ECOLOGICAL & ECONOMIC IMPACTS OF LAND USE AND CLIMATE CHANGE ON COASTAL FOOD WEBS & FISHERIES

How Do Environmental Risks Affect the Profitability of the Aquaculture Industry in Florida?

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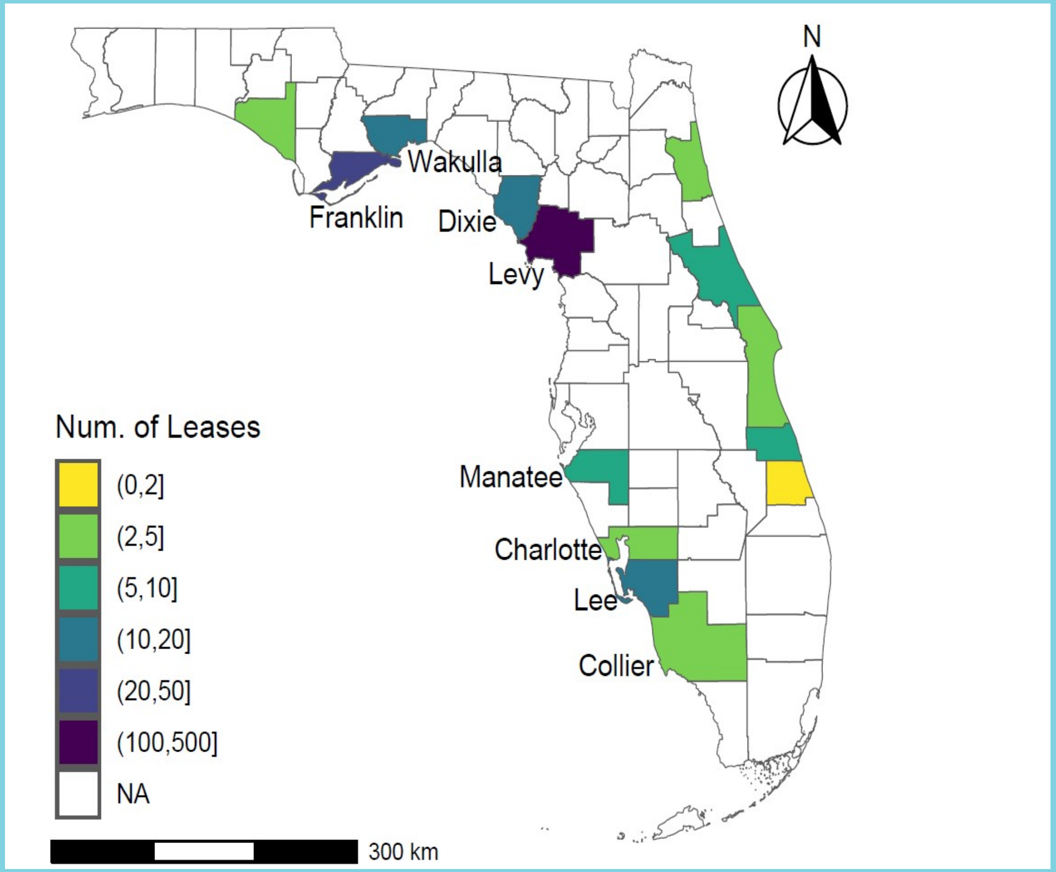
Background

- Clam aquaculture is a significant industry on Florida's Gulf of Mexico coast.
- The Florida aquaculture sector has developed a network of complementary sectors.
- However, clam aquaculture faces strong environmental challenges related to water quality.
  - Harmful Algal Blooms (HAB)
  - Low salinity
  - High temperatures.

Total number of clam shellfish leases by county



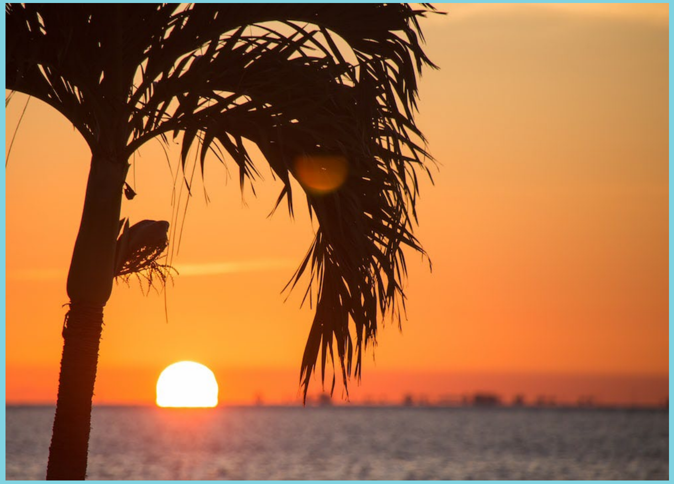
Data Source: FDACS, Public Record Center (2021). FDCA administers the leases, and each lease is 2 acres in size.

Objective

- We create a bioeconomic simulation model to examine the impact of environmental risk on the profitability of clam aquaculture activity at the county level in Florida's Gulf of Mexico.

- We estimate stochastic models taking into account several scenarios at county level.

Main Environmental Risks



HAB

- Shellfish harvesting areas are closed
- Clam producers must suspend operations
- Producers lose profit

Low Salinity Water

- Water salinity, < 10 ppt
- Increase in mortality rate

Hight Temperature Water

- Water temperature, >31^{o}C
- Reduced growth of clams.
- Increase in mortality rate.

