

Fishery Pacific Model

Selected Definitions

A System Dynamics Model of the Pacific Coast Rockfish Fishery

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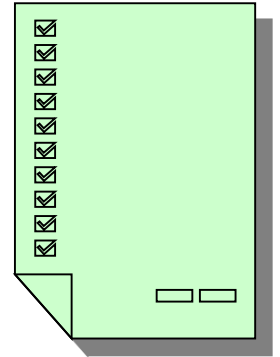
² Ecotrust

July 24th, 2003

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Agenda

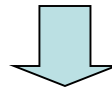
- **Problem Definition**
- **The Model**
- **Model Testing**
- **Policy Analysis**
- **Analysis and Recommendations**
- **Future Work**



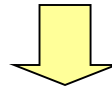
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The Problem

- Populations of Rockfish and other Pacific Coast groundfish dramatically decreased.



- **OVERCAPITALIZATION** is considered the primary cause of fish declination.



- The challenge is how to reduce the fleet without painful economic effects.

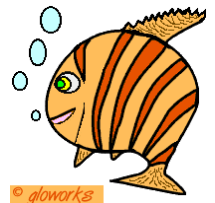
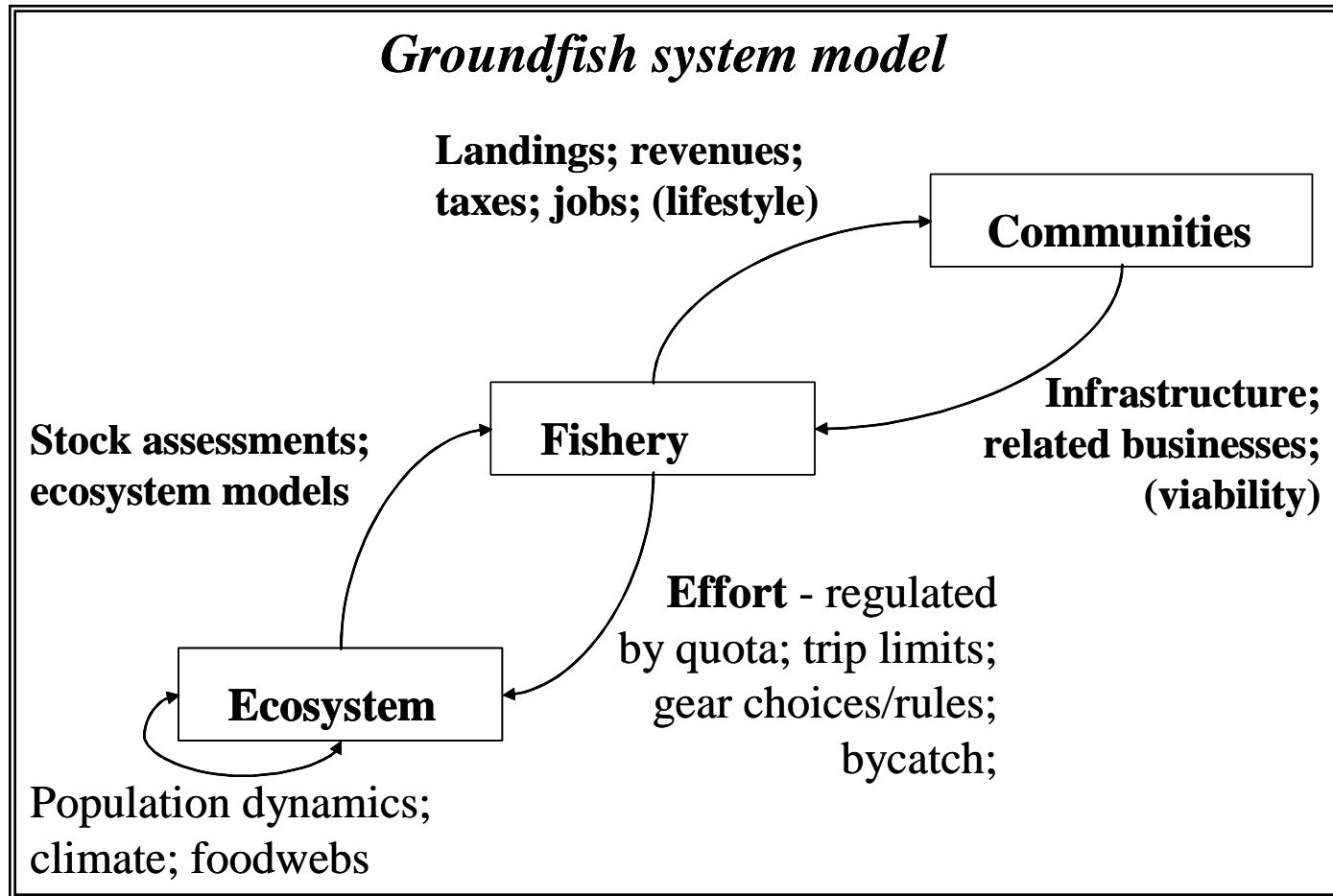
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General Purpose

- Model of the dynamics behavior of the Yellowtail Rockfish of the Pacific coast of the US.
- Generate “endogenously” the historical data for fish population, fishing vessels, regulatory parameters and fish harvest.
- Sensitivity changes to key parameters.

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The Model



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Selected Definitions

- ***Acceptable Biological Catch (ABC)***: An estimate of the amount of fish in tons that could be taken from a stock at its current abundance without jeopardizing it. It is calculated by multiplying the harvest fraction that would produce the MSY times the current biomass.
- ***Annual Recruitment***: The number of fish that mature and become vulnerable to fishing in a given year.
- ***Maximum Sustainable Yield (MSY)***: The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. For species with fluctuating recruitment, the maximum might be obtained by taking fewer fish in some years than in others.

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Selected Definitions (cont.)

- ***BMSY***: The biomass value that corresponds to MSY.
- ***Stock Assessment and Fishery Evaluation (SAFE)***: Report that provide historical data on catch and biomass for different species of fish.
- ***Reports***: Reports that provide historical data on catch and biomass for various species of fish.
- ***Trawl vessels***: Vessels that primarily use trawl gear and account for the majority of groundfish landings (approximately 90%).

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Key Assumptions

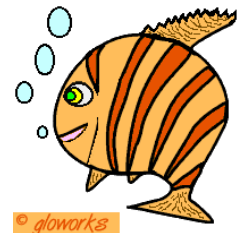
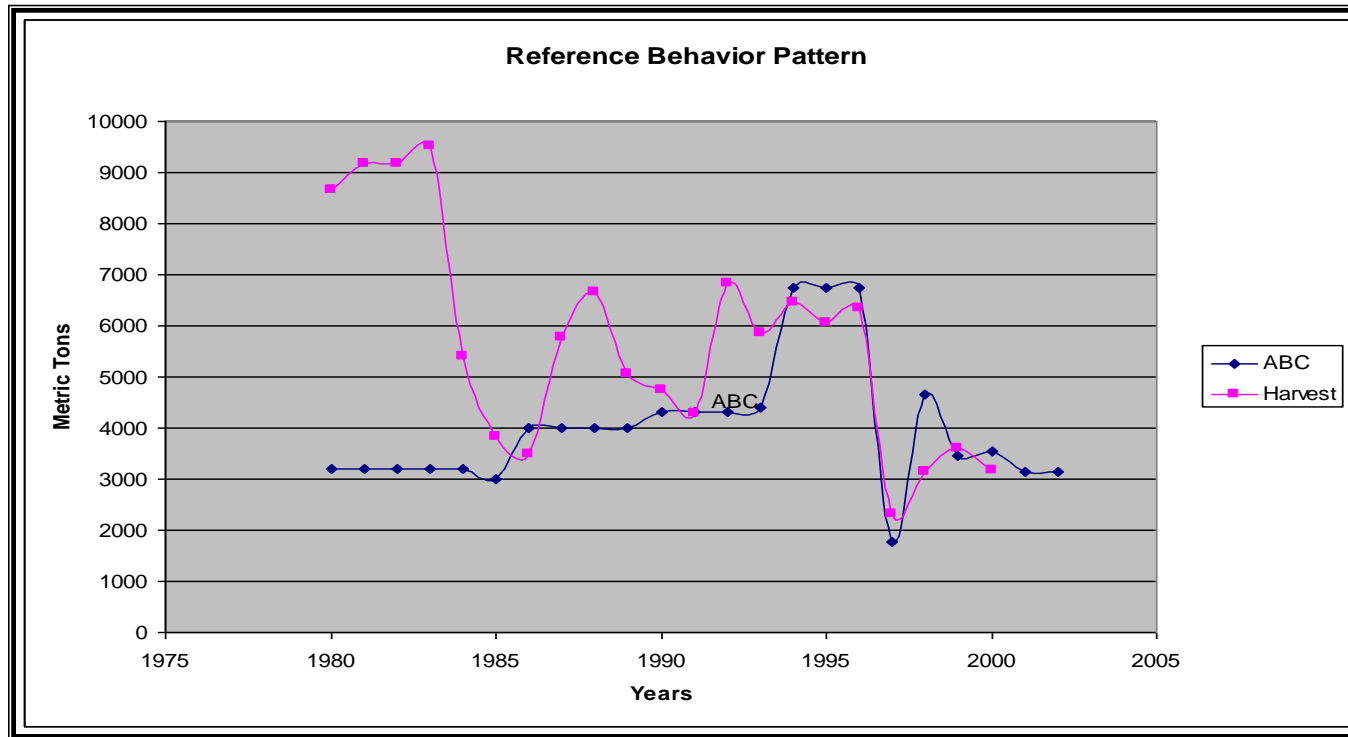
- ***Random variation is ignored:*** Average values from historical information for recruitment rate, spawning, and mortality fish are utilized.
- ***Ecosystem impact:*** The model assumes that fluctuations in ecological variables impact natural mortality rates that affect stocks by up to 20%.
- ***Vessels:*** The number of trawl vessels in the model is assumed to be a fraction of the total number of trawl vessels in use. This fraction is computed to represent the equivalent number of trawl vessels that would be present if the vessels were fishing only for yellowtail.
- ***ABC:*** Acceptable biological catch is calculated yearly in the model, based on triennial biomass surveys. This is the established scientific protocol for stocks assessments, but not always reflected in actual policy.

