Linking Ecological and Economic Models for

Estimating the Ecosystem Services *of* Oyster Reef Restoration

Choptank River Complex, MD

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Fishery-Goal Implementation Team Meeting, Newport News, Virginia, 17 December 2018

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Project Goals

- Develop an ecological trophic model of the Choptank and Little Choptank River System using Ecopath with Ecosim

- Translate the changes in commercial fisheries harvest to regional economic impacts for key economic measures – Output (sales), Labor Income, Value-Added, and Employment

- Compare harvest and regional economic impact estimates across a range of management alternatives

Linking Ecology and Economics

Ecopath with Ecosim

No fish is an island

Output:
Fisheries Landings/ Revenue

IMPLAN

Output:
Employment, Sales, Income

Socio-economic Impact: Jobs & $$$

Restoration Scenarios

Ecopath with Ecosim

No fish is an island

No Reef

Landings Outputs

IMPLAN

Econ Outputs

Jobs &

Young Restored Reef

Landings Outputs

IMPLAN

Econ Outputs

Jobs &

Mature Restored Reef

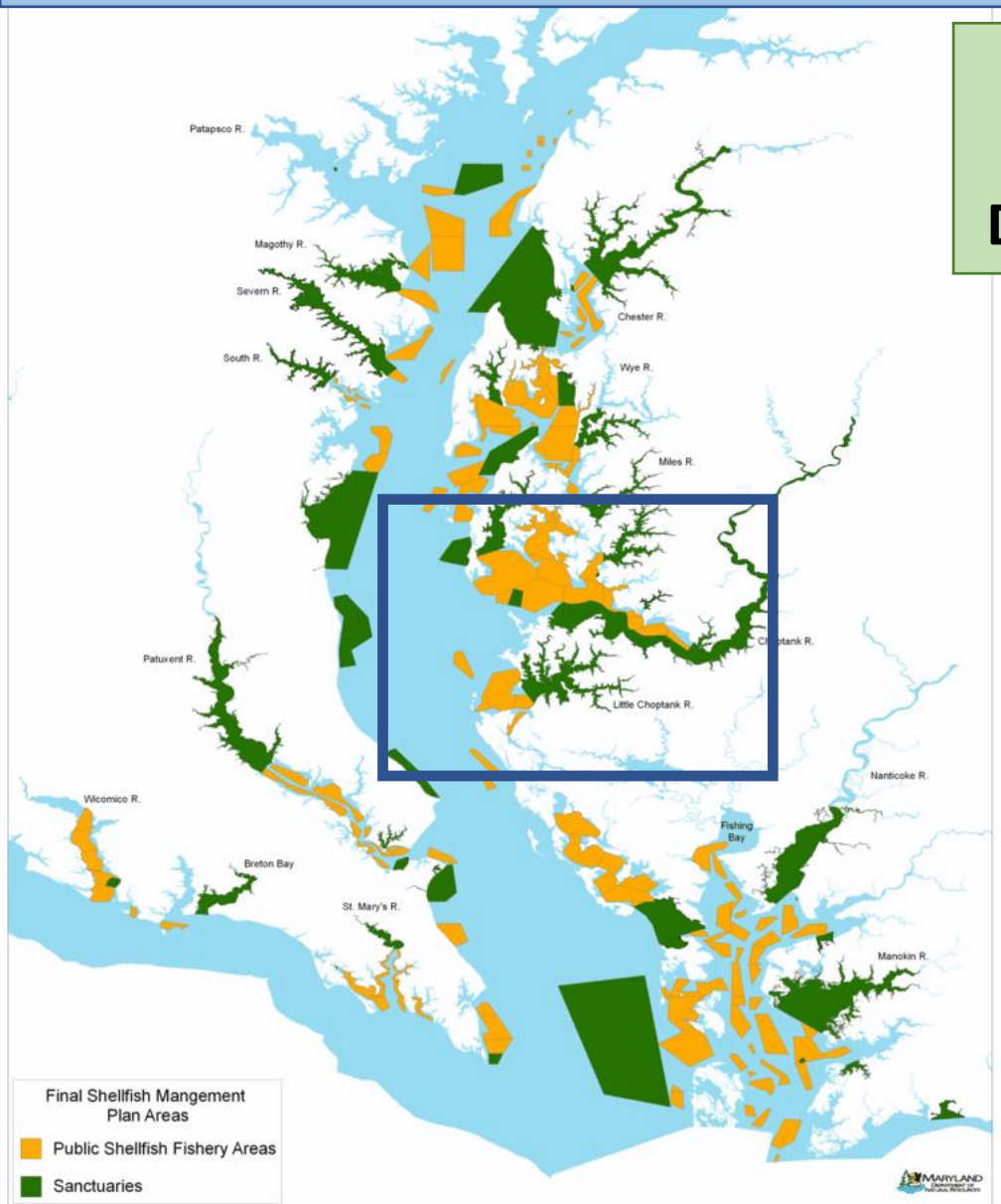
Landings Outputs

IMPLAN

Econ Outputs

Jobs &

Maryland Oyster Sanctuaries



Maryland Oyster Restoration and Aquaculture Development Plan (Dec, 2009)

- Prior to 2009, 1,500 acres of bottom habitat in sanctuaries
- In 2009, 3 new sanctuaries now protecting total of 2,600 acres (9% of habitat)
- In 2010, State of Maryland set aside 24% of remaining oyster habitat, for a total of 6,900 acres protected

Maryland Oyster Restoration

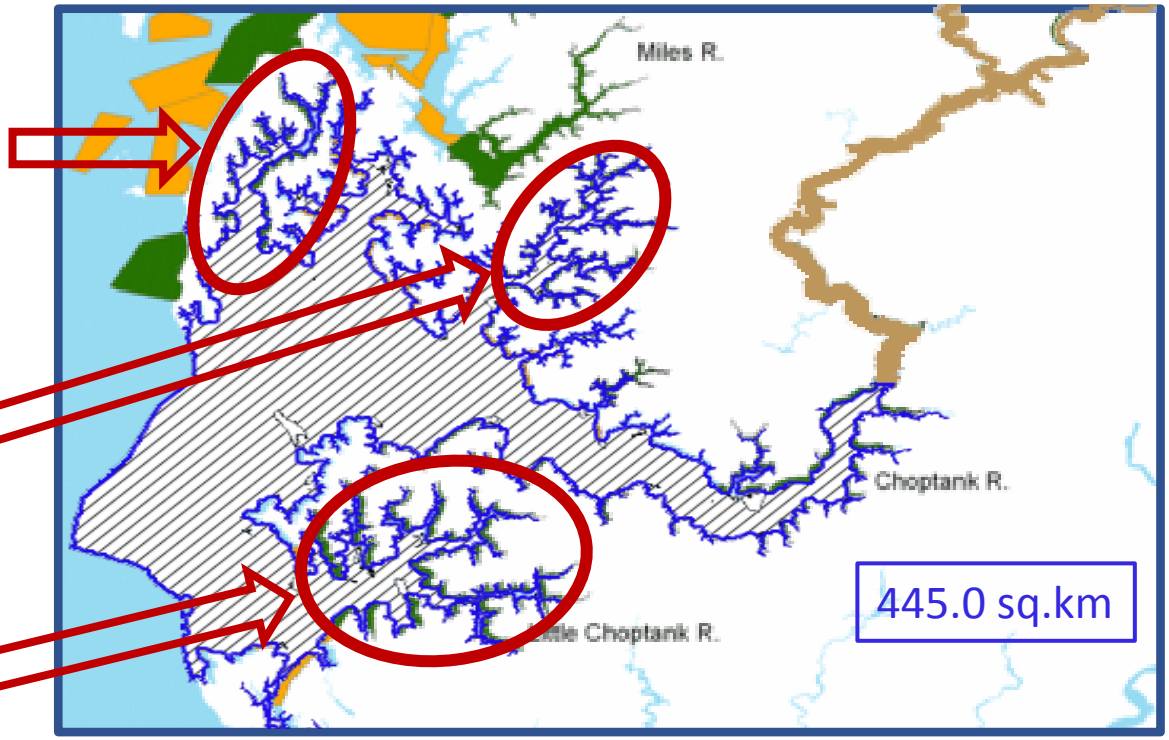
First three tributaries in MD

Chesapeake Bay Watershed Agreement:
Restore 10 tributaries by 2025

Harris Creek
Goal: 377 restored acres
Status: Completed; ~ 2 billion oysters planted

Tred Avon River
Goal: 191 restored acres
Status: Ongoing (20% complete)

Little Choptank River
Goal: 342 restored acres
Status: Ongoing (82% complete)



Estimated Cost - $52 million

Methods - Ecopath with Ecosim

Ecopath with Ecosim

Mass Balance est. group productivity (biomass)

$$\left(\frac{P_i}{B_i}\right) \cdot B_i \cdot EE_i - \sum_{j=1}^{n} B_j \left(\frac{Q_j}{B_j}\right) DC_{ji} - Y_i - E_i - BA_i = 0$$

Where:

- ✓ P_i/B_i is the production to biomass ratio for group *i*
- EE_i is "ecotroph efficiency" (proportion of production used in the system)
- ✓ B_i and B_j are the biomasses of the prey and predators, respectively
- ✓ Q_j/B_j is consumption to biomass ratio
- ✓ DC_{ji} is the fraction of prey *i* in predator *j*'s diet
- ✓ Y_i is catch rate for the fishery for group *i*
- *Ei* is net migration rate
- BA_i is biomass accumulation for group *i*

Energy Balance:

Consumption = production + respiration + unassimilated energy

where:

Production = predation mortality + catches + net migration + biomass accumulation + other mortality

Methods - Ecopath with Ecosim

Selection of Groups

- *Essential management role*
- *Essential ecological role:*
  - ✓ *Field studies (L. Kellogg, NCBO)*
  - ✓ *Previous regional work*
  - ✓ *Literature*

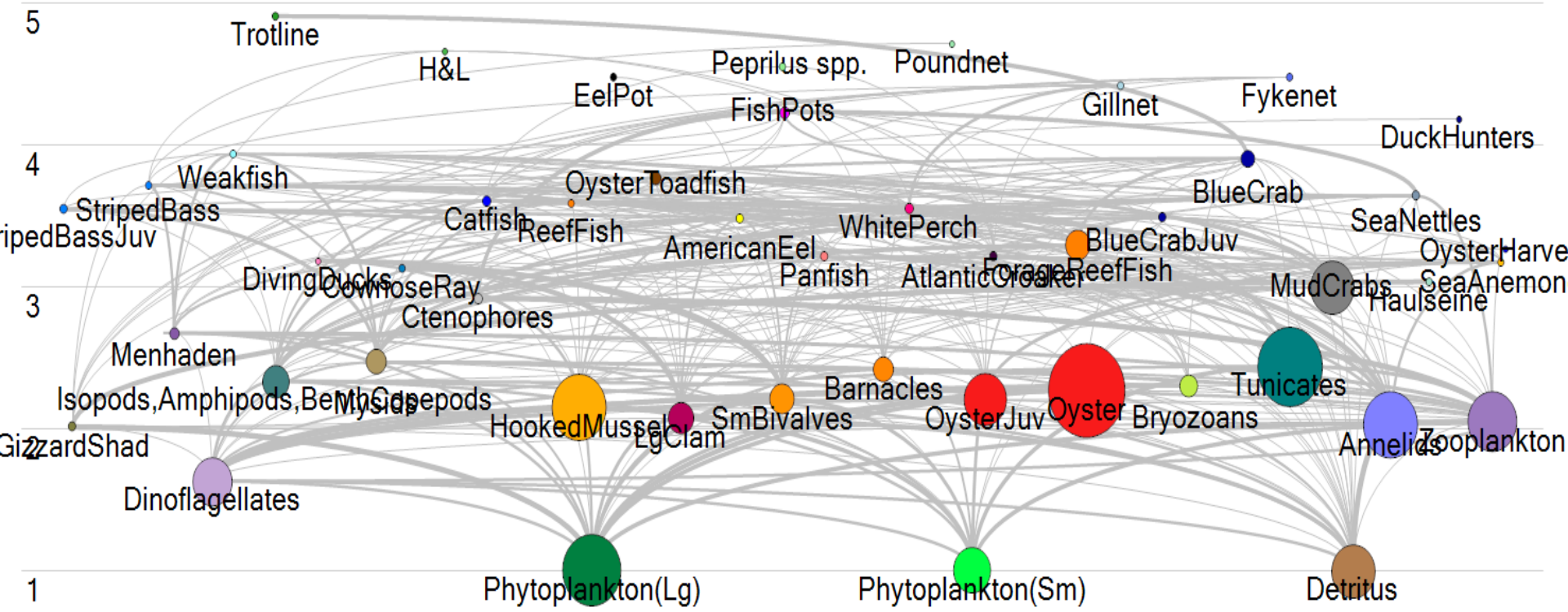
Selection of Fisheries

- *MD DNR*
- *> 2% total value landed (2006 – 2015)*
- *Essential for model function (e.g., duck hunting)*
- *Additional fisheries (e.g., bait clams)*

