# The Effects of Water Quality Improvements on an Open Access Commercial Fishery: Evidence from the Chesapeake Bay Blue Crab Fishery

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# Clean Water Act

- First major US law to address water pollution
- TMDLs must be developed for impaired waterways
- Chesapeake Bay TMDL
  - Costs
  - Benefits
    - Commercial fishing
    - Recreational fishing and other recreational activities
    - Property values
    - Avoided costs of water treatment
    - Co-benefits of BMPs

# TMDL Costs

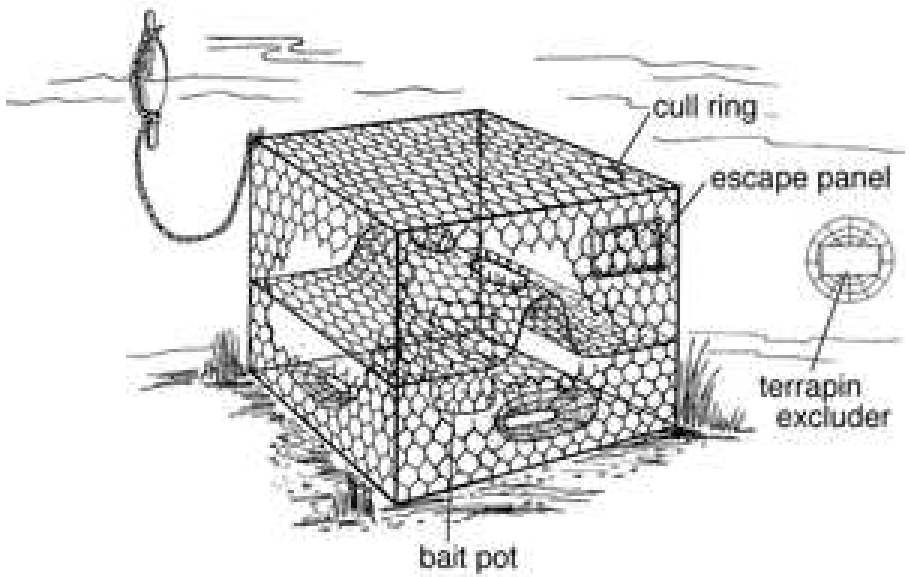
**Table 14: Summary of Costs for Maryland's Interim (2017) and Final (2025) Chesapeake Bay Restoration Strategies**

| Source Sector | Cost of 2017 Strategy 2010 - 2017 (Millions) | Cost of 2025 Strategy[a] 2010 - 2025 (Millions) |
|---|---|---|
| **Agriculture** | **$498** | **$928** |
| **Municipal Wastewater** | **$2,368** | **$2,368** |
| Major Municipal Plants | $2,306 | $2,306 |
| Minor Municipal Plants | $62 | $62 |
| **Stormwater** | **$2,546** | **$7,388** |
| MDOT[c] | $467 | $1,500 |
| Local Government | $2,079 | $5,888 |
| **Septic Systems** | **$824** | **$3,719** |
| Septic System Upgrades | $562 | $2,358 |
| Septic System Connections | $237 | $1,273 |
| Septic System Pumping | $25 | $88 |
| **TOTAL** | **$6,236** | **$14,403** |

a. Cumulative total.

# Blue Crab Fishery

- Over 65% of landings in the Bay
  - $76 million in Maryland (2010)
- Limited Entry
  - May-December season
  - 8 hours/day
  - License-dependent gear type/amount



