West Africa Fisheries and Seafood Bio-economic Assessment Model

Phase II Development Project

Model Version 6.2

prepared for:

New Partnership for Africa's Development (NEPAD)

Food and Agricultural Organizations of the United Nations (FAO)

The World Bank

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Project Goals and Purpose

Goal

Develop an integrated economic and fish resource model of the West Africa region commercial fisheries (marine and freshwater), aquaculture, and seafood sectors.

Purpose

- **Integrate fish biology and industry economic behavior.**
- **Track seafood from the harvest level through added value chains (include waste, recovery, quality, and product forms).**
- **Account for imports and exports.**
- **Calculate costs and benefits and return on investment for major changes in**
  - **Resource management**
  - **Capital**
  - **Technology and infrastructure for each fishery and seafood sector.**
- **Provide a model for use by Ghanaian resource managers and other stakeholders and citizens.**

Other Benefits of the Bio-economic Model

- Provide decision-makers with fish resource and economic analysis for alternative management options.
- Stimulate collection of relevant biological, economic, environmental, and social information.
- Find data limitations and improve data collection and fisheries assessments.
- Use quantitative results to supplement qualitative findings.
- Help improve analytical approaches.
- Provide a convenient tool for West Africa region's countries, regional fisheries bodies (RFB), The World Bank, FAO, NGO's, USAID, and other world agencies to assess management strategies and potential investment programs.

Gulf of Guinea Large Marine Ecosystem

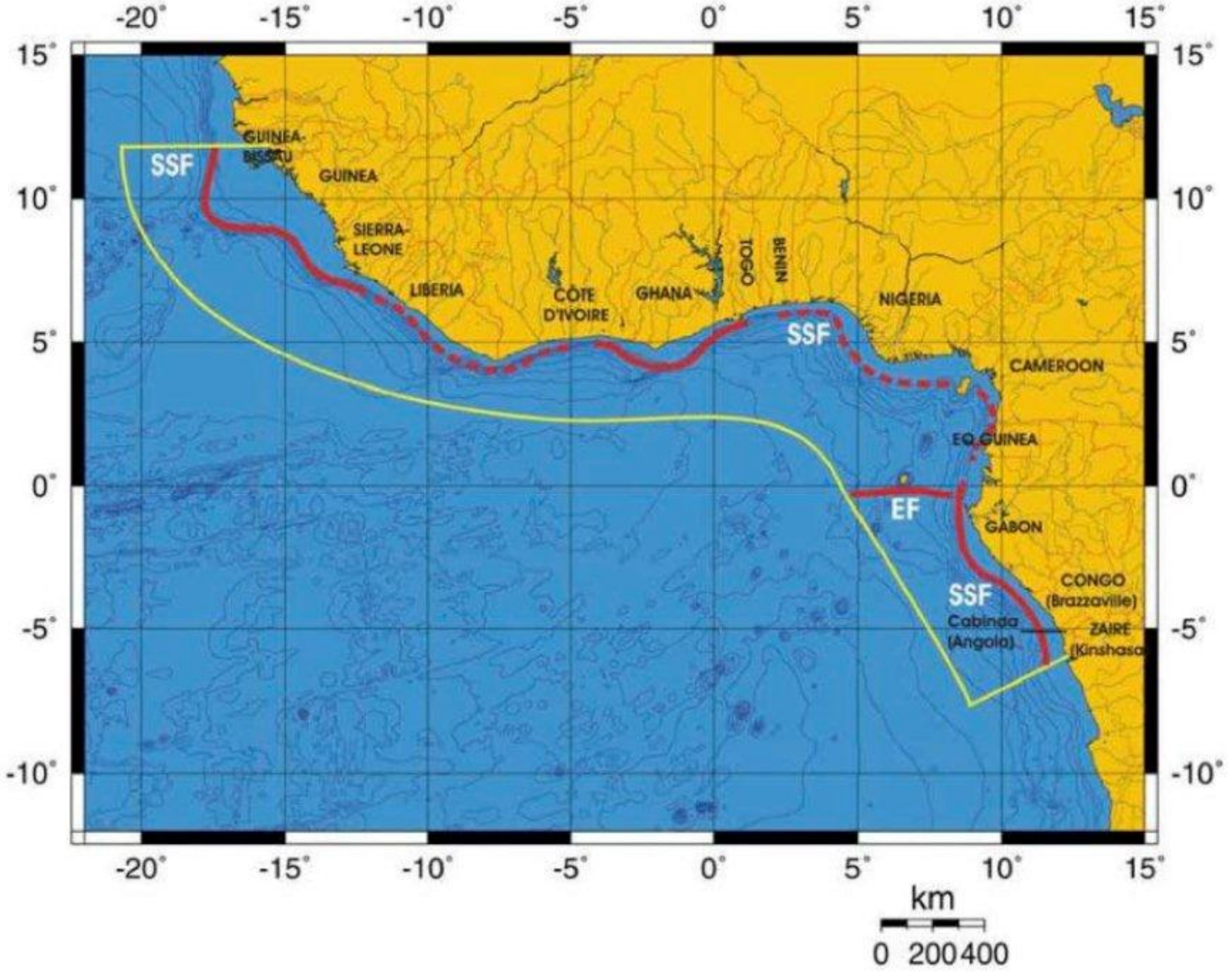


Figure I-2.1. Fronts of the Guinea Current LME. EF, Equatorial Front; SSF, Shelf-Slope Front (solid line, well-defined path; dashed line, most probable location). Yellow line, LME boundary. After Belkin (2009).

Gulf of Ghana Fishing Industry Setting

Background

- Sixteen countries border the Gulf of Guinea *Large Marine Ecosystem (LME).*
- Ghana continental shelf area is 9% of Gulf of Guinea LME's shelf.
- Ghana experiences intense upwelling between July to September.
- Fish harvest availability occurs during upwelling periods.

Gulf of Ghana Fishing Industry Setting

The Fisheries

- Total catch value was $1 billion (USD 2009) in Year 2000, but decreased by 35% in Year 2008.
- Ghana (344.0 thousand mt Year 2008) plus Nigeria (601.4 thousand mt Year 2008) account for more than half the marine landings within the LME.
- Many stocks overexploited and others at full exploitation (Koranteng and Pauly 2004).
- Very high stock size variability due to environmental conditions (Cury and Roy 2002).

Gulf of Ghana Fishing Industry Setting

Regional Management

- Fisheries are not managed regionally within LME.
- No countries manage stocks explicitly using catch quotas or a target stock size.
- Some bordering countries have negotiated access rights with Japan, Korea, Spain, France, and other nations.
- Most bordering countries are WTO signatories and have EU preferential trade status.
- IUU fishing (both nationally and foreign) historically high, but recent world initiatives make new estimates unknown.

Ghana Fishing Industry

Production and Value

- Ghana fishing industry represents 3%-4.5% of the total Ghana GDP.
- Fishing and processing sector employment full-time equivalent approximately 400,000 to 500,000.
- Seafood per capita consumption estimated to be double world average at 27 kg; comprises 60% of animal protein diet.
- Fish product exports about half of all non-traditional export value. Single product form of greatest value is canned tuna.

Ghana Fishing Industry

Production and Value (continued)

- Marine harvest volume about 300 to 400 thousand mt in recent years
  - 23% migratory pelagic (sardinella)
  - 14% other pelagic (anchovy and mackerel)
  - 20% tuna
  - 12% demersals
  - 1% cephalopods
  - 0.01% crustaceans including shrimp
  - residual 30% is a mixed species group that may contain some of the before mentioned species.
- Freshwater harvest volume estimated to be in the range of 25% to 100% of marine harvest volume.