Ecopath with Ecosim

No fish is an island

Food web of restored oyster reef in the Choptank & Little Choptank Rivers



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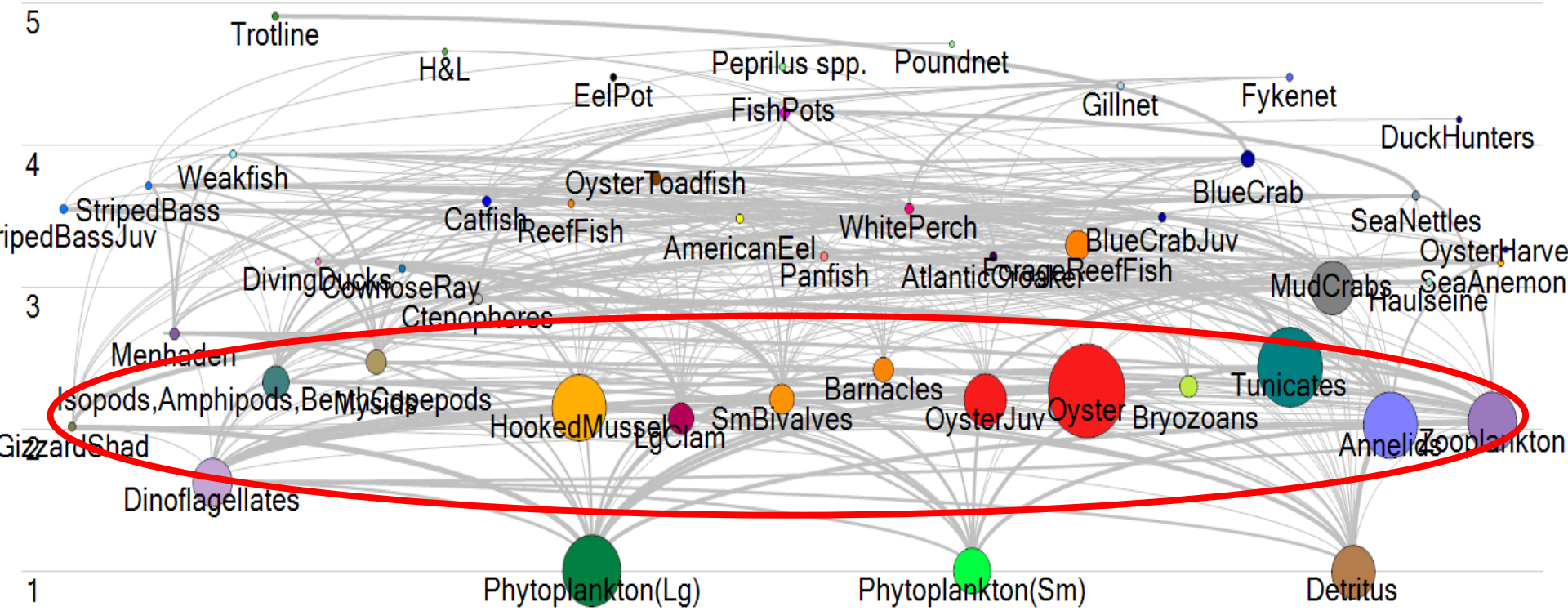
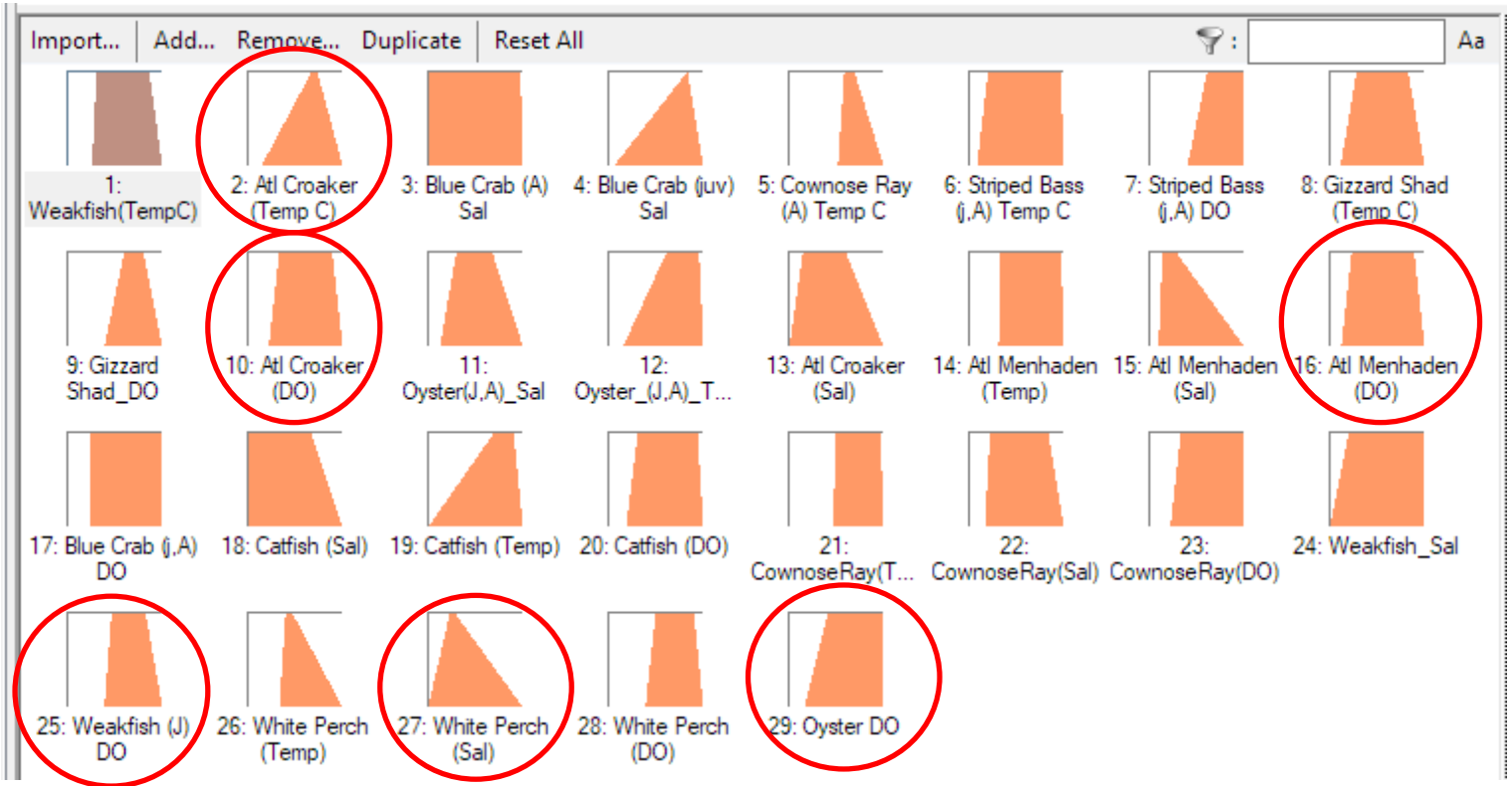


Methods - Ecopath with Ecosim

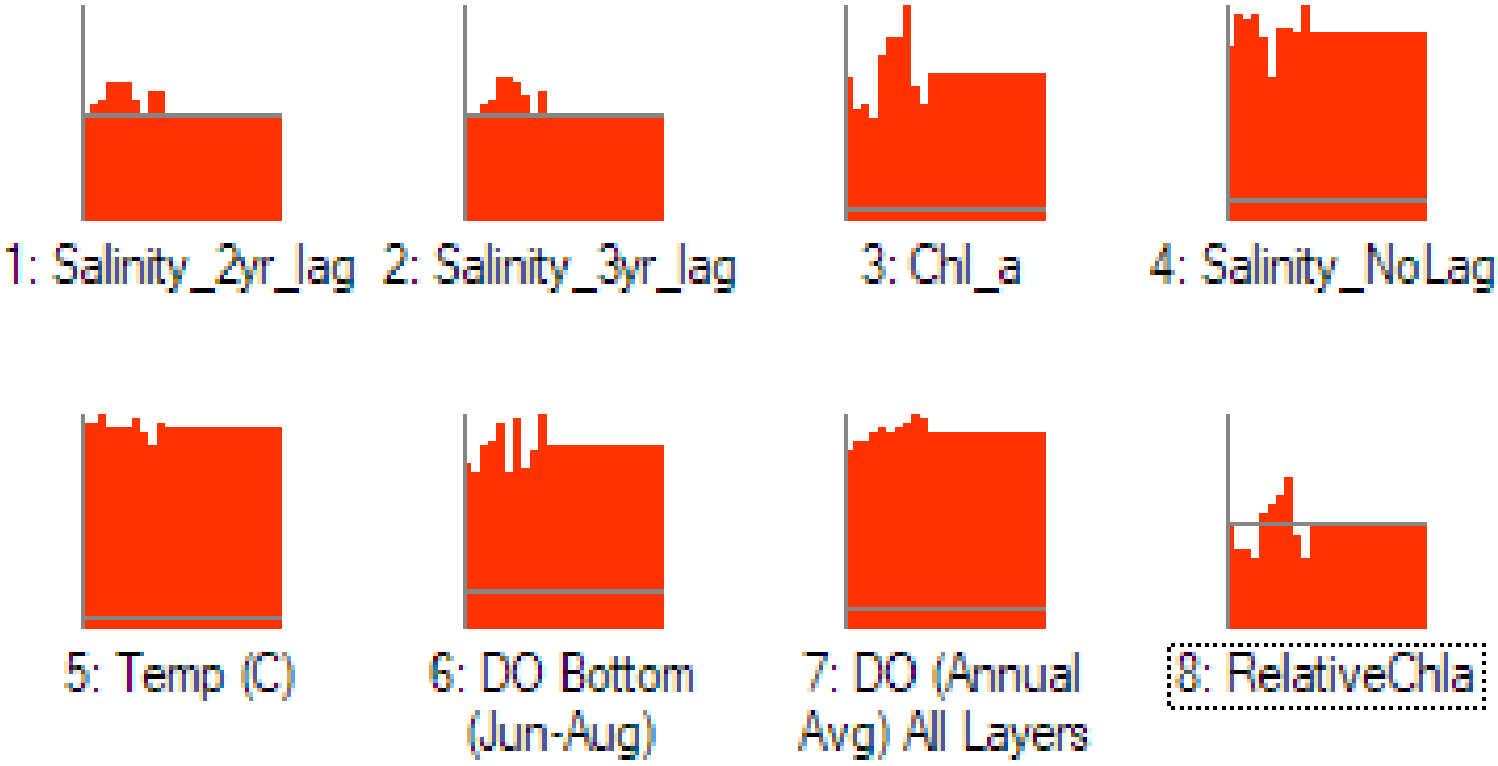
Group populations estimated within constraints of tolerances & optimal conditions for:

- *Temperature*
- *Salinity*
- *DO (average)*
- *DO (bottom)*



Methods - Ecopath with Ecosim

Forcing Function Time Series Developed



Methods - Ecopath with Ecosim

Scenarios Modeled:

- Harvest data – 2006-2015 (the "Base Model")
- 2015 starting point for:

<u>5 policy scenarios:</u>

(1) Current **young restored reef**

(2) Mature reef – *Restoration Goal Achieved throughout sanctuary hard bottom; 15 oysters/m^2* - **increased oyster biomass**

(3) Mature reef w/ FF – **increase oyster biomass & associated filter feeders** (hooked mussels, tunicates, barnacles, anemones)

(4) No oyster sanctuary – *fishing allowed throughout*
reduced oyster biomass, *similar to biomass prior to restoration*
10% of restored oyster biomass remains

(5) No oyster sanctuary –**reduced oysters & additional filter feeders**
10% of restored oyster & FF biomass remains

Methods - Ecopath with Ecosim

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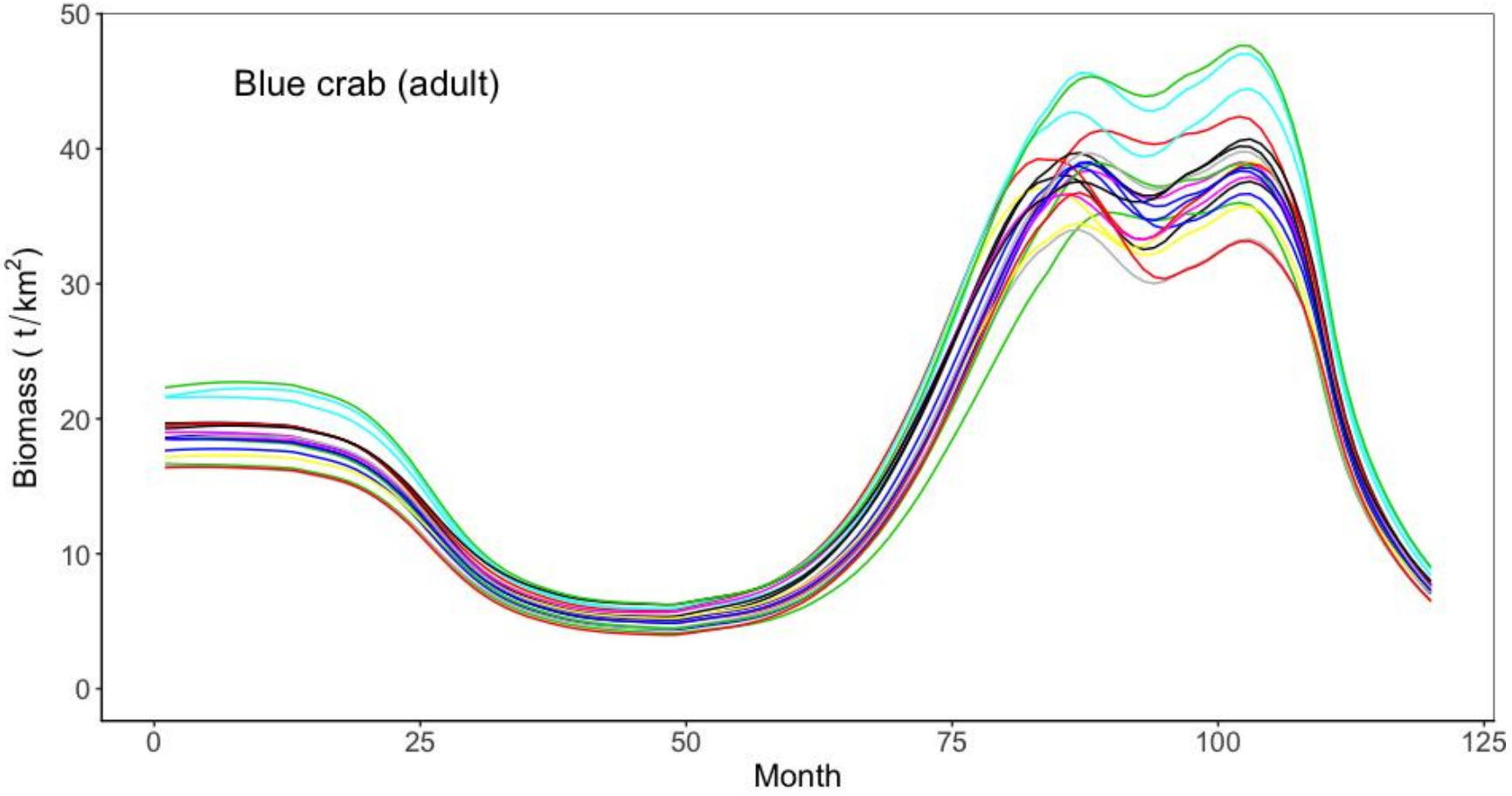
Model Performance - Ecopath with Ecosim