Bioeconomic Model – Stochastic Simulations

1. Biological model
    - Growth function (high temperature events decrease growth)
    - Mortality function (low salinity and high temperature increase mortality)

2. Economic model
    - Cost function
    - Revenue function (HAB events close harvesting areas)
    - Profit function
    - Net Present Value

1. Biological Model

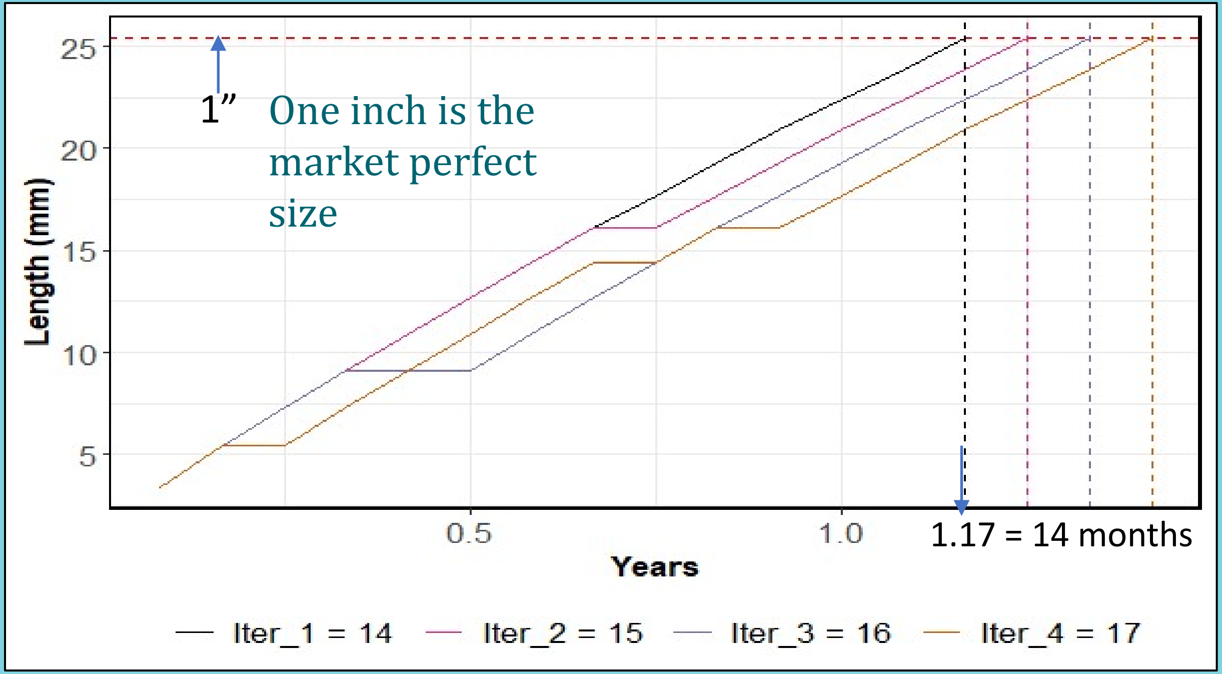
- **Growth Function**

$$L_t = \begin{cases} L_\infty\left[1 - e^{(-K(t-t_0))}\right], & \text{if } T_t = 0 \\ L_{t-1}, & \text{if } T_t = 1 \end{cases} \quad (1)$$

L_t is the clam height
L_∞ is the asymptotic height
k is the growth rate coefficient

t_0 is the theoretical age with zero height
T_t is a binary variable that equals one under high temperatures events

Bertalanffy growth function under high temperature events



1. Biological Model (Mortality and Harvest)

• Mortality

$$M_t = M_{t1} + M_{risk,t} \qquad (2)$$

$$M_{risk,t} = \begin{cases} M_{2t} + M_{3t}, & \text{if } S_t = T_t = 1 \\ M_{2t}, & \text{if } S_t = 1 \text{ and } T_t = 0 \\ M_{3t}, & \text{if } S_t = 0 \text{ and } T_t = 1 \\ 0, & \text{Otherwise} \end{cases} \qquad (3)$$

M_t is the total mortality
M_{t1} is the natural mortality
M_{t2} is the low salinity mortality
M_{t3} is the high temperature mortality

S_t is a binary variable for low salinity events
T_t is a binary variable for high temperature events

• Harvest

$$N_{ti} = \left[N_{ti-g} - \sum_{m=0}^{g}(N_{ti-m}M_t)\right] \qquad (4)$$

$$H_t = \begin{cases} 0, & if\ A_t = 1 \\ H_t, & if\ A_t = 0 \end{cases} \qquad (5)$$

N_{ti} is the number of remaining clams in any cohort i
N_{ti-g} is the number of clams planted g months ago in cohort i
H_t is the number of harvested clams at month t
A_t is a binary variable to define the presence of HAB events.