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Reference Behavior Pattern (RBP)

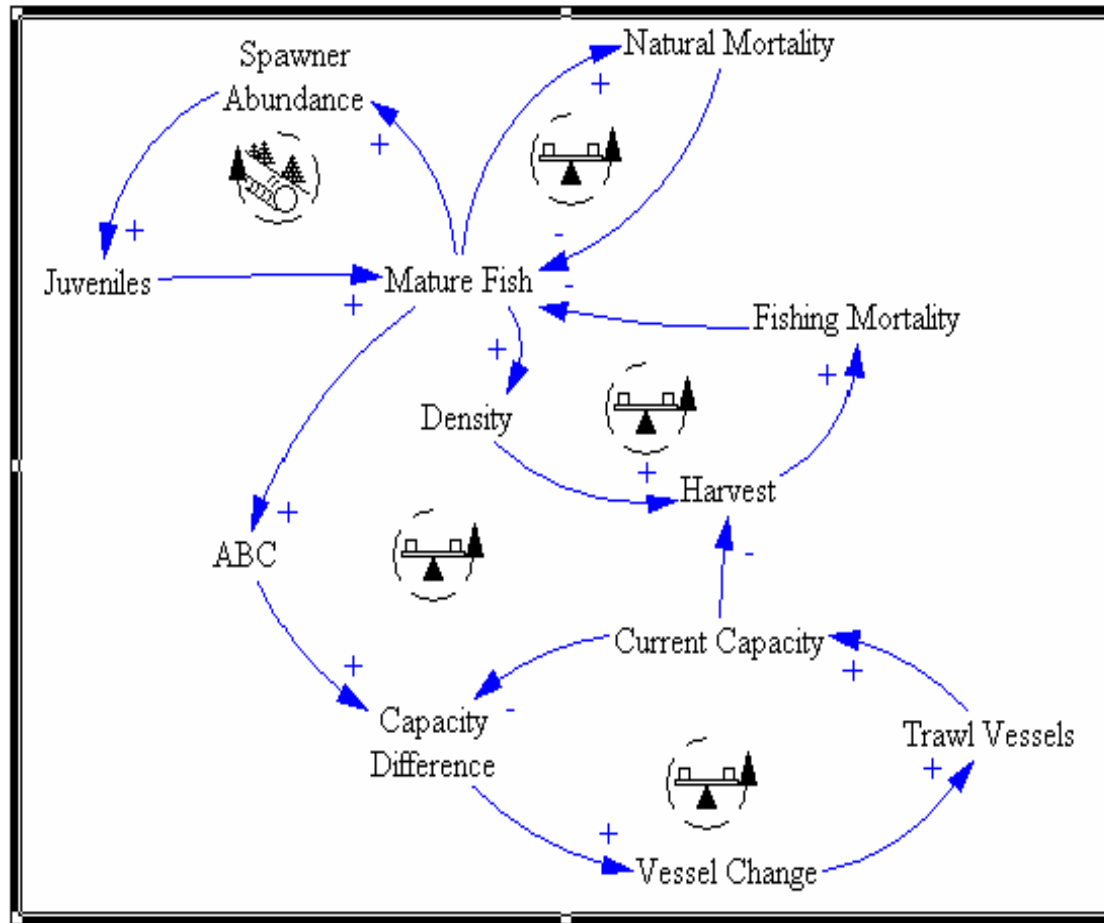
Sebastes flavidus (Yellowtail)

Harvest and ABC Historical Data



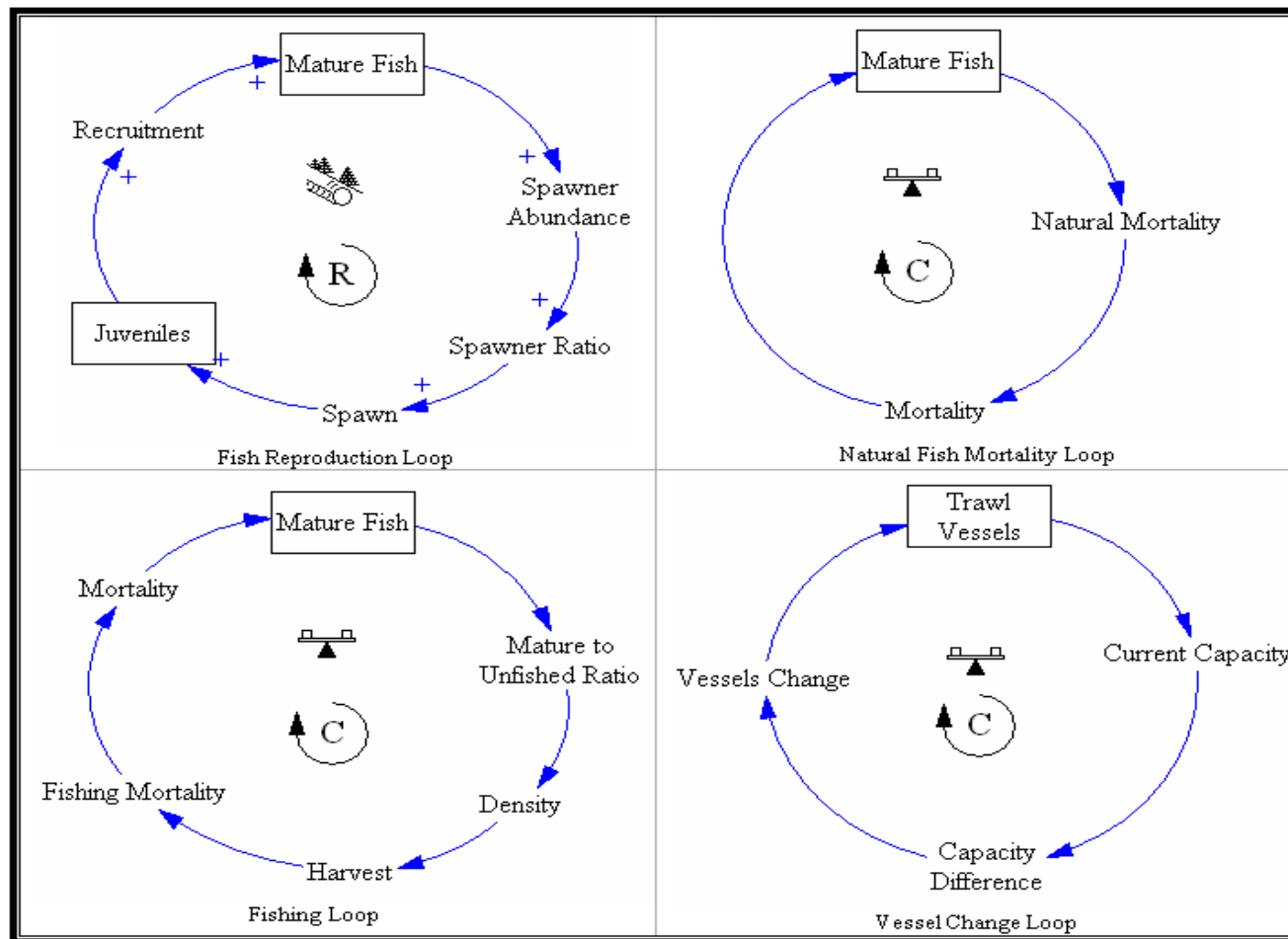
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The Model – Overall causal loop structure



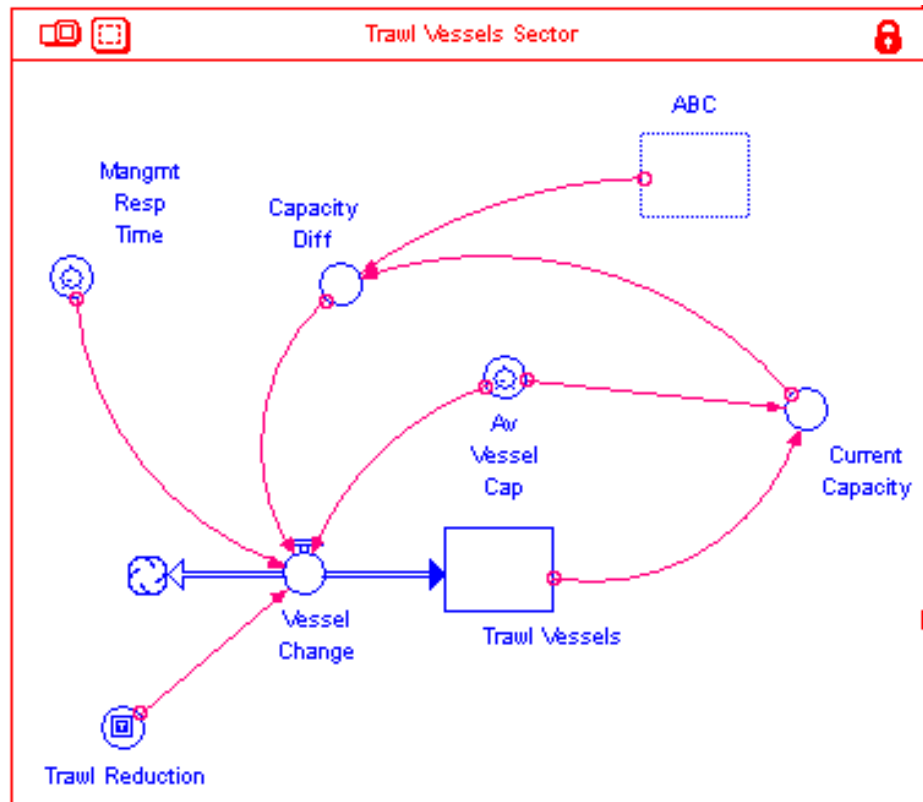
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The Model — Primary feedback loops



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Model - Trawl Vessel Dynamics

