The Impact of Marine Reserves on Recreational Salmon Catch and Salmon Angler Behavior Along the Oregon Coast

Linfield University Undegraduate; Zharyck Lopez

Introduction

Why are Marine Reserves important in Oregon?

- Recreational fishing has major economic, cultural, and social importance in Oregon.
- In 2019, saltwater recreational fishing supported about $120 million in income and nearly 2,000 jobs in the state economy(TRG, 2021a).
- Increasing threats to marine ecosystems have created a need for stronger ocean conservation efforts, including the establishment of Marine Reserves (FOA, 2018).

What are Marine Reserves (MRs)?

- Marine Reserves are fully protected ocean areas where taking marine species is prohibited
- Oregon Ocean Policy Advisory Council established five Marine Reserves in 2012 after legislation passed in 2009 to protect biodiversity, monitoring, and reduce ecosystem decline(OPAC 2012).

What does this study examine?

- Understanding both catch outcome and angler behavior is essential for evaluating the overall impacts of Marine Reserves
- It analyzes how anglers respond behaviorally to Marine Reserves through:
    - Changes in fishing effort, location choice, fishing strategies

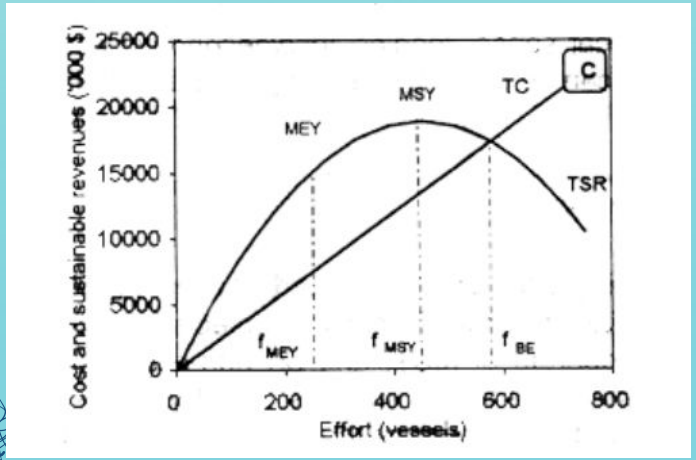
Literature review

- Fox et al. (2022). *Oregon recreational fishers' knowledge, support, and perceived impacts of marine reserves*. Ocean and Coastal Management
  - Marine Reserved significantly affected avid saltwater anglers in Oregon.
  - Anglers mainly adapted by changing fishing locations, trip frequency, and target specie
  - Behavioral substitution was more common than leaving the fishery entirely
- Lester et al. (2009). *Biological effects within no-take marine reserves: a global synthesis*. Marine Ecology
  - No-take Marine Reserves increse fish biomass, density, and average size.
  - Potential spillover effects may improve catch rates outside reserve boundaries.
  - Ecological benefits could influence long-term recreational fishing outcomes.

Methods– Hicks et al. (2023)

Empirical framework based on the Gordon-Schaefer Model linking fish stock dynamics with recreational fishing behavior.

$$\frac{\Delta S}{\Delta t} = \frac{\delta S}{\delta t} = rS(t)(1 - \frac{S(t)}{K})$$



- Salmon Harvest depends on:
  - Fish biomass
  - Fishing effort
  - Environmental Conditions
- MRs are modeled as policy shocks that restrict access to fishing areas and reduce harvest pressure.
- The model incorporates
  - MSY (Maximum Sustainable Yield)
  - MEY (Maximum Economic Yield)
  - Biological Equilibrium
- Reduced fishing effort within reserves may increase biomass and generate spillover benefits for anglers outside reserve boundaries

Empirical Models

Model 1: Ecological Effects

$$SalmonCatch_{it} = \beta_0 + \beta_1 Rec.Effort + \beta_2 EstimatedStocks_{it} + \beta_3 PDO_t + \beta_4 dummy\_Rerserve1_i + \beta_5 dummy\_Reserve2_i + \varepsilon_{it}$$

Model 2: Behavioral Effects

$$Effort_t = \alpha_0 + \alpha_1 StockChange_{1t} + \alpha_2 Catch_{2i} - \alpha_3 Distance_{3i} + \alpha_4 PDO_{4i} - \alpha_5 Knowledge_{5i} + \epsilon_{it}$$

Data

Salmon Rec. Catch

- Measures annual Coho and Chinnok recreational landings
- From ODFW (2001-2023)
- Newport, Coos Bay, Tillamook, and Columbia River ports adjancent to MRs

Salmon Rec. Effort

- Annual rec. effort for Coho and Chinook Salmon
- From ODFW

Salmon Stock Estimates

- Proxy for regional Salmon stock
  - Derived from Columbia River min. return – min. escapement estimates
  - From Pacific Fishery Management Council

PDO (Pacific Decadal Oscillation)

- Climate variability indicator affecting salmon survival and producticty
- From NOAA

Distance

- Proxy for travel and fishing accessibility
- Based on approx. distance from Newport to each MR

Knowledge

- Proxy for angler awareness of MR
- From outreach, tourism exposure, accessibility, engagement
- Normalized on 0-1 scale

Snapshot of Data

Panel Data (2001–2023)

Variable	Average	# of observations
Rec. Salmon Catch	14694.96	92
Rec. Salmon Effort	18862.83	92
PDO	-0.73826	92
Salmon Stocks	837922.2	92
Reserve Dummy	1 or 0	3 Reserves
Distance (mile)	63.5	3 Reserved
Knowledge Index	0.63	3 Reserves