# Overview

- Bio-economic model
- Fisherman choice model
- Application to TMDL
- Conclusion

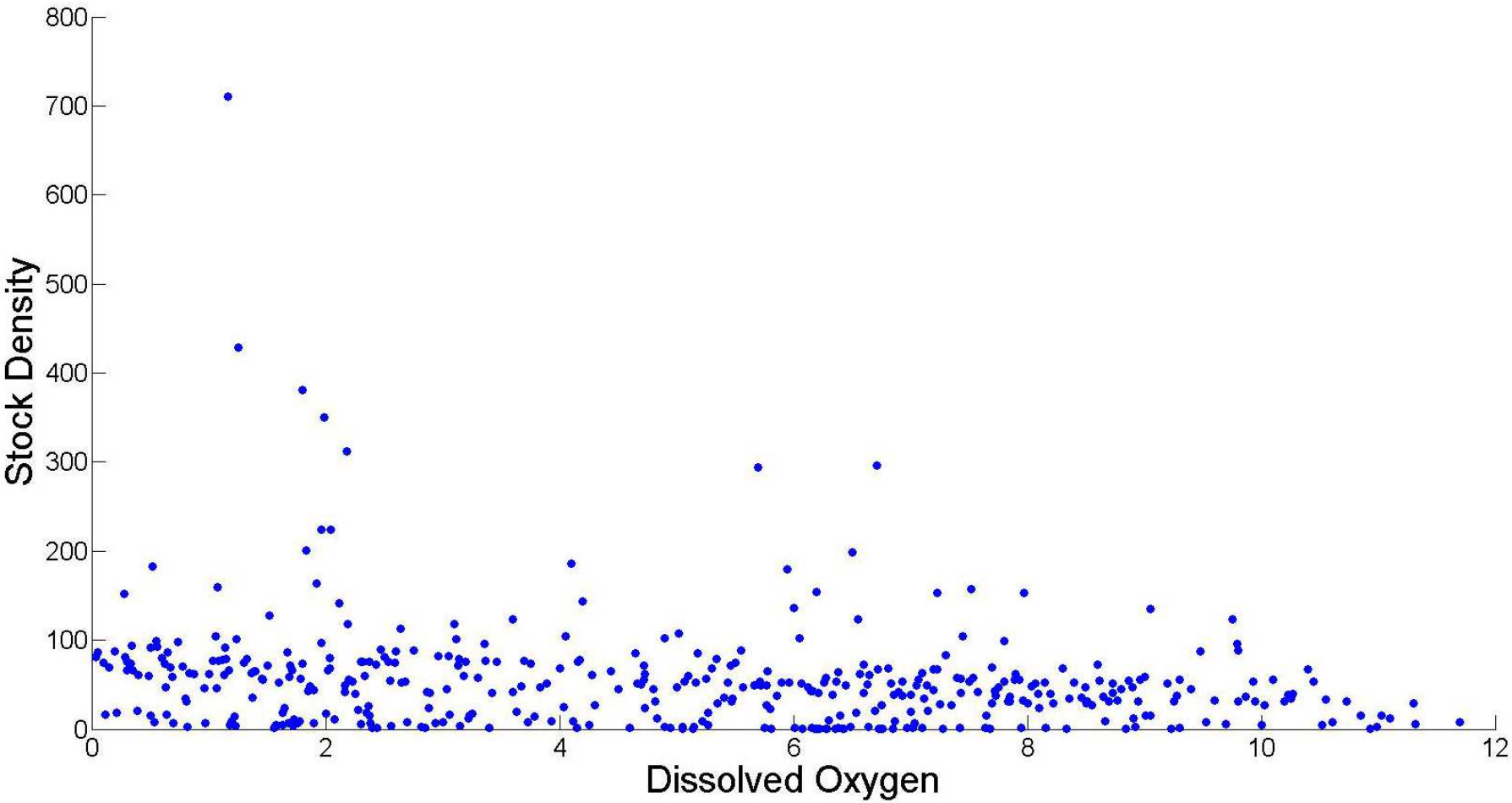
# Bio-Economic Model

$$Stock_{j,t} = f(Stock_{j,t-1}, Harvest_{j,t-1}[, WQ_{j,t}])$$
$$Harvest_{i,j,t} = f(Effort_{i,j,t}, Skill_{i,j,t}, Stock_{j,t}[, WQ_{j,t}])$$