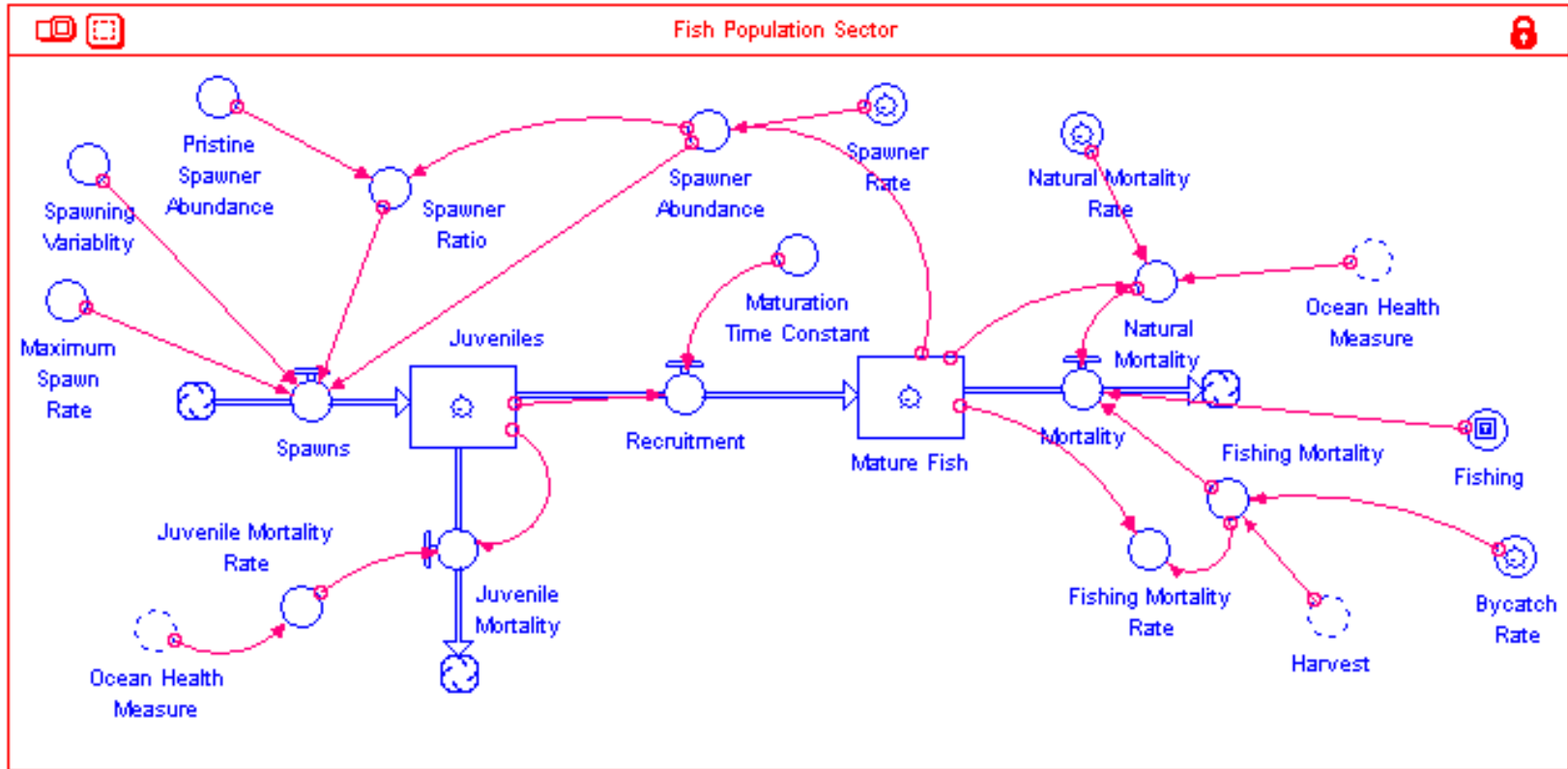


- Trawl vessels are modeled as a stock that could increase or decrease over time.
- There are not new vessels entry to the fleet. Instead, vessels modify their participation.
- New vessels are added to the fleet when are plentiful and removed from the fleet when fish stocks are down.

Trawl Vessels = $f(\text{supply and demand})$

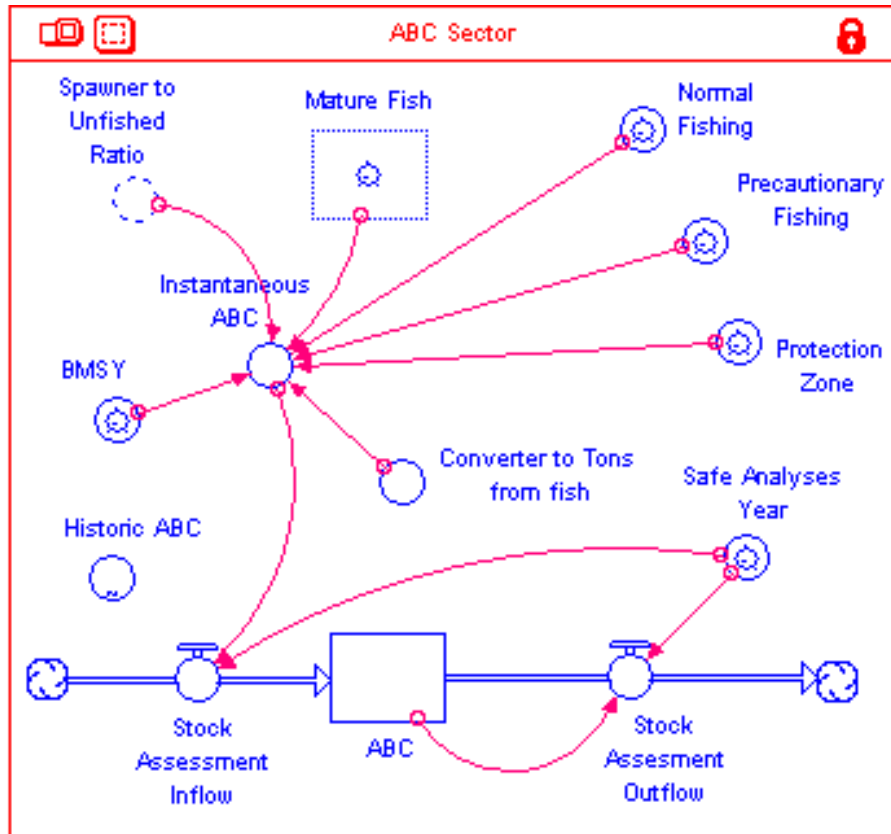
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Model - Fish Population



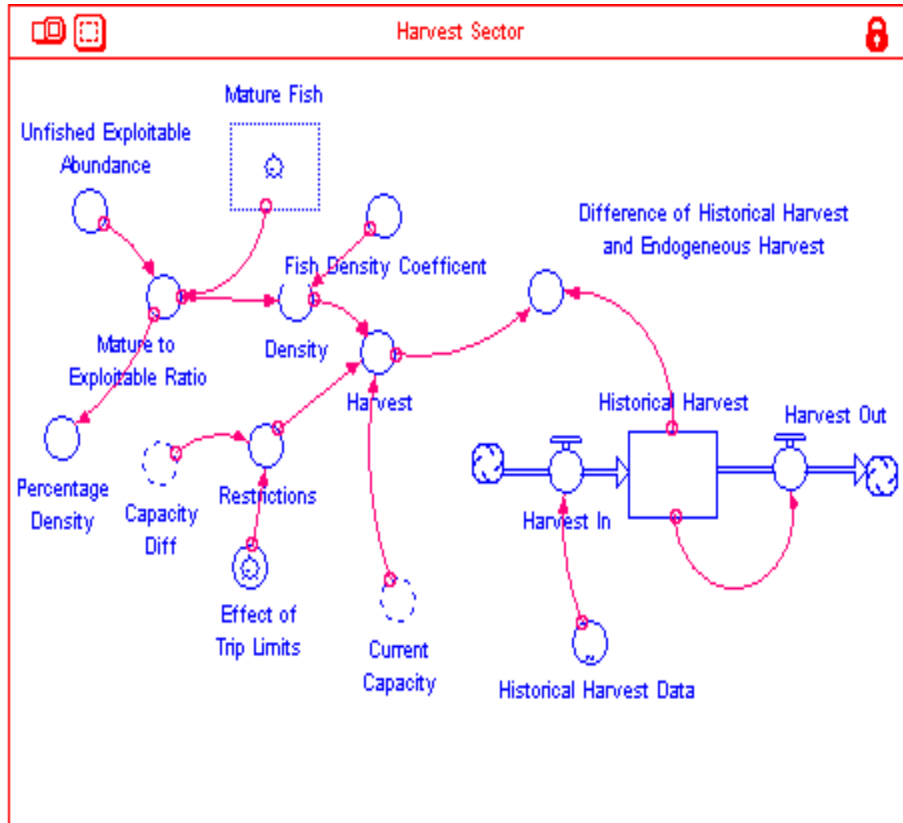
Modeled as two (2) separate stocks, *Juveniles* and *Mature Fish*.

