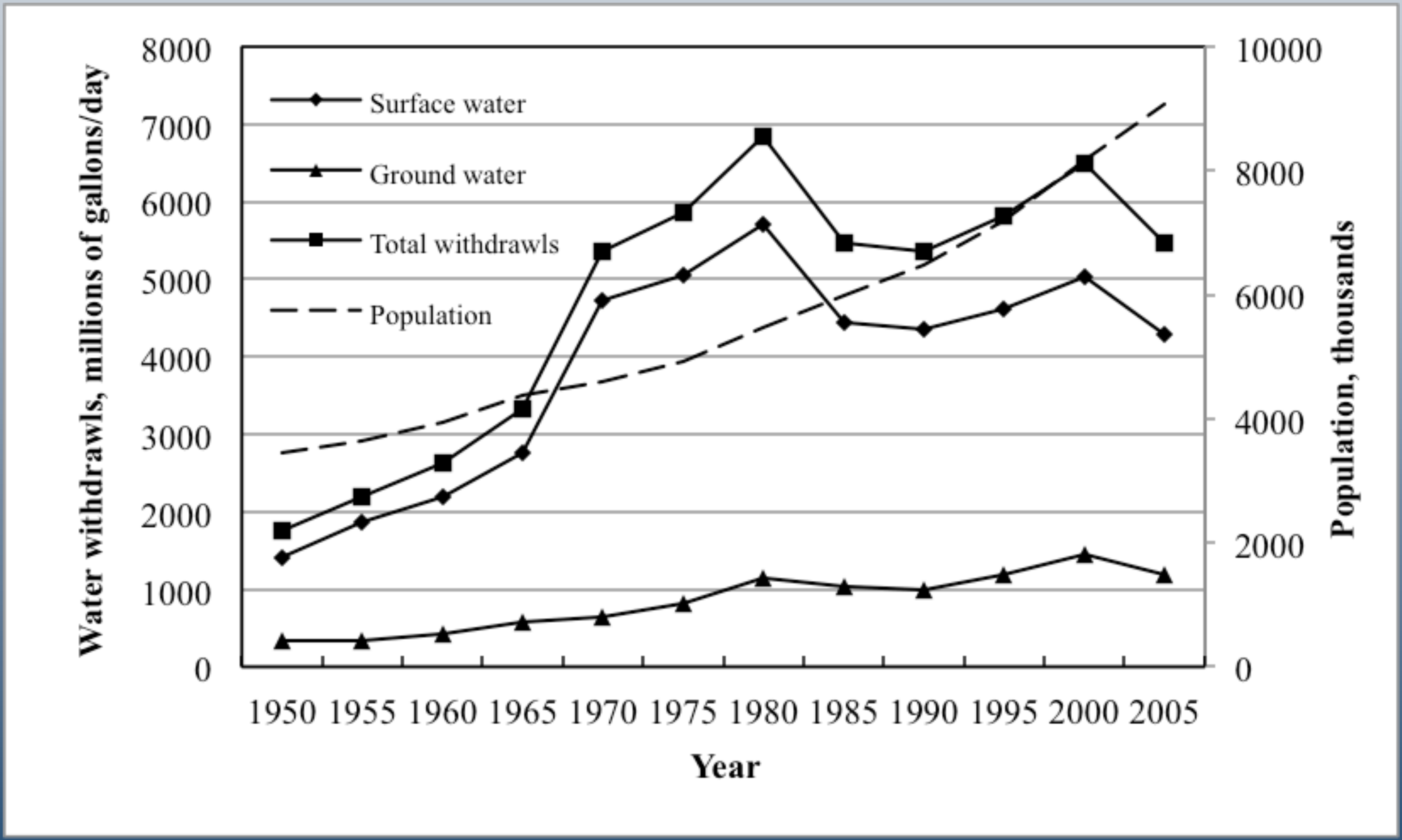
# Background and purpose

Lowest point for fishery (early-2000s) coincided with historic drought conditions; reversal of a marginal recovery in 2010 similarly coincided with another severe drought