Ghana Fishing Industry

Management

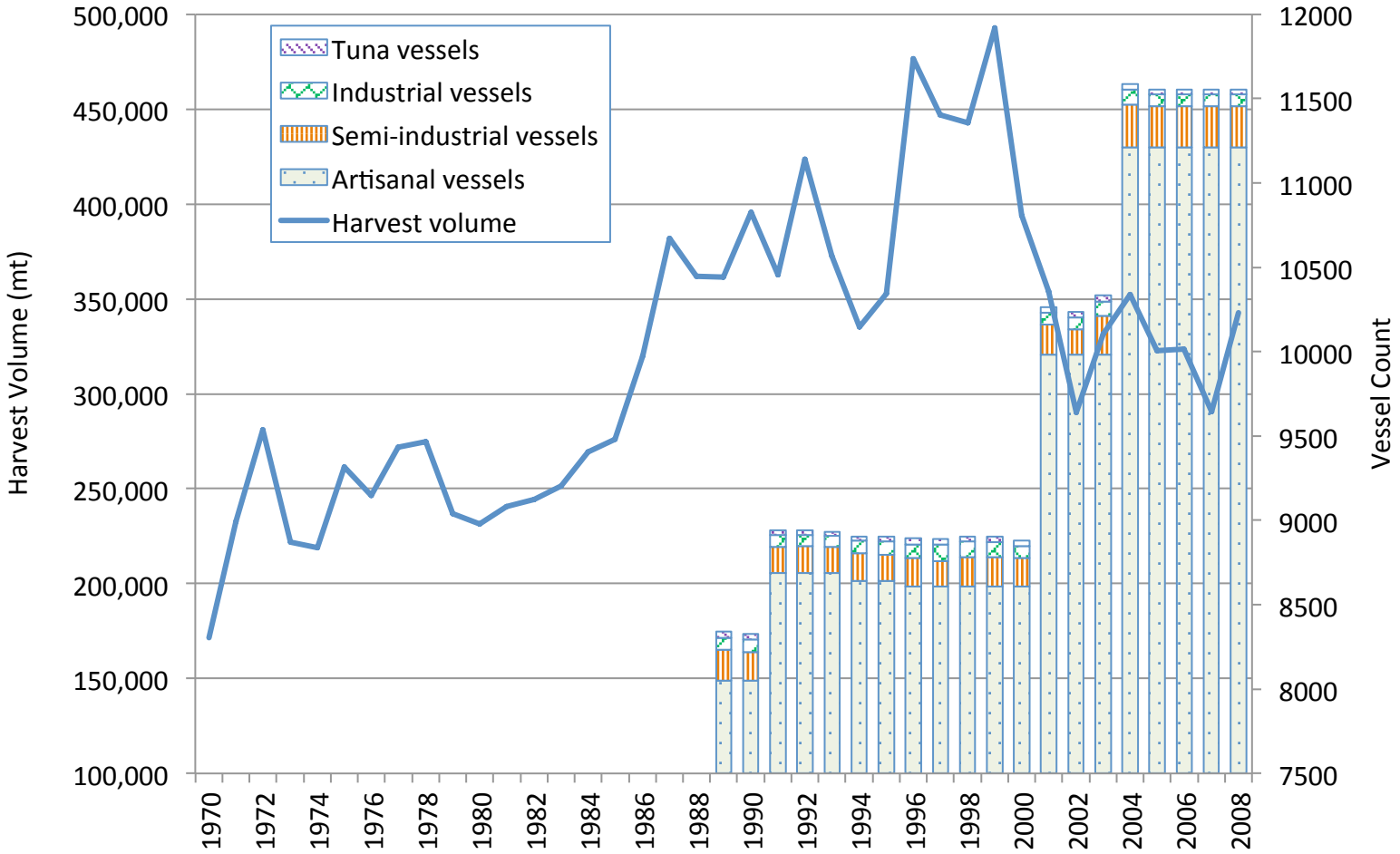
- Artisanal sector is open-access, government subsidized, and suffers under unsustainable fishery practices. However, important to poverty alleviation and cultural interests.
- Governance codified in Fishing Act of 2002 (Act 625) and Fisheries Regulations 2010 (LI 1968).
  - All vessels to be licensed; minimum mesh size can be specified in management plans; no pair trawling allowed.
  - Industrial fishing requires majority Ghanaian ownership; ad valorem tax (until 2003) licensing fees (after 2003).
  - Industrial fishing prohibited on fishing grounds less than 30 meters or 6 nautical miles, whichever is greater.
  - Prohibits lights, bamboo fence, FAD's -- cannot use noxious chemical or explosive devices.

Ghana Fishing Industry

Enforcement

- Enforcement historically criticized as lax; however:
  - 2 new surveillance boats purchased from China (USD $39 million) delivery Ghana Navy 2011,
  - U.S. has provided 4 speed boats and conducts joint patrols.

Historical Marine Harvest Volume and Vessel Counts



Sources: Volume from FAO Country Profiles up to 1999; volume 2000 to 2008 from personal communication with Doris Yeboah, Ghana Department of Fisheries, provided to Gil Sylvia in August 2010. Vessels from FAO Country Profiles up to 1999; vessels 2000 to 2008 from FAO Big Numbers Project (2009).

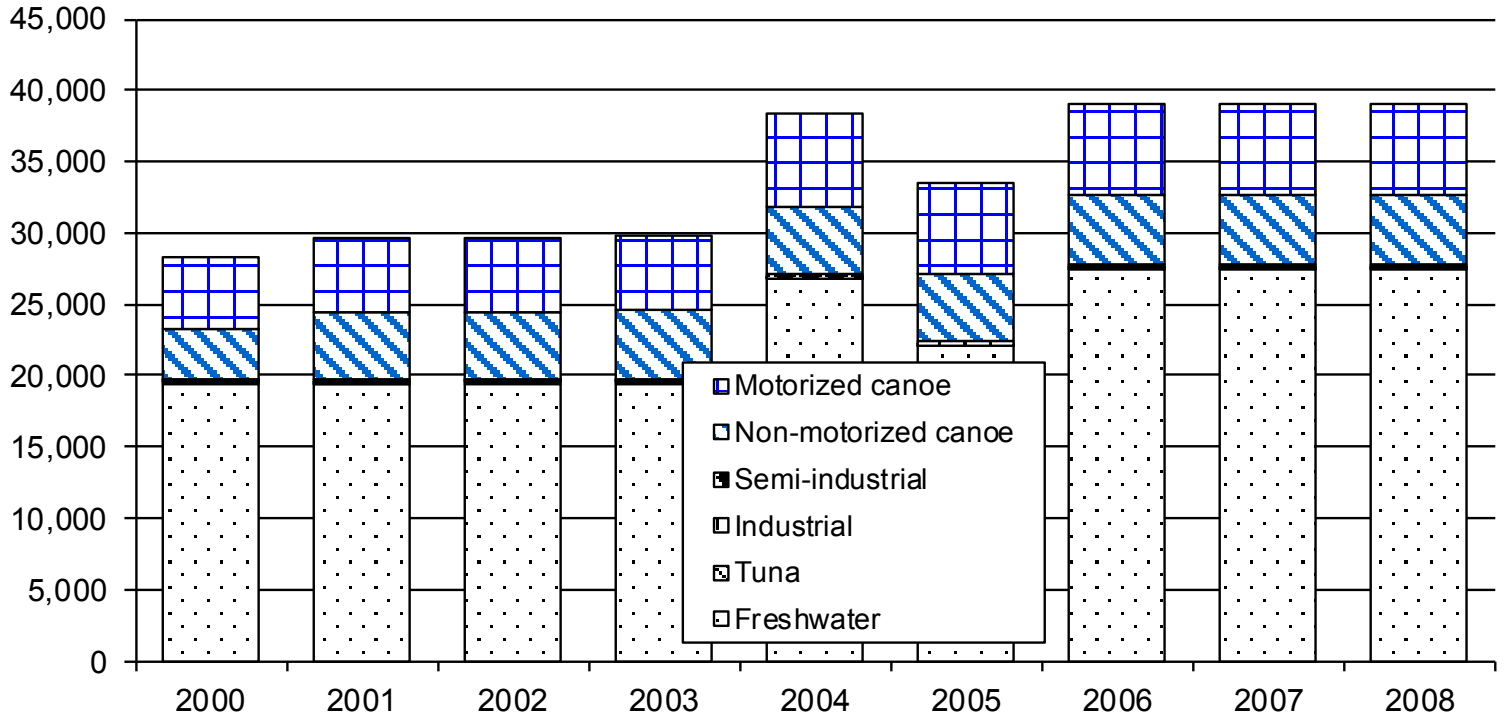
Freshwater Harvest Estimates – *(Wide Range of Estimates)*

			All Inland						
	Lake Volta				Quantity	Value (USD			
Year	Vessels	Quantity	Share	Vessels	(mt)	millions)	Explanation		
2006				27,482	398,344	865	Big Numbers Project report (2009		
2000		251,000	79%	22,008	319,000		MOFA (2006)		
1998	24,035	80,000	90%	26,706	88,889		Braimah (2000)		
1991	17,500	38,088	90%	19,444	42,320		Braimah (1995)		
1979		40,000					Vanderpuye (1984)		
1975	13,815						Coppola and Agadzi (1976)		
1970	12,074						Bazigos (1970)		
1969		69,000					Vanderpuye (1984)		