2. Economic Model

- **Cost**

$$C_t = N_t w_t l_t + N_t v_t \qquad (6)$$

C_t is the total cost per clam at month
N_t is the number of planted clams
w_t is the wage rate per minute
l_t is the number of minutes of labor used per clam
v_t is the capital cost per clam at month

- **Revenue**

$$R_t = \sum_{q=1}^{3} \delta H_t D_q P_{q,t} \qquad (7)$$

R_t is the revenue
δ is the % of clams that achieve market size
D_q is the probability of being a clam of type q (1", 7/8", and pasta),
$P_{q,t}$ is the price per clam for type q

- **Profit**

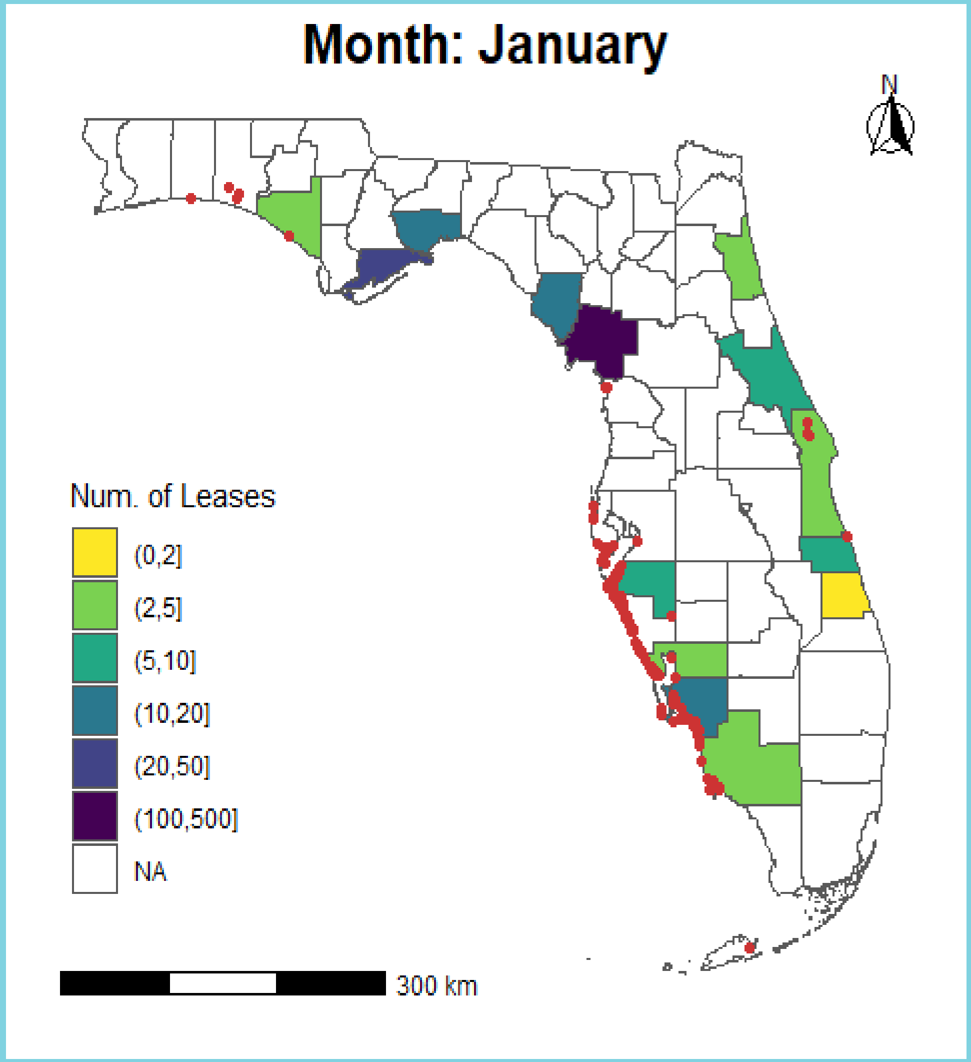
$$\pi_t = R_t - C_t \qquad (8)$$