- Monte Carlo Simulation
- Biomass
- n = 20



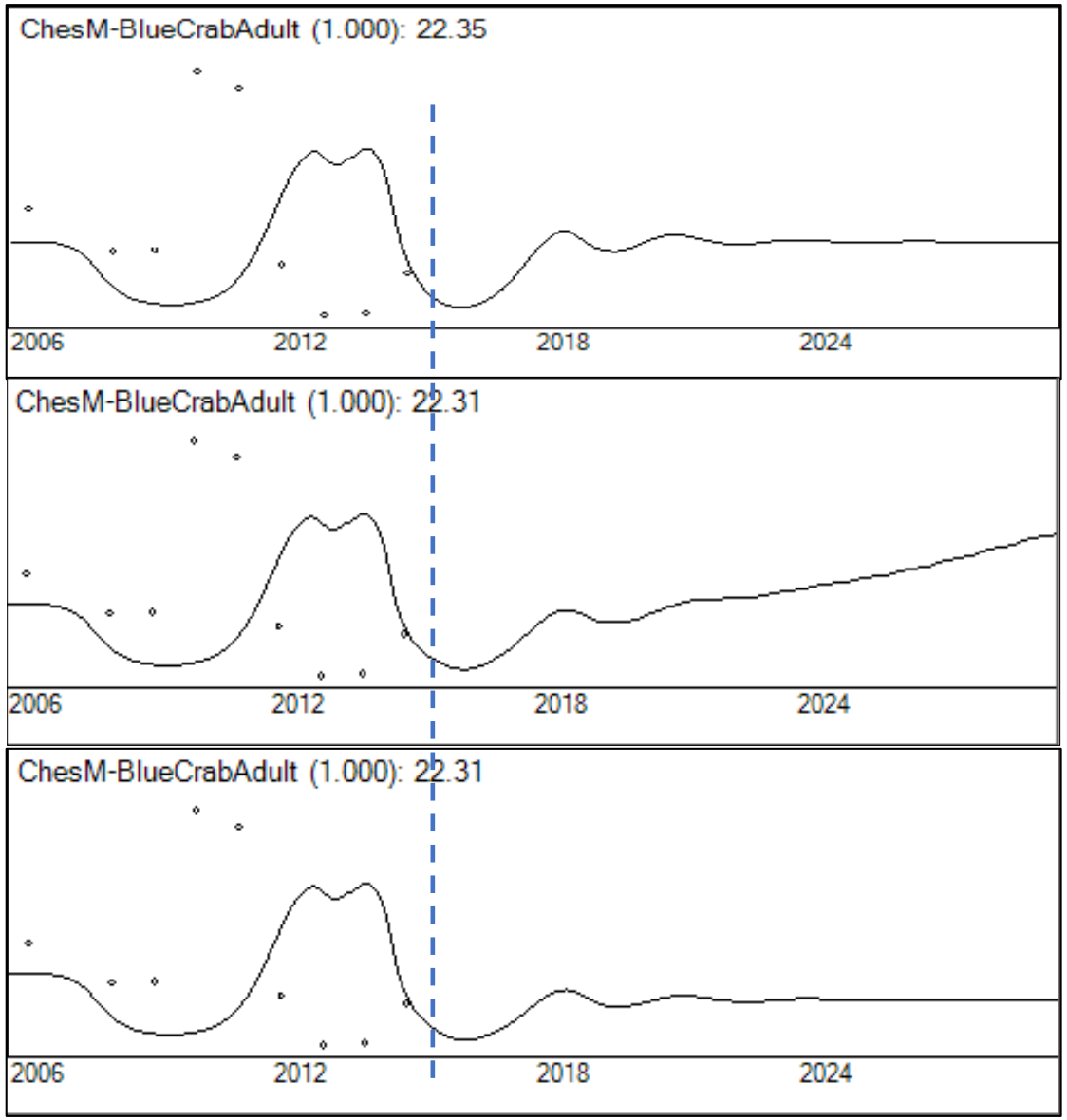
Ecopath with Ecosim: *15 year (simulation) scenarios*

Scenario

1 – Young Reef

3 – Mature Reef

5 – No Reef



Biomass Harvested Across Scenarios

Scenario	Clamming (Bait)	Trotline	Poundnet	Gillnet	Eel pots
1 - Current Young Reef	--	--	--	--	--
3 - Mature Oyster Reef (w/ FF)	-6% < - 50	+79% 2.4M	+5% ~0.01M	+44% 0.4M	+8% 0.01M
5 - Fished Down Oysters (w/ FF)	+6% < 50	-31% -0.9M	+5% ~0.01M	-14% 0.1M	-16% -0.02M

Translating Harvests into Revenues

- Simple approach – multiplied total harvest (in pounds) by mean, species-specific per-unit prices
- Whether or not this approach is “reasonable” depends on supply changes, extent of the market, availability of substitutes, etc.
- Choptank River System, while important, is relatively small component of Chesapeake Bay seafood production, which also face import competition from other states and countries.

Regional Economic Impact Analysis

Output (sales) – Measure of sales in regional economy

Labor Income – All forms of employment income (employee comp and proprietor)

Value-Added – Difference between gross output (sales) minus cost of inputs.

Employment – Full time and part-time workers

Each of the above Socio-economic metrics can be measured in...

Direct Effects – Series of expenditure changes as a result of an activity or policy

Indirect Effects – Impact of local industries buying goods and services from other local industries

Induced Effects– Re-spending of labor income – employee compensation and proprietor income

Total Impacts = Direct Effects + Indirect Effects + Induced Effects

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Translating Revenues into Impacts

- Need to know how commercial fishers allocate these revenues across expenditure categories
  - Enables the estimation of “Ripple Effect” via backwards-linked supply chain linkages
- Use IMPLAN – Regional Economic Impact Model
  - Equipped with production functions describing how each of the 528 pre-loaded industry sectors proportionally allocates expenditures to generate a dollar of output.
- Generic commercial fishing sector in IMPLAN judged to be insufficiently precise for our purposes
  - Small vessel fishery of Choptank very different than other U.S. fisheries

Commercial Fisher Cost-Earnings Data

- The project team developed a custom sector representative of the Choptank commercial fishery for use in IMPLAN
- Interviews were conducted with 12 commercial fishers working across nine fishing gear sector
- Tom Ihde led semi-structured interviews with each commercial fisher to obtain their best estimate of how they allocate expenditures and earnings across different categories

Custom Cost Functions Developed for the Choptank Region

Cost Categories	Clamming (Bait)	Trotline	Poundnet	Gillnet	Eel pots	Oyster Harvests: Power dredge	Oyster Harvests: Skipjack	Oyster Harvests: Hand tongs	Oyster Harvests: Dive
Repair/maint	23.2	6.2	29.2	9.9	14.8	7.7	11.3	3.6	11.7
Mooring	2.7	3.0	0.0	2.9	2.6	2.9	4.7	2.0	4.9
Shop expenses	5.9	2.1	0.0	6.5	1.9	3.6	2.9	2.7	3.8
Office expenses	1.6	1.9	0.0	2.2	0.3	1.7	2.5	3.5	0.9
Permit fees	4.6	4.1	0.9	6.4	1.1	4.4	8.4	3.7	9.6
Vehicle costs	7.2	7.9	14.6	8.7	4.0	8.7	11.3	9.3	10.8
Travel costs	2.5	1.8	0.0	2.3	1.6	2.0	2.5	2.7	0.9
Association fees	1.2	1.8	2.7	1.0	0.7	1.6	2.5	2.7	2.9
Professional fees	2.8	1.3	3.7	2.8	1.1	1.5	5.8	0.7	1.9
Insurance	3.1	2.8	0.0	1.0	0.3	2.0	4.3	1.3	0.0
Fishery monitoring costs	0.5	0.0	0.0	1.7	0.0	0.4	0.0	0.0	2.8
Non-crewshare labor costs	0.9	1.7	0.0	1.5	1.1	0.3	1.5	0.0	0.0
Fuel	13.5	9.9	7.3	14.8	9.0	12.7	5.5	8.2	9.8
Food	0.9	2.8	0.0	4.7	0.9	2.2	2.5	2.1	4.0
Ice	0.0	3.0	0.0	0.0	0.2	0.3	3.3	0.0	0.0
Bait	0.0	9.6	0.0	0.0	11.8	0.0	0.0	0.0	0.0
Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Communications costs	2.8	2.5	3.7	3.2	0.3	2.2	3.3	2.9	3.4
Fishing supplies	3.9	5.9	3.7	5.2	3.7	3.9	4.4	3.1	1.9
Crew supplies	3.6	1.8	3.7	3.8	1.9	2.7	5.1	1.8	5.3
Catch handling costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other costs	0.0	2.3	0.0	3.1	0.0	2.4	0.0	0.0	0.0
Crew share costs	7.6	0.9	30.7	11.8	15.4	5.3	9.1	0.0	16.2
Proprietary Income	11.8	26.6	0.0	6.5	27.4	31.4	9.1	49.7	9.1

Ecological Findings

- **Finding 1: Increase in Commercial Harvest**
  - Mature Oyster Reef supports an increase in biomass harvested of:
    - 45% relative to Young Reef
    - 80% relative to Fished Down Scenario

- **Finding 2: Oyster-Associated Filter Feeders Matter**
  - Accounting for filter feeders on oyster reefs affects fisheries harvest by between 11% and 17%

Ecological Findings

- **Finding 3: Large Predicted Increase in Blue Crab Harvest with Oyster Reef Restoration**
  - Mature Oyster Reef supports increase in harvest of:
    - 80% relative to Young Reef
    - 160% relative to Fished Down Scenario

- **Finding 4: Finfish: Large Predicted Change in White Perch Harvest; Negligible Change to Striped Bass**
  - Mature Oyster Reef supports increase in harvest of:
    - 110% relative to Young Reef
    - 650% relative to Fished Down Scenario

Economics Findings

- **Finding 5: Total Dockside Sales**
  - Mature Oyster Reef supports an increase in dockside sales of:
    - $4.5 million relative to Young Reef
    - $11 million relative to Fished Down Scenario
- **Finding 6: Multiplier Effects for Sales**
  - Multiplier Effect of 2.03
    - For each dollar of dockside sales an additional $1.03 of economic output is generated in Dorchester and Talbot Counties
    - Small increase for Bay counties and MD

Economics Findings

- **Finding 7: Regional Economic Impacts**

Differences in Total Regional Economic Effects, by Economic Measure and Across Scenarios		
	Young Reef -> Mature Reef w/ FF	Fished Down Reef w/ FF -> Mature Reef w/ FF
Output (Sales) **Total value of production**	+ $10.2 m	+ $23.1 m
Labor Income **All forms of income (employee and owner compensation)**	+ $4.8 m	+ $9.2 m
Value-Added **Difference between output and cost of intermediate inputs**	+ $8.6 m	+ $16.0 m
Employment **Full and part-time annual jobs**	+ 183 jobs	+ 360 jobs

Economics Findings

- **Finding 7: Regional Economic Impacts**

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	Young Reef -> Mature Reef w/ FF	Fished Down Reef w/ FF -> Mature Reef w/ FF
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Employment Full and part-time annual jobs	+ 183 jobs	+ 360 jobs

Summary

- **Final report** reviewed by project team, minor revisions completed. Report submitted to NFWF
- **Construction expenditures** economic impacts
  - Indirect and Induced Output = ~ $70 million
  - Annual Jobs = 653
- **Spatial extention** – Ecopath w/ Ecosim & Ecospace Spatial model potential next step
- **Next steps** include submission of manuscripts to Marine Policy, Ecological Modeling

Thank You!

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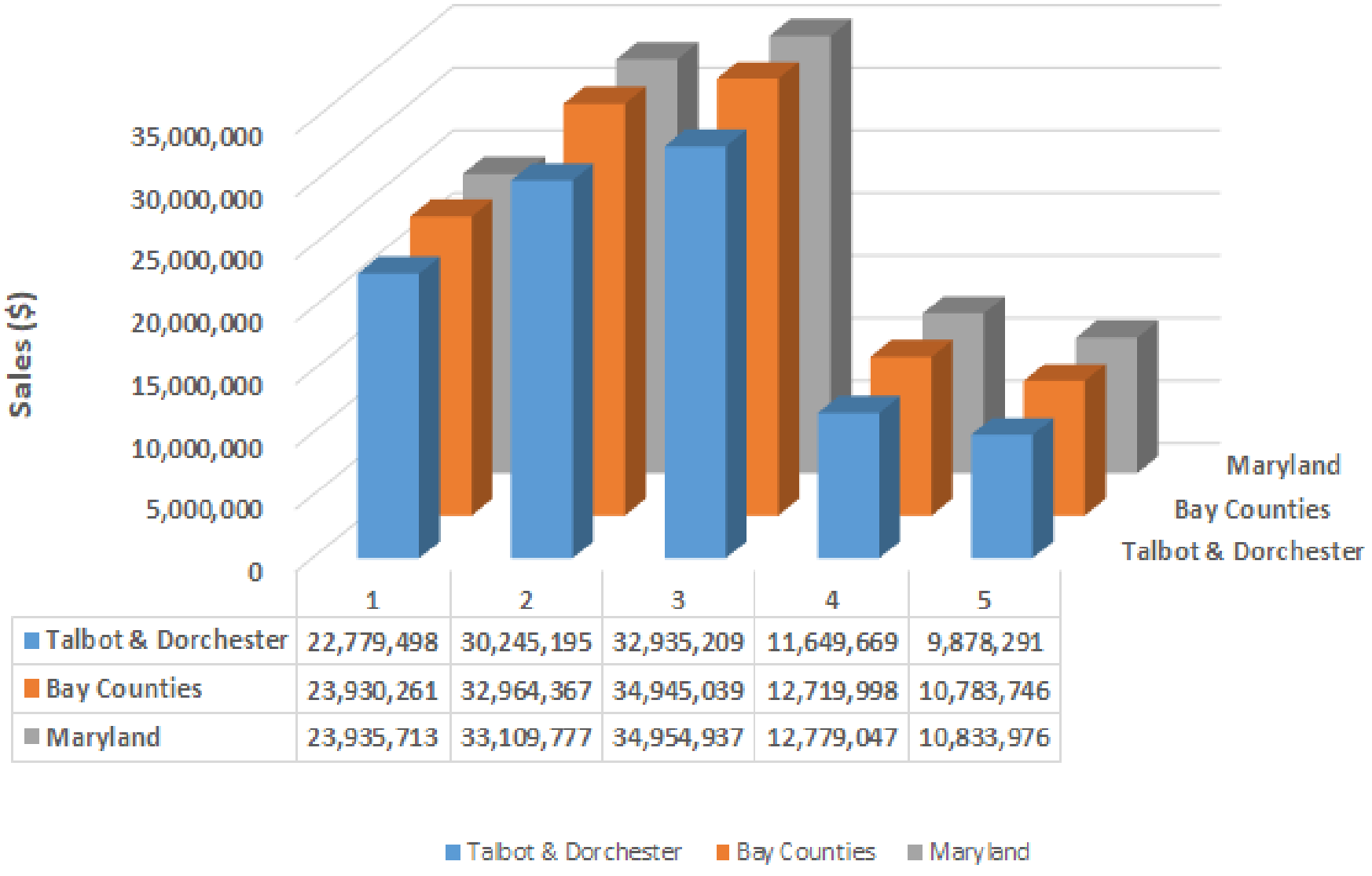
Extra Slides
for
Discussion