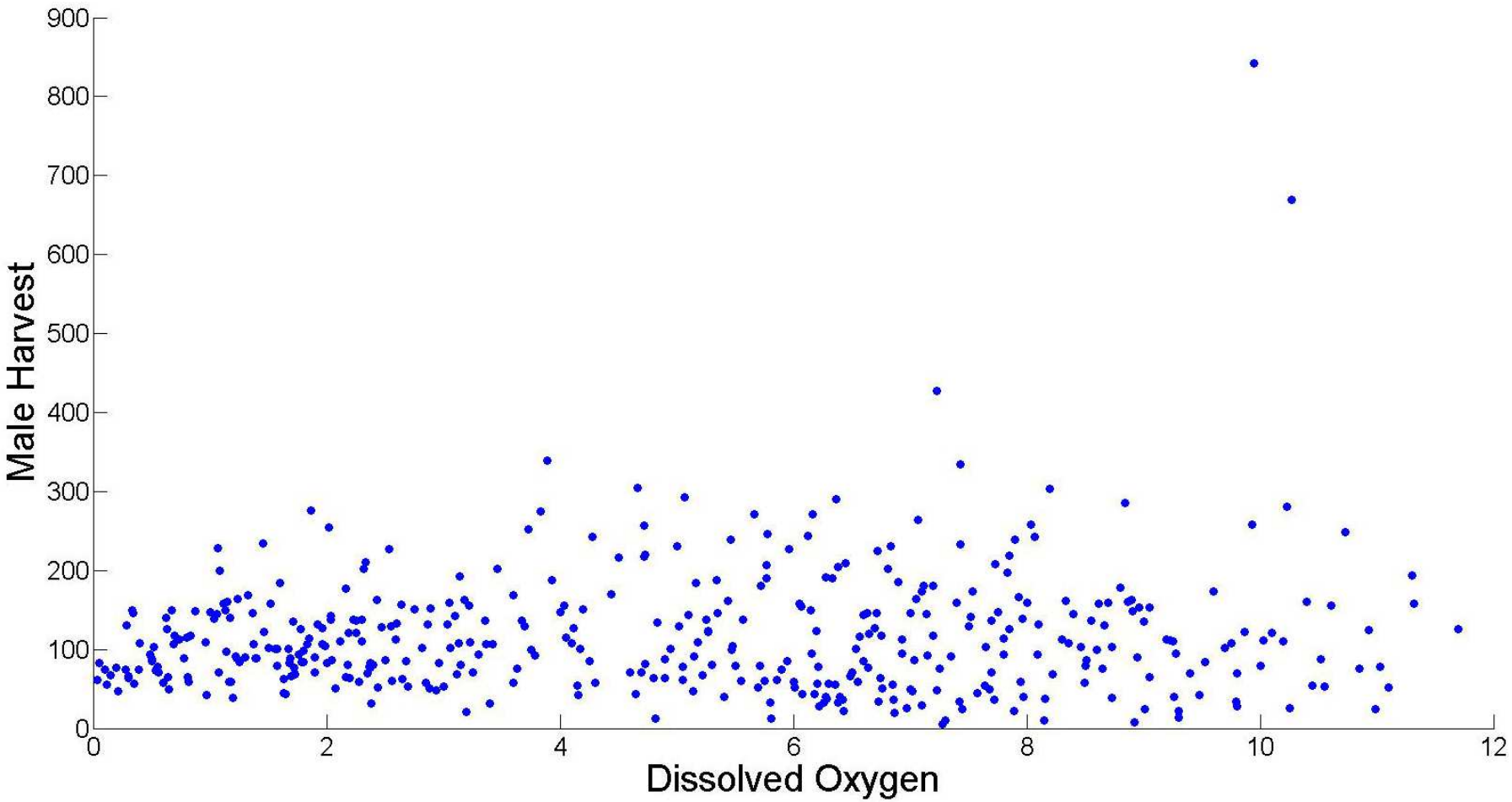
Question: What is the role of water quality?
Hypotheses:

