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

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

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

### 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.

### 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

Motorized canoe
Non-motorized canoe
Semi-industrial
Industrial
Tuna
Freshwater
Catch Per Vessel by Vessel Sector in 2000 to 2008
(1 of 2)

- Marine Canoe
  - $R^2 = 0.4298$

- Semi-Industrial
  - $R^2 = 0.2856$

- Industrial Trawl
  - $R^2 = 0.0012$

- Industrial Shrimp
  - $R^2 = 0.0174$
Catch Per Vessel by Vessel Sector in 2000 to 2008
(2 of 2)

Tuna

\[ R^2 = 0.0418 \]

Freshwater

Catch Per Vessel (mt)
Bioeconomic Model Development

Model contains three components:

1. Fish resource component using Gordon-Schaefer surplus production function (other functions may be substituted).
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

<table>
<thead>
<tr>
<th>Equations</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stock Size</strong> ($X_{(t+1)}$) = $X_t + r X_t (1 - (X_t / K)) - Y_t$</td>
<td>• Equilibrium between natural growth/mortality and harvest mortality.</td>
</tr>
<tr>
<td><strong>G =</strong> $X_{(t+1)} - X_t$</td>
<td>• Constant price and constant cost per effort.</td>
</tr>
<tr>
<td>where: G = stock size growth, i.e. $\Delta X / \Delta t$</td>
<td>• Catchability coefficient over time unaffected by technology changes.</td>
</tr>
<tr>
<td>r = intrinsic rate of growth</td>
<td></td>
</tr>
<tr>
<td>$X =$ stock size</td>
<td></td>
</tr>
<tr>
<td>$K =$ carrying capacity for stock biomass</td>
<td></td>
</tr>
<tr>
<td>$Y =$ harvest yield</td>
<td></td>
</tr>
<tr>
<td>$t+1 =$ time one period in the future</td>
<td></td>
</tr>
</tbody>
</table>

Harvest yield uses Gordon-Schaefer harvest function:

<table>
<thead>
<tr>
<th>Y = qEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>where: E = effort measured in a vessel year</td>
</tr>
<tr>
<td>q = catchability</td>
</tr>
</tbody>
</table>
Component 2
Sectoral Component Equations and Limitations

Equations

\[
\text{Profit} = \sum (H - L - V - F)_j
\]
\[
\text{Net Economic Benefit} = \sum (P + L - D - O)_j
\]
\[
\text{Resource Rent} = \sum (P + L - D - O - NP)_j
\]

- 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

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

Notes: Percents are sectors’ fishery share for initial conditions.
## Component 3

### Food Balance Component Equations and Limitations

<table>
<thead>
<tr>
<th>Equations</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consumption per Capita</strong> ($C_0$) = ($A_0 + L_0 \sum W_{i,0} - \sum E_{i,0}) / P$</td>
<td>• Consumption is from FAO that uses food balance equation based on harvest weight. General population surveys use processed weight.</td>
</tr>
<tr>
<td>where: C = consumption per capita</td>
<td>• Does not explicitly account for subsistence fishing, i.e. the fisheries production term includes all harvest dispositions.</td>
</tr>
<tr>
<td>W = marine and freshwater fish production</td>
<td>• Port-harvest loss rate imputed from other studies.</td>
</tr>
<tr>
<td>L = (1 - h), h = post-harvest loss and non-food utilization rate</td>
<td>• Harvest non-food proportions are from informal interviews and held constant over the projection period, while fish meal market can be highly variable.</td>
</tr>
<tr>
<td>A = aquaculture production</td>
<td></td>
</tr>
<tr>
<td>I = imports</td>
<td></td>
</tr>
<tr>
<td>E = exports</td>
<td></td>
</tr>
<tr>
<td>P = population</td>
<td></td>
</tr>
<tr>
<td>i = product forms, i.e. canned tuna, etc.</td>
<td></td>
</tr>
<tr>
<td>t = time, 0 is initial conditions</td>
<td></td>
</tr>
<tr>
<td><strong>Imports</strong> ($I_{t+1}$) = ($P_{t+1} * C_0$) - ($L_0 \sum W_{i} - \sum E_{i} + A)_{t+1}$</td>
<td></td>
</tr>
</tbody>
</table>

---

Component 3 provides a detailed equation for calculating consumption per capita ($C_0$) and imports ($I_{t+1}$). The consumption equation includes factors such as aquaculture production ($A_0$), post-harvest loss ($L_0$), and various product forms ($W_{i,0}$, $E_{i,0}$, etc.). The imports equation incorporates end-of-period population ($P_{t+1}$) and adjusted consumption ($C_0$) to account for changes in harvest and export parameters. Limitations include the use of harvest weight in FAO data, the absence of subsistence fishing, and the use of imputed port-harvest loss rates.
Model Use Flow Diagram

Assemble fishing industry and fish resource information /1

Determine initial policy objectives; formulate management strategies

Reshape policy objectives

Microsoft Excel computer software

With action case workbook
Change inputs and drivers

Comparison workbook
Review pertinent indicators for economic wealth and fish health

Outcomes balanced with objectives?