Results - Caveats

- Specific to Talbot and Dorchester Counties
- Estimates are on annual basis
- 3 scenarios:
    - "Current Young Reef" represents present conditions
        - established sanctuaries with restored oysters
        - compared to:
    - retention of sanctuaries to allow oysters & other filter feeders to continue to grow
    - removal of sanctuaries, allowing unrestricted oyster harvest throughout, and a return to pre-restoration condition
- Harvests in analysis include the active fisheries of the area

Economic Impacts By Region Analyzed in IMPLAN

Total Output (Sales)



	1	2	3	4	5
Talbot & Dorchester	22,779,498	30,245,195	32,935,209	11,649,669	9,878,291
Bay Counties	23,930,261	32,964,367	34,945,039	12,719,998	10,783,746
Maryland	23,935,713	33,109,777	34,954,937	12,779,047	10,833,976

Results

Differences in Total Economic Effects, by Economic Measure & Across Scenarios		
	Mature Reef (w/ FF) compared to Young Reef	
Sales (Output)	+ $10.0 million	
Labor Income	+ $4.8 million	
Value-Added	+ $8.6 million	
Employment (full and part-time jobs)	+ 183 jobs	

Results

Differences in Total Economic Effects, by Economic Measure & Across Scenarios		
	Mature Reef (w/ FF) compared to Young Reef	**Mature Reef (w/ FF) compared to No Sanctuary (w/ FF)**
Sales (Output)	+ $10.0 million	+ $22.8 million
Labor Income	+ $4.8 million	+ $9.2 million
Value-Added	+ $8.6 million	+ $15.9 million
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Results

Differences in Total Economic Effects, by Economic Measure & Across Scenarios		
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Sales (Output)	+ $10.0 million	+ $22.8 million
Labor Income	+ $4.8 million	+ $9.2 million
Value-Added	+ $8.6 million	+ $15.9 million
Employment (full and part-time jobs)	+ 183 jobs	+ 360 jobs

- *Multiplier effect for sales = 2.03; i.e., for each $1 of dockside sales (direct), and **additional** $1.03 of economic activity (indirect + induced) generated from inter-industry transactions & additional regional spending through employee wages & business owner income*

Results

Annual Total Sales Effects

Scenario	Total Effect	Difference from Current Young Reef
Current Young Reef	$ 23 million	--
Mature (w/ FF)	$ 33 million	$ 10 million
No Sanctuary (w/FF)	$ 10 million	- $13 million

Summary

- *Substantial increase in commercial fishing – related socio-economic effects to the region from retaining restored oyster reefs and allowing them to mature*
- *Substantial reduction in commercial fishing – related socio-economic effects from eliminating sanctuaries*
- *Model estimates focus on commercial harvester sales and the backwards-linked supply chain effects - this does not include forward-linked industries such as processors, wholesalers, and retailers*
- *Inclusion of other filter feeders has an important impact for ES estimates*
  - Compared to scenarios that did not accommodate for the increased/decreased production of filter feeders, saw 11-17% change
- *Blue Crab (and White Perch) harvest change drove the economic impacts*
- *Multiplier effect for sales = 2.03 (direct)*
  *- For each $1 of dockside sales, an **additional** $1.03 of economic activity is generated (indirect + induced)*

Next Step?

A spatial modeling approach (Ecospace) will be required to parse changes in oyster harvests by area (i.e., to capture dynamics of oyster growth and harvest effects outside sanctuary areas)

Summary

Ecopath with Ecosim

- *Worked very well to project expected change in landed value for variety of different fisheries*
  - *#1 vs. #3*
    - *Blue crab – 80% increase in projected landed value*
    - *Gillnet – 44% increase in projected landed value*
  - *#5 vs. #3*
    - *Blue crab – 62% decrease in landed value*
    - *Gillnet – 40% decrease in landed value*
- *A spatial model approach (Ecospace) will be required to parse changes in oyster harvests by area (i.e., to capture dynamics of oyster growth and harvest effects outside sanctuary areas)*
- *Variability plots*

IMPLAN

- *Preliminary results appear reasonable and useful*
- *Dorchester & Talbot Counties will have the greatest share of impacts*
- *Bay States and State-wide (Maryland only) results will increase total impacts (all categories), but additions are expected to be much less than those seen in the 2-county model*
- *Impact losses range 54-55% for "No sanctuary" vs. "Status quo"*

Ecopath with Ecosim: *15 year scenarios*

Translate Harvest to Dockside Revenues

- *Prices – MD DNR dealer reports*
- ***A:** Choptank fishery is small component of total fishery*
  - ✓ ***Consequently, no price effects***

Ecopath with Ecosim: *15 year scenarios*

Biomass, Wet Weight (MT)

Fishery	Group	1 - Status Quo	3 - Mature Oyster & FF (increase)	5 - No Sanctuaries (Oyster & FF decreases)
Trotline	Blue Crab	18.67	33.47	12.81
Multiple Gears	Striped Bass	1.70	1.70	1.89
Multiple Gears	White Perch	3.89	8.23	1.08

Ecopath with Ecosim: *15 year scenarios*

Price: $/lb =	*$7.70*	*$1.86*	*$0.77*	*$0.48*	*$2.16*	*$12.67*			
Scenario	**Clamming (Bait)**	**Trotline**	**Poundnet**	**Gillnet**	**Eel pots**	**Power dredge**	**Skipjack**	**Hand tongs**	**Dive**
#1 Status Quo	**$6,001**	**$5,557,125**	**$135,589**	**$419,167**	**$220,637**	**$1,837,132**	**$245,533**	**$2,668,206**	**$113,766**
#2 Mature: Oyster Increase	**$5,703**	**$9,123,748**	**$135,938**	**$465,005**	**$234,280**	**$1,837,132**	**$245,533**	**$2,668,206**	**$113,766**
#3 Mature: Oyster + FF Increase	**$5,618**	**$9,962,487**	**$142,392**	**$602,635**	**$237,454**	**$1,837,132**	**$245,533**	**$2,668,206**	**$113,766**
#4 No Sanct: Oyster Decrease	**$6,181**	**$4,587,821**	**$137,498**	**$415,421**	**$221,147**	**$104,002**	**$13,900**	**$151,050**	**$6,440**
#5 No Sanct: Oysters + FF Decrease	**$6,346**	**$3,813,736**	**$142,997**	**$361,140**	**$185,118**	**$104,002**	**$13,900**	**$151,050**	**$6,440**

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#4 No Sanct: Oyster Decrease	**$6,181**	**$4,587,821**	**$137,498**	**$415,421**	**$221,147**	**$104,002**	**$13,900**	**$151,050**	**$6,440**
#5 No Sanct: Oysters + FF Decrease	**$6,346**	**$3,813,736**	**$142,997**	**$361,140**	**$185,118**	**$104,002**	**$13,900**	**$151,050**	**$6,440**

Results

Ecopath with Ecosim: *15 years of event conditions*

Price: $/lb =	*$7.70*	*$1.86*	*$0.77*	*$0.48*	*$2.16*	*$12.67*			
Scenario	**Clamming (Bait)**	**Trotline**	**Poundnet**	**Gillnet**	**Eel pots**	**Power dredge**	**Skipjack**	**Hand tongs**	**Dive**
#1 Status Quo	**$6,001**	**$5,557,125**	**$135,589**	**$419,167**	**$220,637**	**$1,837,132**	**$245,533**	**$2,668,206**	**$113,766**
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Results

Ecopath with Ecosim: *15 year scenarios*

	Price: $/lb =	*$7.70*	*$1.86*	*$0.77*	*$0.48*	*$2.16*
	Scenario	**Clamming (Bait)**	**Trotline**	**Poundnet**	**Gillnet**	**Eel pots**
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Regional Economic Impact Analysis

Used to assess the change in economic activity resulting from an event occurring in a certain area. Economic activity is measured in terms of changes in the following **types** of impacts:

- **Output** (local business sales)
- **Value-added** (total output minus intermediate inputs)
- **Labor income** (proprietor and employee wages)
- **Employment** (# of full and part time workers)

For each of these, there are different **sources** of impacts

Regional Economic Impact Analysis

Sources of impacts

Output as an example:

Direct Effects – initial spending. For fish harvest, this is the spending on supplies (e.g., bait, nets), crew wages, and proprietor income. For output, this is equal to total dockside revenues.

Indirect Effects –business to business spending indirectly caused by direct effects. For example, the fishing net maker buying raw materials to make net is an indirect effect.

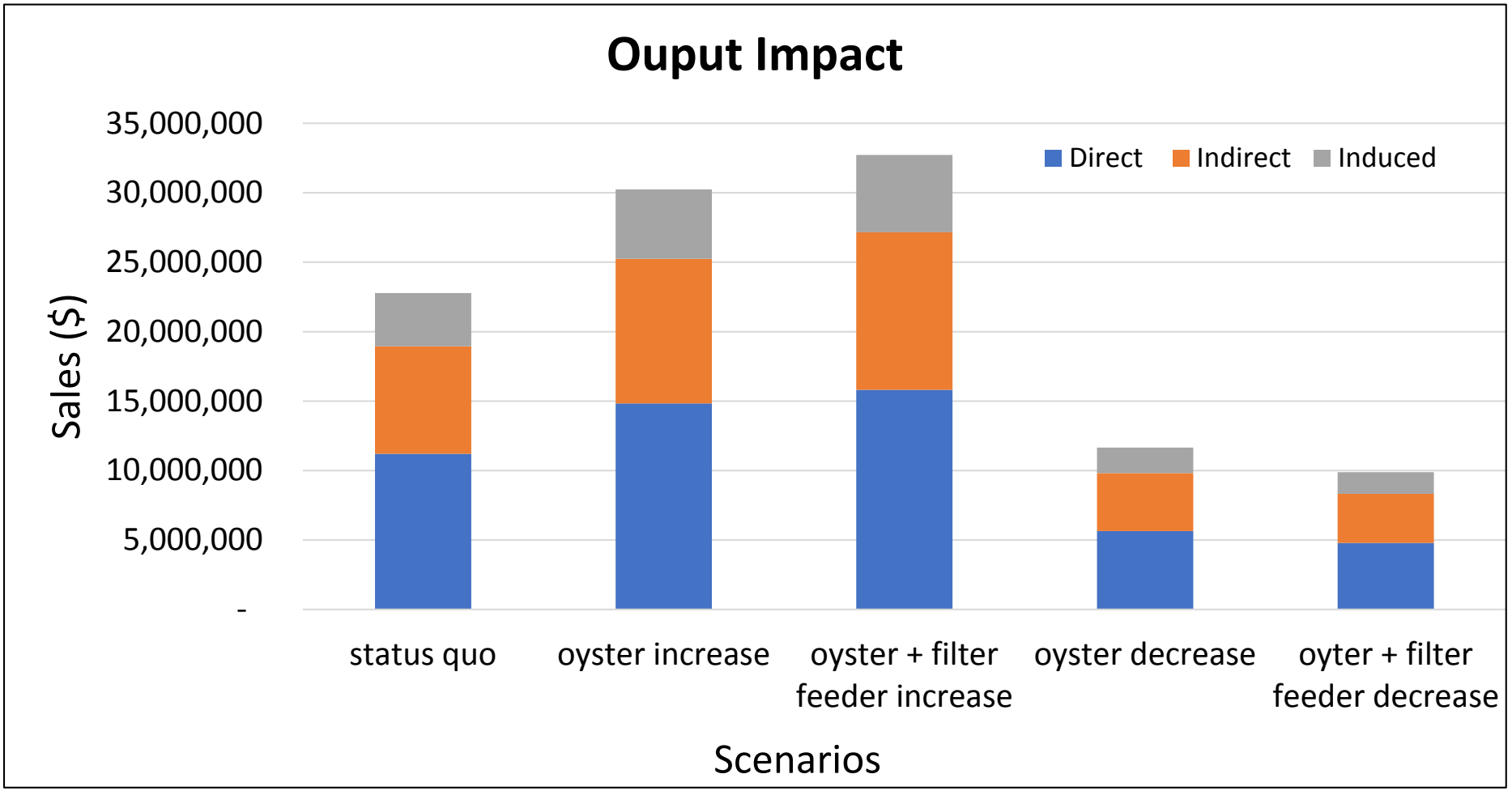
Induced Effect – The result of increased personal income caused by direct and indirect effects. For example, the spending by crew at local businesses is an induced effect.