- **Net Present Value**

$$NPV = \sum_{y=1}^{10} \frac{\sum_{t=1}^{12} \pi_t}{(1+r)^y} \qquad (9)$$

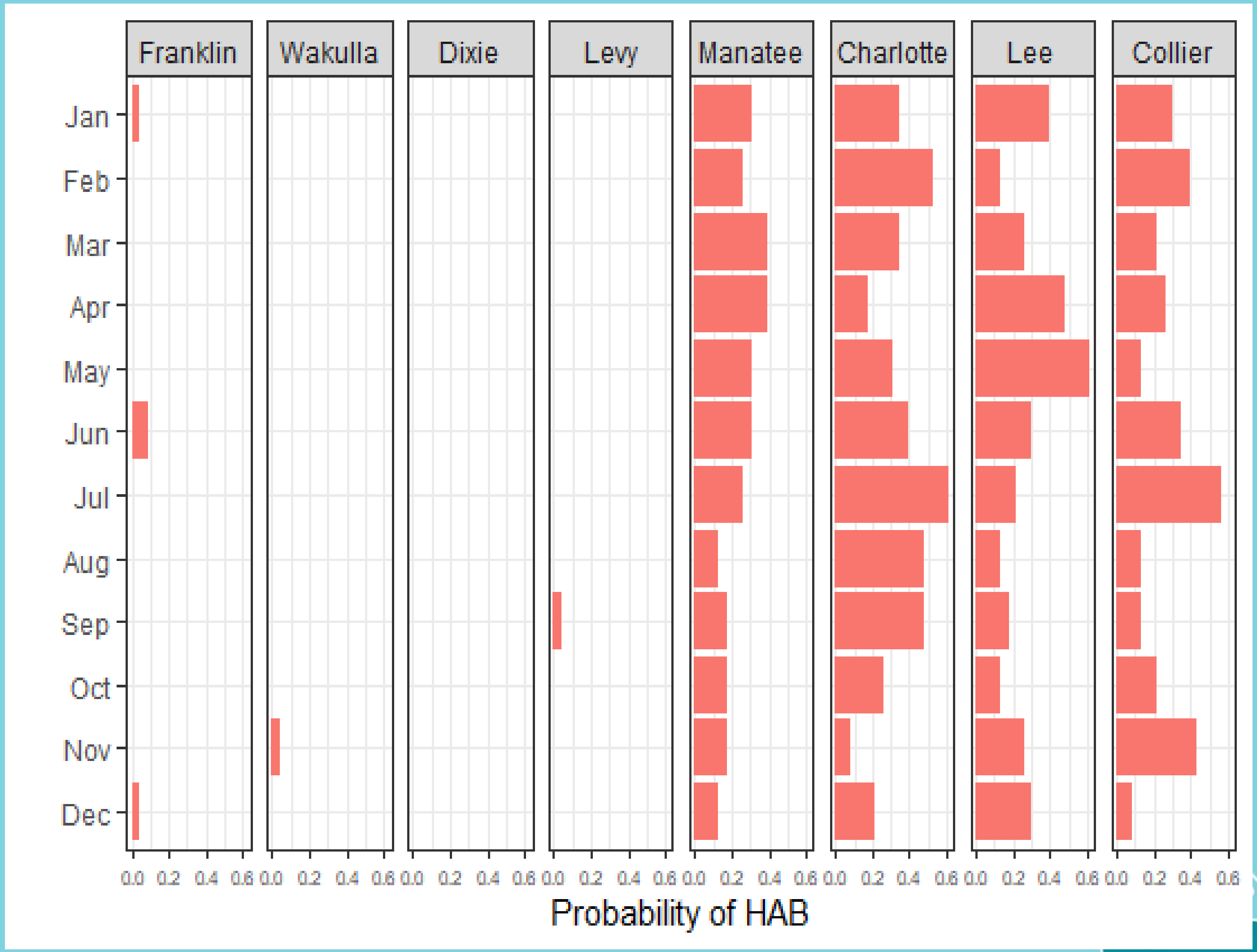
Data: Harmful Algal Blooms

Samples with HAB



Note: The HAB database come from FWC and FWRI.
Red points represent samples with more than 5,000 cells per liter (Karenia brevis organism)

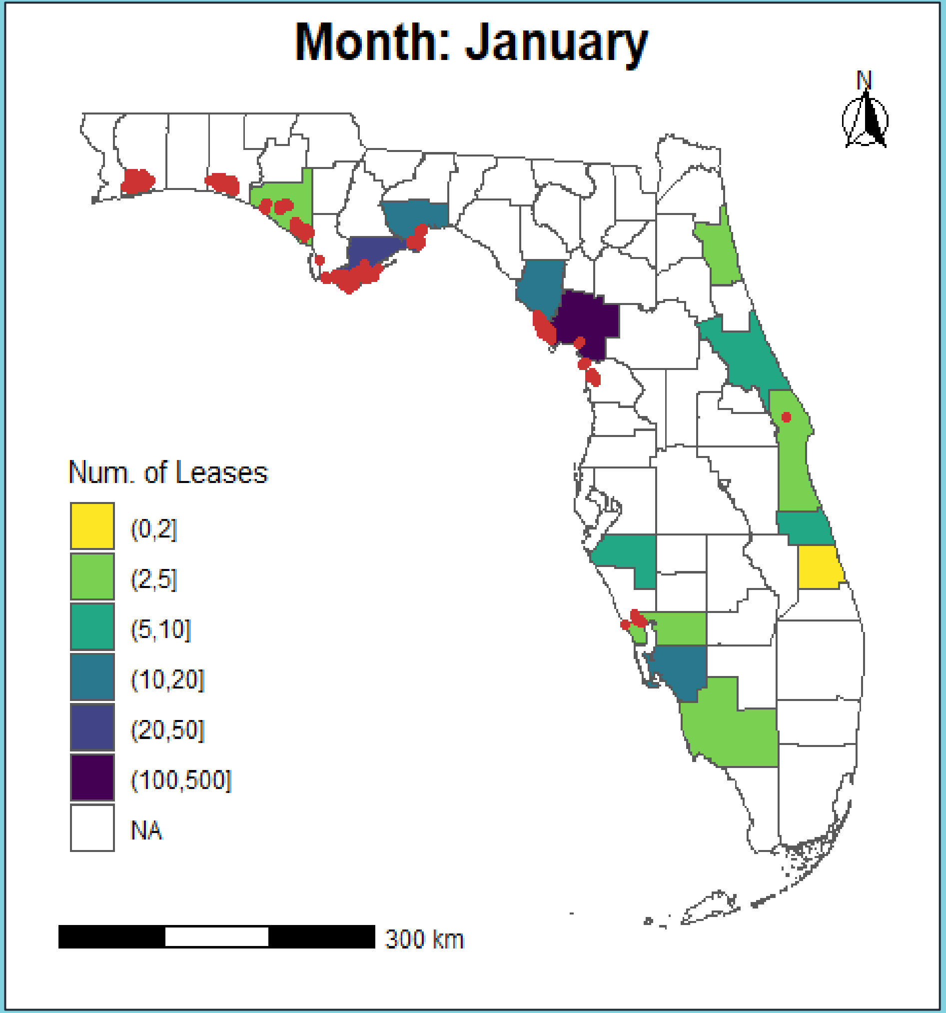
Probability of HAB by Month and County (2000 - 2022)



Note: the probability is equal to the number of months with HABs presence (more than 5,000 cells per liter) dived by total number of months between 2000 and 2022 (23).