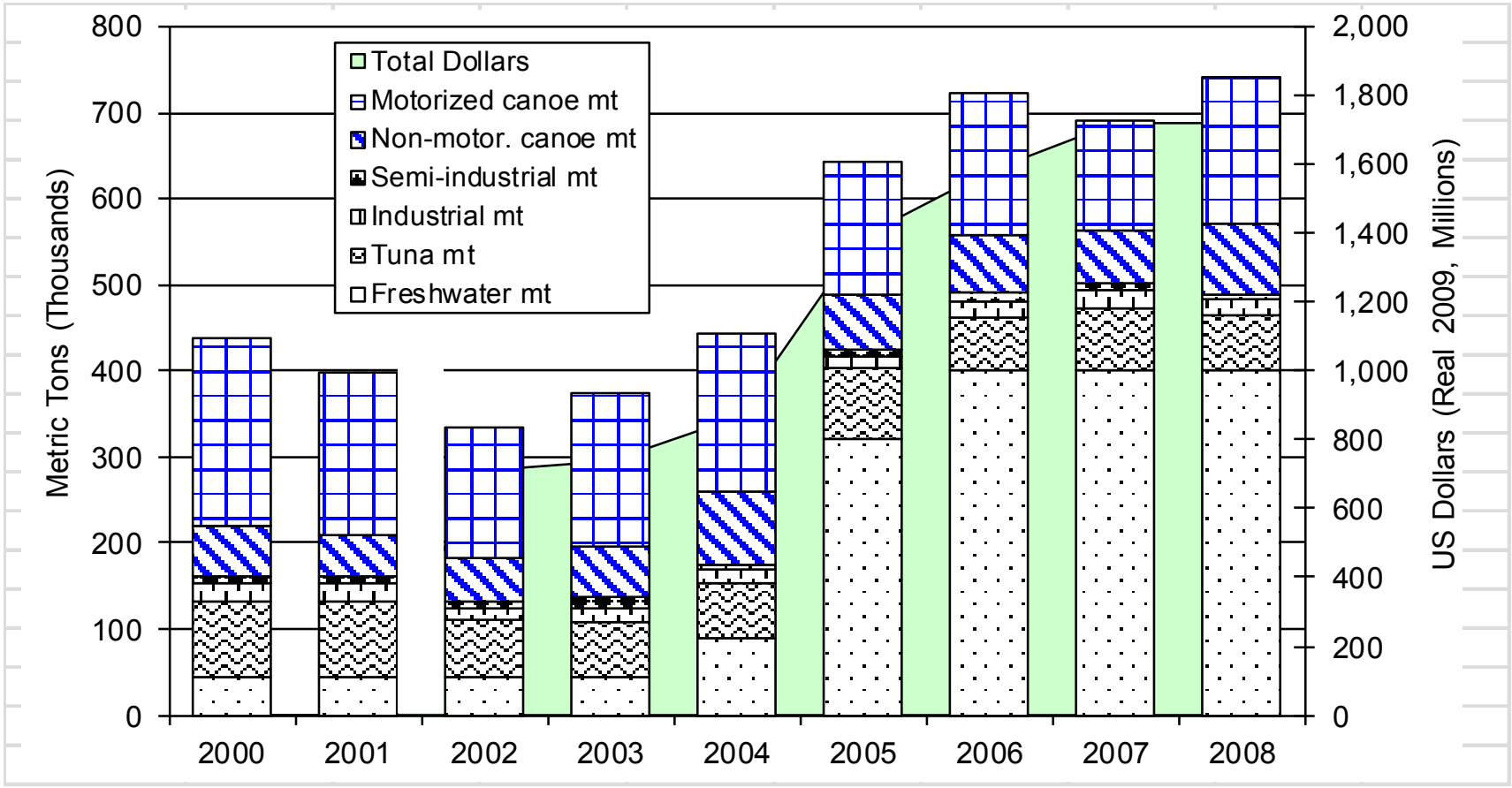
Notes:
1. The yellow highlighted estimates are adopted for model input. Vessels in 2000 estimated using CPUE in 2006. Year 2000 data was adopted for inland commercial fisheries model initial conditions.
2. Lake Volta 90 percent share of all inland fisheries from several studies as reported in Béné (2007). The MOFA (2006) study estimated share is 79 percent.
3. The Ghana Department of Fisheries official Lake Volta estimate for Year 1997 was 60,000 mt. The figure was criticized as an undercount by factor of 3 by de Graaf and Ofori Danson (1997), Kunzel (1998), and Braimah (2000). The Department's official figure for Year 2007 is 74,500.
4. The FAO Big Numbers Project (2009) explains Year 2006 data is from Braimah (2008).

Sources: Estimates from tables and narrative discussion found in Béné (2007), Ministry of Food and Agriculture and Directorate of Fisheries (2006), or FAO Big Numbers Project (2009).

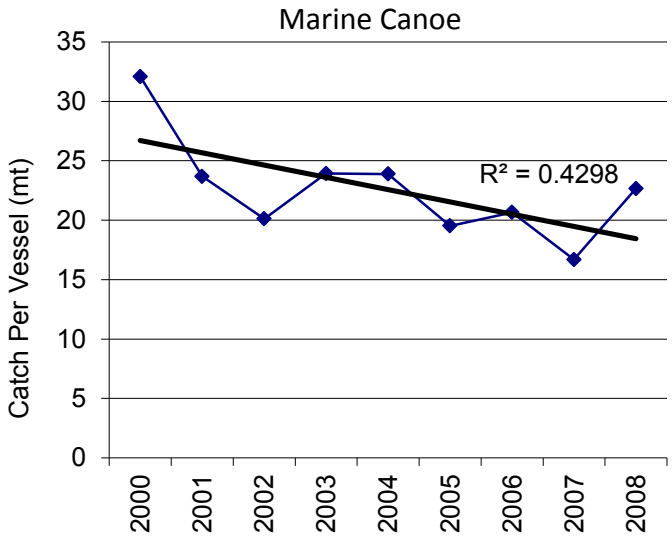
Vessels by Sector in 2000 to 2008

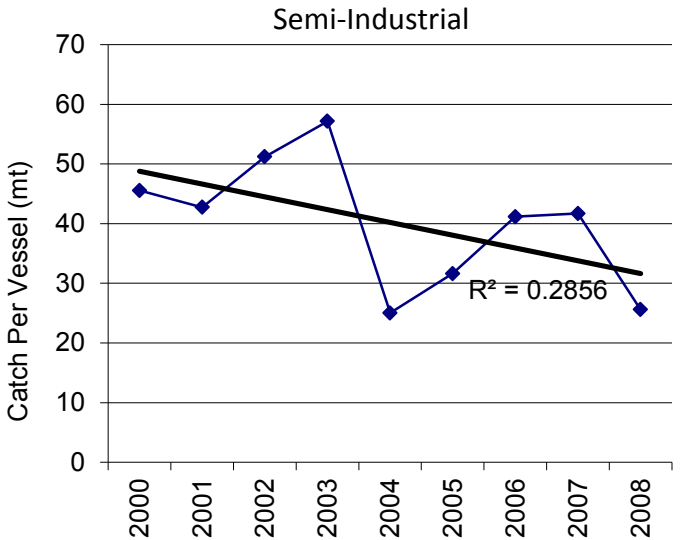


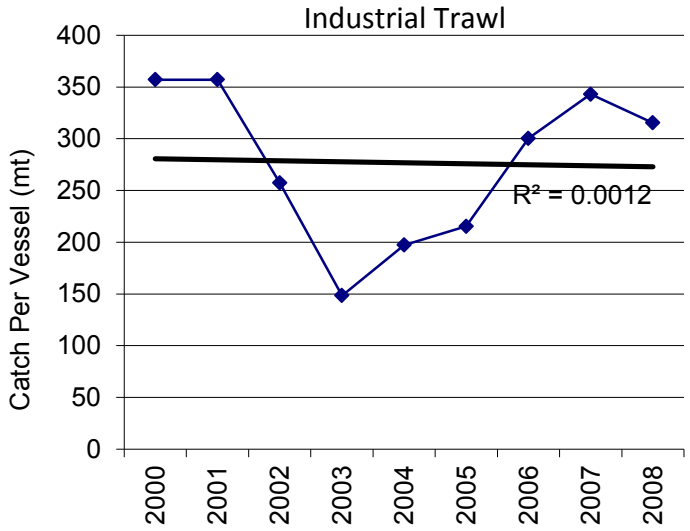
Landings by Sector in 2000 to 2008

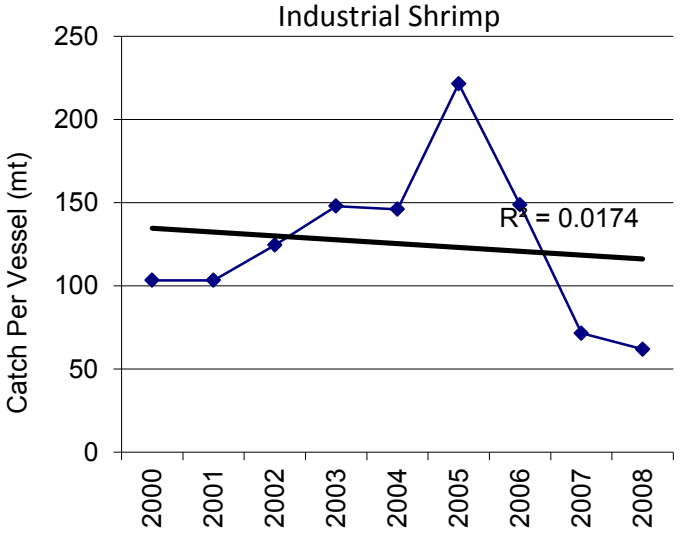


Catch Per Vessel by Vessel Sector in 2000 to 2008 (1 of 2)