Results: Ecological Effects

Results of Model Linear Regression Analysis

*Note: * p< .05, **p< .01 , ***p< .001*

Variable	Coef.	*SE*	T Stat	*P*
(Intercept)	-1.206e+03	3.426e+03	-0.382	0.703693
Rec. Effort	3.922e-01	7142e-02	5.492	3.98e-07***
Salmon Stocks	1.537e-02	3.034e-03	5.064	2.32e-06***
PDO	-5.732e+02	1.023e+03	-0.560	0.576643
dummy_R1	-4.710e+03	2.285e+03	-2.061	0.042308*
dummy_R2	-9.352e+03	2.55e+03	-3.660	0.000434***

R-squared: 0.506
Adjusted R-squared: 0.477
Residual Std. Error: 8,645
F-Statistic: 17.62
P-value: 5.571e-12***

Results: Behavioral Effects

Results of Model Linear Regression Analysis

*Note: * p< .05, **p< .01 , ***p< .001*

Variable	Coef.	*SE*	T Stat	*P*
(Intercept)	228,300	63,020	3.623	0.00049***
Salmon Stock	-0.0031	0.0045	-0.685	0.4595
Rec. Catch	0.662	0.1205	5.491	3.98e-07***
Distance(miles)	-1399	3.98	-3.514	0.000706***
PDO	1180	1325	0.891	0.376
Knowledge	-202,200	60,020	-3.669	0.00113**

R-squared: *0.389*
Adjusted R-squared: *0.354*
Residual Std. Error: *11,230*
F-Statistic: *10.97*
P-value: *3.472e-08**

Part 2 Results: Ecological

- Marine Reserves have a statistically significant effect on recreational catch, indicating that spatial restrictions meaningfully influence harvest outcomes.
- Catch is strongly driven by fishing effort and underlying resource availability, consistent with standard fisheries production theory.
- Environmental conditions contribute to catch outcomes, but their influence is weaker once effort and stock conditions are accounted for.
- Overall, results suggest that ecological outcomes are primarily shaped by human activity levels and biological abundance, with Marine Reserves introducing localized constraints on harvest.
- The findings indicate that Marine Reserves function mainly as spatial limitations on access rather than broad drivers of system-wide catch changes.

Part 2 Results: Behavioral

- Angler effort is primarily influenced by access costs and expected fishing success, rather than environmental variability.
- Spatial factors play a key role, as anglers adjust participation based on travel considerations and proximity to fishing locations.
- Awareness of regulatory or spatial restrictions is associated with changes in participation decisions and site selection behavior.
- Biological and climate conditions have a limited direct effect on effort once behavioral and spatial factors are included.
- Overall, fishing effort reflects adaptive decision-making in response to access constraints and perceived fishing quality.

Conclusion

- Marine Reserves in Oregon influence recreational fisheries through ecological effects plus angler behavioral adaptation.
- Results suggest anglers respond mainly through changes in fishing location, effort, trip frequency, and target species.
- Findings also indicate possible spillover benefits from higher biomass near reserve boundaries.
- Future research could strengthen the analysis through:
    - Fixed effects models to control for unobserved regional or time-specific variation
    - Corrections for non-spherical errors, including heteroskedasticity or autocorrelation
    - Expanded angler-level behavioral data for improved estimation accuracy
- Overall, combining ecological dynamics with behavioral responses provides a broader framework for evaluating Marine Reserve policy impacts.

Resources

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R-Results

lm(formula = Data$Rec. Catch ~ Data$Rec. Effort (Angler Trips) + Data$Salmon Stocks + Data$PDO + Data$R1_dummy + Data$R2_Dummy)

Residuals: Min 1Q Median 3Q Max -37619 -5412 -539 4582 26424 Coefficients: Estimate Std. Error t value Pr(>|t|) (Intercept) -1.307e+03 3.426e+03 -0.382 0.703693 Data$Rec. Effort (Angler Trips) 3.922e-01 7.142e-02 5.492 3.98e-07 *** Data$Salmon Stocks 1.537e-02 3.034e-03 5.064 2.32e-06 *** Data$PDO -5.732e+02 1.023e+03 -0.560 0.576643 Data$R1_dummy -4.710e+03 2.285e+03 -2.061 0.042308 * Data$R2_Dummy -9.352e+03 2.555e+03 -3.660 0.000434 *** --- Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 Residual standard error: 8645 on 86 degrees of freedom Multiple R-squared: 0.506, Adjusted R-squared: 0.4773 F-statistic: 17.62 on 5 and 86 DF, p-value: 5.571e-12

lm(formula = data2$`Rec. Effort (Angler Trips)` ~ data2$`Salmon Stocks` + data2$`Rec. Catch` + data2$`Distance(mile)` + data2$PDO + data2$Knowledge) Residuals: Min 1Q Median 3Q Max -10791 -4768 -1581 3043 93856 Coefficients: Estimate Std. Error (Intercept) 2.283e+05 6.302e+04 data2$`Salmon Stocks` -3.069e-03 4.479e-03 data2$`Rec. Catch` 6.620e-01 1.205e-01 data2$`Distance(mile)` -1.399e+03 3.980e+02 data2$PDO 1.180e+03 1.325e+03 data2$Knowledge -2.022e+05 6.002e+04 t value Pr(>|t|) (Intercept) 3.623 0.000493 *** data2$`Salmon Stocks` -0.685 0.495039 data2$`Rec. Catch` 5.492 3.98e-07 *** data2$`Distance(mile)` -3.514 0.000706 *** data2$PDO 0.891 0.375672 data2$Knowledge -3.369 0.001129 ** --- Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1 Residual standard error: 11230 on 86 degrees of freedom Multiple R-squared: 0.3894, Adjusted R-squared: 0.3539 F-statistic: 10.97 on 5 and 86 DF, p-value: 3.472e-08

Thank You