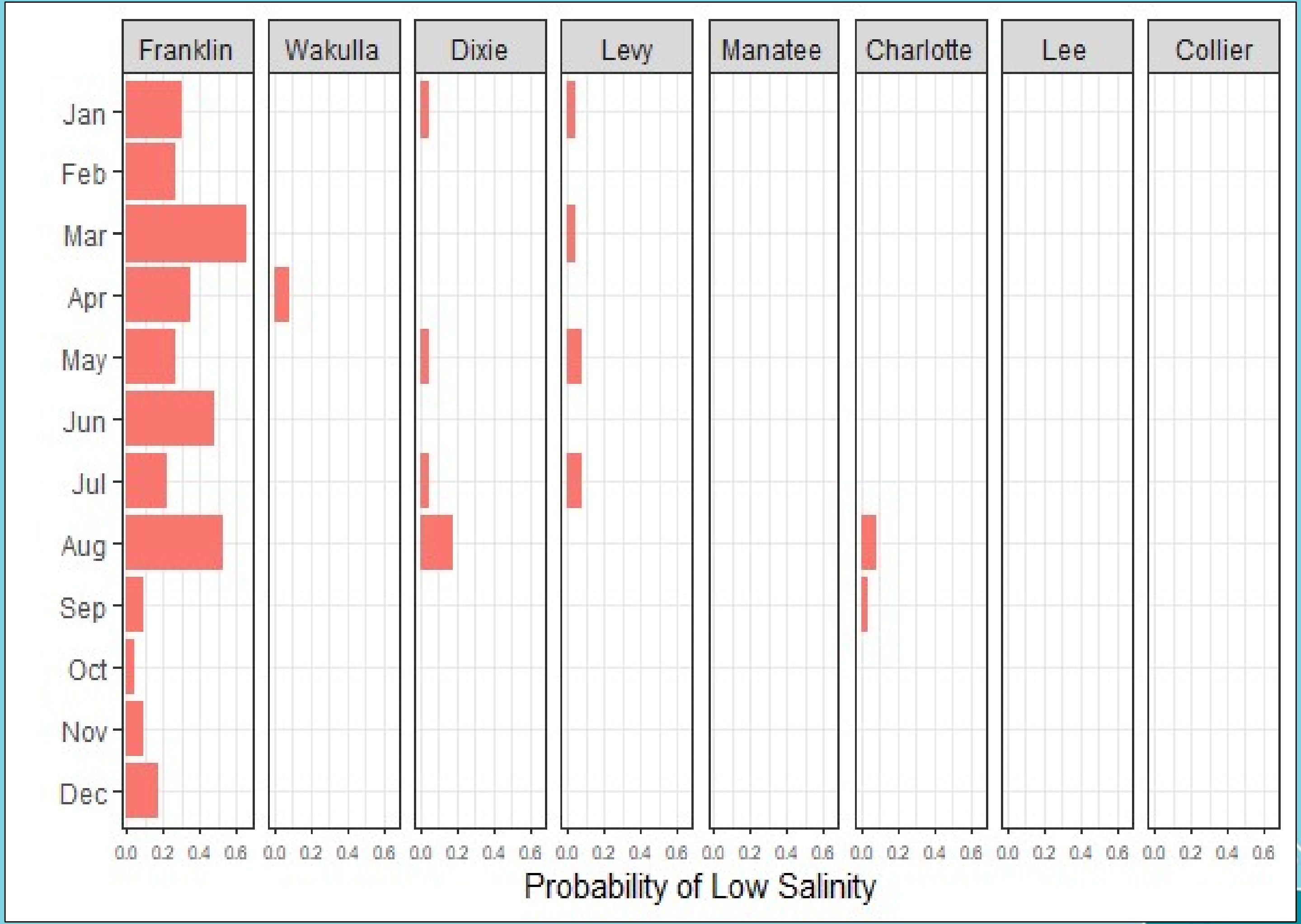
Data: Low Salinity

Samples with Low Salinity



Note: Data comes from FDACS from 2000 to 2022.
Red points represent samples with less than 10 ppt.