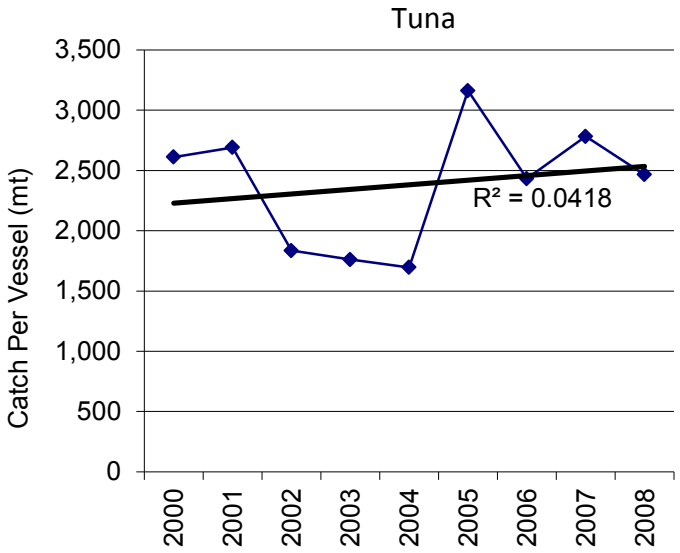


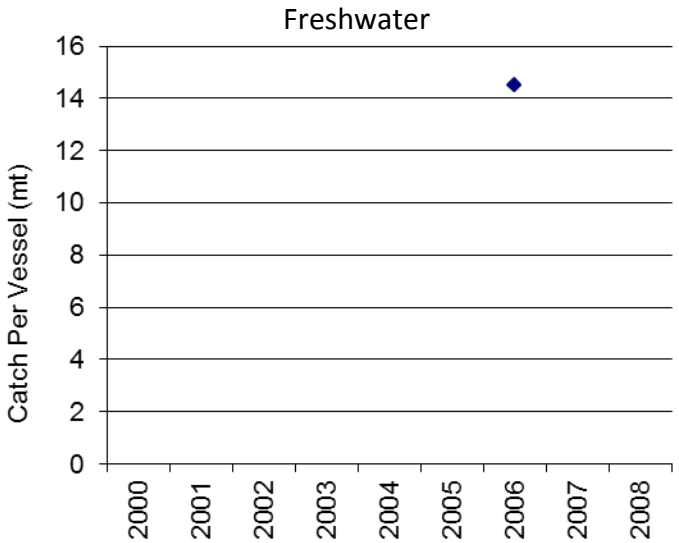






Catch Per Vessel by Vessel Sector in 2000 to 2008 (2 of 2)





Bioeconomic Model Development

Model contains three components:

1. Fish resource component using Gordon-Schaefer surplus production function (other functions may be substituted).
2. Economic sectoral component using cost-earnings accounting statement and capital asset value assumptions.
3. Food balance component based on FAO consumption definitions.

Bioeconomic Model Development

Model relies on historical data series for catch and effort.

- Independent exogenous values (termed *inputs* and *drivers*) are required (and built in).
- The package of supplied values define policy objectives and management strategies to be tested.
- The model generates 30 year "solutions" so that a comparison of one case (such as **with-action**) and another case (such as **status quo**) can be made.

Bioeconomic Model Development

There are a multitude of model outputs (tables and graphs)

- Fish stock size and annual fishing mortality (catch)
- Economic indicators:
  - For each fishery
  - For each industry sector
    - Marine
    - Freshwater
    - Processing
    - Aquaculture
- Special Model Utility for comparing cases

Component 1
Fish Resource Component Equations and Limitations

Equations

Stock Size ($X_{(t+1)}$) = X_t + r X_t (1 - (X_t / K)) - Y_t

$G = X_{(t+1)} - X_t$

where: G = stock size growth, i.e. $\Delta X / \Delta t$

r = intrinsic rate of growth

X = stock size

K = carrying capacity for stock biomass

Y = harvest yield

t+1 = time one period in the future

Harvest yield uses Gordon-Schaefer harvest function:

$Y = qEX$

where: E = effort measured in a vessel year

q = catchability

Limitations

- Equilibrium between natural growth/ mortality and harvest mortality.
- Constant price and constant cost per effort.
- Catchability coefficient over time unaffected by technology changes.

Component 2
Sectoral Component Equations and Limitations

Equations

Profit = $\sum (H - L - V - F)_j$

Net Economic Benefit = $\sum (P + L - D - O)_j$

Resource Rent = $\sum (P + L - D - O - NP)_j$

P = profit

NEB = net economic benefit

RR = resource rent

H = harvest times price

L = labor

V = other variable expenses (fuel, bait, etc.)

F = fixed expenses, incl. licensing fees

D = depreciation

O = opportunity cost of labor and capital

NP = normal profit (adopted 20%)

j - sectors

Notes: Owners can include different entities for motor, hull, and gear.

Limitations

- Profits do not include earnings from non-harvesting activities such as tendering, transportation services, etc.
- Net economic benefit and resource rent is calculated from an industry (rather than national welfare) accounting perspective.
- Accounting pro forma income statements from different studies in different years using different definitions.

Fishing Industry Definition and Shares

	Sectors								
Fishery	Marine Canoe	Semi-Industrial	Industrial Trawl	Industrial Shrimp	Industrial Subtotal	Tuna	Marine Total	Fresh-water	Total
Small pelagic	14.8%						4.5%		
Medium/large pelagic	3.2%	8.0%					1.1%		
Migratory pelagic	33.2%	30.5%	2.0%		2.0%		10.6%		
Demersal	15.4%	3.9%	31.2%	0.2%	31.5%		6.3%		
Cephalopod		0.1%	13.7%	0.6%	14.4%		0.7%		
Small tuna						61.7%	6.6%		
Large tuna						28.1%	3.0%		
Shrimp				1.1%	1.1%		0.1%		
Freshwater								100.0%	
Subtotal assessed	66.7%	42.5%			48.9%	89.9%	32.9%	100.0%	46.3%
Mixed species groups	33.3%	57.5%			51.1%	10.1%	67.1%	0.0%	53.7%
Total	100.0%	100.0%			100.0%	100.0%	100.0%	100.0%	100.0%

Notes: Percents are sectors' fishery share for initial conditions.

Component 3
Food Balance Component Equations and Limitations

Equations

Consumption per Capita (C_0) = $(A_0 + L_0 \sum W_{i,0} - \sum E_{i,0}) / P$

where:

C = consumption per capita

W = marine and freshwater fish production

L = (1 - h), h = post-harvest loss and non-food utilization rate

A = aquaculture production

I = imports

E = exports

P = population

i = product forms, i.e. canned tuna, etc.

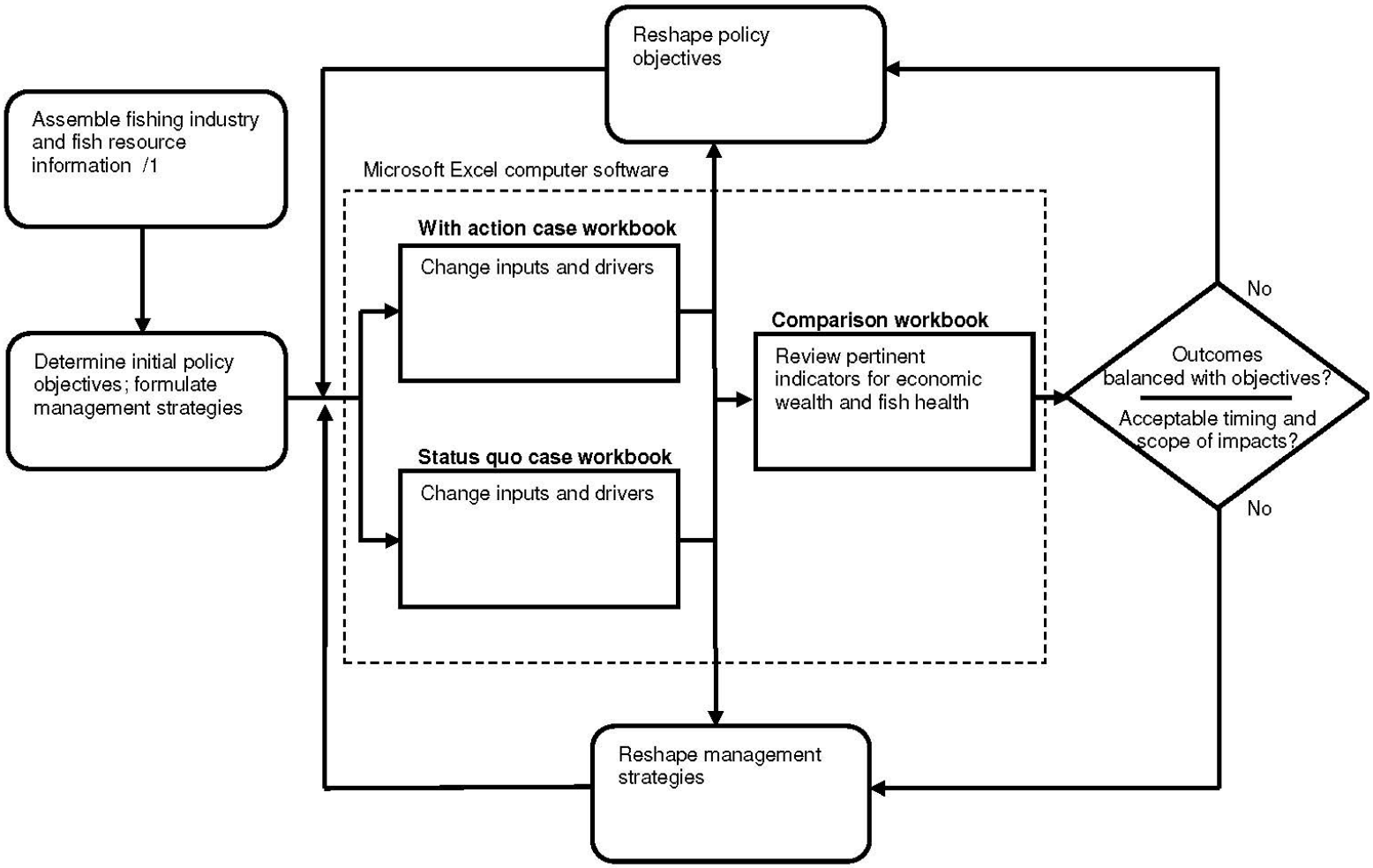
t = time, 0 is initial conditions

Imports $(I_{t+1}) = (P_{t+1} * C_0) - (L_0 \sum W_i - \sum E_i + A)_{t+1}$

Limitations

- Consumption is from FAO that uses food balance equation based on harvest weight. General population surveys use processed weight.
- Does not explicitly account for subsistence fishing, i.e. the fisheries production term includes all harvest dispositions.
- Port-harvest loss rate imputed from other studies.
- Harvest non-food proportions are from informal interviews and held constant over the projection period, while fish meal market can be highly variable.