# Background and purpose

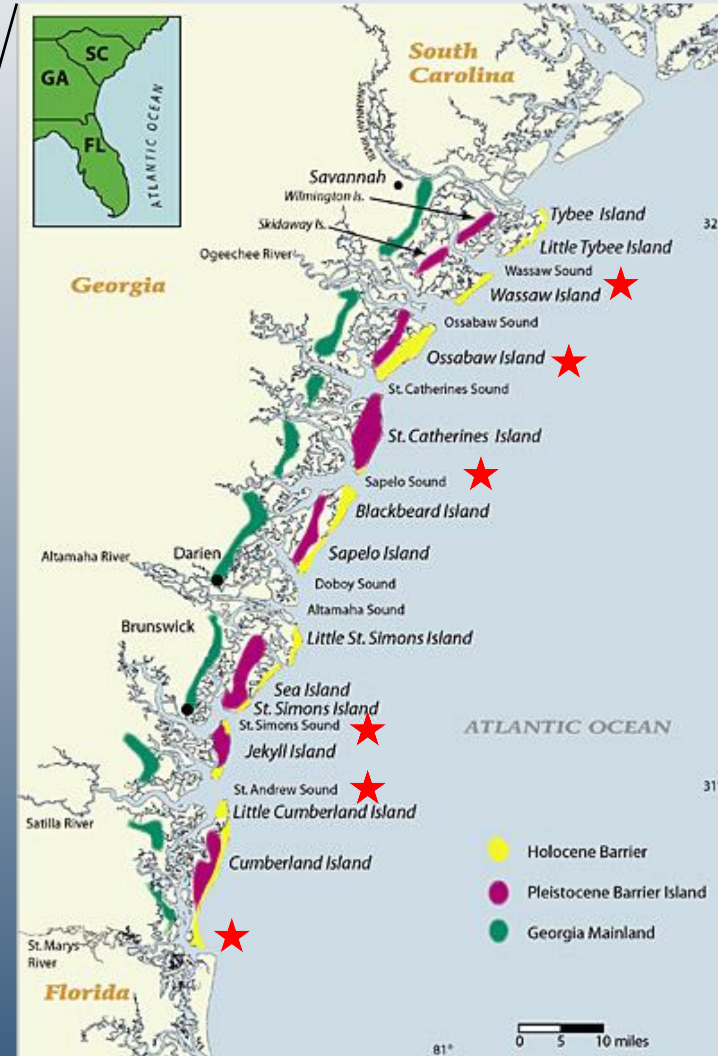
Drought has played a major factor, but water withdrawals have increased dramatically since 1950



# Empirical Approach

Focus on six sounds

- Three riverine, three tidal
- Represents ~55% of harvests from 2001 to 2012
- Treat sounds as independent fisheries