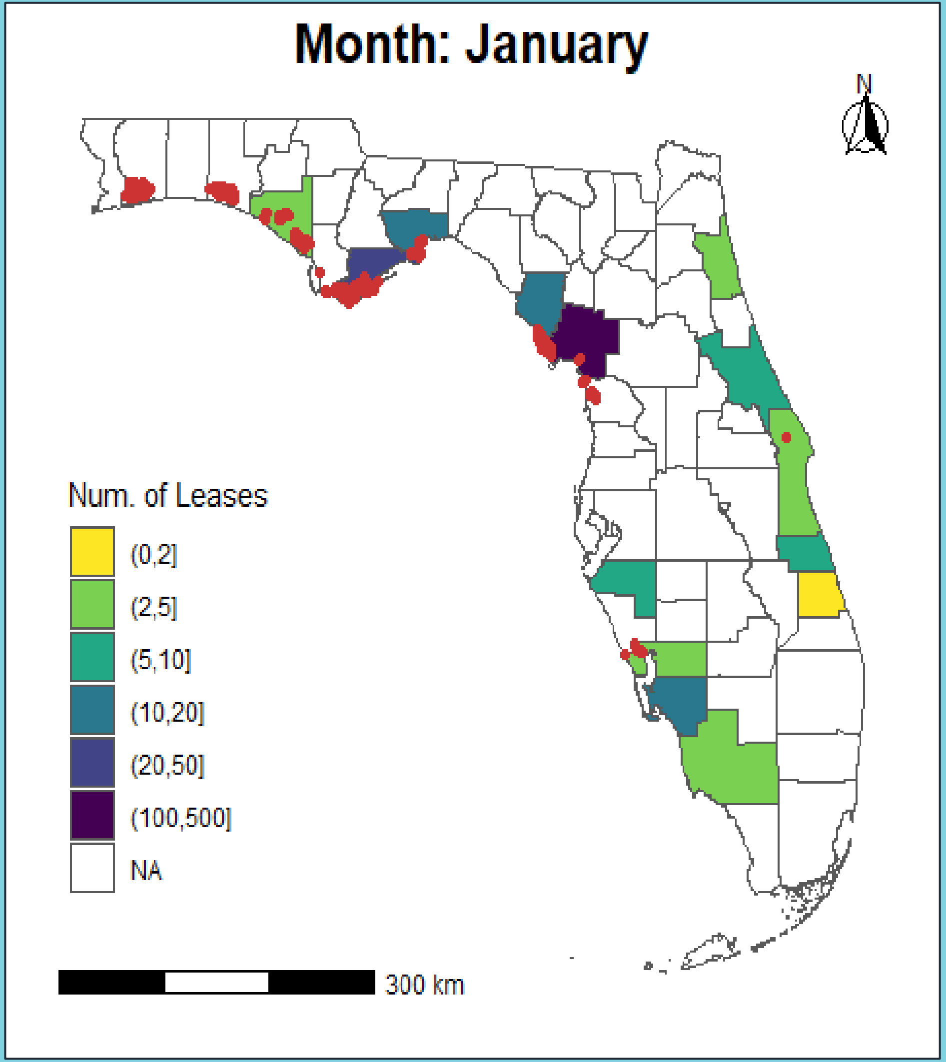
Probability of Low Salinity by Month and County (2000 - 2022)



Note: The probability is equal to the Number of months with average low salinity (less than 10 ppt.) dived by total number of months between 2000 and 2022 (23).

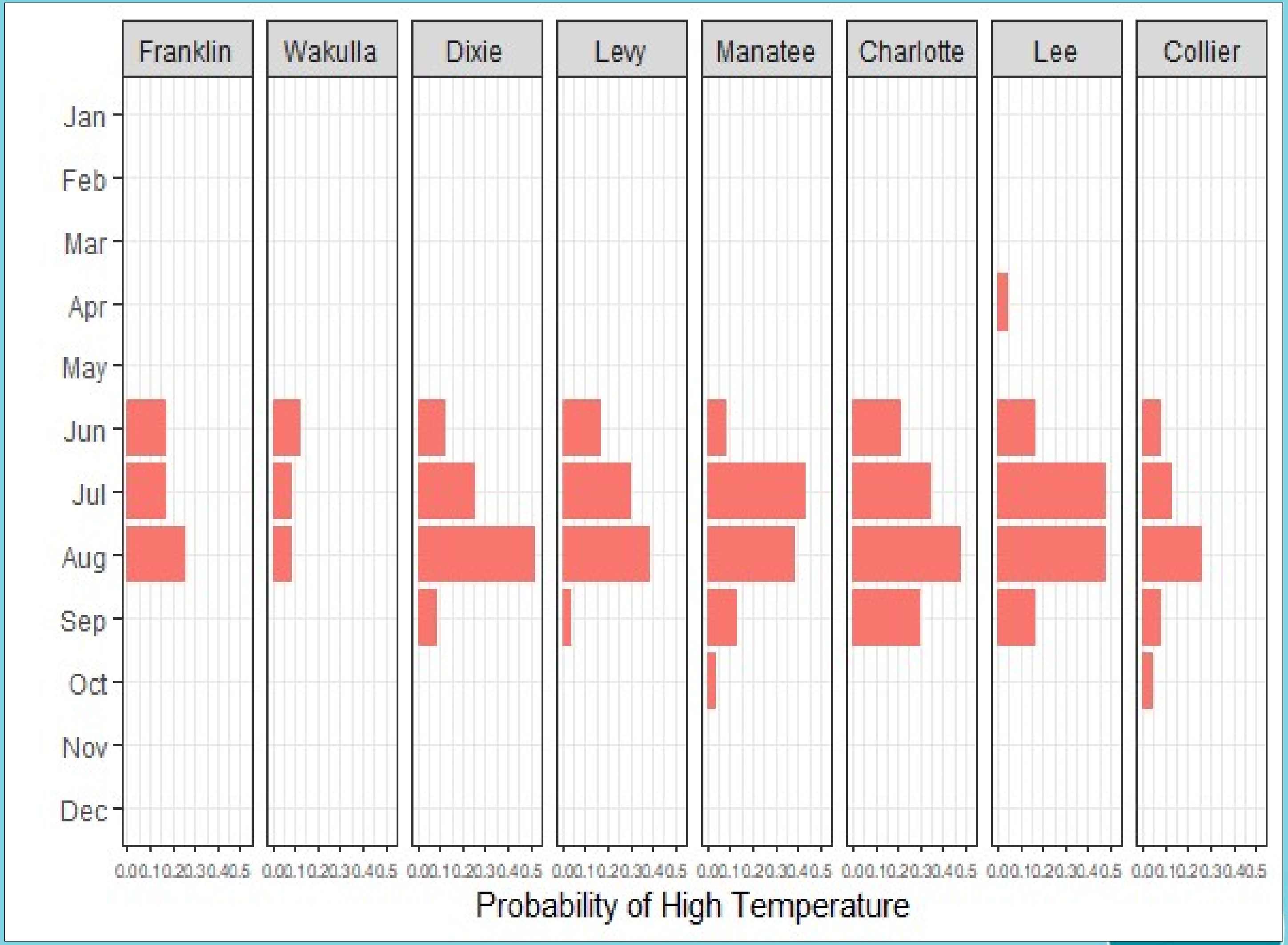
Data: High Temperature

Samples with High Temperature



Note: Data comes from FDACS from 2000 to 2022.
Red points represent samples with more than 31ºC.