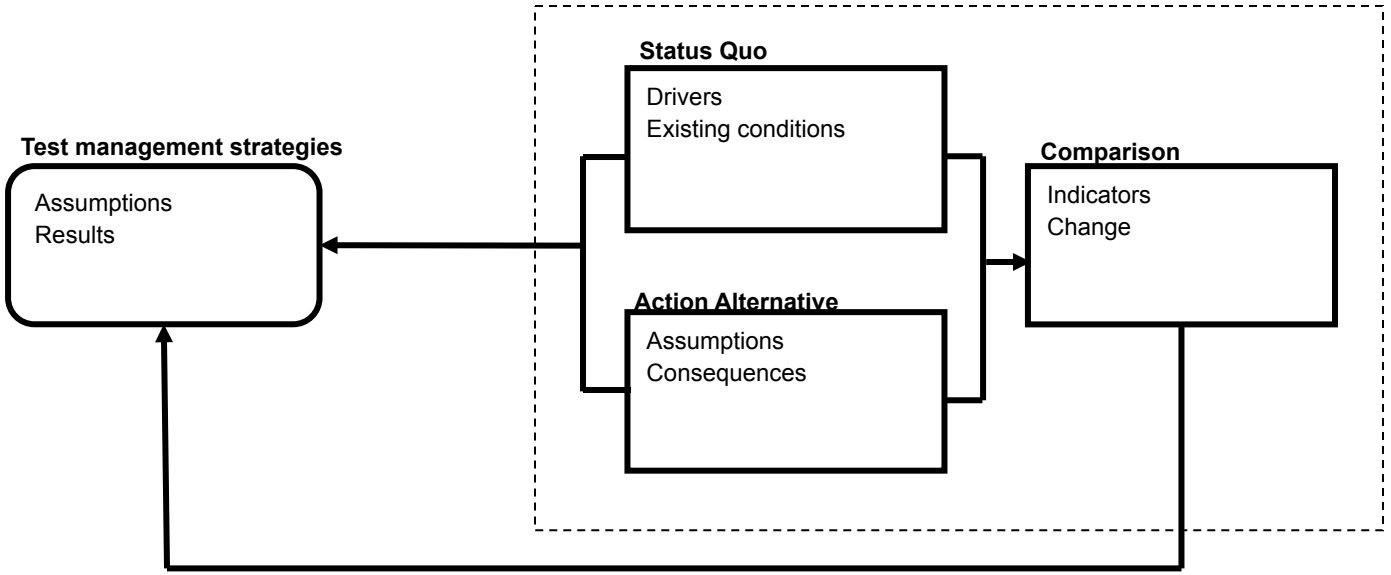
Model Use Flow Diagram



Model Operation Mode

Demonstration Mode

Development Mode



Model Summarizes Fishing Industry and Fish Resource Information

Examples

- Landings (harvest volume and value) by sector and by species
- Vessel counts by sector
- Marine and freshwater biomass trends
- Aquaculture production
- International trade
- Processing post-harvest loss and recovery yields
- Firm level accounting pro formas
- Governance (management, enforcement costs, etc.)

Example of Objectives, Strategies, and Measures

Example Policy Objectives	**Outcome Measures**
Industry benefits	Economic rent
Social benefits	Employment
Stock health	X / X_{MSY}
Trade balance	Net imports
Economic development	Added value

Example Management Strategies	**Outcome Measures**
Rationalize harvesting capacity	Vessels
Increase industry self-sufficiency	Transfers, subsidies
Increase efficiency	CPUE, asset per harvest value
Balance stock productivity	F / F_{MSY}
Fishing industry investment	BCA

Model Independent Variables for Status Quo Case

INPUTS

Header Block
Case: Base

Investment Strategy
Investment amount (millions): $00.00
Loan share: 100.0%
Loan interest rate: 0%
O&M increase per year (millions): $0
Typical private interest rate: 15%
Typical private loan term (years): 20
Typical capital lifespan vessel and facilities: 10
Discount rate: 5.0%

Labor Opportunity
Labor cost probability: 50%
Wage (hourly): $0.30

Fishery Effort
Canoe vessel: increase 200 vessels per year for 10 years, then no change
Semi-industrial: decrease 3 semi-industrial vessels per year over 30 years
Industrial: no change
Tuna: no change
Freshwater: increase 200 vessels per year for 10 years, then no change

DRIVERS

Finance and Government Policy Conditions
Finance
Loan and grant drawdowns: 1
Loan term (years): 30
Project horizon (years): 30
Government Policy
Import tariffs: $2 million per year sequestered for fisheries and aquaculture programs
Harvest and processor licensing: ad-valorem ex-vessel starting Year 6: 0.0%

Market and Production
Marine Fisheries
Harvest prices: no change
Canoe price differential: -20%
Freshwater fisheries
Harvest prices: no change
Processing
Operations: no change, 0% for Year 6 increases in product recovery
Price: no change, 0% for Year 6 increases in economic yield
Post-harvest loss: 20%
Aquaculture
Variable cost: no change; 0.0% to year 10, 0.0% year 11 to 30
First sale price: flat until Year 10 then decrease by 1% per year; 0.0% to year 10, -1.0% year 11 to 30
Annual production increase (mt): increase production by 1,000 mt per year for 30 years; 1,000 to year 10, 1,000 year 11 to 30
Trade
Population growth per year: 2.1%
Tariff import rate (not incl. VAT): 5%
Non-food utility rate: 5%

Model Independent Variables for With-Action Case

INPUTS

Header Block
Case: Investment

Investment Strategy
Investment amount (millions): $55.04
Loan share: 89.5%
Loan interest rate: 0%
O&M increase per year (millions): $5
Typical private interest rate: 15%
Typical private loan term (years): 20
Typical capital lifespan vessel and facilities: 10
Discount rate: 5.0%

Labor Opportunity
Labor cost probability: 50%
Wage (hourly): $0.30

Fishery Effort
Canoe vessel: no change
Semi-industrial: 50% reduction in Year 6
Industrial: 100% reduction in Year 6
Tuna: no change
Freshwater: no change

DRIVERS

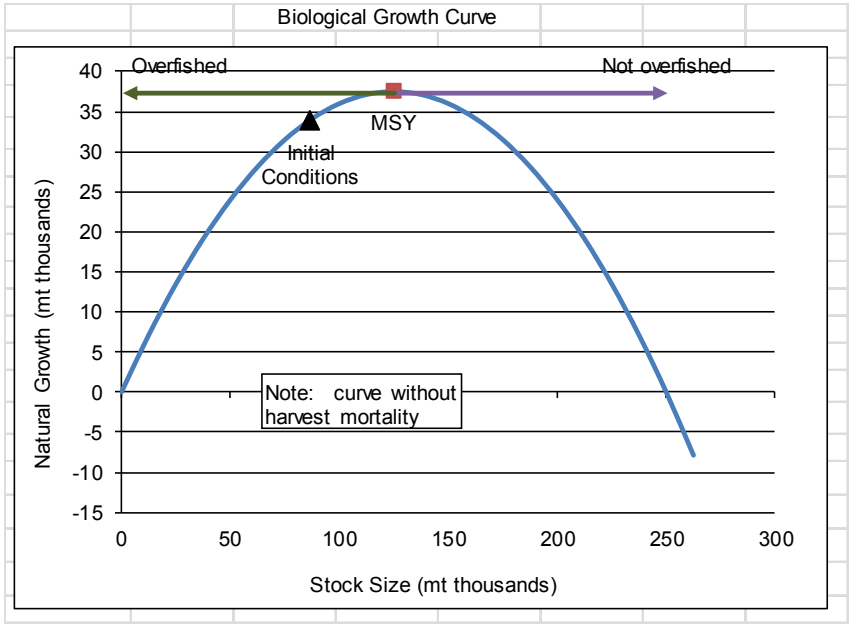
Finance and Government Policy Conditions
Finance
Loan and grant drawdowns: 5
Loan term (years): 30
Project horizon (years): 30
Government Policy
Import tariffs: $2 million per year sequestered for fisheries and aquaculture programs
Harvest and processor licensing: ad-valorem ex-vessel starting Year 6: 0.5%