Model – ABC



- The PFMC sets ABC based on prescribed rules, the triennial SAFE surveys, and other rules.
- $ABC = f(\text{Spawner_Percentage})$

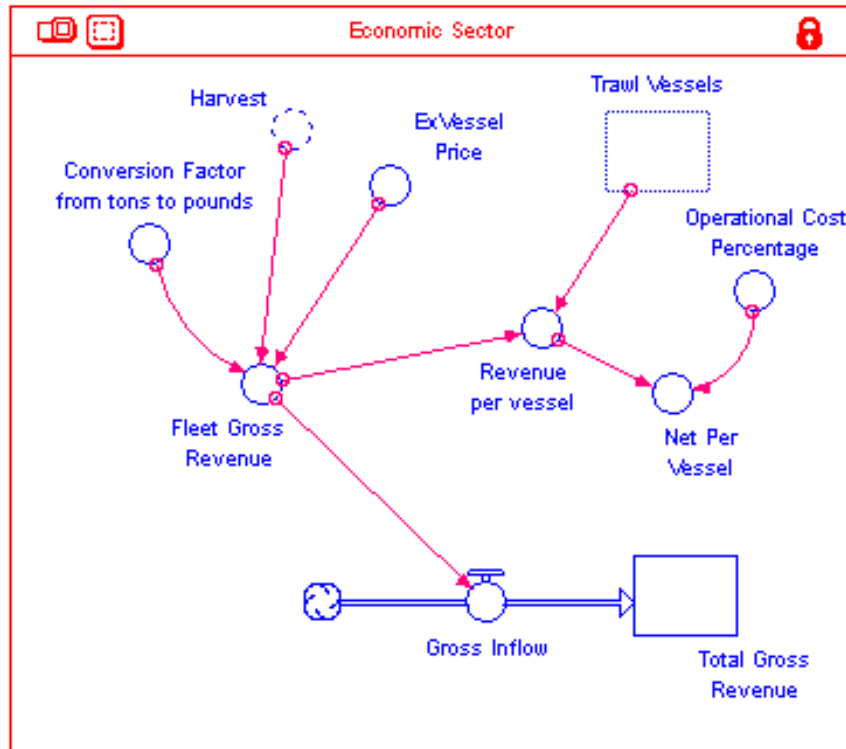
Model — Harvest



- $\text{Harvest} = [\text{Current_Capacity} - (\text{Restrictions}/\text{Density})]$
- $\text{Restrictions} = \text{Capacity Difference} * \text{Trip Limits Efficiency}$
- $\text{Density} = \text{Mature to Unfished ratio} / \text{Fish Density Coefficient}$

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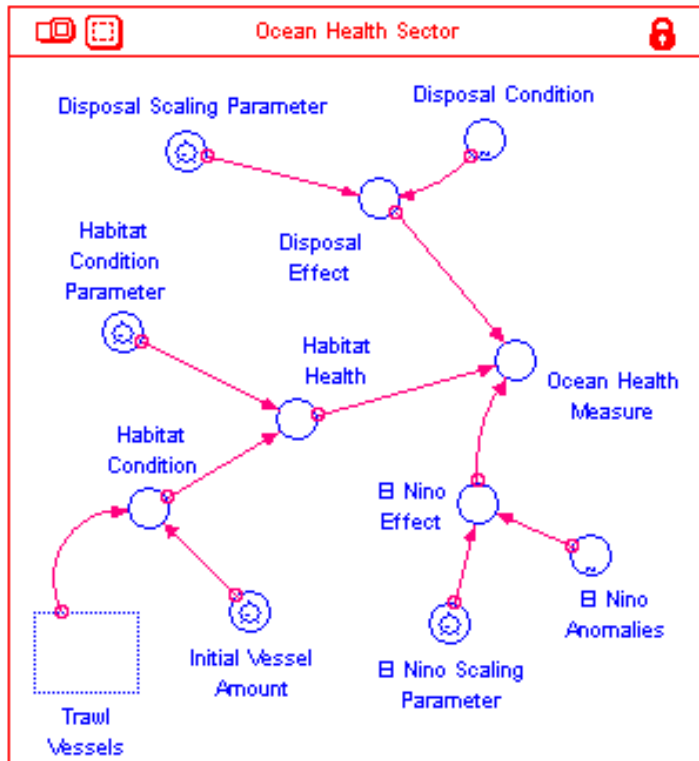
Model – Economic Sector



- Translate harvest into revenues and profits.
- Revenues are accumulative.

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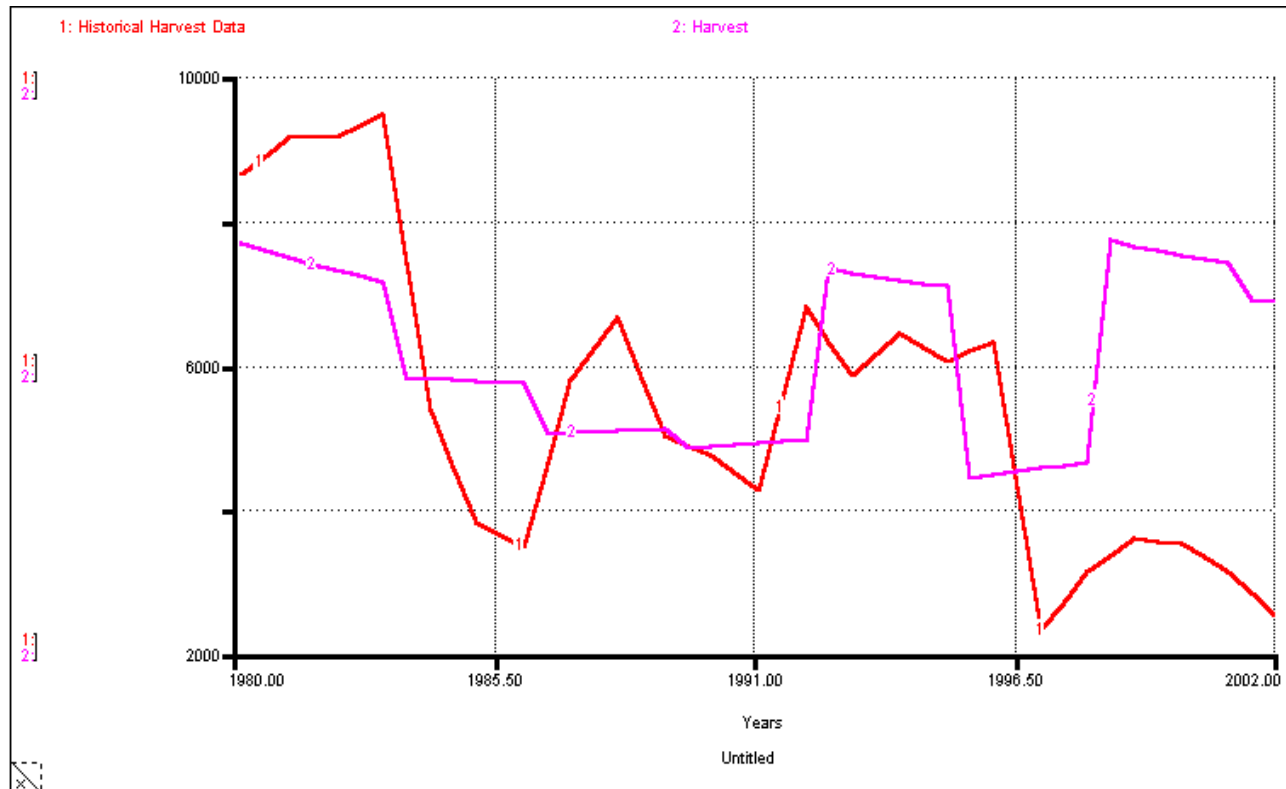
Model – Ocean Health



- Exogenous factors from “*Disposal Effects and El Niño effects.*”
- Endogenous effects from “*Habitat Health.*”

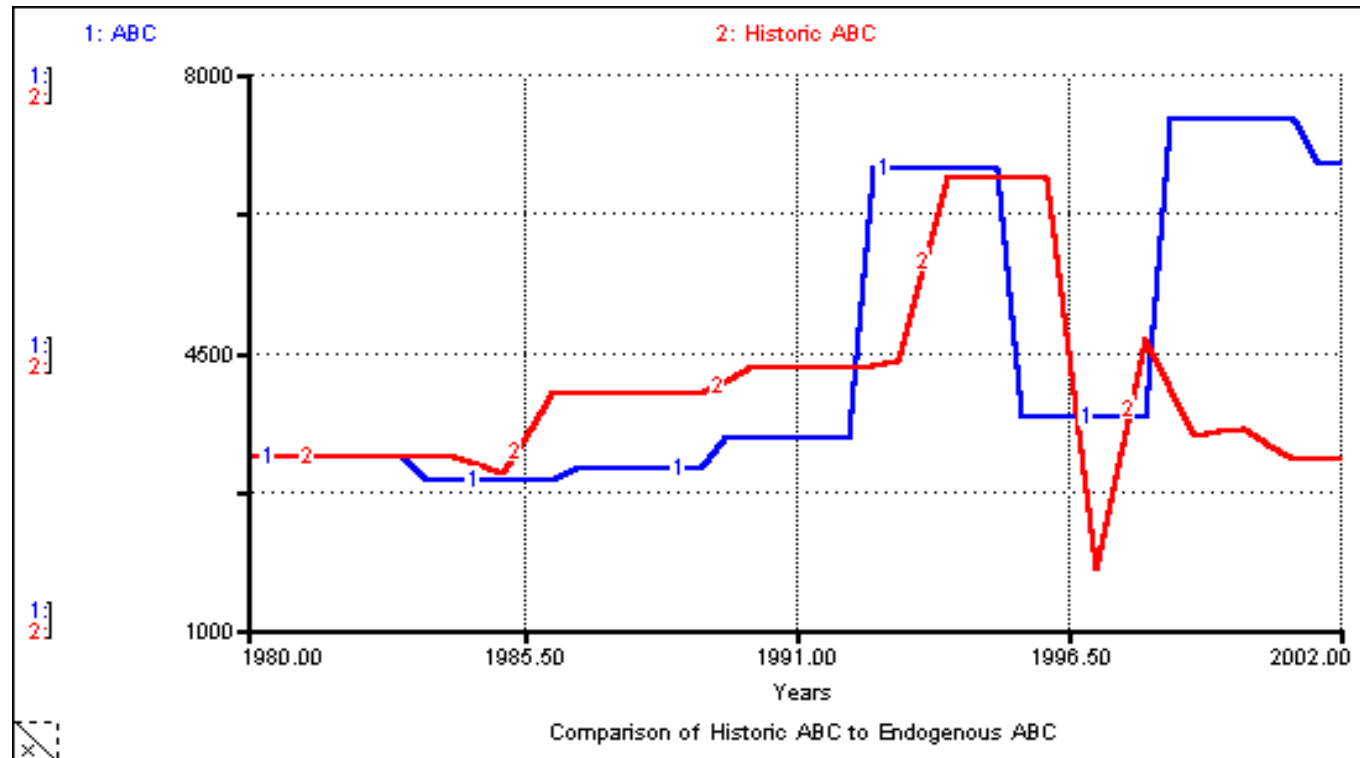
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Model — Historical harvest vs. calculated from the Model