1. Mortality
2. Availability
3. Distribution

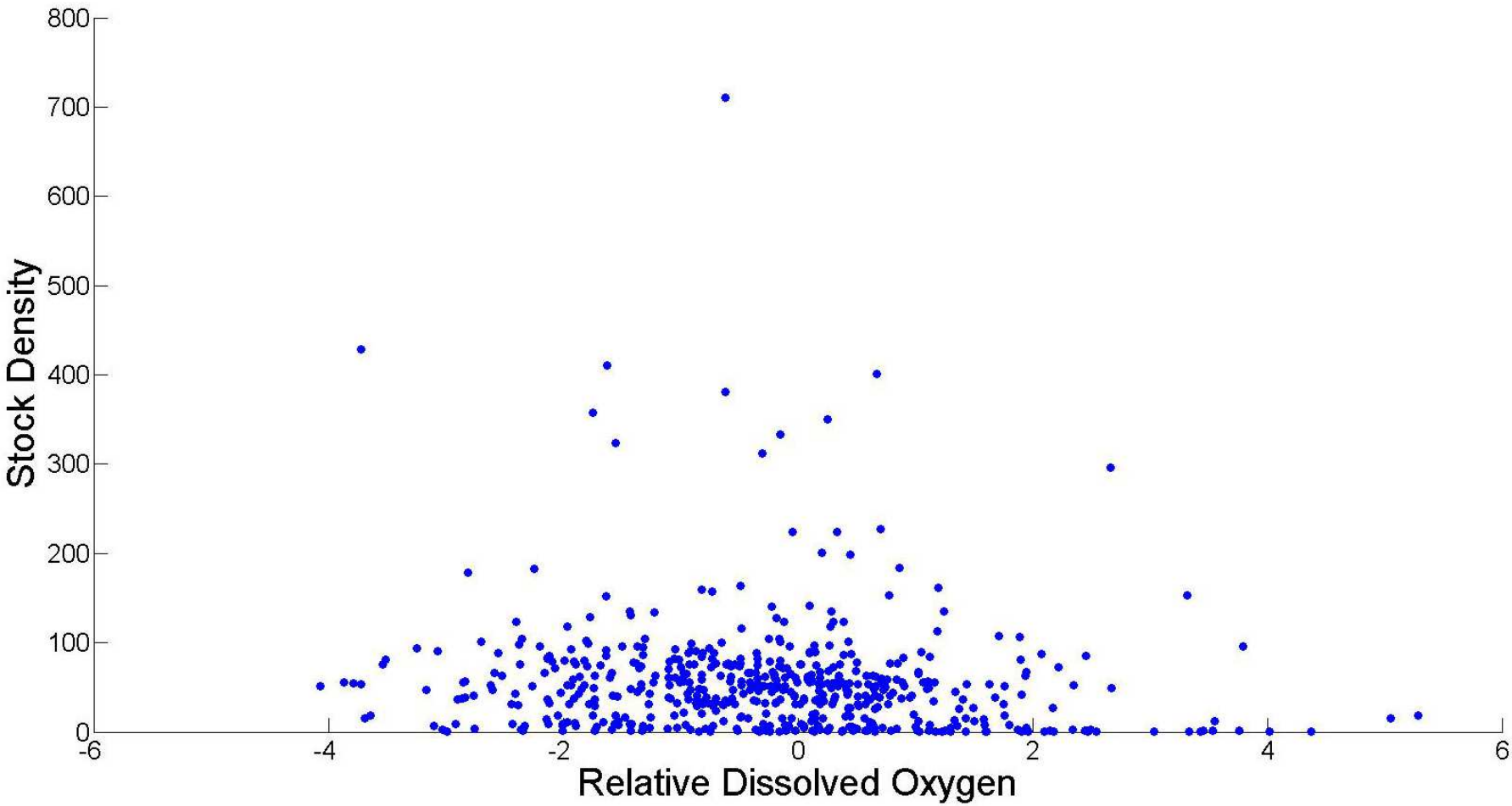
# Data Plots


800
700
600
500
400
300
200
100
0
Stock Density
0
2
4
6
8
10
12
Dissolved Oxygen

# Data Plots


Male Harvest
Dissolved Oxygen
0
100
200
300
400
500
600
700
800
900
0
2
4
6
8
10
12