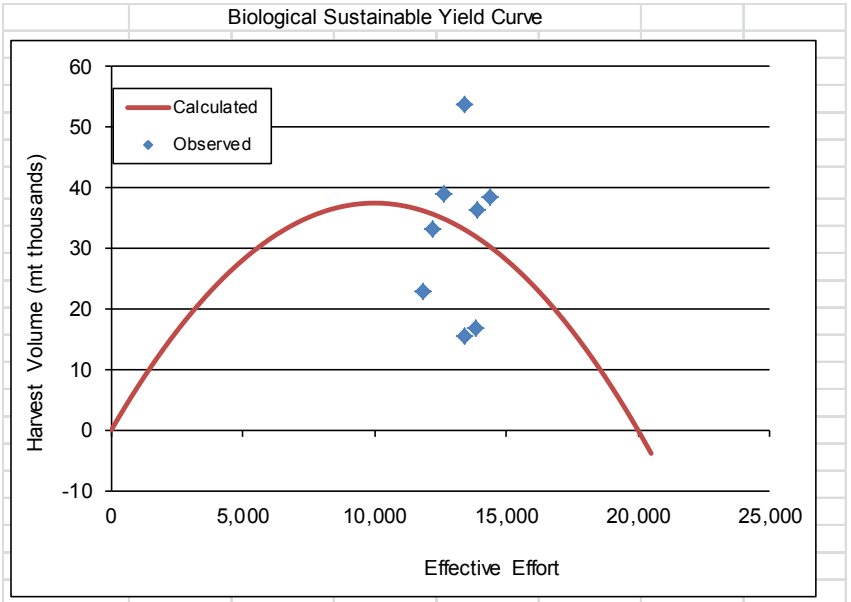
Market and Production
Marine Fisheries
Harvest prices: flat until Year 6, then increase by a total of 2% over 10 years then flat, except tuna no change
Canoe price differential: -20%
Freshwater fisheries
Harvest prices: flat until Year 6, then increase by a total of 2% over 10 years then flat
Processing
Operations: increase recoveries by 3% starting Year 6
Price: increase ex-processor sale price by 2% starting Year 6
Post-harvest loss: Smoker 20%, Fresh 10%, Frozen 10%, Tuna 2.5%
Aquaculture
Variable cost: decrease by 1% per year for 10 years then 1/2% per year
First sale price: flat until Year 10 then decrease by 1% per year
Annual production increase (mt): increase production by 1,000 mt per year for 30 years
Trade
Population growth per year: 2.1%
Tariff import rate (not incl. VAT): 5%
Non-food utility rate: 5%

Example of Model Use
Investment Case Versus Status Quo

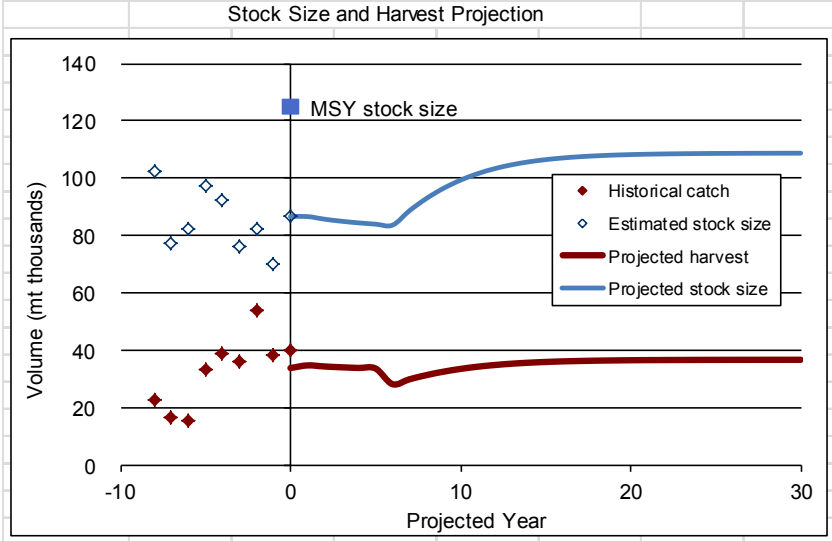
Action	Status Quo	Investment
$ Amount	$0	$55 million 0% interest
Canoes	No caps	Cap at 11,213 canoes
Semi-indus	3 fewer/year	50% reduction Year 6
Industrial	No change	100% reduction Year 6
Fish Price	No change	2%/year
Prod. Recov.	No change	3% increase begin Year 6
Landings Tax	None	0.5% starting Year 6

Results: Fish Sector -- Demersal Fishery -- With-Action Case





Biological Sustainable Yield Parameters and Goodness of Fit Statistics					
Equation Parameters		MSY Results		Harvest Estimation	
r	0.6	X	125,000	SSE	2,208
K	250,000	Y	37,500	R^2	0.01
q	0.000030	E eff	10,000	Sum diff.	10,994

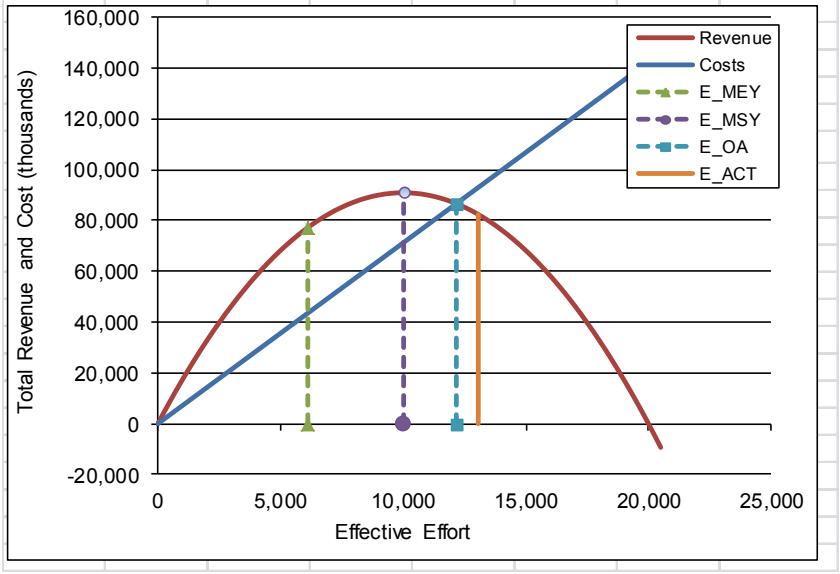


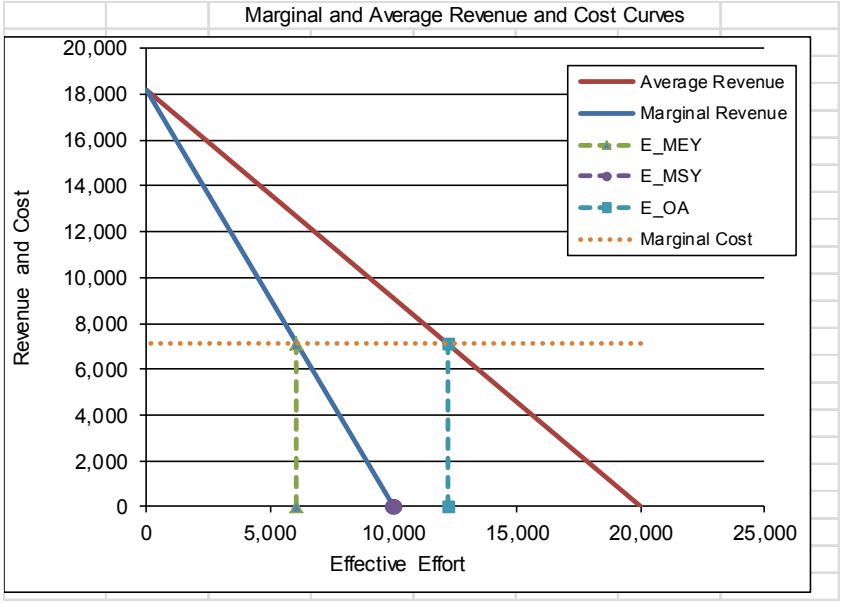
Note: 1. Year zero (initial conditions) for the projections will have discontinuities from historical data series because assumptions (such as trend estimating) and averaging were used to derive year zero measures.