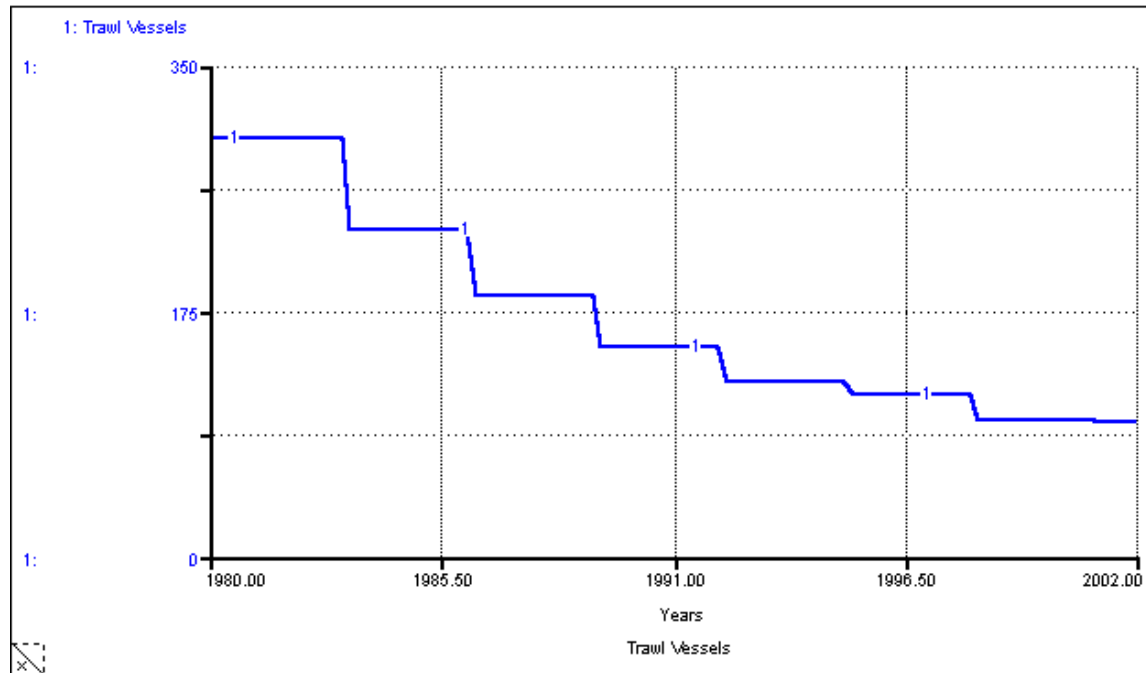
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Model – ABC from the Model vs. historical data



Fishery Pacific Model

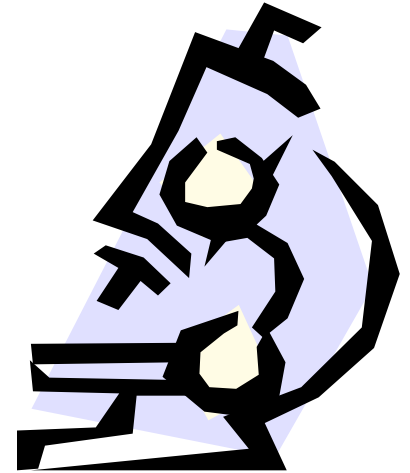
Model — Trawl vessels over time calculated by the Model



Fishery Pacific Model

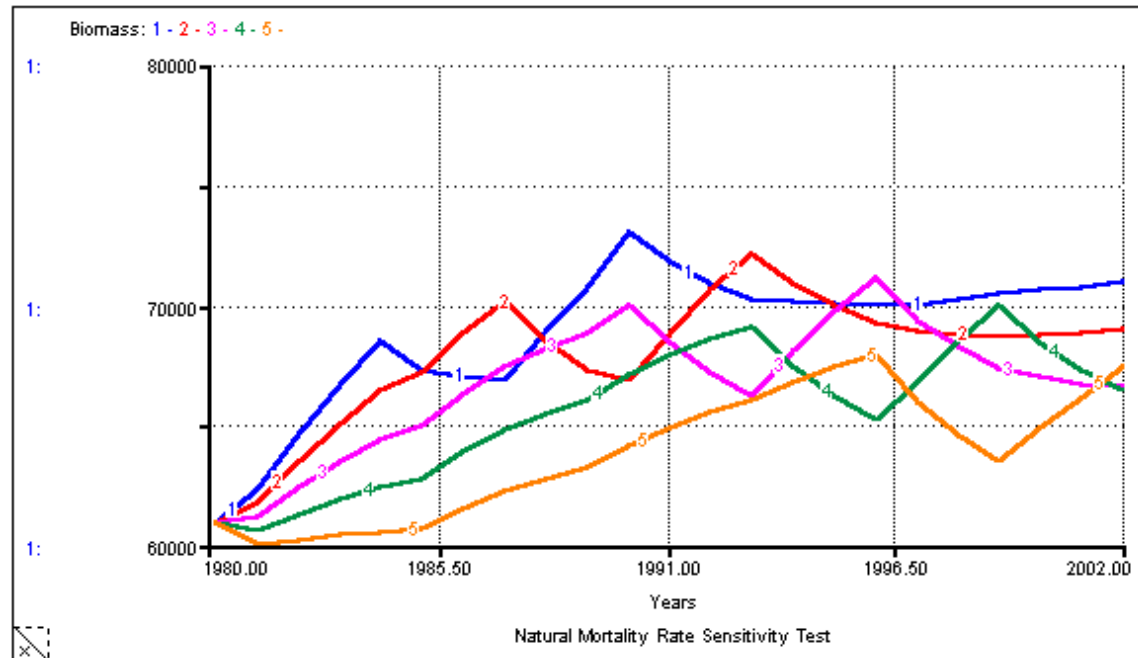
Model Testing

- The values of each parameter were varied over a range 50% above and below.



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Testing – Natural Mortality Sensitivity

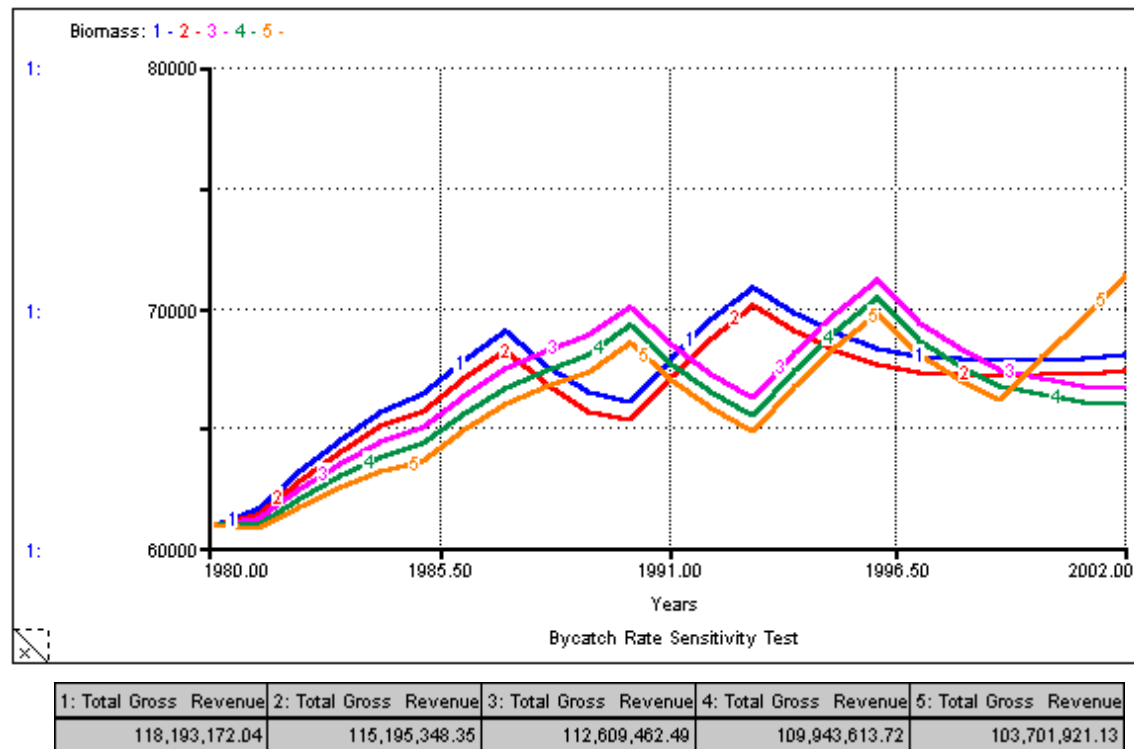


1: Total Gross Revenue	2: Total Gross Revenue	3: Total Gross Revenue	4: Total Gross Revenue	5: Total Gross Revenue
132,338,296.16	122,078,006.26	112,609,462.49	101,857,893.18	91,188,039.49

NMR affects Biomass and TGR. Increasing NMR reduces the TGR and significantly impacts the Biomass.

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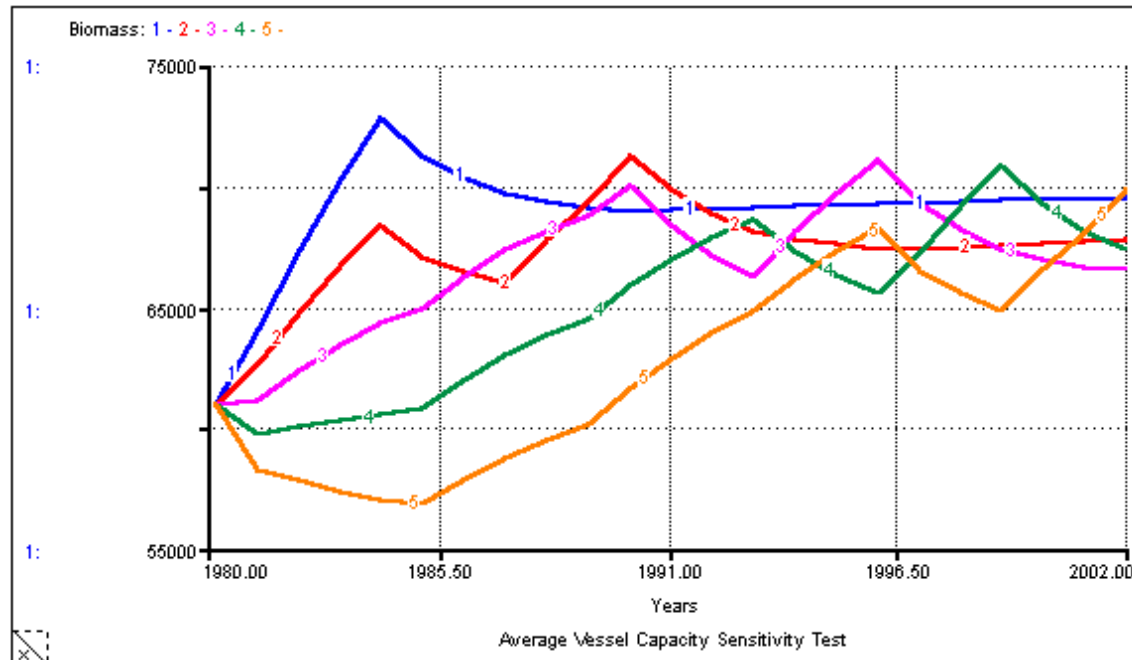
Testing - Bycatch Sensitivity



The model is less sensitivity to Bycatch Rate. Fluctuations differences between the runs are based in the delays in the triennial ABC.