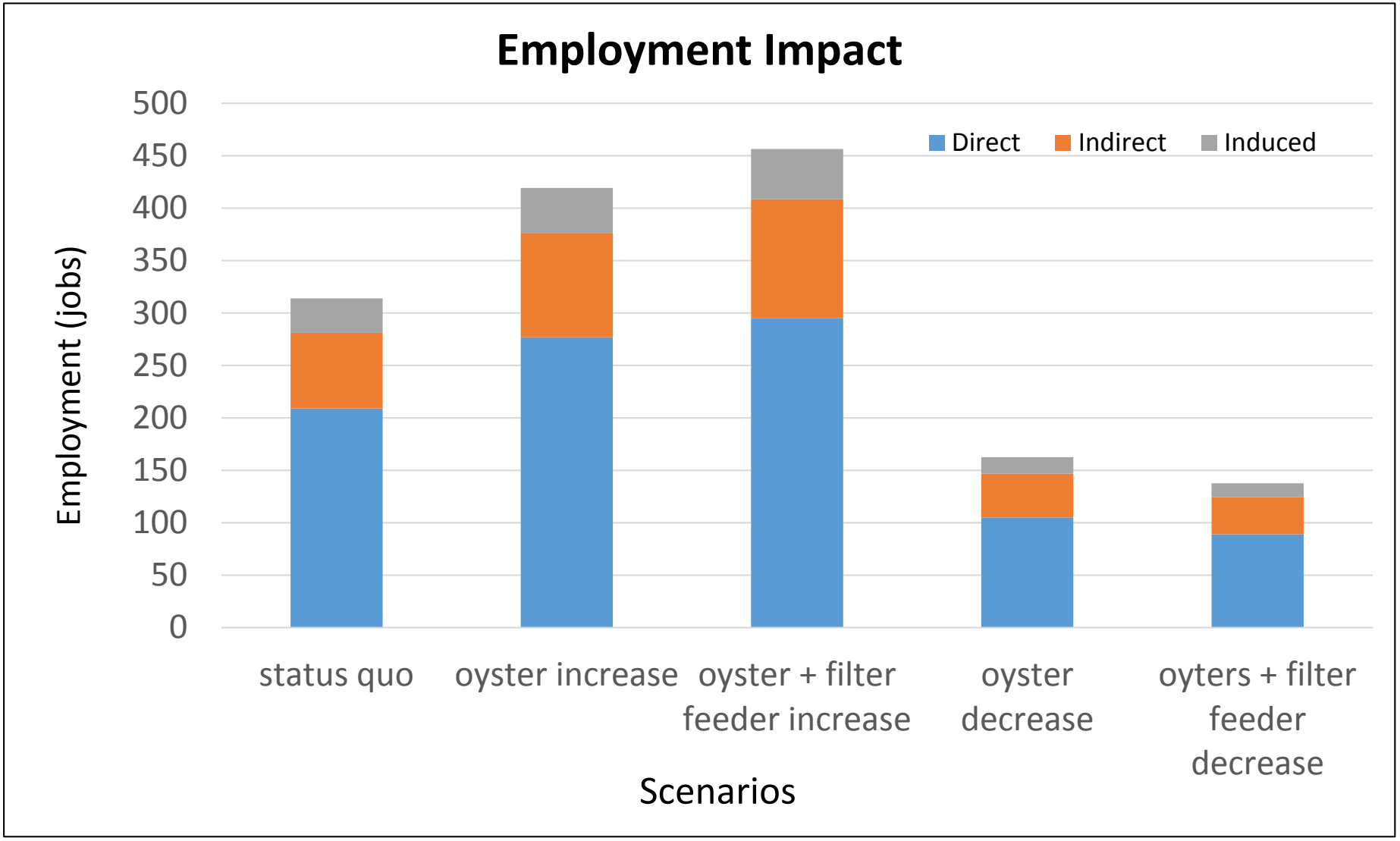
Our calculation of Direct Effects

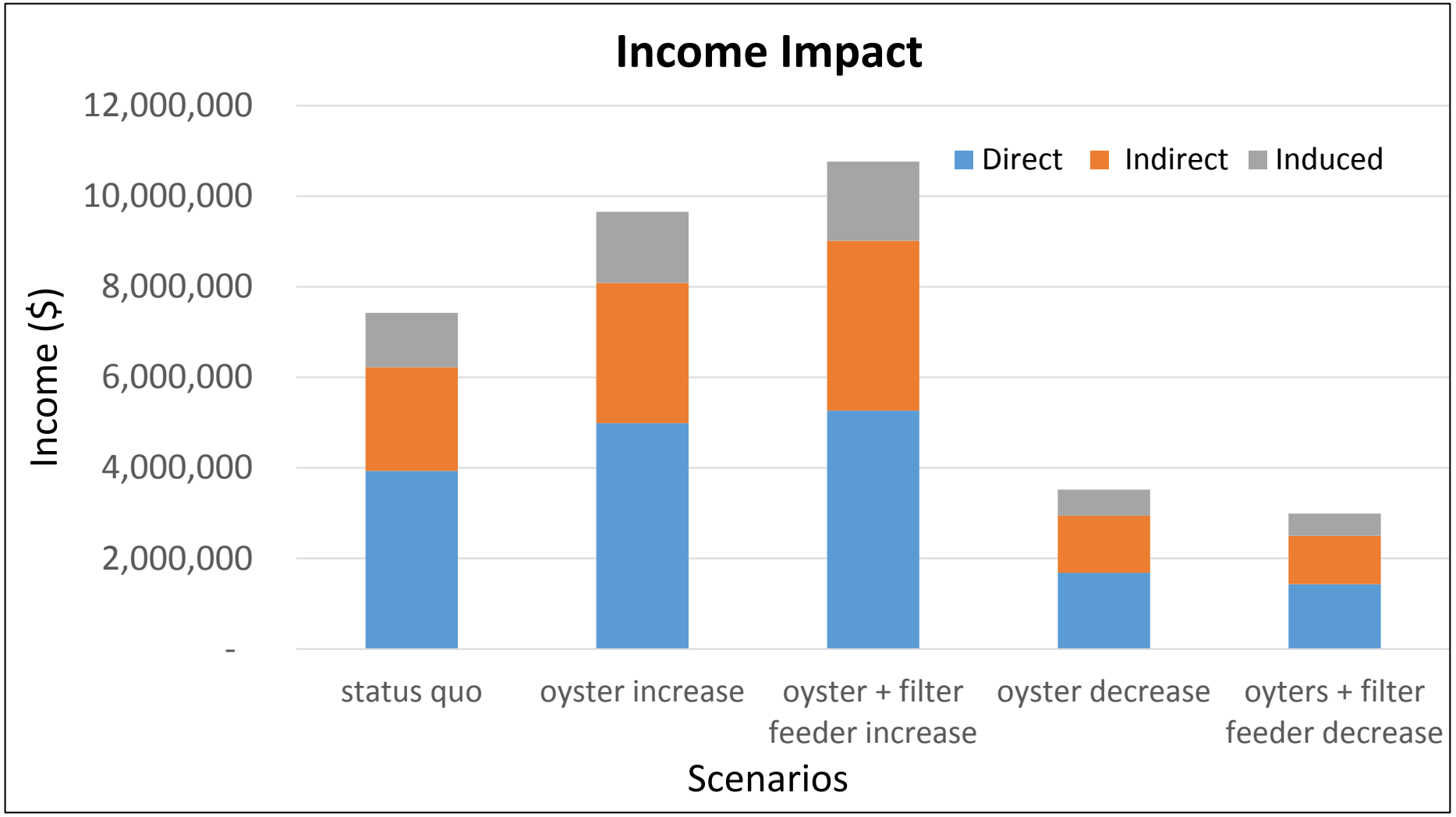
Direct Effects

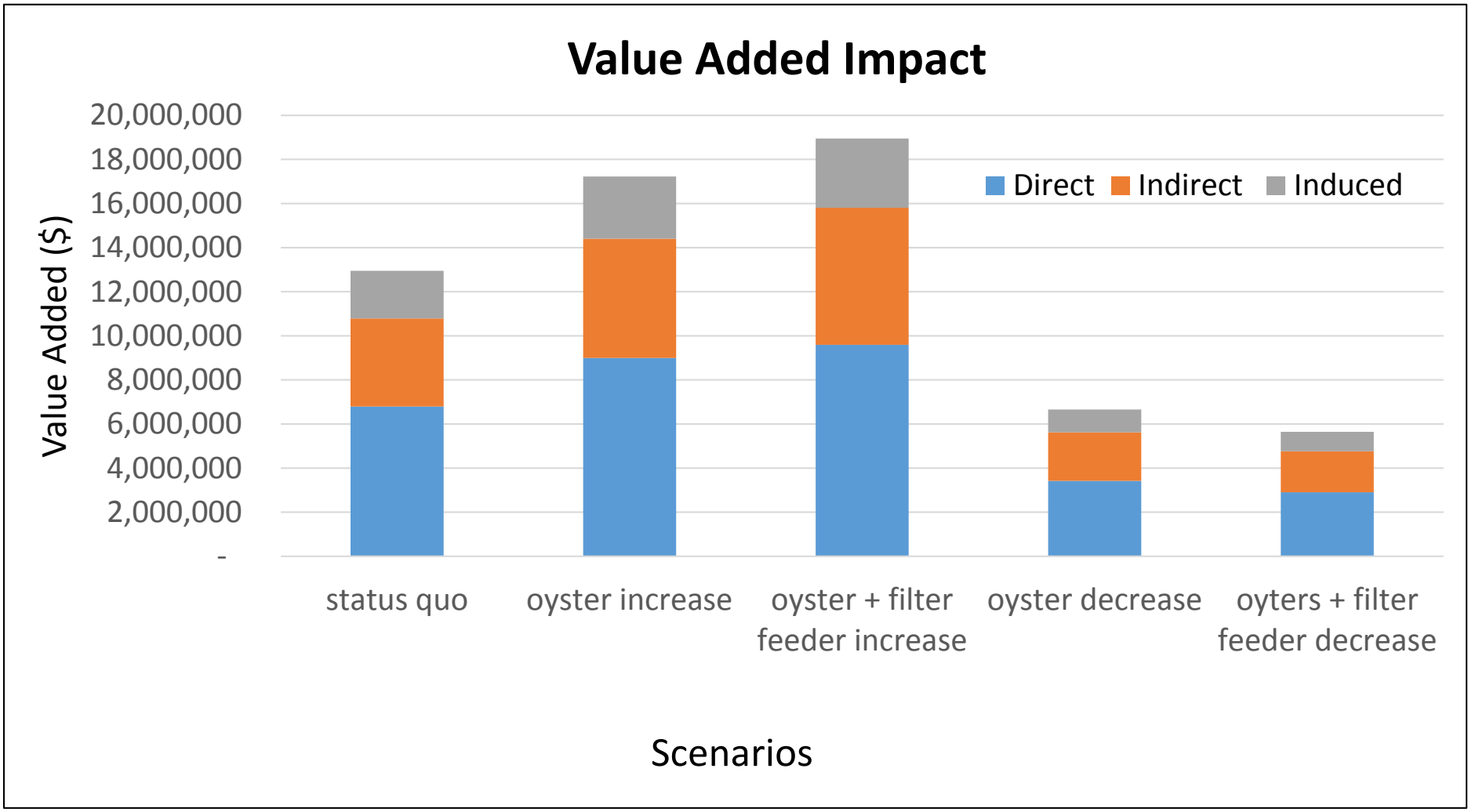
- Sales/Output: ex-vessel revenue
  - EwE biomass harvested multiplied by 2015 mean per-unit price
- Employment:
  - Apply Commercial Harvester ratio of Direct Sales (MD FEUS 2015) per Direct job (MD FEUS 2015) to Direct Sales (above) to estimate Commercial Harvester direct jobs
- Income: Proprietor income + crew share
  - Sales/Output minus crew and proprietor income
- Value Added: commercial fishing sector output to value added ratio

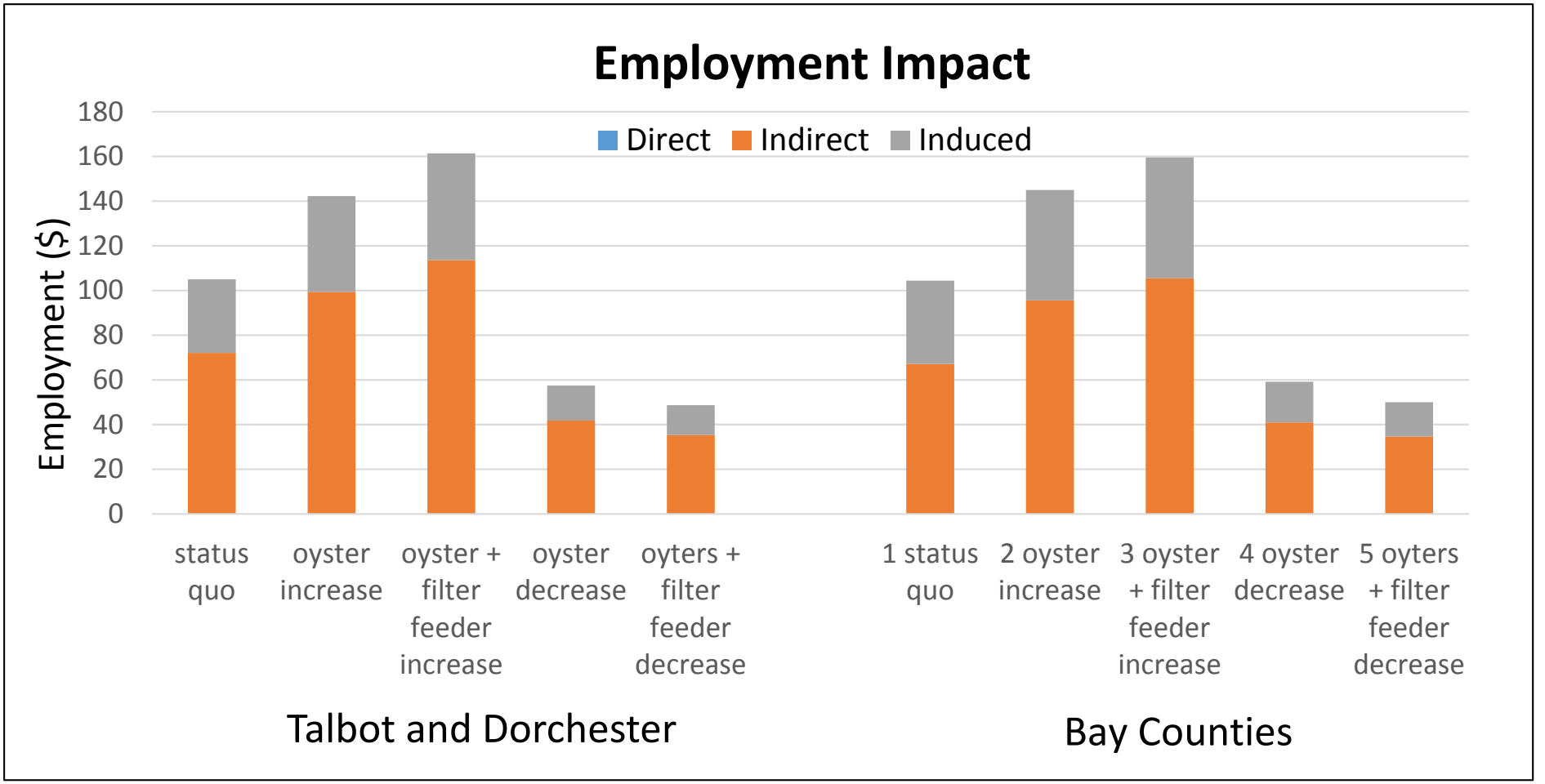
Indirect and Induced Effects - IMPLAN Generated