# Data Plots

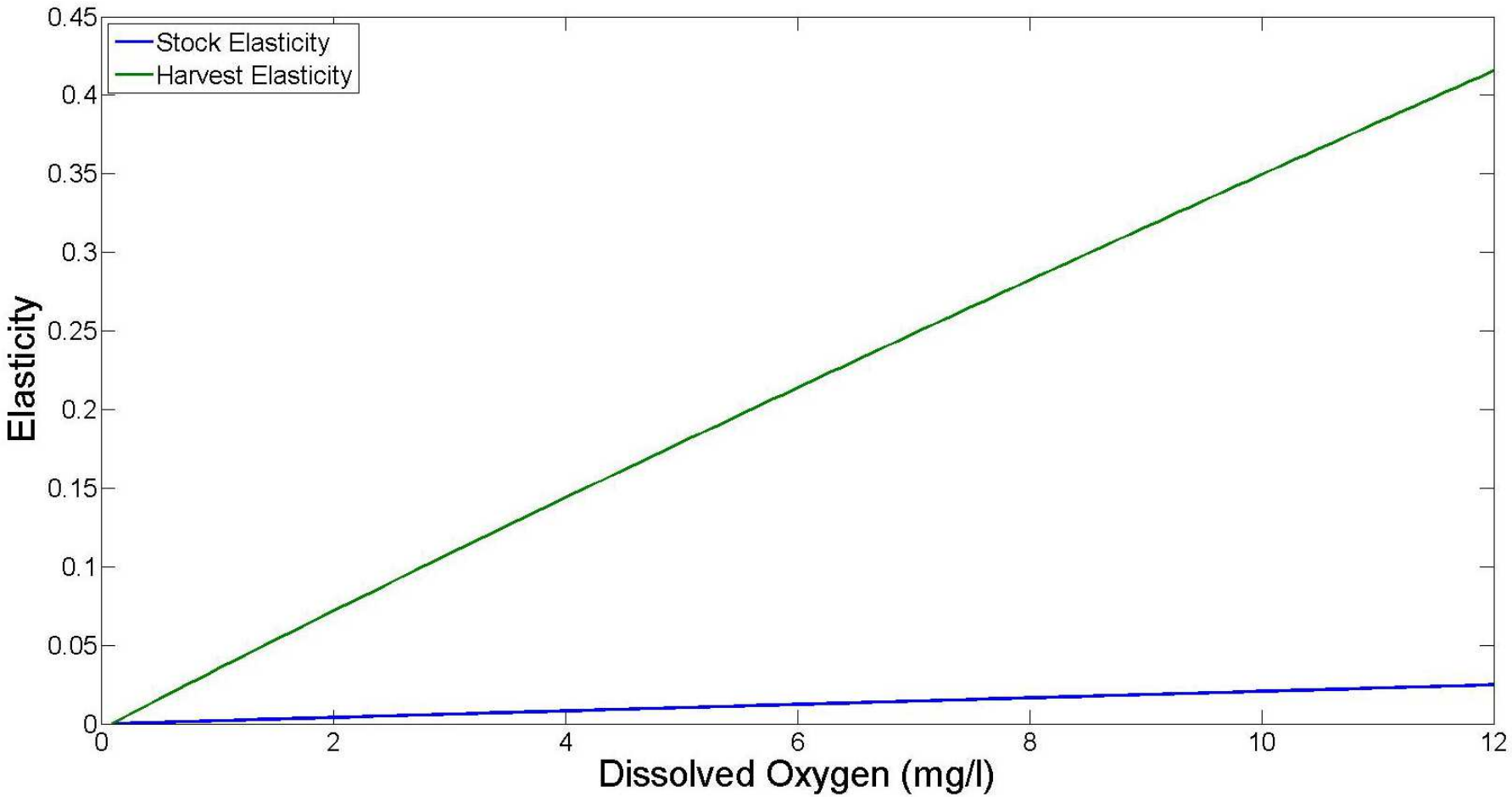

800
700
600
500
400
300
200
100
0
Stock Density
-6
-4
-2
0
2
4
6
Relative Dissolved Oxygen

# Results

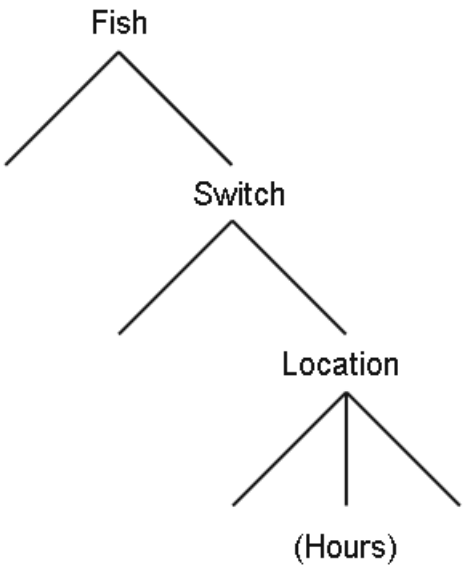
| | Mortality | Availability | Availability 2 | Distribution |
|---|---|---|---|---|
| Density | | | | |
| Lagged Density | 0.11*** | 0.11*** | 0.09*** | 0.12*** |
| | (0.002) | (0.002) | (0.002) | (0.002) |
| Lagged Male Harvest | 0.002*** | 0.002*** | -0.0001*** | 0.002*** |
| | (0.0001) | (5.86E-4) | (6.40E-5) | (5.87E-5) |
| $\sqrt{DO}$ | -11.80*** | – | – | – |
| | (0.32) | | | |
| $\Delta DO$ | – | – | – | 1.33*** |
| | | | | (0.11) |
| Constant | 89.67*** | 45.80*** | 55.78*** | 46.74*** |
| | (2.32) | (2.00) | (2.00) | (2.00) |
| Male Harvest | | | | |
| Density | 0.71*** | 0.83*** | 0.44*** | 0.82*** |
| | (0.01) | (0.01) | (0.02) | (0.01) |
| Age | -1.07*** | -1.10*** | -1.13*** | -1.10*** |
| | (0.03) | (0.03) | (0.03) | (0.03) |
| Hours | 36.11*** | 35.68*** | 36.24*** | 36.27*** |
| | (0.16) | (0.16) | (0.17) | (0.16) |
| $\sqrt{DO}$ | – | 10.25*** | 5.92*** | – |
| | | (0.56) | (0.58) | |
| Constant | -57.13*** | -78.42*** | -41.98*** | -64.14*** |
| | (2.16) | (2.47) | (2.62) | (2.19) |
| Number of Observations | 367,478 | 367,478 | 339,509 | 367,478 |