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Testing — Average Vessel Capacity (AVC) Sensitivity



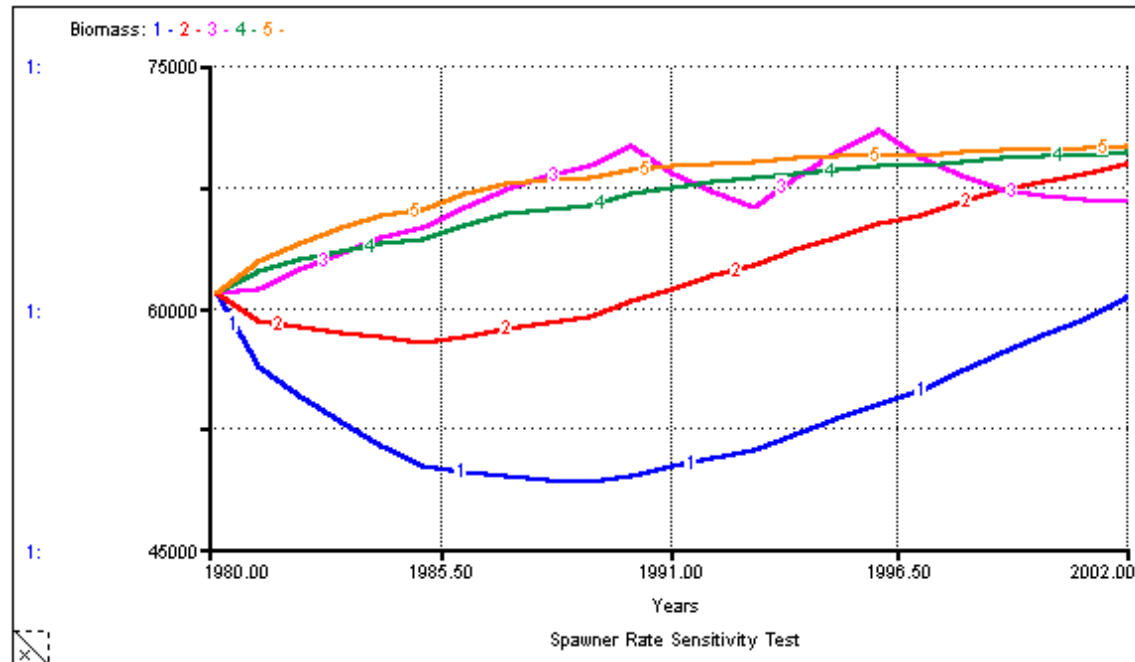
1: Total Gross Revenue	2: Total Gross Revenue	3: Total Gross Revenue	4: Total Gross Revenue	5: Total Gross Revenue
113,585,620.30	112,854,338.86	112,609,462.49	110,901,733.95	107,870,719.24

The higher the AVC, the longer it takes to reach a sustainable equilibrium. However, the TGR is NOT effected significantly by ABC changes.

Biomass is more sensitive than TGR to changes in AVC.

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Testing — Spawner Rate (SR) Sensitivity

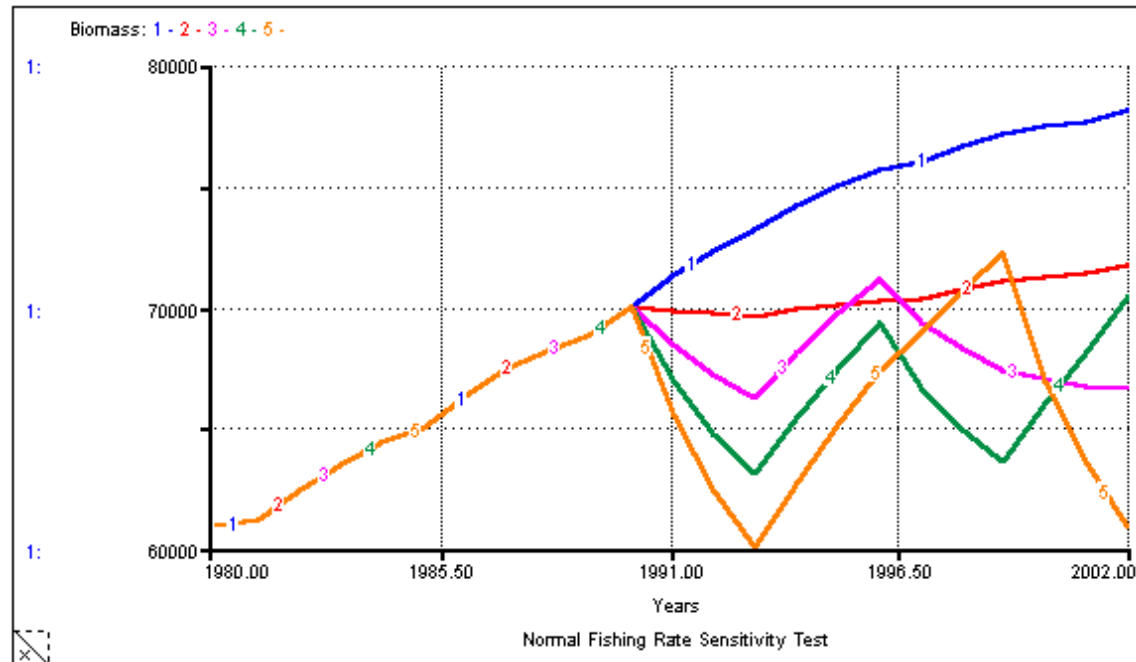


1: Total Gross Revenue	2: Total Gross Revenue	3: Total Gross Revenue	4: Total Gross Revenue	5: Total Gross Revenue
64,523,406.17	92,021,829.39	112,609,462.49	120,310,400.62	122,935,346.49

The model is very sensitive to the parameter SR.

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Testing — Normal Fishing Rate (NFR) Sensitivity

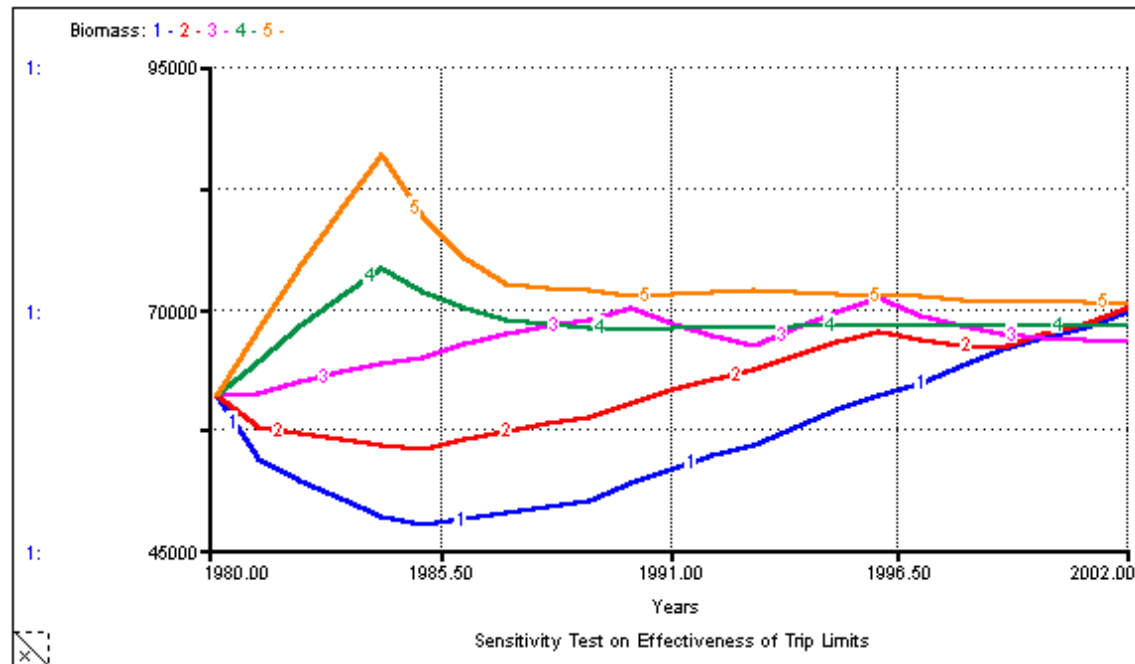


1: Total Gross Revenue	2: Total Gross Revenue	3: Total Gross Revenue	4: Total Gross Revenue	5: Total Gross Revenue
103,887,613.01	109,220,647.52	112,609,462.49	109,954,758.84	115,959,155.47

The biomass is very sensitive to changes in NPR. But this is not true for TGR, which varies by only a few percent.