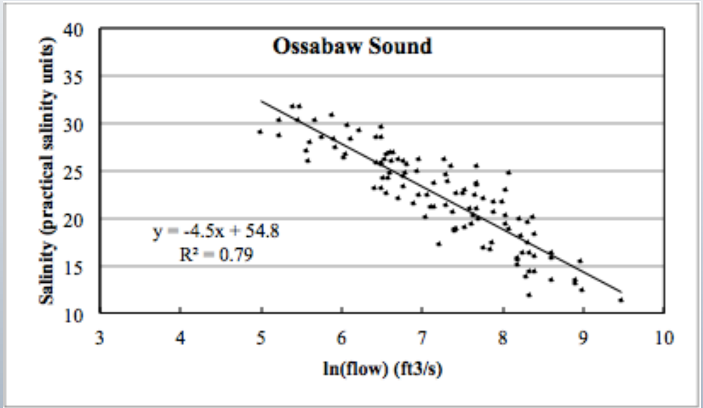
# Empirical Approach

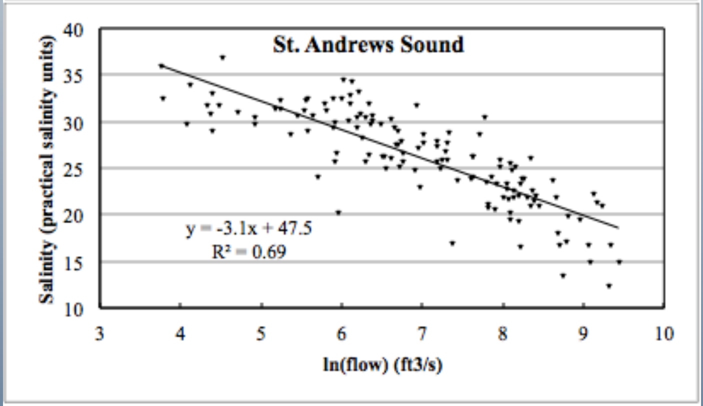
Structural, bioeconomic model of the fishery; multiple life stages; quarterly transitions

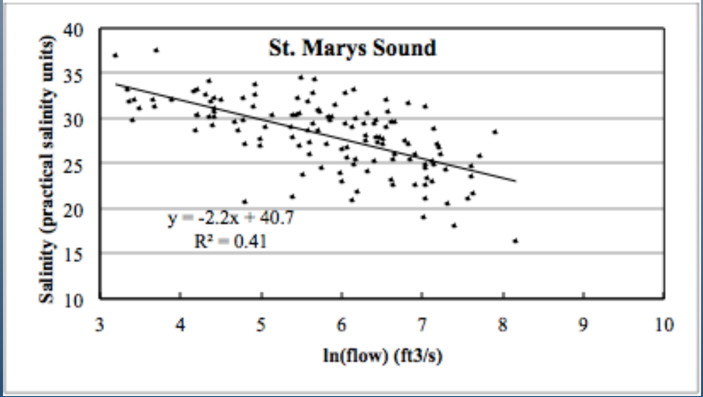
- Do reductions in freshwater inputs negatively impact the fishery?
- If so, identify specific biophysical mechanisms

Focus on salinity

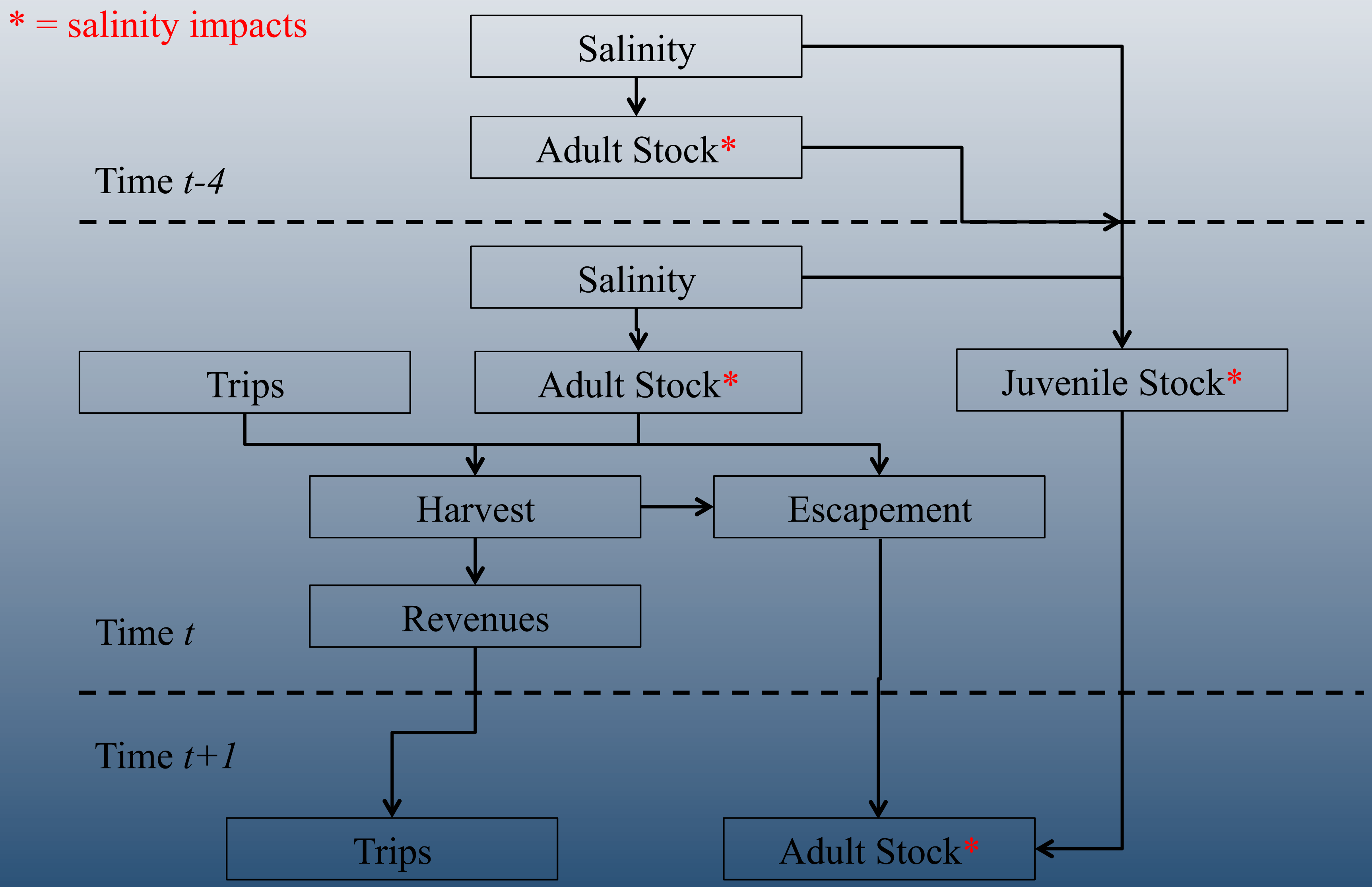
- Able to account for unmonitored freshwater sources
- Good proxy for flow in river-dominated sounds (estuaries)
- Increase statistical power