Probability of High Temperature by Month and County (2000 - 2022)



Note: The probability is equal to the Number of months with average high temperature (more than 31ºC) dived by total number of months between 2000 and 2022 (23).

Stochastic Simulations

Our analysis simulates a representative clam grower where we take into account deterministic and stochastic variables.

1. Deterministic variables: Decisions made by growers.

- Planted clams
- Labor minutes per clam
- The capital used per clam

2. Stochastic variables: Variables that growers can not control

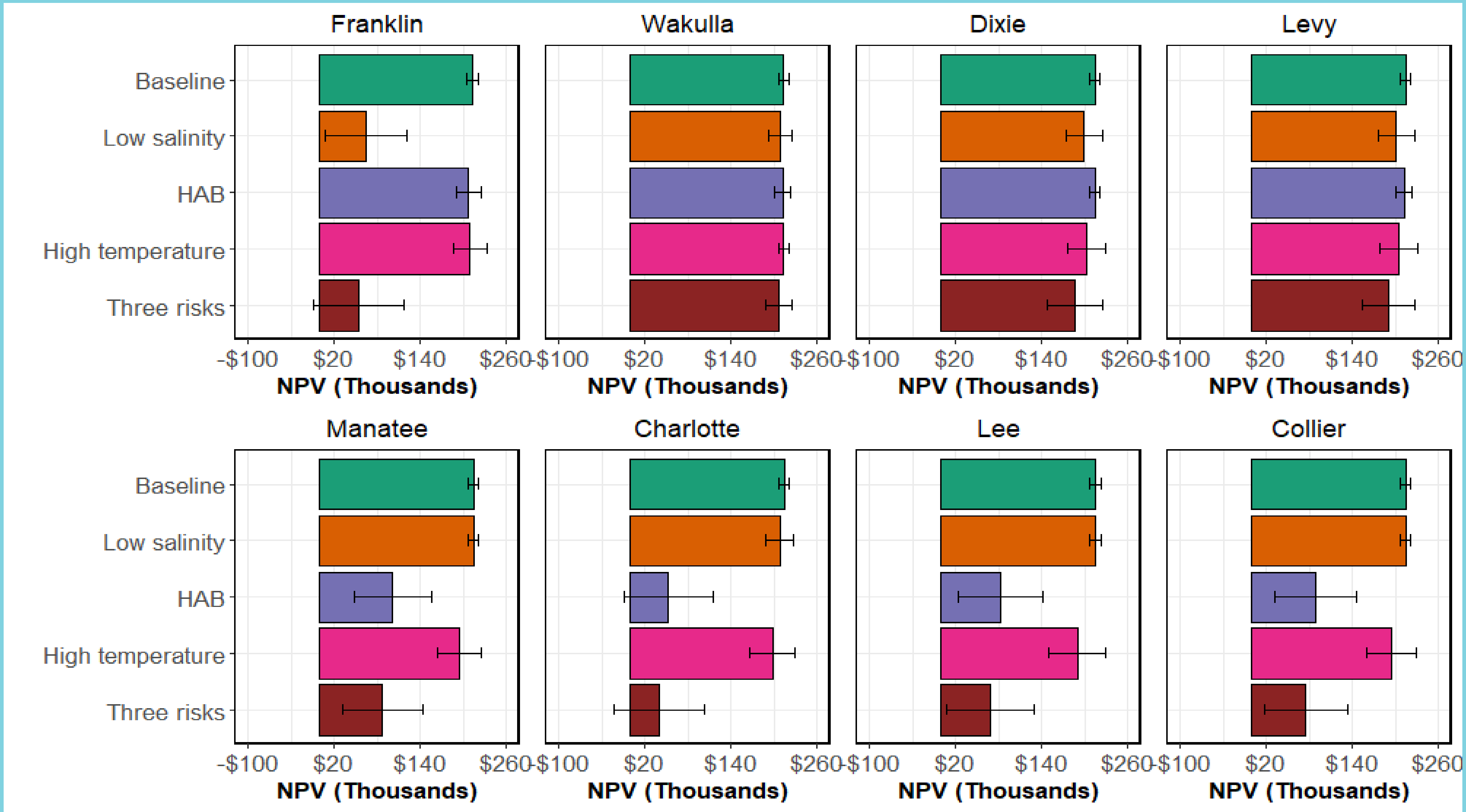
- Mortality rates (natural, low salinity, and high temperature)
- Environmental risk events (HAB, low salinity, and high temperature)
- Type of clam (1”,7/8”, and pasta)
- Prices (we assume no stochastic – constant prices)

Simulations: 10 years, 120 months, 1,000 iterations per month, 120,000 iterations