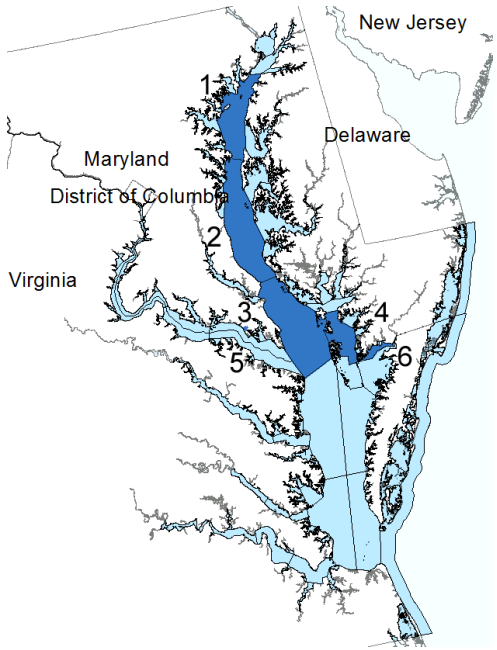
*Statistical significance at 10% level
**Statistical significance at 5% level
***Statistical significance at 1% level

# Results


Stock Elasticity
Harvest Elasticity
Elasticity
Dissolved Oxygen (mg/l)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12

# Fisherman Choice Model




$$Fish_{i,t} = f(Skill_{i,t}, Regulation_t, Weather_t)$$

$$Switch_{i,j,t} = f(E(Crab\ Stock_{j,t}))$$

$$Location_{i,j,t} = f(E(Profits_{i,j,t}), E(Number\ of\ Fishermen_{i,j,t}))$$

$$Hours_{i,j,t} = f(P^*_{i,j,t}, Skill_{i,t}, Regulation_t, Weather_t)$$

# Two Data Sets

Fishermen Log Book Data

- 2000-2010
- 1,473 unique fishermen
- 786,296 observations
- 393,734 trips (50%)
- 1,322 switches (0.8%)

GPS Buoy Data

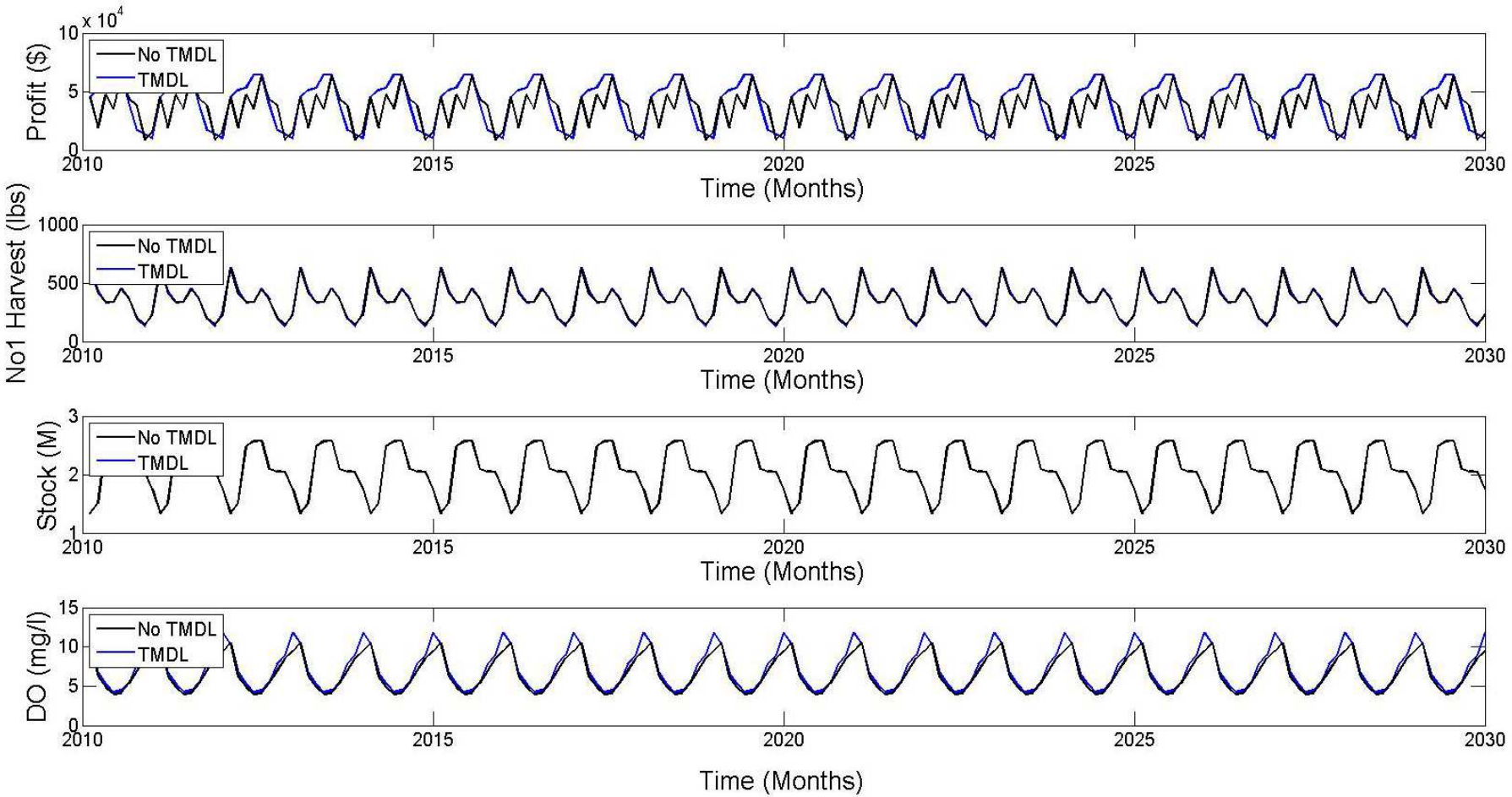
- 2002-2004,2007-2011
- 263 unique fishermen
- 51,883 observations
- 9,634 trips (19%)
- 4,476 switches (46%)