# Empirical Approach



# Empirical approach

Four-equation system

- Evolution of adult stock; recruitment
- Effort transition; harvest production function

$$X_{q+1,s} = \theta_0 + \theta_1 sal_{q+1,s} + \theta_2 temp_{q+1,s} + \theta_3 \left( X_{q,s} - h_{q,s} \right) + \theta_4 R_{q,s} + \varepsilon$$

$$\ln\left( \frac{R_{q,s}}{X_{q+1,s}} \right) = \eta_0 + \eta_1 sal_{q,s} + \eta_2 sal_{q-4,s} + \eta_3 temp_{q,s} + \eta_4 temp_{q-4,s} + \eta_5 X_{q-4,s} + \varepsilon$$

$$\ln\left( h_{q,s} \right) = \alpha_0 + \alpha_1 \ln\left( tr_{q,s} \right) + \alpha_2 \ln\left( X_{q,s} \right) + \varepsilon$$

$$tr_{q,s} - tr_{q-4,s} = \beta_0 + \beta_1 \left( p_{q-1,s} \cdot h_{q-1,s} - p_{q-5,s} \cdot h_{q-5,s} \right) + \varepsilon$$

Quarter and sound fixed effects; year trend variable

System estimated via Zellner's SUR

- Allows for correlation in error structure between equations

# Data and Estimation

Harvest and stock abundance data from GDNR

- Commercial harvest: 1989-2012, > 200K trip obs
- Stock survey trawls (w/ salinity, temp): 1976-2012, >90K obs

Estimate system from 2001-2012 (data quality issues)

- Adults: escapement, juveniles (q-1) (1%); salinity (q) negative (10%)
- 1 ppt increase in salinity -> 4% lower abundance
- Recruitment: spawning stock (q-4) (1%); salinity (q) negative (1%); salinity (q-4) negative (5%)
- 1 ppt increase in salinity (q), 13% fewer juvs; 1 ppt increase in salinity (q-4), 7% fewer juvs
- Harvest and effort adjustment equations as expected

Robustness checks: Alternative salinity specifications, recruitment structure; full time series – results are robust