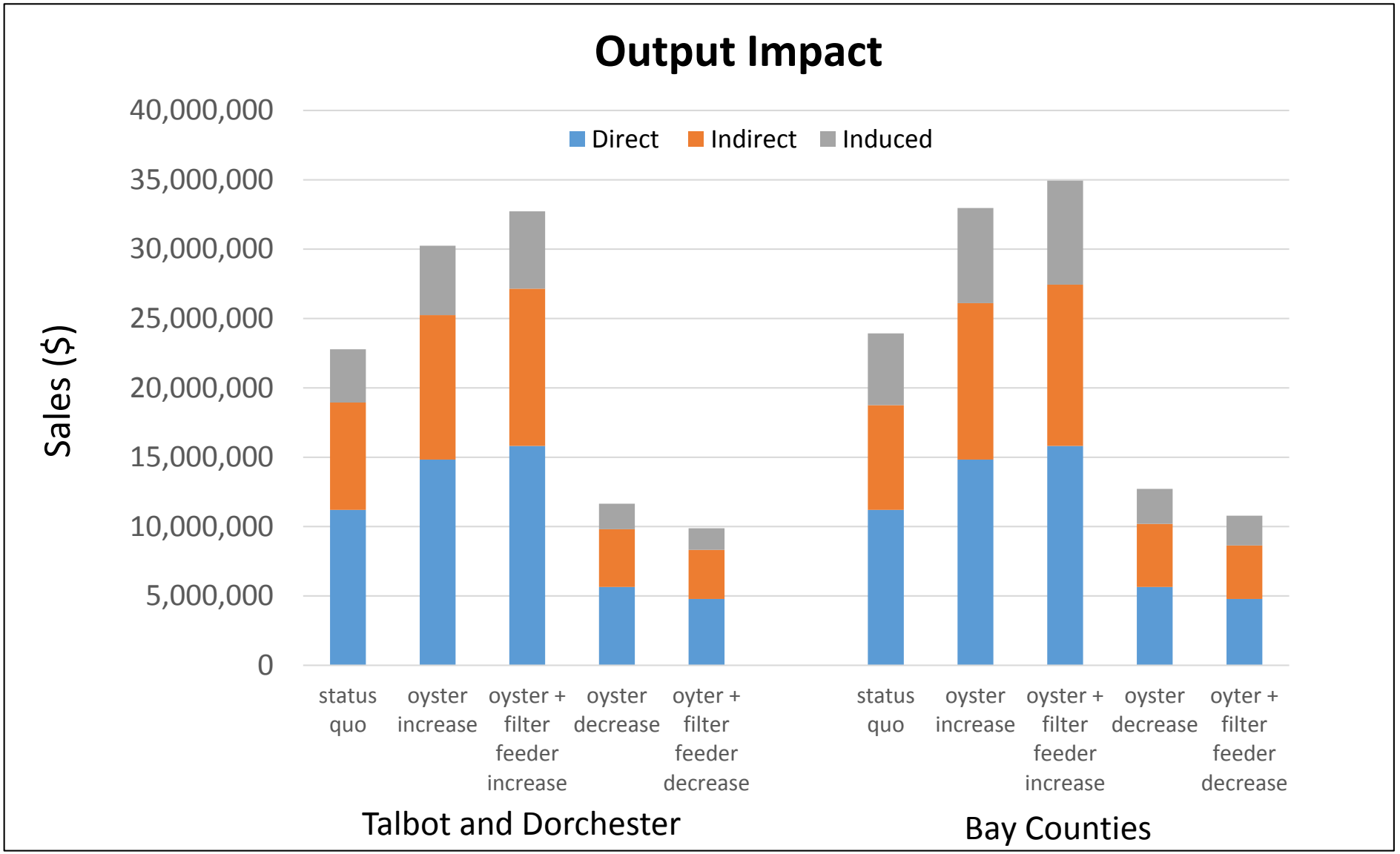

Ouput Impact
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
Sales ($)
Direct
Indirect
Induced
status quo
oyster increase
oyster + filter feeder increase
oyster decrease
oyter + filter feeder decrease
Scenarios


Employment Impact
500
450
400
350
300
250
200
150
100
50
0
Employment (jobs)
Direct
Indirect
Induced
status quo
oyster increase
oyster + filter feeder increase
oyster decrease
oyters + filter feeder decrease
Scenarios


Income Impact
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
-
Income ($)
Direct
Indirect
Induced
status quo
oyster increase
oyster + filter feeder increase
oyster decrease
oyters + filter feeder decrease
Scenarios


Value Added Impact
20,000,000
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
-
Value Added ($)
Direct
Indirect
Induced
status quo
oyster increase
oyster + filter feeder increase
oyster decrease
oyters + filter feeder decrease
Scenarios


Employment Impact
Direct
Indirect
Induced
Employment ($)
180
160
140
120
100
80
60
40
20
0
status quo
oyster increase
oyster + filter feeder increase
oyster decrease
oyters + filter feeder decrease
1 status quo
2 oyster increase
3 oyster + filter feeder increase
4 oyster decrease
5 oyters + filter feeder decrease
Talbot and Dorchester
Bay Counties


Output Impact
Sales ($)
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
Direct
Indirect
Induced
status quo
oyster increase
oyster + filter feeder increase
oyster decrease
oyter + filter feeder decrease
status quo
oyster increase
oyster + filter feeder increase
oyster decrease
oyter + filter feeder decrease
Talbot and Dorchester
Bay Counties

Economic Impact of Oyster Reef Restoration

We ran analysis on the economic impact of $52.8 million of oyster reef restoration during 2012-2016 period.

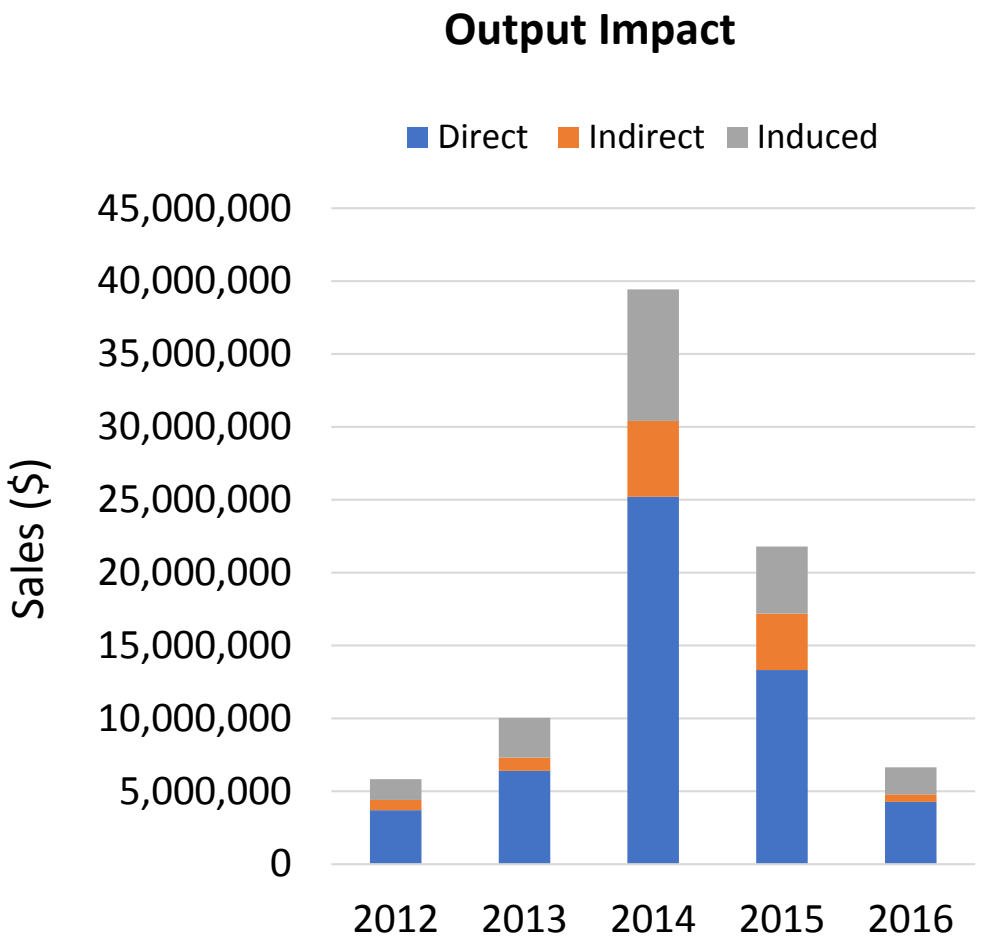
Input: expenditures

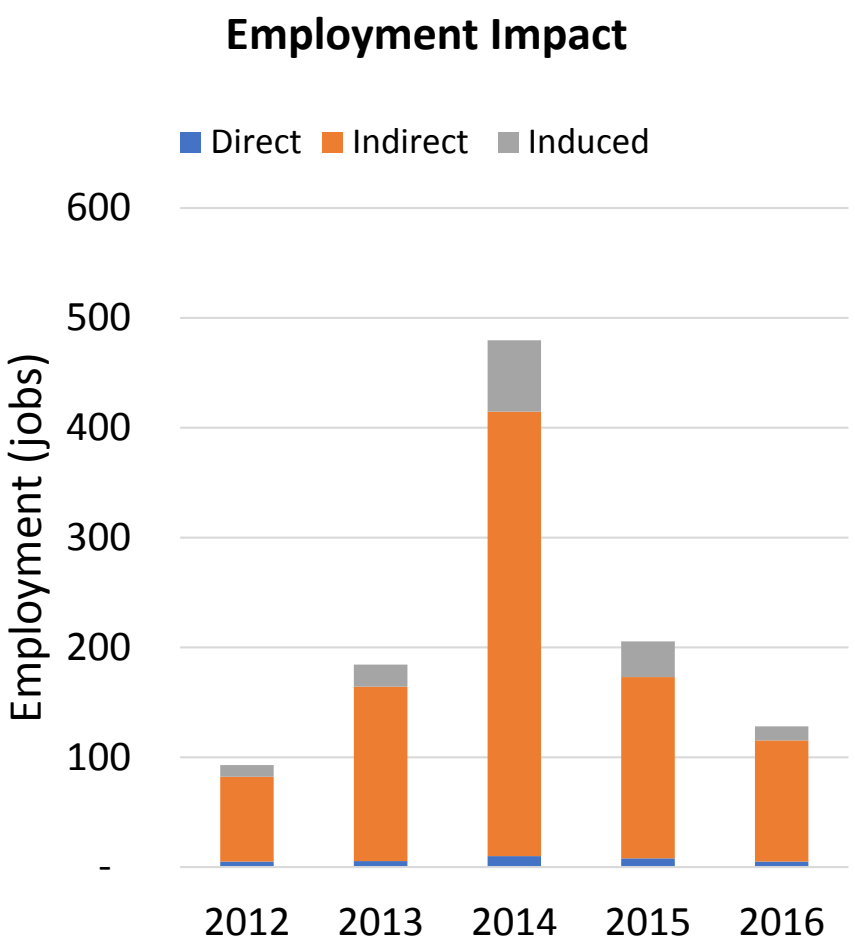
Year	Oyster reef projects* (US$)
2012	3,700,000
2013	6,400,000
2014	25,202,800
2015	13,316,000
2016	4,276,000
Total	52,894,800

Output: IMPLAN

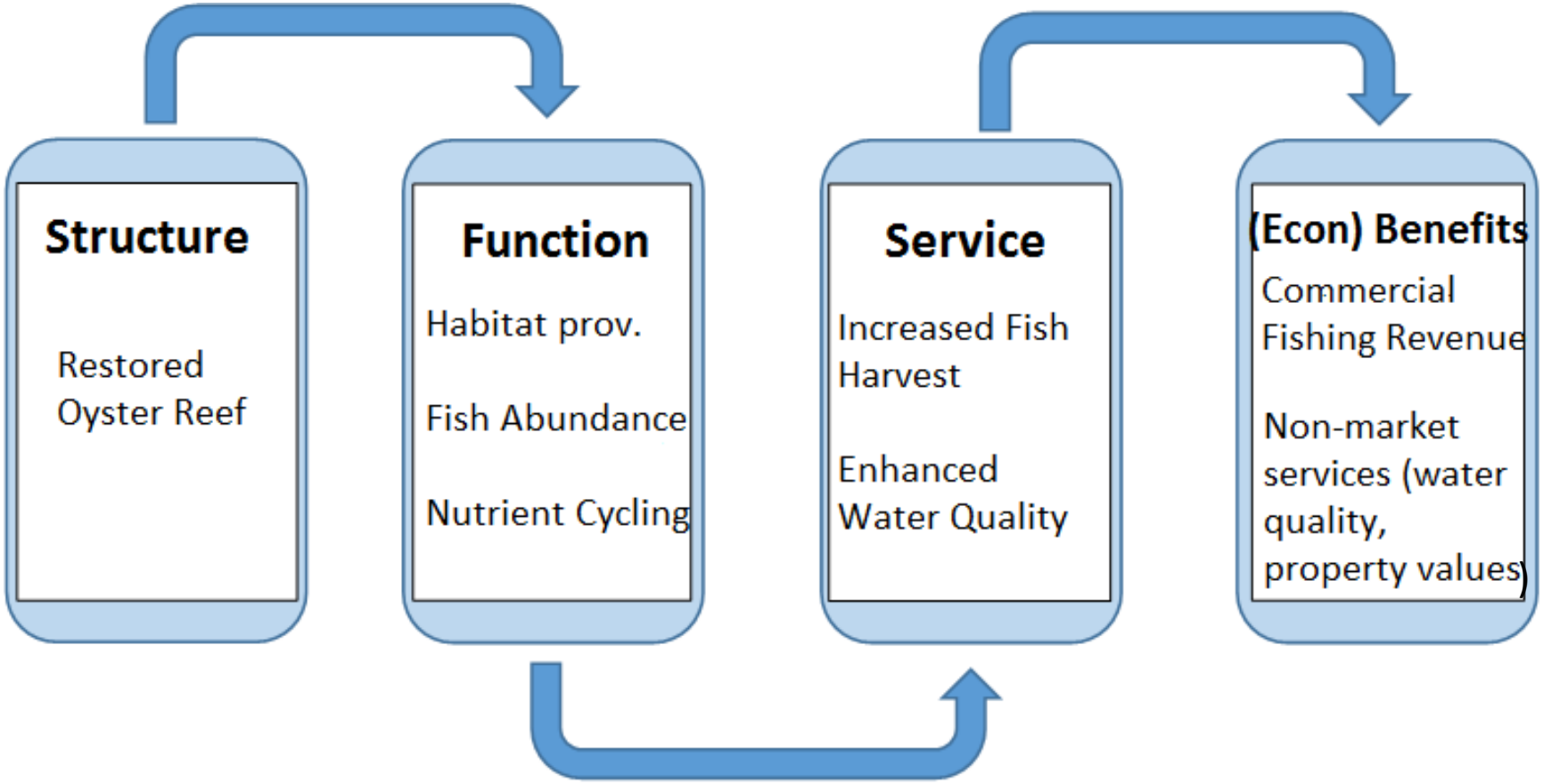
- $5.8 to $39.4 mil total output generated
- Annual average of 218 jobs supported from 2012 through 2016
- 480 total jobs supported in peak year 2014
- $2.7 to $15.9 mil of labor income generated from supported jobs, 2012-2016