Acceptable timing and scope of impacts?

No

Status quo case workbook
Change inputs and drivers

Reshape management strategies

No
Model Operation Mode

Demonstration Mode

Development Mode

Test management strategies

Assumptions
Results

Status Quo
Drivers
Existing conditions

Action Alternative
Assumptions
Consequences

Comparison
Indicators
Change
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

<table>
<thead>
<tr>
<th>Example Policy Objectives</th>
<th>Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry benefits</td>
<td>Economic rent</td>
</tr>
<tr>
<td>Social benefits</td>
<td>Employment</td>
</tr>
<tr>
<td>Stock health</td>
<td>$X / X_{\text{MSY}}$</td>
</tr>
<tr>
<td>Trade balance</td>
<td>Net imports</td>
</tr>
<tr>
<td>Economic development</td>
<td>Added value</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Example Management Strategies</th>
<th>Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rationalize harvesting capacity</td>
<td>Vessels</td>
</tr>
<tr>
<td>Increase industry self-sufficiency</td>
<td>Transfers, subsidies</td>
</tr>
<tr>
<td>Increase efficiency</td>
<td>CPUE, asset per harvest value</td>
</tr>
<tr>
<td>Balance stock productivity</td>
<td>$F / F_{\text{MSY}}$</td>
</tr>
<tr>
<td>Fishing industry investment</td>
<td>BCA</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Action</th>
<th>Status Quo</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ Amount</td>
<td>$0</td>
<td>$55 million 0% interest</td>
</tr>
<tr>
<td>Canoes</td>
<td>No caps</td>
<td>Cap at 11,213 canoes</td>
</tr>
<tr>
<td>Semi-indus</td>
<td>3 fewer/year</td>
<td>50% reduction Year 6</td>
</tr>
<tr>
<td>Industrial</td>
<td>No change</td>
<td>100% reduction Year 6</td>
</tr>
<tr>
<td>Fish Price</td>
<td>No change</td>
<td>2%/year</td>
</tr>
<tr>
<td>Prod. Recov.</td>
<td>No change</td>
<td>3% increase begin Year 6</td>
</tr>
<tr>
<td>Landings Tax</td>
<td>None</td>
<td>0.5% starting Year 6</td>
</tr>
</tbody>
</table>
Results: Fish Sector -- Demersal Fishery -- With-Action Case

### Biological Growth Curve

- Overfished
- Not overfished
- Initial Conditions

Note: curve without harvest mortality

### Biological Sustainable Yield Curve

- Calculated
- Observed

### Stock Size and Harvest Projection

<table>
<thead>
<tr>
<th>Equation Parameters</th>
<th>MSY Results</th>
<th>Harvest Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>X: 125,000</td>
<td>SSE: 2,208</td>
</tr>
<tr>
<td>K</td>
<td>Y: 37,500</td>
<td>R²: 0.01</td>
</tr>
<tr>
<td>q</td>
<td>E eff: 10,000</td>
<td>Sum diff.: 10,994</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Measure</th>
<th>Effective Effort (000)</th>
<th>Harvest Revenue ($000)</th>
<th>Average Marginal Revenue</th>
<th>Marginal Revenue</th>
<th>Marginal Cost</th>
<th>Economic Rent ($000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_MEY</td>
<td>6,084</td>
<td>31.8</td>
<td>77,011</td>
<td>12,657</td>
<td>7,123</td>
<td>33,671</td>
</tr>
<tr>
<td>E_MSY</td>
<td>10,000</td>
<td>37.5</td>
<td>90,956</td>
<td>9,096</td>
<td>0</td>
<td>19,726</td>
</tr>
<tr>
<td>E_OA</td>
<td>12,169</td>
<td>35.7</td>
<td>86,678</td>
<td>7,123</td>
<td>7,123</td>
<td>0</td>
</tr>
<tr>
<td>E_ACTUAL</td>
<td>13,062</td>
<td>34.0</td>
<td>82,429</td>
<td>6,311</td>
<td>7,123</td>
<td>-10,612</td>
</tr>
</tbody>
</table>

### Economic Sustainable Yield Curve

![Economic Sustainable Yield Curve](image)

### Marginal and Average Revenue and Cost Curves

![Marginal and Average Revenue and Cost Curves](image)
Projected Marine Harvest Across All Sectors for With-Action Case

Harvest Volume (mt thousands)

Project Year

Historical Total

Assessed

Mixed

Historical Assessed

Historical Total

Projected Year

1 6 11 16 21 26
Results: Investment Case Versus Status Quo
Selected Performance Indicators