# Results - Log Book Data

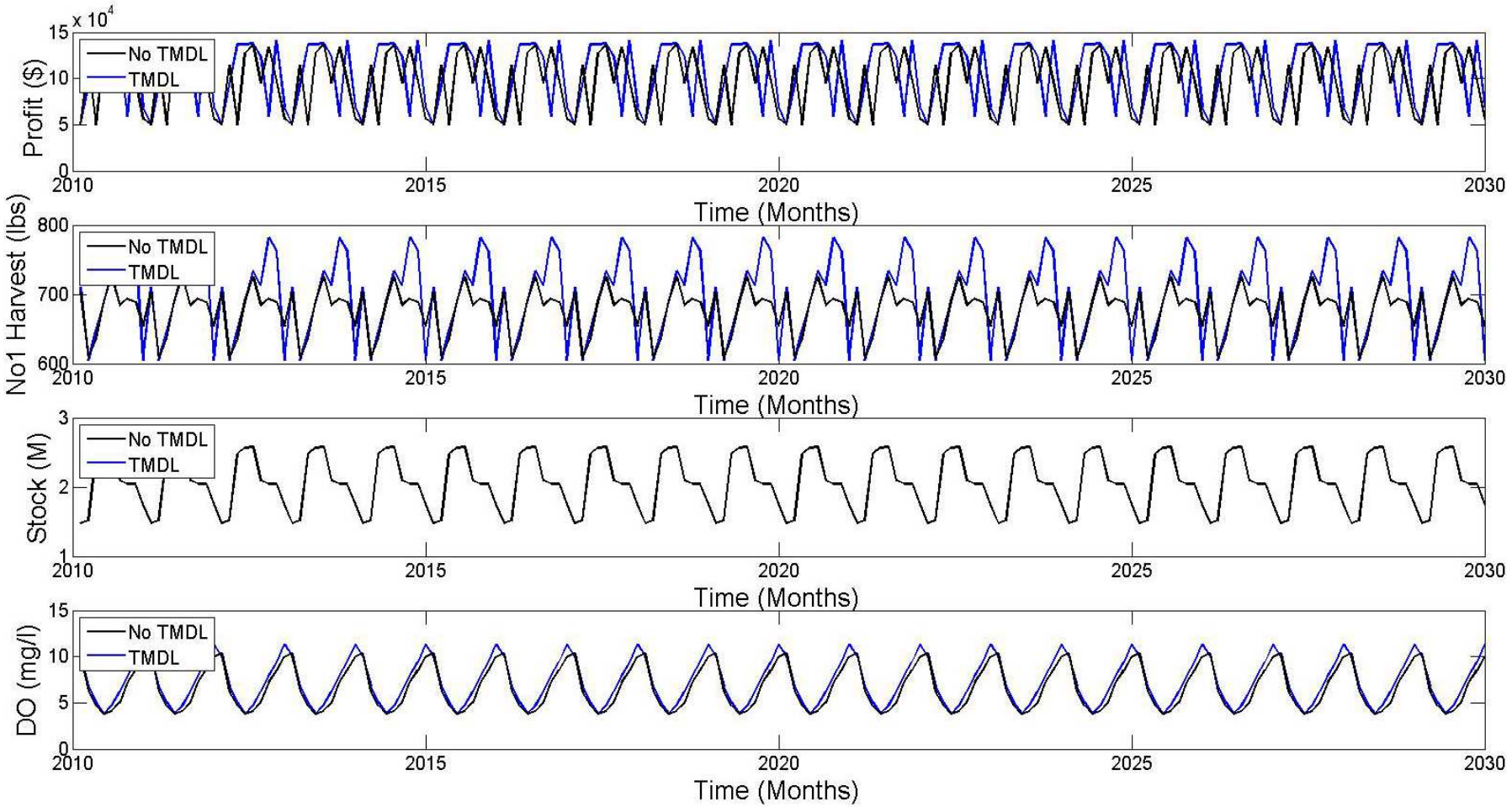
| Fish | | Switch | | Location | |
|---|---|---|---|---|---|
| Sun/Mon | -0.35*** | Spring/North | -0.02 | E(Profit) | 0.17*** |
| | (0.05) | | (0.02) | | (0.02) |
| Age | 0.01 | Summer/North | -0.78*** | E(N) | 0.02*** |
| | (0.02) | | (0.02) | | (0.002) |
| $Age^2$ | -0.0002 | Fall/North | -0.85*** | | |
| | (0.0002) | | (0.03) | | |
| Air Temp | 0.004*** | $IV_l$ | 0.51*** | | |
| | (0.001) | | (0.03) | | |
| Wind Speed | -0.10*** | Constant | -5.35*** | | |
| | (0.01) | | (0.09) | | |
| Cloud Cover | -0.05*** | | | | |
| | (0.01) | | | | |
| Precip Type | -0.06*** | | | | |
| | (0.03) | | | | |
| $IV_s$ | 0.96*** | | | | |
| | (0.19) | | | | |
| Constant | 0.34 | | | | |
| | (0.43) | | | | |
| Observations | 133,634 | | 391,812 | | 15,937 |
| Clusters | 1,325 | | 1,371 | | – |
| Replications | 500 | | 500 | | – |
| LL | -91,585.11 | | -16,680.86 | | -4,594.40 |