Reef Restoration





From Restoration to Benefits



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PATUXENT ENVIRONMENTAL AQUATIC RESEARCH LABORATORY PEARL

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NOAA U.S. DEPARTMENT OF COMMERCE

NATIONAL FISH AND WILDLIFE FOUNDATION

Ecosystem-Economic Impact Analysis

Two Sets of Analyses:

1) Projected fish & shellfish harvests that occur as a result of different management alternatives
   - Ecopath with Ecosim
   - IMPLAN

     Three study areas

     (1) Dorchester & Talbot counties
     (2) All Bay counties
     (3) Maryland

2) Oyster reef construction
   - IMPLAN

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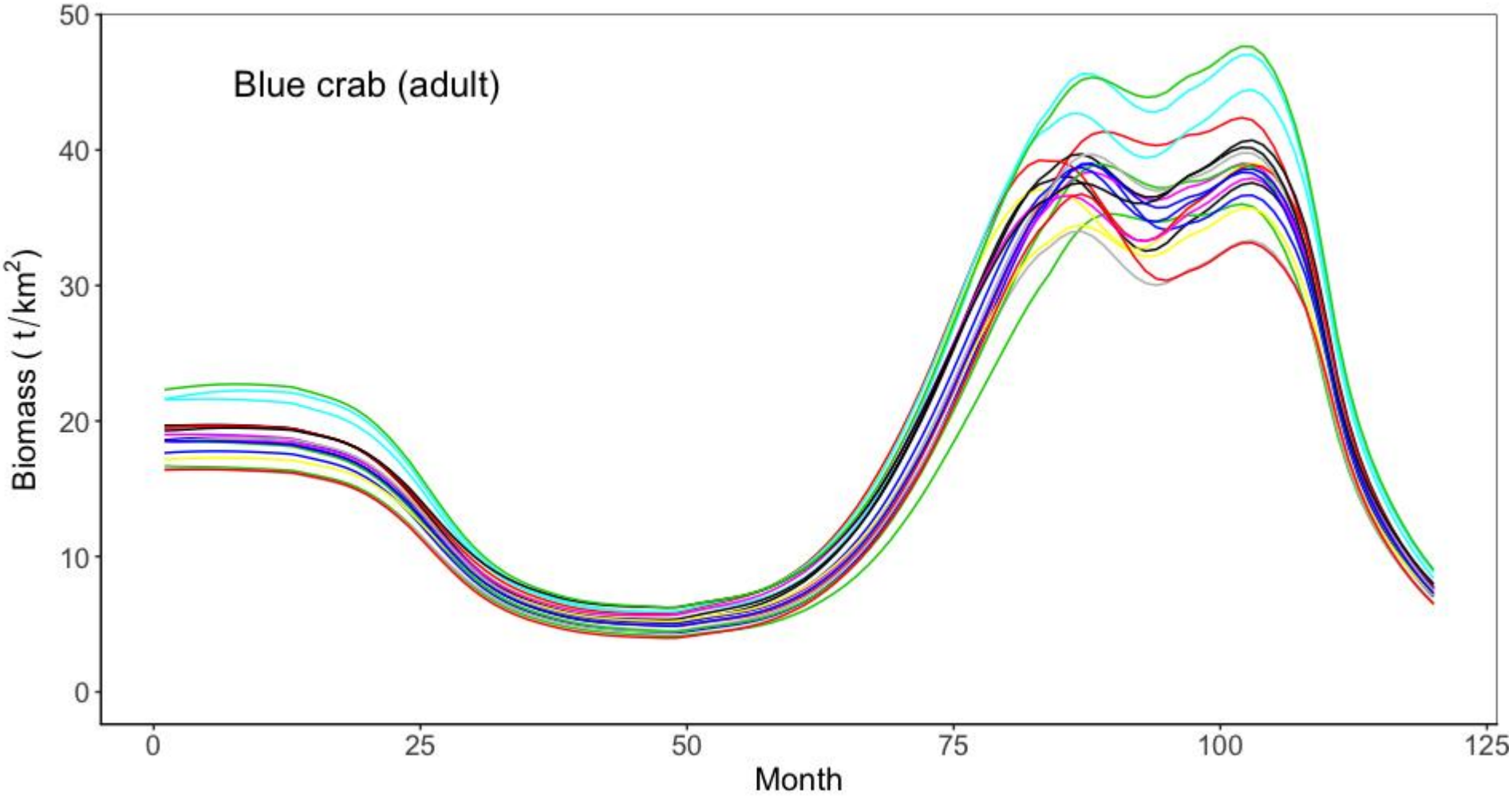
Ecopath with Ecosim

Sensitivities - Biomass



Ecopath with Ecosim

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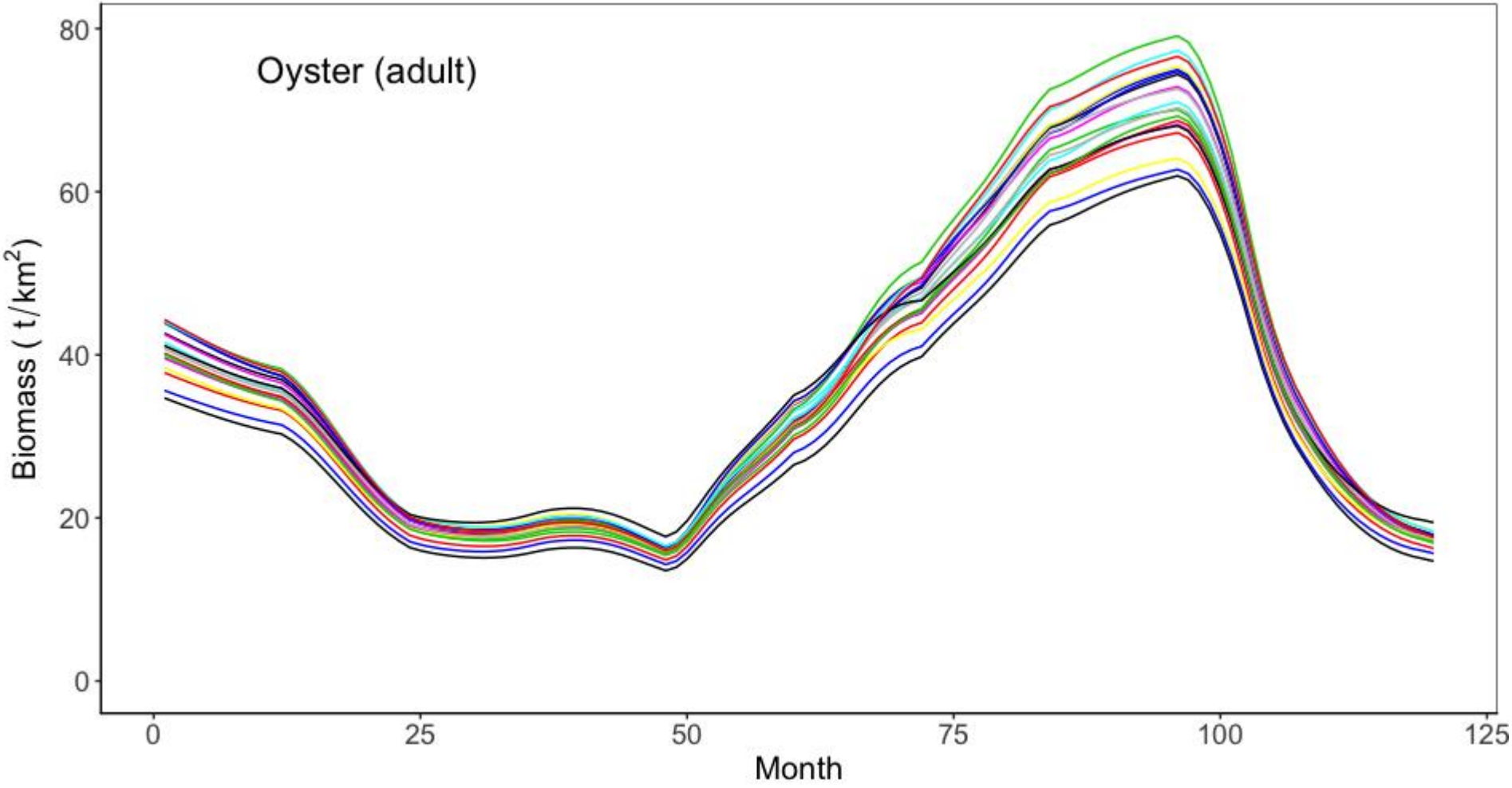

Ecopath with Ecosim

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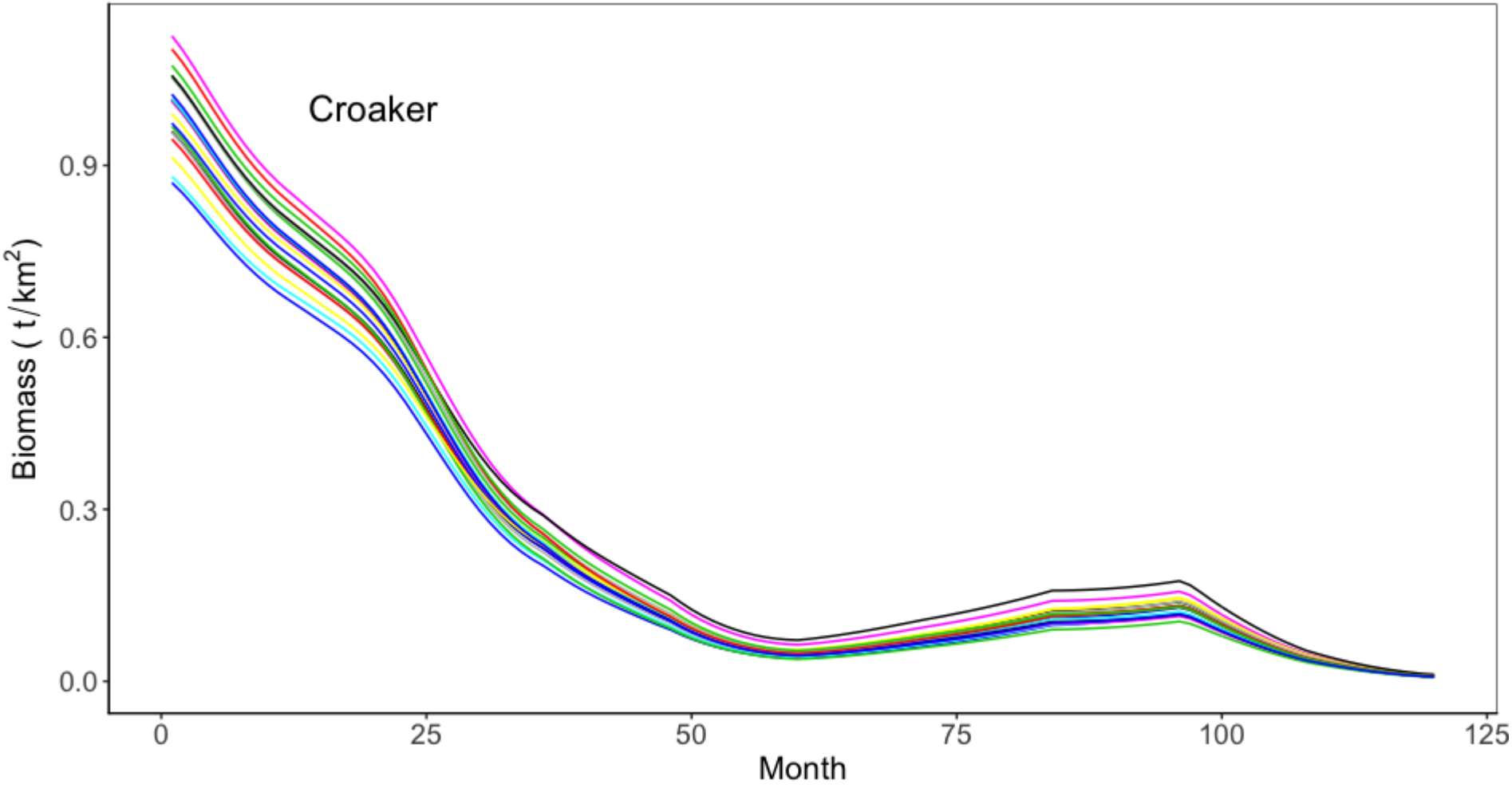