Fish Model Sectors, Demersal Fishery

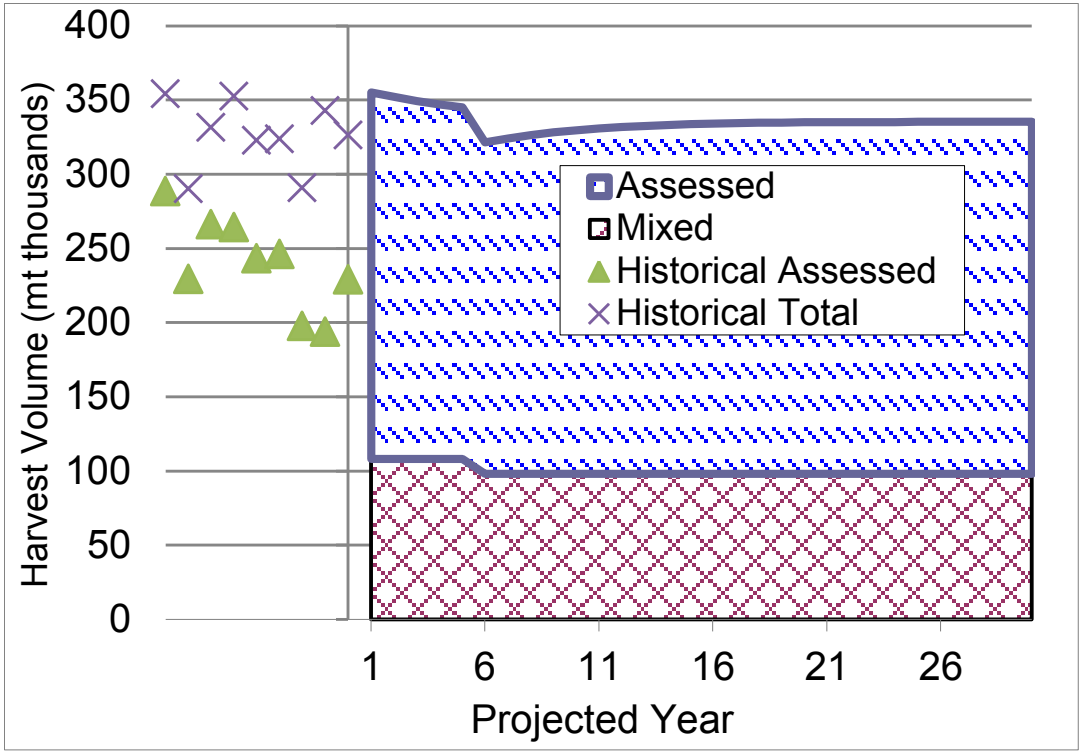
Economic Sustainable Yield Relationships

Measure	Effective Effort	Harvest (000)	Revenue ($000)	Average Revenue	Marginal Revenue	Marginal Cost	Economic Rent ($000)
E_{MEY}	6,084	31.8	77,011	12,657	7,123	7,123	33,671
E_{MSY}	10,000	37.5	90,956	9,096	0	7,123	19,726
E_{OA}	12,169	35.7	86,678	7,123		7,123	0
E_{ACTUAL}	13,062	34.0	82,429	6,311		7,123	-10,612



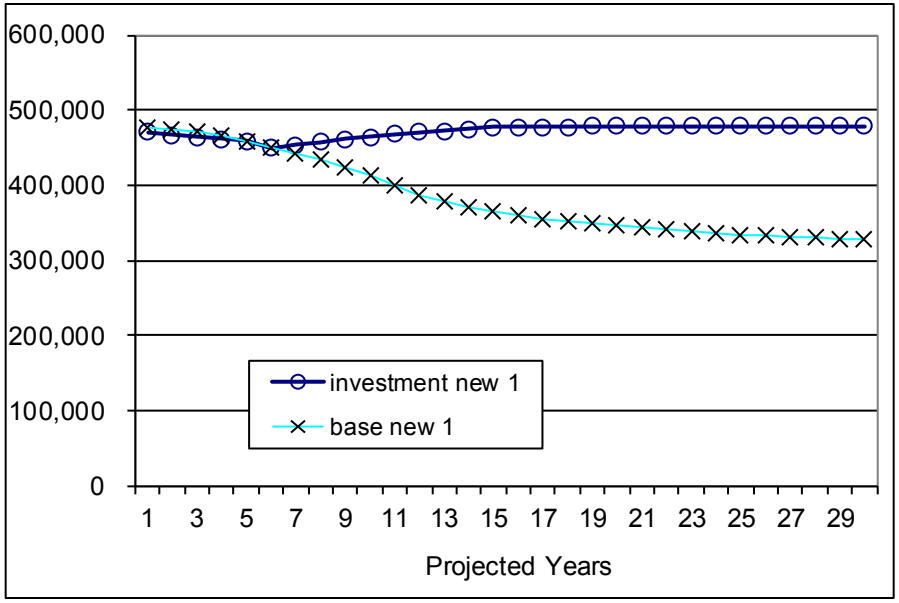


Projected Marine Harvest Across All Sectors for With-Action Case

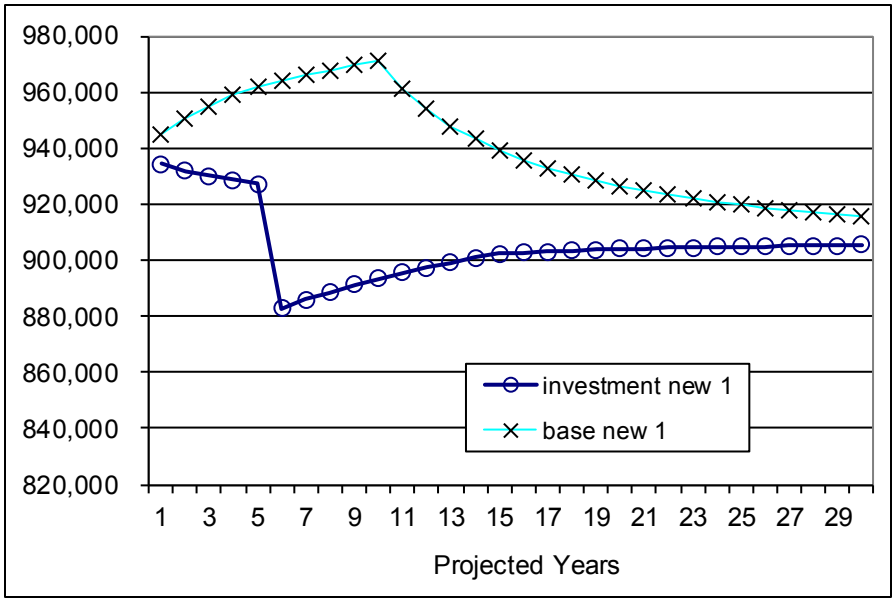


Results: Investment Case Versus Status Quo
Selected Performance Indicators

Total Net Economic Benefits (000's) (harvest sector)



Total Employment



Results: Investment Case Versus Status Quo

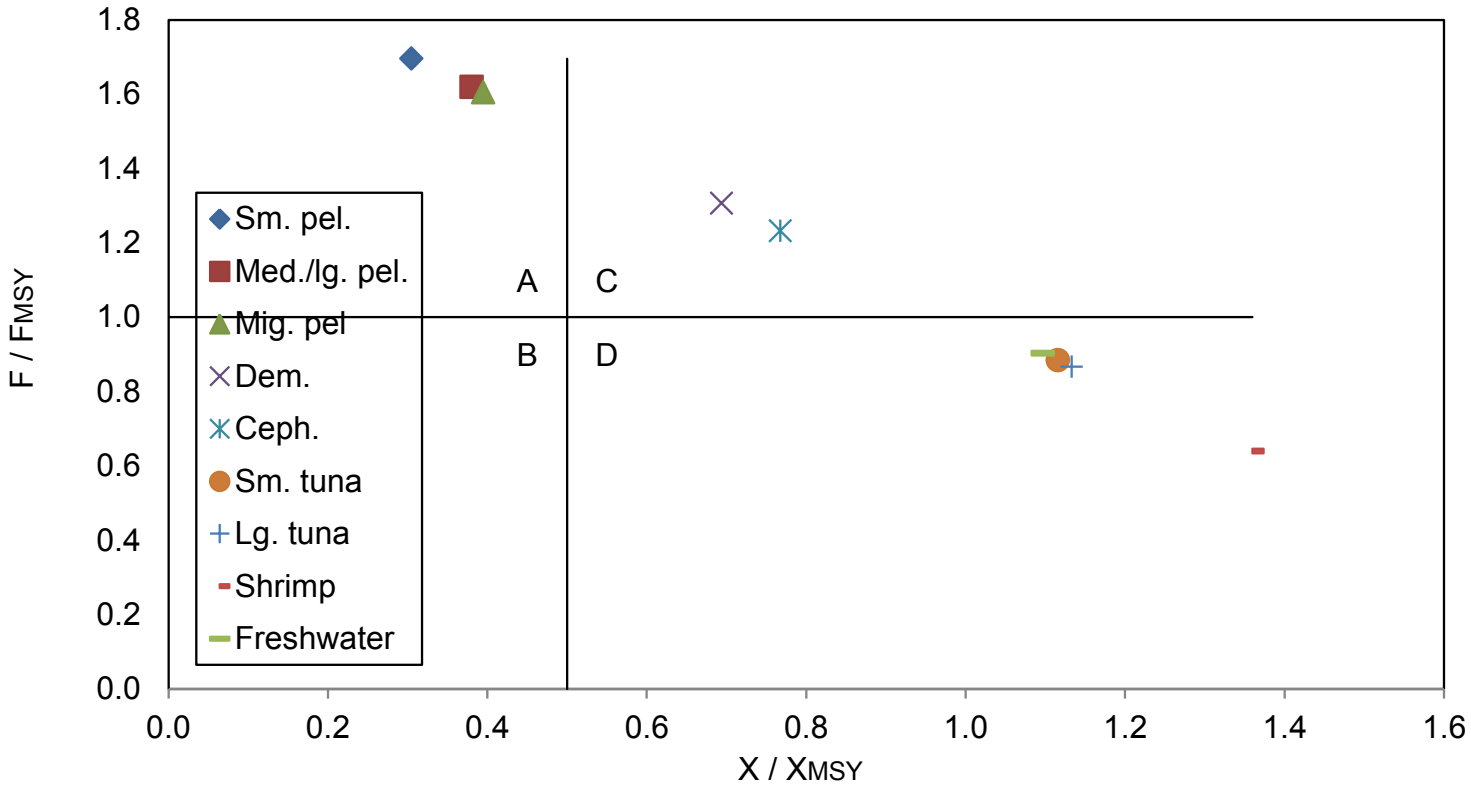
Measure	Artisanal by Power Source Category			Semi-industrial	Industrial	Tuna	Freshwater	Aquaculture	Processors	All Harvest	All Sectors
	Motorized	Non-Motorized	Total								
NPV Investment Case											
Net economic benefits ($000 2009 USD)	1,873,762	1,009,110	2,882,871	41,652	32,470	574,580	3,671,908	339,913	4,724,544	7,203,482	12,267,939
Resource rent ($000 2009 USD)	740,778	641,641	1,382,419	6,825	(31,994)	78,332	1,297,963			2,733,545	2,733,545
Distribution of benefits ($000 2009 USD)											
Returns to labor	1,534,783	591,520	2,126,303	50,785	64,464	744,372	3,215,838	43,780	5,435,625	6,201,762	11,681,167
Returns to owners	2,433,796	1,143,882	3,577,678	36,967	80,580	545,873	5,099,542	354,545	5,723,768	9,340,640	15,418,952
Transfers to government (license fees)	20,508	6,652	27,160	504	0	8,912	42,808	0	0	79,384	79,384
NPV Base Case											
Net economic benefits ($000 2009 USD)	1,265,733	759,689	2,025,422	31,901	91,463	574,580	3,499,439	301,398	4,856,430	6,222,805	11,380,633
Resource rent ($000 2009 USD)	280,137	440,024	720,161	(1,522)	(123,811)	78,332	1,110,242			1,783,402	1,783,402
Distribution of benefits ($000 2009 USD)											
Returns to labor	1,335,126	514,570	1,849,697	48,736	215,273	744,372	3,236,499	43,780	5,461,131	6,094,577	11,599,488
Returns to owners	2,117,188	995,077	3,112,265	35,476	269,092	545,873	5,132,306	316,030	6,063,568	9,095,010	15,474,608
Transfers to government (license fees)	0	0	0	0	0	0	0	0	0	0	0
Net Benefit (Investment Minus Base Case)											
Net economic benefits ($000 2009 USD)	608,029	249,421	857,449	9,751	(58,992)	0	172,469	38,515	(131,885)	980,677	887,306
Resource rent ($000 2009 USD)	460,641	201,618	662,258	8,346	91,817	0	187,721			950,143	950,143
Distribution of benefits ($000 2009 USD)											
Returns to labor	199,657	76,950	276,607	2,049	(150,809)	0	(20,661)	0	(25,506)	107,185	81,679
Returns to owners	316,608	148,806	465,414	1,491	(188,512)	0	(32,764)	38,515	(339,800)	245,629	(55,656)
Transfers to government (license fees)	20,508	6,652	27,160	504	0	8,912	42,808	0	0	79,384	79,384