# Economic Impact

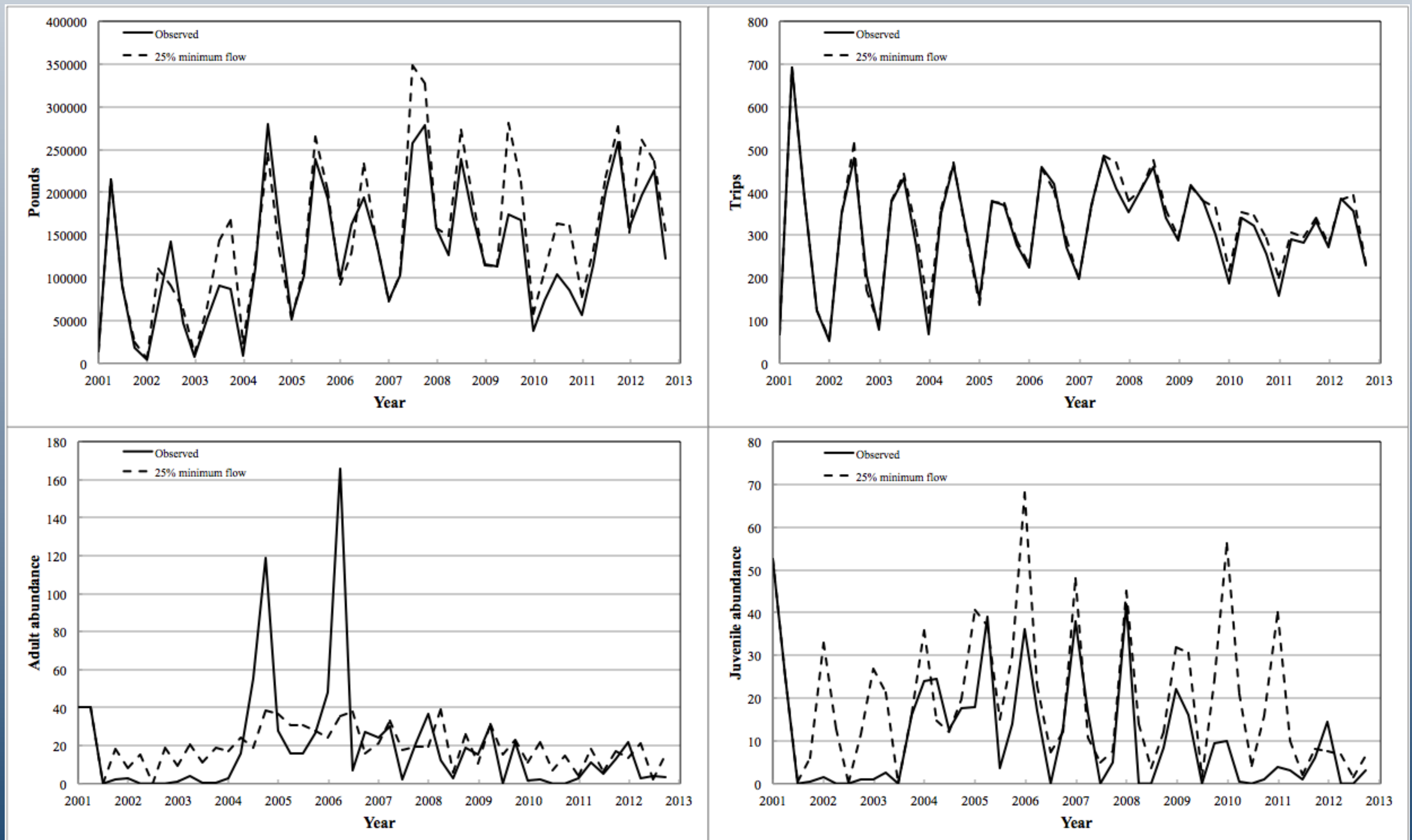
Develop counterfactual salinity profiles from a simulated minimum flow standard (MFS)