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

Projected Years

Total Employment

Projected Years

- investment new 1
- base new 1
### Results: Investment Case Versus Status Quo

#### Artisanal by Power Source Category

<table>
<thead>
<tr>
<th>Measure</th>
<th>Motorized</th>
<th>Non-Motorized</th>
<th>Total</th>
<th>Semi-industrial</th>
<th>Industrial</th>
<th>Tuna</th>
<th>Freshwater</th>
<th>Aquaculture</th>
<th>Processors</th>
<th>All Harvest</th>
<th>All Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV Investment Case</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net economic benefits ($000 2009 USD)</td>
<td>1,873,762</td>
<td>1,009,110</td>
<td>2,882,871</td>
<td>41,652</td>
<td>32,470</td>
<td>574,580</td>
<td>3,671,908</td>
<td>1,297,963</td>
<td></td>
<td>12,267,939</td>
<td></td>
</tr>
<tr>
<td>Resource rent ($000 2009 USD)</td>
<td>740,778</td>
<td>641,641</td>
<td>1,382,419</td>
<td>6,825</td>
<td>(31,994)</td>
<td>78,332</td>
<td>2,733,545</td>
<td>2,733,545</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution of benefits ($000 2009 USD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Returns to labor</td>
<td>1,534,783</td>
<td>591,520</td>
<td>2,126,303</td>
<td>50,785</td>
<td>64,464</td>
<td>1,382,419</td>
<td>43,780</td>
<td>5,435,625</td>
<td>6,201,762</td>
<td>11,681,167</td>
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</tr>
<tr>
<td>Returns to owners</td>
<td>2,433,796</td>
<td>1,143,882</td>
<td>3,577,678</td>
<td>36,967</td>
<td>5,099,542</td>
<td>1,297,963</td>
<td>9,340,640</td>
<td>15,418,952</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfers to government (license fees)</td>
<td>20,508</td>
<td>6,652</td>
<td>27,160</td>
<td>504</td>
<td>0</td>
<td>42,808</td>
<td>0</td>
<td>79,384</td>
<td>79,384</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPV Base Case</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net economic benefits ($000 2009 USD)</td>
<td>1,265,733</td>
<td>759,689</td>
<td>2,025,422</td>
<td>31,901</td>
<td>91,463</td>
<td>574,580</td>
<td>3,499,439</td>
<td>1,110,242</td>
<td>1,783,402</td>
<td>11,380,633</td>
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</tr>
<tr>
<td>Resource rent ($000 2009 USD)</td>
<td>280,137</td>
<td>440,024</td>
<td>720,161</td>
<td>(1,522)</td>
<td>(123,811)</td>
<td>78,332</td>
<td>1,783,402</td>
<td>1,783,402</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution of benefits ($000 2009 USD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Returns to labor</td>
<td>1,335,126</td>
<td>514,570</td>
<td>1,849,697</td>
<td>48,736</td>
<td>215,273</td>
<td>744,372</td>
<td>43,780</td>
<td>5,461,131</td>
<td>6,094,577</td>
<td>11,599,488</td>
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</tr>
<tr>
<td>Returns to owners</td>
<td>2,117,188</td>
<td>995,077</td>
<td>3,112,265</td>
<td>35,476</td>
<td>269,092</td>
<td>545,873</td>
<td>5,132,306</td>
<td>6,063,568</td>
<td>9,095,010</td>
<td>15,474,608</td>
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</tr>
<tr>
<td>Transfers to government (license fees)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Net Benefit (Investment Minus Base Case)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net economic benefits ($000 2009 USD)</td>
<td>608,029</td>
<td>249,421</td>
<td>857,449</td>
<td>9,751</td>
<td>3,513</td>
<td>574,580</td>
<td>(25,816)</td>
<td>319,822</td>
<td>6,222,805</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource rent ($000 2009 USD)</td>
<td>460,641</td>
<td>201,618</td>
<td>662,258</td>
<td>8,346</td>
<td>91,817</td>
<td>187,721</td>
<td>544,145</td>
<td>544,145</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution of benefits ($000 2009 USD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Returns to labor</td>
<td>199,657</td>
<td>76,950</td>
<td>276,607</td>
<td>2,049</td>
<td>70,809</td>
<td>269,092</td>
<td>38,515</td>
<td>15,418,952</td>
<td>245,629</td>
<td>(55,656)</td>
<td></td>
</tr>
<tr>
<td>Returns to owners</td>
<td>316,608</td>
<td>148,806</td>
<td>465,414</td>
<td>1,491</td>
<td>(188,512)</td>
<td>38,515</td>
<td>245,629</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfers to government (license fees)</td>
<td>20,508</td>
<td>6,652</td>
<td>27,160</td>
<td>504</td>
<td>0</td>
<td>42,808</td>
<td>0</td>
<td>79,384</td>
<td>79,384</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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

Seafood consumption per capita (kg): 29.6
Population growth per year: 2.1%

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!