List of Parameters

Parameter	Symbol	Value	Unit	Source
Biological Model				
Asymptotic height of the clam	L_{∞}	85.86	mm	(Jones et al., 1990)
Growth rate coefficient	k	0.35	$year^{-1}$	(Jones et al., 1990)
Theoretical age when clams have zero length	t_0	0.28	year	(Jones et al., 1990)
Market size	L	25.4	mm	(IFAS, 2014)
Economic model				
Wage rate per clam	w	0.009	$USD	(IFAS, 2014)
Number of minutes of labor used per clam	l	0.036	minutes	(Adams et al., 2004)
Capital cost per clam	v	0.035	$USD	(IFAS, 2014)
Little neck size (1") size price	P_{q1}	0.16	$USD	(IFAS, 2014)
7/8" size price	P_{q2}	0.14	$USD	(IFAS, 2014)
Pasta size price	P_{q3}	0.08	$USD	(IFAS, 2014)
Proportion of clams that achieve market size	δ	0.95	%	(Moor et al., 2022)
Discount rate	r	0.06	%	(IFAS, 2014)
Number of plated clams	N	66,667	units/month	(IFAS, 2014)
Probability of Little neck (1")	D_{q1}	0.7	%	(IFAS, 2014)
Probability of 7/8"	D_{q2}	0.2	%	(IFAS, 2014)
Probability of pasta	D_{q3}	0.1	%	(IFAS, 2014)

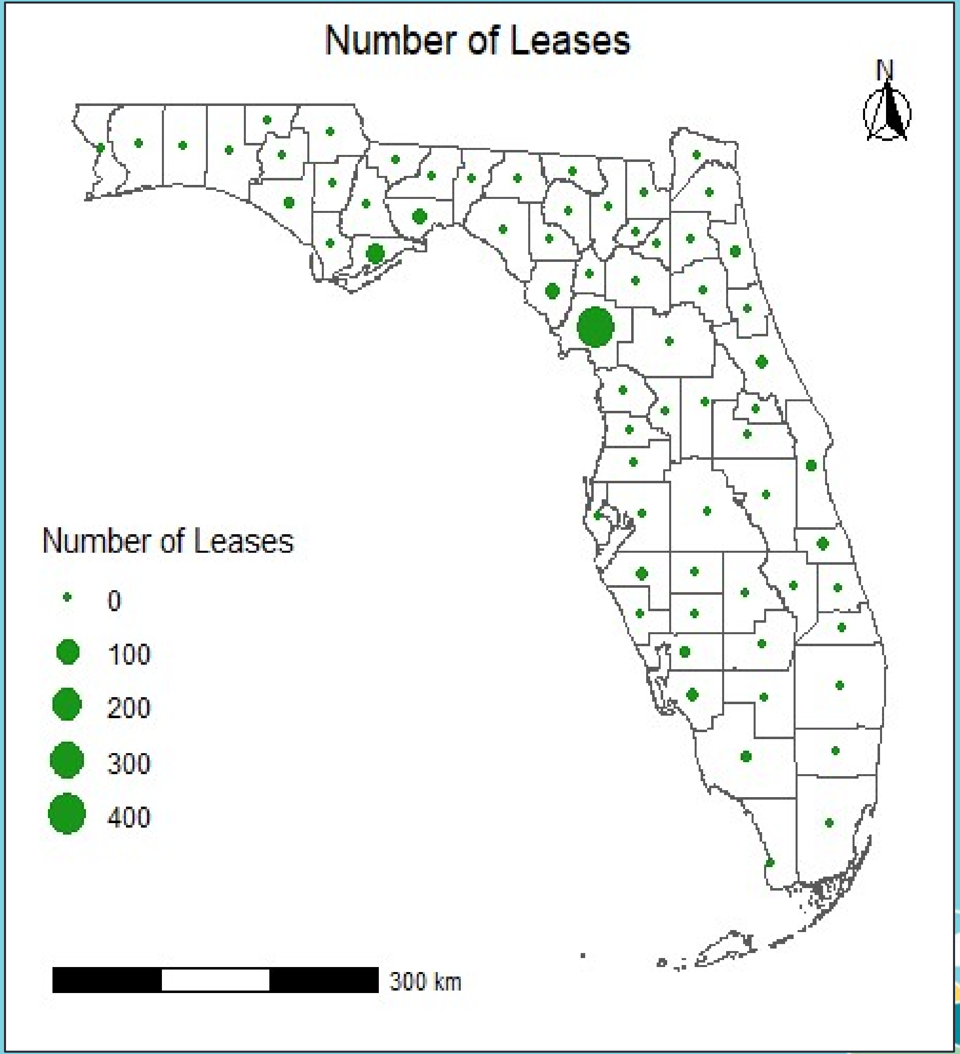
Results - Simulation for Net Present Value by County (10 years)



Note: We use 1,000 iterations per month, as we have 120 months, then 120,000 iterations.

Relative Change

County	Relative change (%) - Compared with the baseline (1)	Numer of clam leases (2021) (2)	Share of clam leases (3)	Weighted relative change (4) = (1)*(3)
Charlotte	-66.9%	3	0.6%	-0.4%
Collier	-50.3%	3	0.6%	-0.3%
Dixie	-15.5%	16	3.0%	-0.5%
Franklin	-28.8%	48	8.9%	-2.6%
Lee	-83.2%	15	2.8%	-2.3%
Levy	-18.7%	428	79.1%	-14.8%
Manatee	-48.6%	10	1.8%	-0.9%
Wakulla	-5.3%	18	3.3%	-0.2%
Total		541	100.0%	



Data Source: FDACS, Public Record Center (2021).
FDCA administers the leases, and each lease is 2 acres in size.

Conclusions

- Counties in the northern part of the west coast are more affected by low salinity events, while the counties in southern areas are more affected by HAB events.

- Considering the number of leases per county, Levy and Franklin are the most affected counties where the low salinity risk is the main issue for these counties.

Thank you!

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