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Testing — Effectiveness of Trip Limits (ETL) Sensitivity

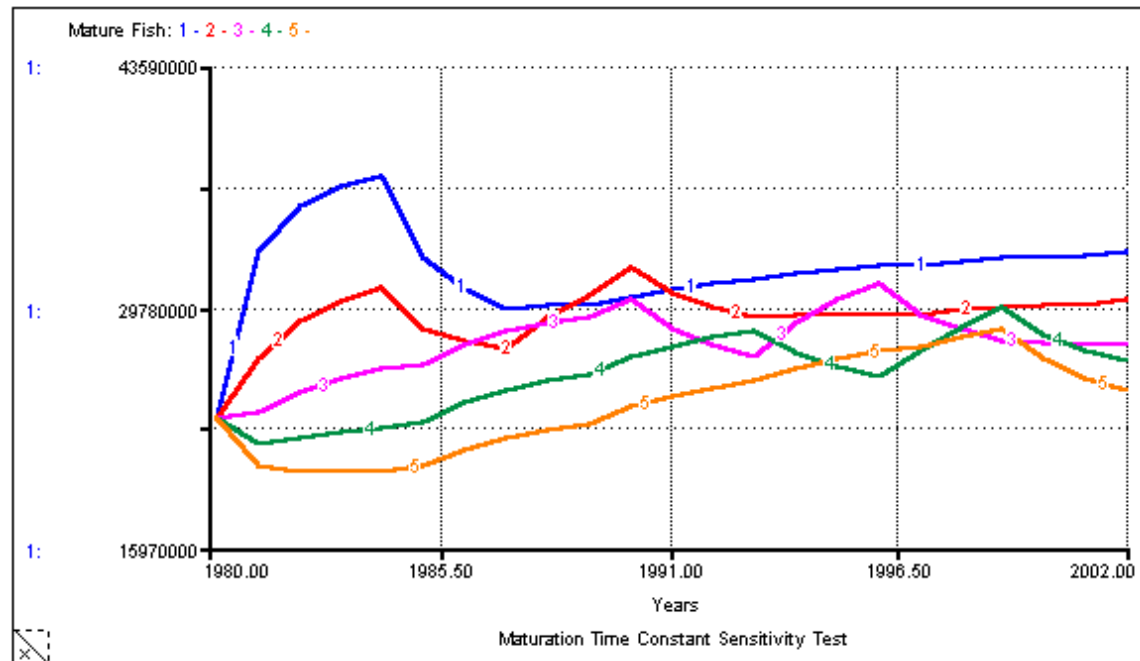


1: Total Gross Revenue	2: Total Gross Revenue	3: Total Gross Revenue	4: Total Gross Revenue	5: Total Gross Revenue
102,612,170.63	107,568,084.38	112,609,462.49	112,325,345.53	110,102,110.15

Higher values of ETL tend to better sustain the environment.

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Testing — Maturation Time Constant (MTC) Sensitivity

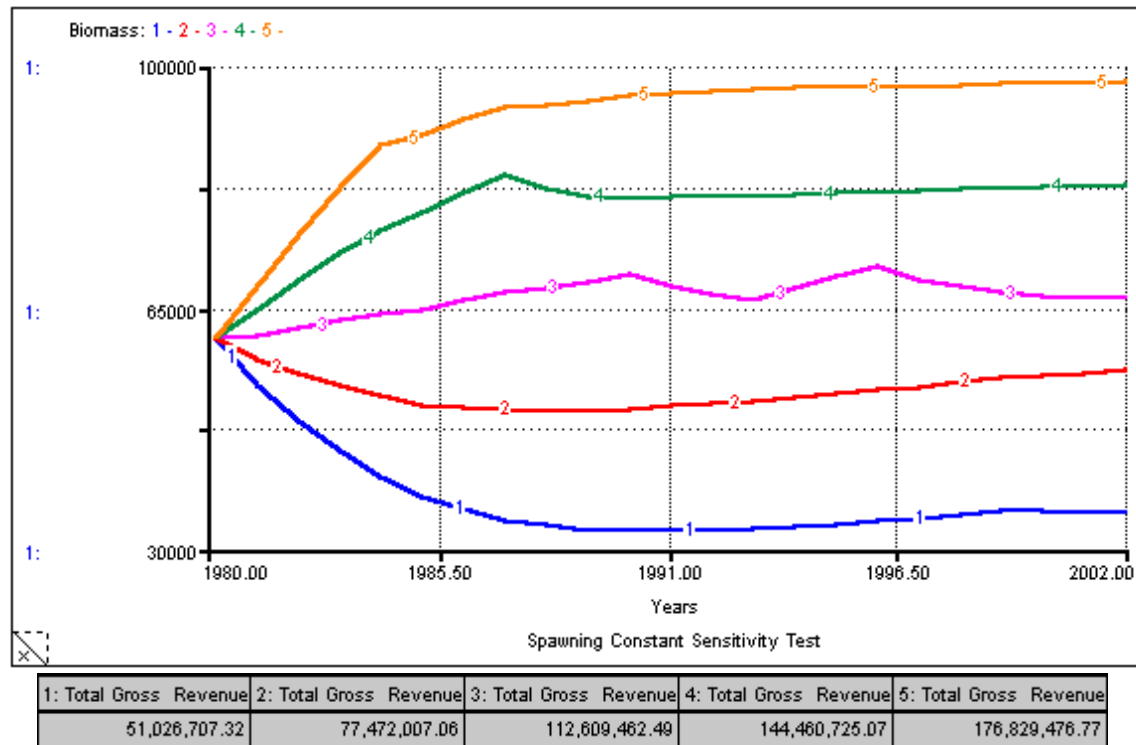


1: Total Gross Revenue	2: Total Gross Revenue	3: Total Gross Revenue	4: Total Gross Revenue	5: Total Gross Revenue
159,615,070.14	132,946,461.63	112,609,462.49	95,255,226.18	82,445,433.41

The model is highly sensitive to MTC. Shorter MTC tends to reinforce MF population, yielding higher TGR. Higher values of MTC result in much lower biomass and TGR.

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Testing — Maturation Time Constant (MTC) Sensitivity



The biomass is very high sensitive to changes in MTC.

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Testing – Sensitivity Analysis Summary

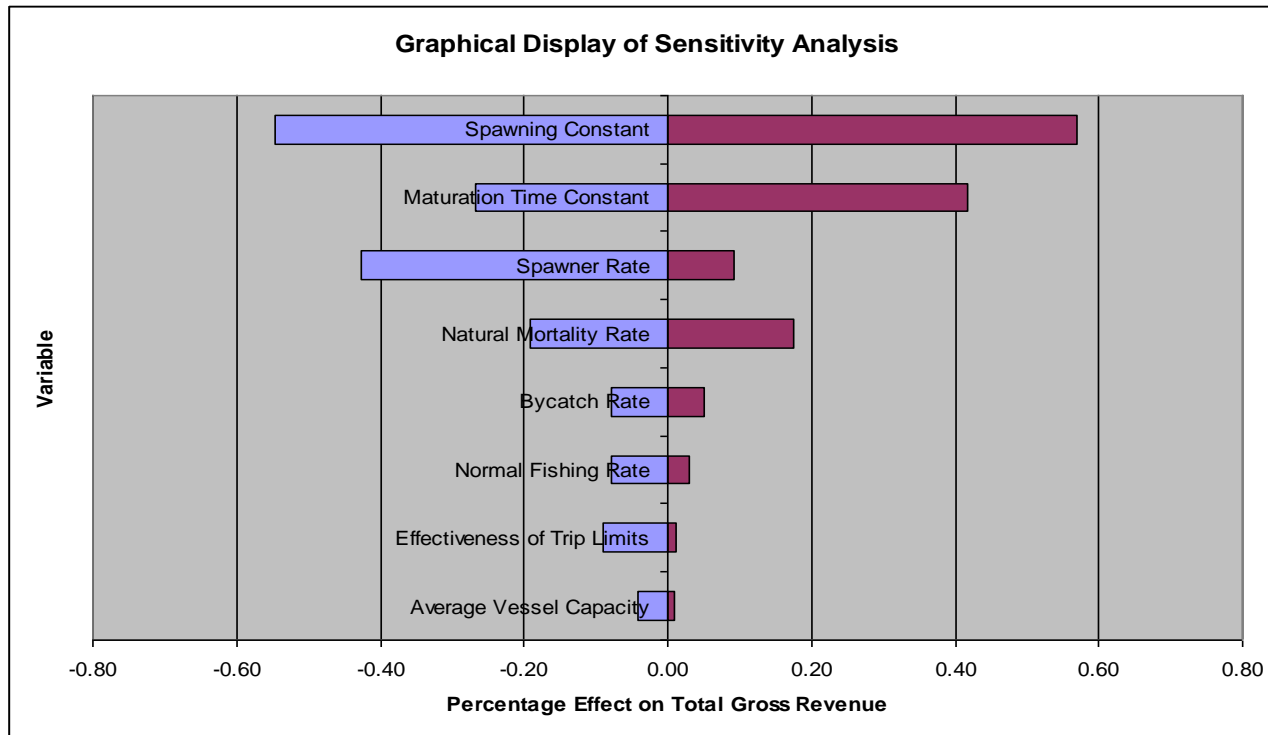
	Range (-50%)	Initial Value	Range (+50%)	Total Gross Revenue (TGR) Million \$ Base Value = 112 Million \$	
				TGR at low value	TGR at high value
Natural Mortality Rate	0.05	0.1	0.15	\$132	\$91
Bycatch Rate	0.06	0.12	0.18	\$118	\$104
Av. Vessel Capacity (in Tons)	40	80	120	\$114	\$108
Spawner Rate	0.205	0.41	0.615	\$65	\$123
Normal Fishing Rate	0.105	0.21	0.315	\$104	\$116
Effectiveness of Trip Limits	0.365	0.73	1.095	\$103	\$110
Maturation Time Cons. (years)	2	4	6	\$160	\$82
Spawning Cons.	0.12	0.24	0.36	\$51	\$177