*Statistical significance at 10% level
**Statistical significance at 5% level
***Statistical significance at 1% level

# Open Access Results



# "Managed" Results



# Comparison of Results

| | Open Access | "Managed" |
|---|---|---|
| Stock (crabs) | 651.47<br>(3.19E-5%) | 28,710.06<br>(1.39E-3%) |
| Harvest (lbs) | 1,380.08<br>(1.51%) | 4,332.80<br>(2.39%) |
| Trip (#) | 733.28<br>(1.69%) | 0<br>(0%) |
| Trip Harvest (lbs/#) | -0.004<br>(-0.17%) | 0.05<br>(2.39%) |
| Profit ($) | 870,640.83<br>(13.88%) | 1,761,143.57<br>(10.25%) |
| CS ($) | 6,679.92 | 19,450.07 |

# Conclusion

- Estimated a bio-economic model of the blue crab fishery
  - Water quality affects the availability of the crabs
  - Stock and harvest respond inelastically to changes in water quality
- Estimated a fisherman behavior model
  - Switching occurs more frequently than previously assumed
- Simulated the effects of the TMDL on the blue crab fishery
  - Benefits are likely to be small
  - Managing commercial fisheries may lead to greater benefits

# Results - GPS Buoy Data

| Fish | | Switch | | Location | |
|---|---|---|---|---|---|
| Sun/Mon | -0.53*** | Spring/North | -0.15*** | E(Revenue) | 0.06*** |
| | (0.04) | | (0.01) | | (0.01) |
| Air Temp | -0.0001 | Summer/North | -0.50*** | E(N) | 0.03*** |
| | (0.004) | | (0.05) | | (0.0005) |
| Wind Speed | -0.86*** | Fall/North | -0.42*** | | |
| | (0.04) | | (0.07) | | |
| Cloud Cover | -0.02 | Year Trend | -0.43*** | | |
| | (0.02) | | (0.01) | | |
| Precip Type | 0.42*** | $IV_l$ | 0.42*** | | |
| | (0.06) | | (0.06) | | |
| $IV_s$ | 0.99*** | Constant | 2.70*** | | |
| | (0.04) | | (0.17) | | |
| Constant | -0.95*** | | | | |
| | (0.19) | | | | |
| Observations | 7,303 | | 9,014 | | 21,863 |
| Clusters | 252 | | 263 | | – |
| Replications | 100 | | 100 | | – |
| LL | -3,539.77 | | -4,925.72 | | -6,551.25 |

*Statistical significance at 10% level
**Statistical significance at 5% level
***Statistical significance at 1% level