Notes: 1. The table measure is NPV of net economic benefits which is sometimes called economic rent. Net economic benefits includes depreciation cost, and opportunity cost of labor and capital. The opportunity cost of labor is based on alternative livelihood choice for skipper/crew members.

2. The distribution of harvest net economic benefits is among three groups: incomes to skipper/crew; net income to hull, motor, gear and other owners; and, net transfers to government. Taxes on sector profits are not included.

Source: Study.

Stock Status Determination for Initial Conditions



Notes: 1. Vertical and horizontal lines correspond to biological determinates for maximum sustainable stock growth X_{MSY} (overfished status) given maximum sustainable fishing mortality F_{MSY} (overfishing status). The panel demarcations can be interpreted to be:

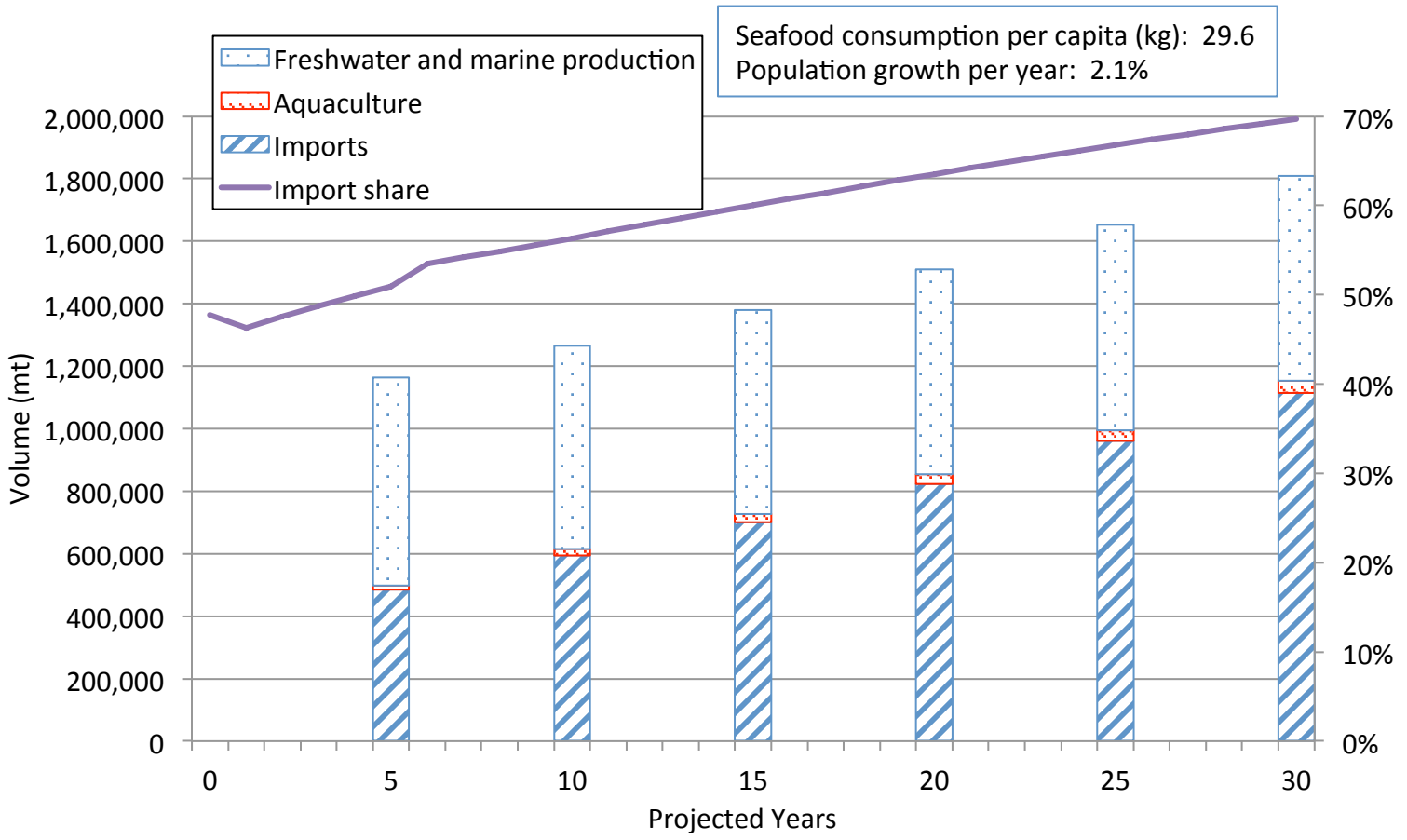
A: Overfishing is occurring; stock is overfished.

B: Overfishing is not occurring; stock is overfished.

C: Overfishing is occurring; stock is not overfished.

D: Overfishing is not occurring; stock is not overfished.

Projected Consumption and Seafood Supply Sources



Notes: 1. Freshwater and marine production excludes non-food less exports.

Model Improvements

1. **Introduce risk/uncertainty for economic and environmental parameters.**
2. **Refine effort measurement to make it more representative of management techniques to be tested (i.e. gear selectivity, trip number and duration, seasonal and spatial closures, etc.).**
3. **Improve cost-earning sub-model for breakeven analysis and determining tax, subsidy, and fishing industry private investment investigations.**
4. **Add regionalization so that community distributive impacts can be shown.**
5. **Review general economic modeling research to determine status for including indirect/induced economic impacts; and NEV measures. It may be appropriate to use other similar African economies research and benefit transfer techniques.**
6. **Include optimization mode allowing user to systematically evaluate tradeoffs among multiple objectives (e.g., maximize rent, raise social benefits, conserve fish resources).**
7. **Incorporate any new information from added value chain analysis research, including post-harvest loss improvements, seafood quality, and product form development.**
8. **Resolve freshwater historical catch estimates and review appropriate Lake Volta production function.**
9. **Endogenize harvest price predictions, although any modeling will be challenging given substitution and scarcity issues.**
10. **Add dimensions for assisting with using the model for government policy and fishery management decision making.**

Possible Questions About Presentation

- Assembled data?
  - Fishing industry structure, fish resources, monetary drivers?
- Modeling methods
  - Biological, sectoral, food consumption?
- Outcome performance indicators?
- Policy objectives and management strategies to be tested?
  - Constrain effort?
  - Assign fishing rights?
  - Rationalize capacity?
  - Social concerns?
  - Aquaculture development?
  - Government transfers?
- Model improvements?

Thank You for the Presentation Opportunity!