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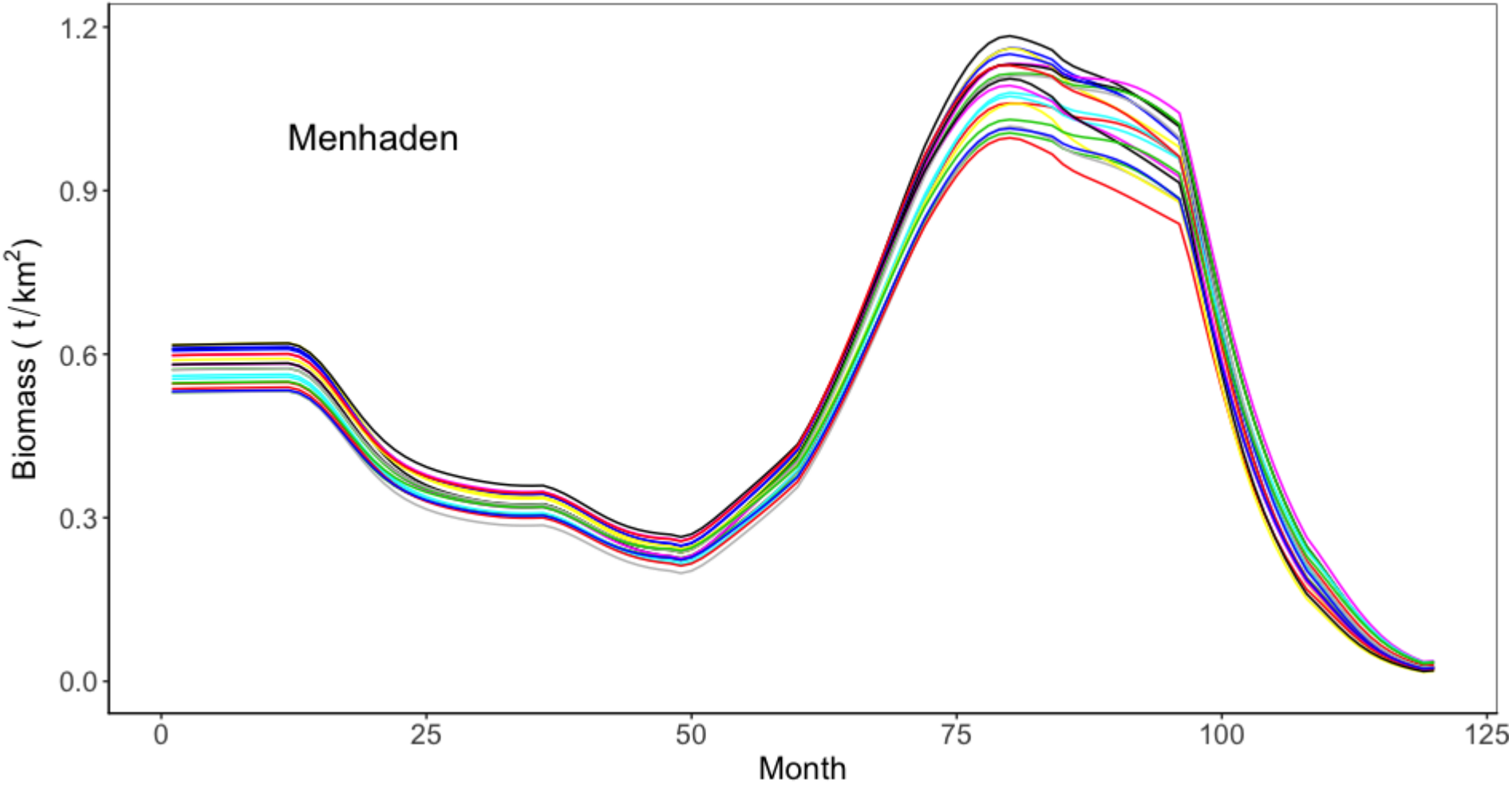

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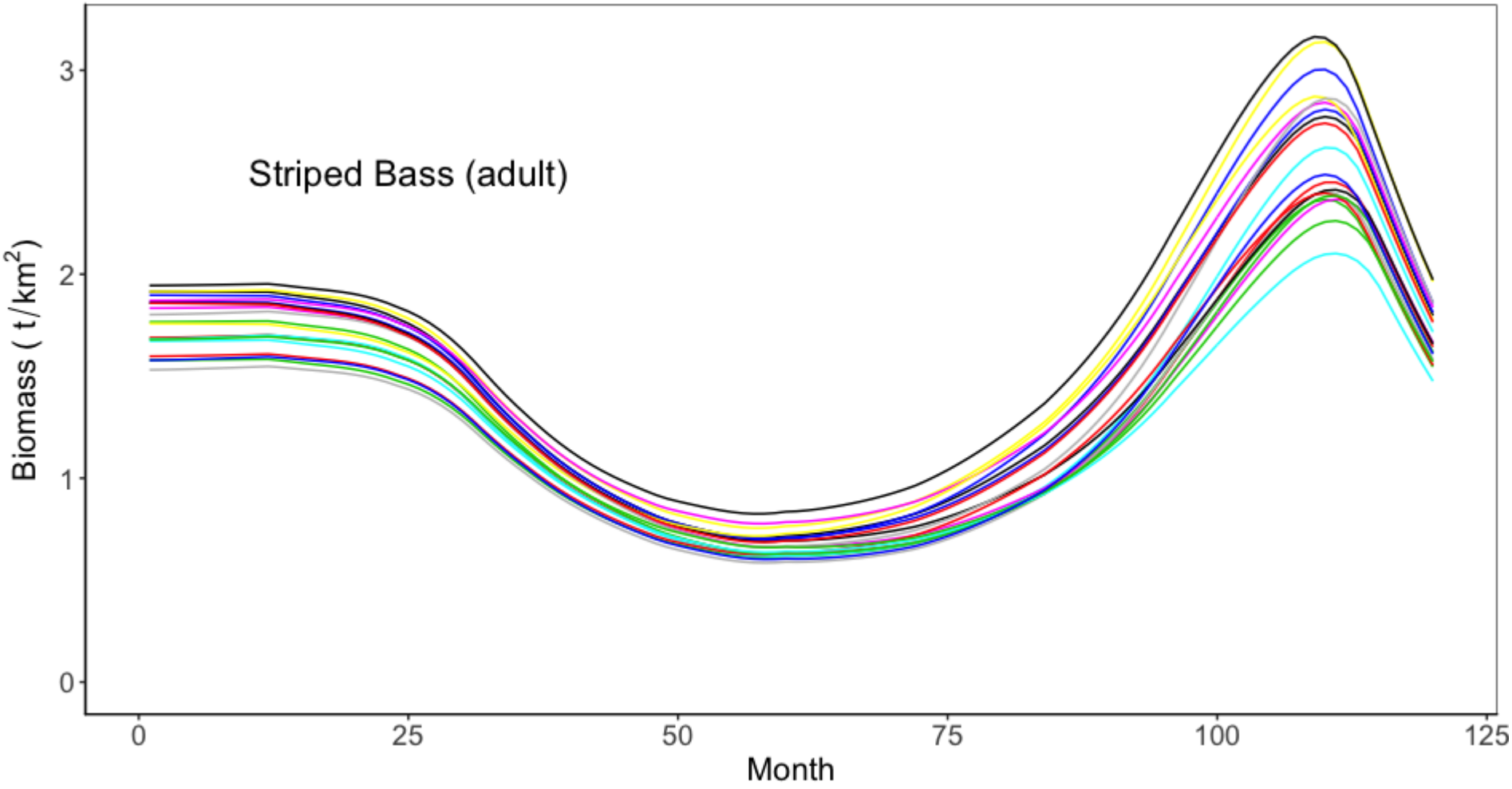
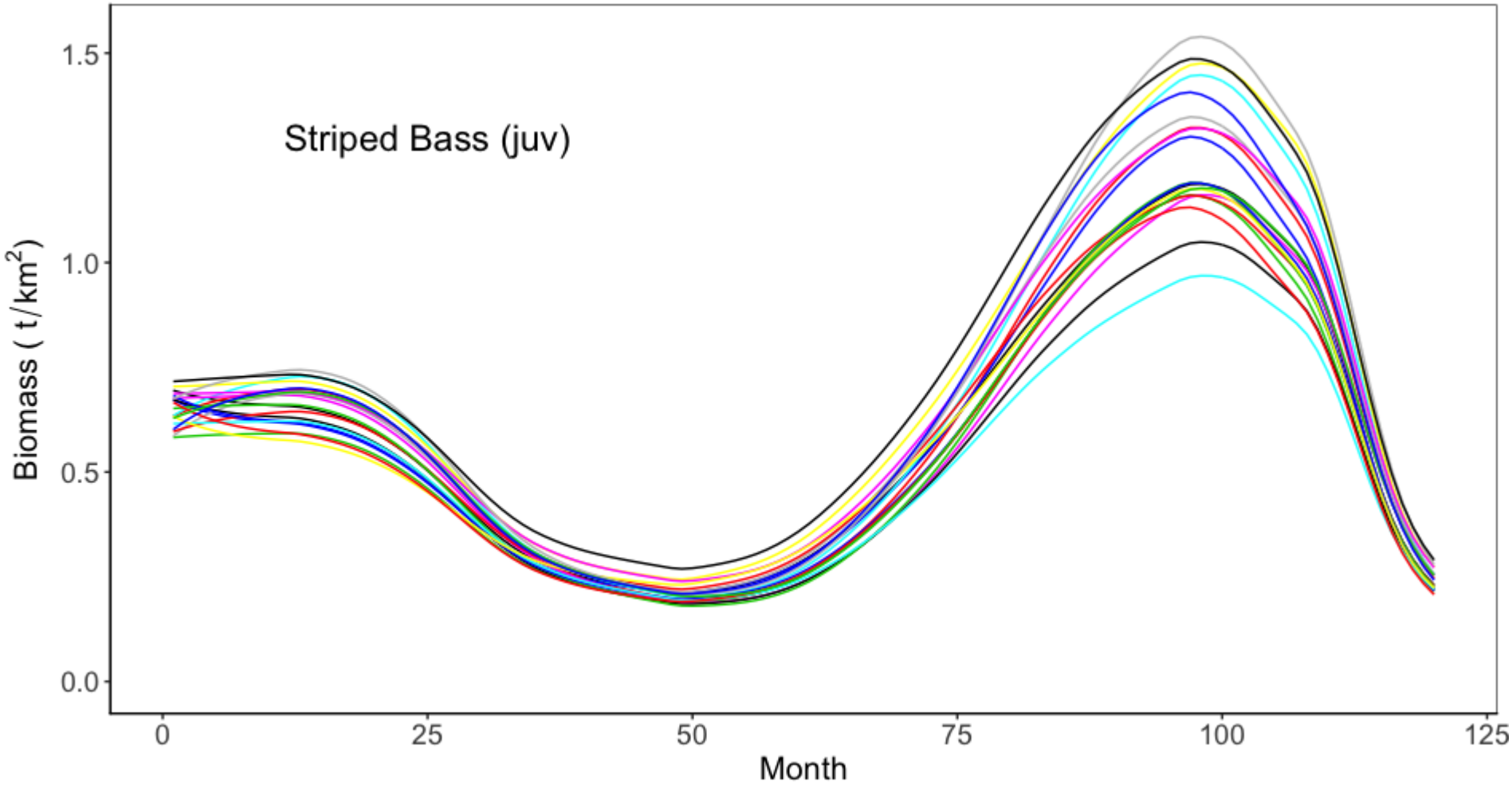


Ecopath with Ecosim

Sensitivities - Biomass



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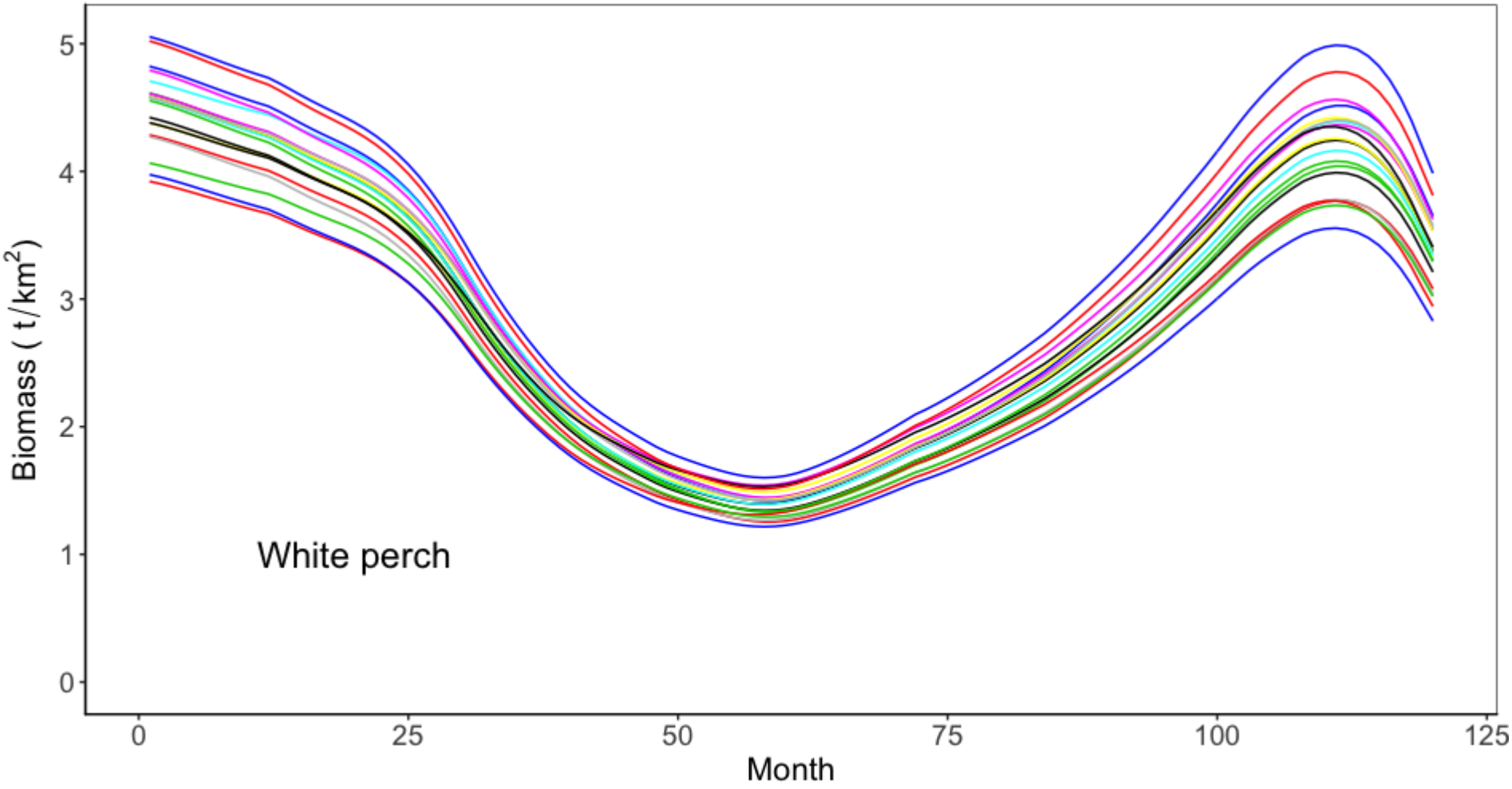

Landed Value by Fishery for each Event Modeled

Objective: Examine the economic impacts of oyster reef restoration to commercial fisheries

Two pieces needed:

(1) Prediction of harvest changes due to event:
Management decisions for future of sanctuary areas
– EwE

(2) Understanding of how harvest change will affect landed value for each major commercial fishery
Two pieces needed:
– Average price for each harvested species
  ○ Sum weighted avg. price (by fishery) to calculate landed values by fishery
  A: fixed prices over time
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  ○ 31 interviews, covered all major fisheries in region

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