- As if, in three riverine sounds, flow were maintained @ >25% of seasonal historical (>1960) averages

| Sound (river) | | Flow ($ft^3/s$) (2001-2012) | Flow ($ft^3/s$) (1960-2012) | 25% min flow ($ft^3/s$) | # binding quarters | Salinity (PSU) | 25% min salinity (PSU) |
|---|---|---|---|---|---|---|---|
| Ossabaw (Ogeechee) | Mean | 1,496 | 2,242 | 1,514 | 12 of 44 | 24.30 | 23.14 |
| | SD | 1,566 | 2,048 | 1,531 | | 4.77 | 4.12 |
| | Min | 72 | 72 | 277 | | 13.78 | 13.78 |
| | Max | 6,611 | 13,003 | 6,611 | | 32.94 | 29.16 |
| St. Andrews (Satilla) | Mean | 1,641 | 2,280 | 1,748 | 18 of 44 | 26.25 | 24.92 |
| | SD | 2,035 | 2,456 | 1,938 | | 3.94 | 2.94 |
| | Min | 43 | 43 | 301 | | 17.13 | 17.13 |
| | Max | 9,213 | 12,513 | 9,213 | | 35.17 | 29.45 |
| St. Marys | Mean | 538 | 622 | 560 | 16 of 44 | 29.53 | 27.74 |
| | SD | 664 | 613 | 638 | | 3.30 | 2.24 |
| | Min | 24 | 24 | 97 | | 23.38 | 23.38 |
| | Max | 2,693 | 3,507 | 2,693 | | 37.55 | 30.98 |

# Economic Impact

Perform counterfactual, recursive simulation of fishery outcomes in three riverine sounds, assuming MFS (Ossabaw shown)



# Economic Impact

Improvements in fishery revenue ranging from 13-18%

| | | Total | | | Average | |
|---|---|---|---|---|---|---|
| Sound | | Pounds | Revenue | Trips | Adults | Juveniles |
| | Actual | 5,859,303 | $5,443,606 | 13791 | 18.6 | 10.0 |
| Ossabaw | 25% Min | 6,751,835 | $6,413,160 | 14339 | 19.4 | 19.3 |
| | % Dif | 15.2% | 17.8% | 4.0% | 4.3% | 92.8% |
| | Actual | 5,147,541 | $4,681,558 | 20385 | 13.3 | 7.1 |
| St. Andrews | 25% Min | 5,699,699 | $5,293,000 | 20727 | 14.8 | 17.3 |
| | % Dif | 10.7% | 13.1% | 1.7% | 11.4% | 144.3% |
| | Actual | 2,464,449 | $2,056,656 | 10254 | 11.5 | 7.0 |
| St. Marys | 25% Min | 2,837,854 | $2,398,257 | 10452 | 12.4 | 17.8 |
| | % Dif | 15.2% | 16.6% | 1.9% | 8.1% | 153.4% |

Sounds represent 35% of historical harvest volume, two largest rivers in GA not included (Savannah, Altamaha) due to lack of data (represent additional ~30%)

# Discussion

Implied "value" of water

- ~ $1-7 / acre-ft

Comparable to some agricultural valuations

- Estimated annuity value of water rights in Georgia (hedonic model of land prices, Petrie and Taylor, 2004): $35
- Meta-analysis of values (Fredrick et al. (2006)) for Southeast US: $18 mean, $7 median (across all value types, including improved recreational opportunities)

Caveats (among others)

- Uncertainty, thresholds, habitat interactions
- Not a marginal value; quarters with high fishery value likely correlated with value for agriculture, other uses

# Discussion

A lower bound?

- Simulation represents small proportion fishery, other harvests could be considered to occur in outflow areas, but not included
- Unable to generate observed spikes in adult abundance
- Shrimp also depend on estuaries and moderate salinity
- Massive marsh dieback in 2000-2002 linked to elevated salinity, led to significant loss of land, reduced storm and erosion protection
- Recreational crabbing not considered at all, potentially more valuable than commercial fishery (Evans, 1996)

Georgia currently does not consider coastal resources in water management plans

- Common practice, water resource managers dominated by historical concern for agriculture, municipal needs
- Fishery interests far less coordinated… second-order “tragedy”

# Thank you

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