Table summarizes the results of sensitivity testing



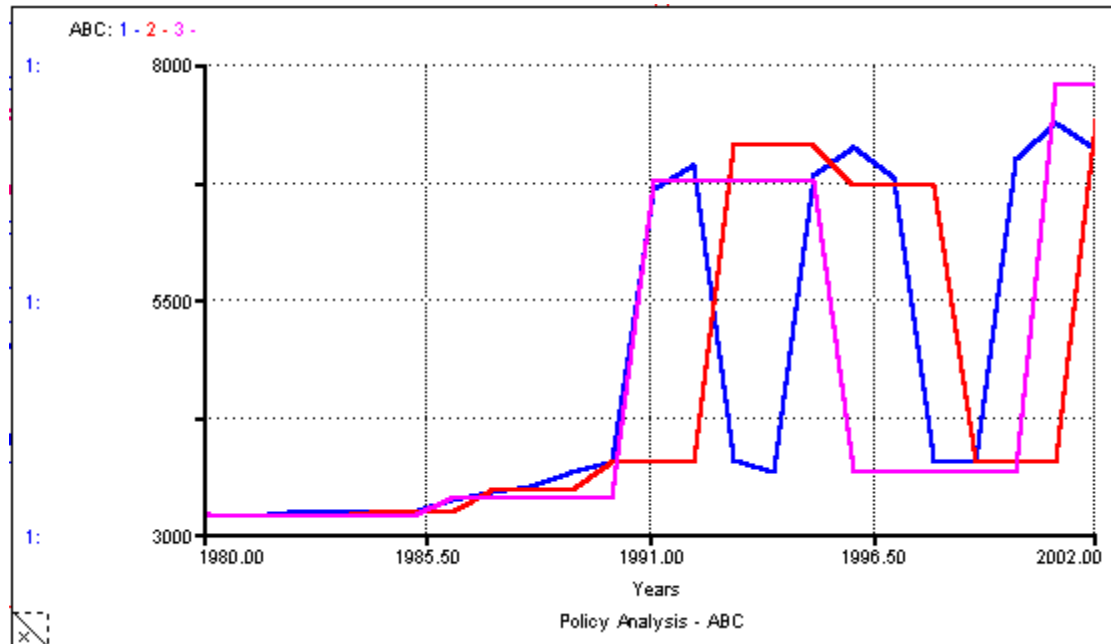
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Testing – Sensitivity test results portrayed graphically



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Policy Analysis – Maximum Sustainable Yield (MSY)

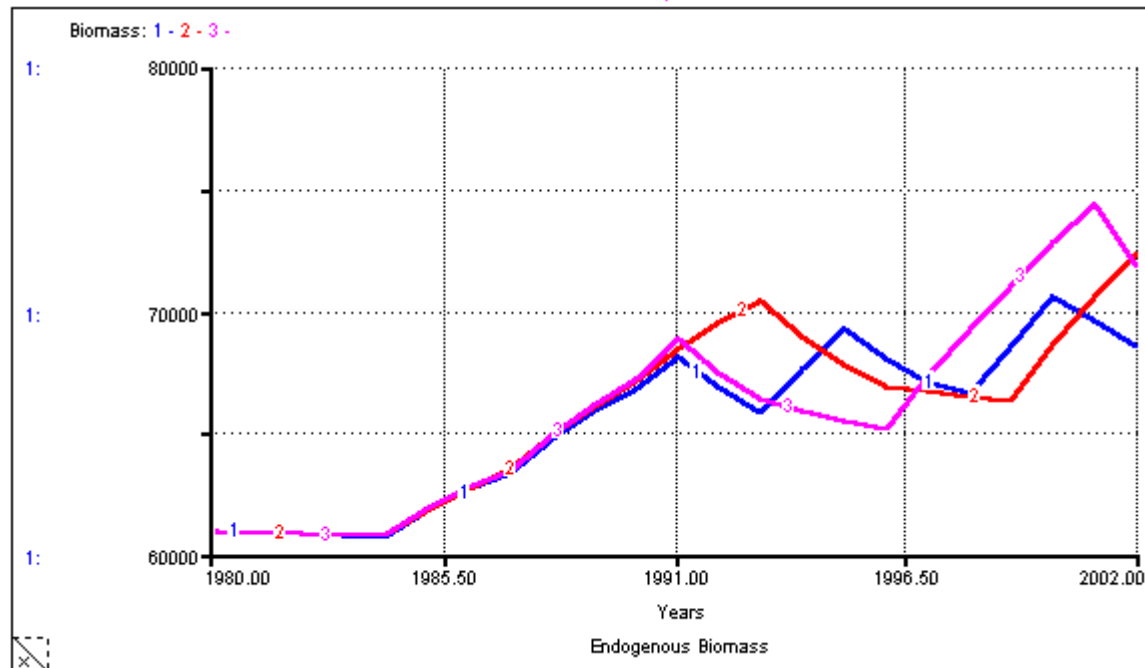


1: Total Gross Revenue	2: Total Gross Revenue	3: Total Gross Revenue
109,338,284.27	106,690,207.66	107,037,329.00

The “40-10 Policy” – above 40% is the normal zone; 25%-40% is the precautionary zone; 10%-25% is the protection zone; below 10% is known as extinction zone and no fishing is allowed.

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Policy Analysis – Maximum Sustainable Yield (MSY)

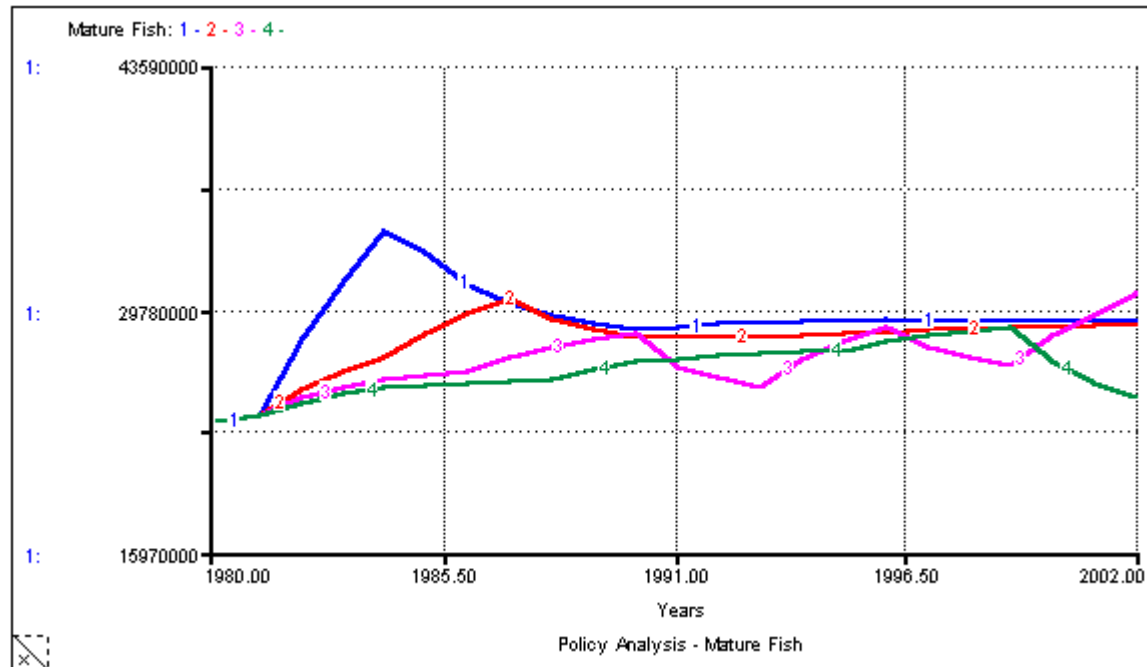


How often the ABC is calculated ($N = 1, 3, 5$)

Results suggested “Policy” for reducing fluctuations in the groundfish fishery.

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Policy Analysis – Management Response Time (MRT)



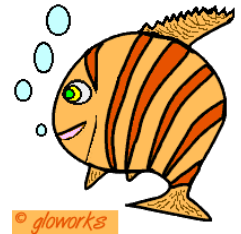
1: Total Gross Revenue	2: Total Gross Revenue	3: Total Gross Revenue	4: Total Gross Revenue
107,570,454.81	110,037,788.74	111,236,138.18	117,238,053.46

The lower the MRT value, the more quickly MF recovers and returns to the MSY value, suggesting that MRT should be less than five years for best results.

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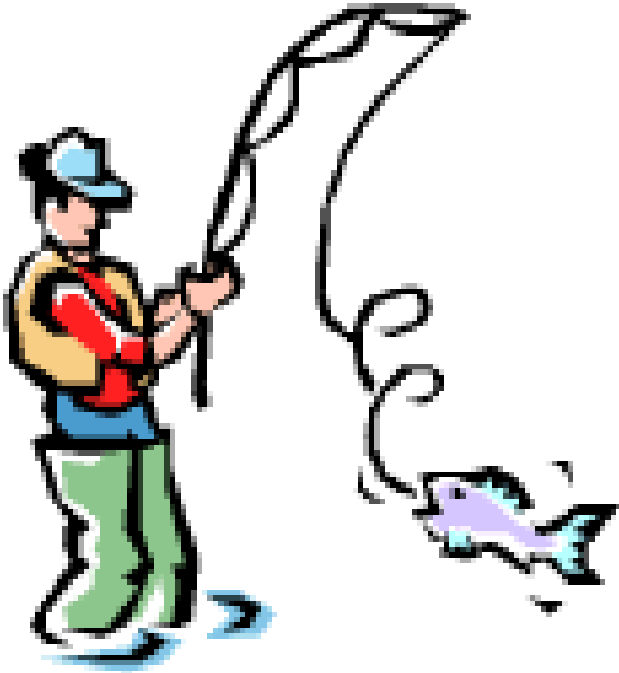
Future Work

- **Implementing Economic and Social Factors.**
- **Incorporating dynamic trip limits.**
- **Connecting the economic side of the system to the fishery, trawl vessels, and thus the harvest.**
- **Improving how the model incorporates changes in ocean health.**
- **Considering population dynamic models that include the age, size and weight of fish.**
- **Incorporating Catch per Unit Efficiency (CPUE) index.**



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Backup slides



Backup
Information

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The Problem – backup slides

- Since 1983, groundfish revenues have fallen by 69% and landings of rockfish have decreased 78%.
- Catch limits for various species of rockfish have declined 78%-89%.
- January 2000 the West Coast groundfish fisheries were declared a federal disaster. *Source: (EcoWorld 2000).*



Return