Aquaculture and Capture Fisheries: Toward An Integrated Economic-Ecological Analysis

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Outline

- Ecosystem-based management
- The Economic-Ecological Framework
- Economic Interactions between Commercial Fishing and Aquaculture
- Ecological Interactions between Commercial Fishing and Aquaculture
- Summary

Sustaining Marine Fisheries (NRC 1999)

- Goal of sustainability in fishery management requires an understanding of larger ecosystem processes
- We cannot manage ecosystems *per se*
- EBM is: "…an approach that takes all major ecosystem components and services into account in managing fisheries…"
- Humans are integral parts of the ecosystem
- We can attempt to manage human activities (e.g., fishing and aquaculture)

EBM Framework (NRC 1999)

- <u>Stresses</u>
- Harvesting single fish species

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- Harvesting multiple fish species
- Habitat degradation
- Deterioration of environmental quality

- <u>Responses</u>
- Single-species stock effects

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- Trophic linkages
- Food web models

<u>Benefits</u>

Commercial surpluses

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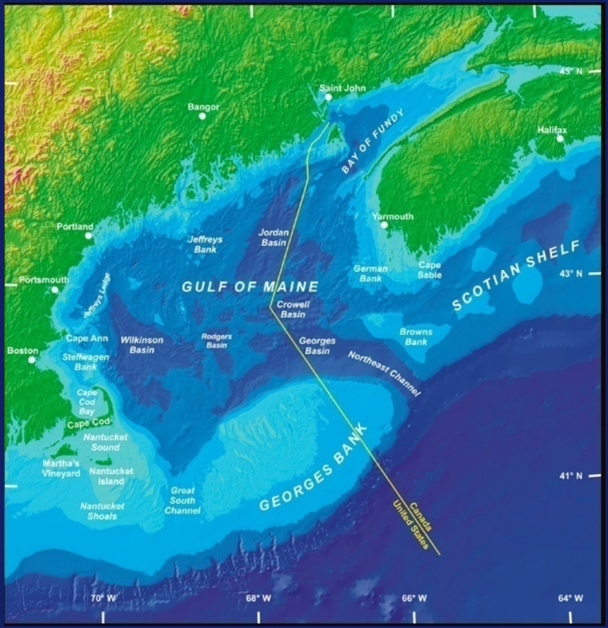
Commercial surpluses
Recreational fisheries
Subsistence fisheries
Other non-market benefits

Aquaculture

Ecosystem-Based Management

(normative aspects)



- Place-based
- Humans are a component
- Science-based
  - Maintains ecosystem integrity
  - Enhances ecosystem resilience
  - Adaptive
- Integrated (species, sectors):
  - Accounts for intra- and inter-system linkages
  - Considers feedbacks between natural and social systems
- Considers cumulative impacts
- Engages multiple stakeholders
  - Collaborative problem-solving and solution-finding

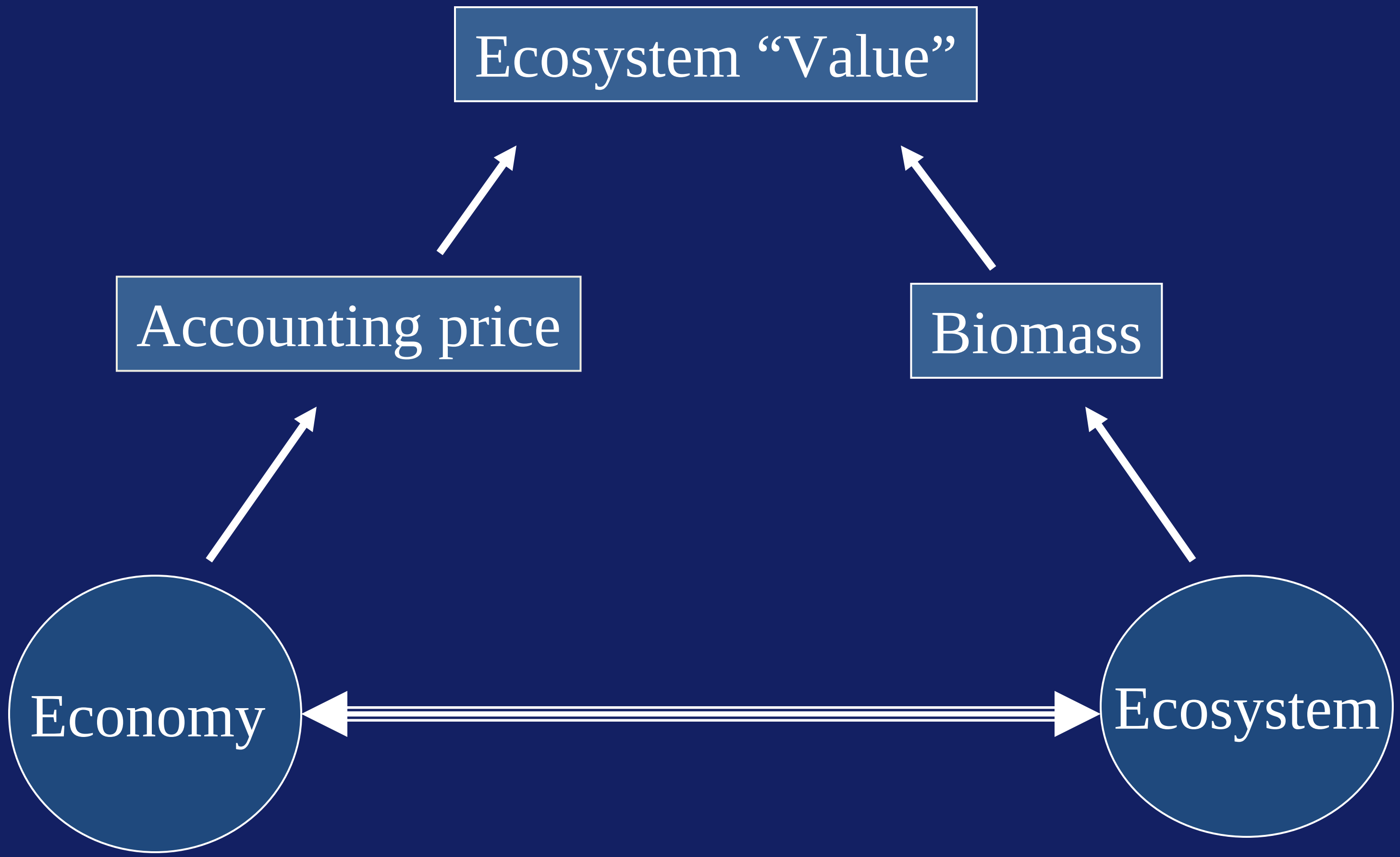
EBM Challenges

(Leslie and McLeod 2007)

- To implement EBM, a society needs:
  - A common vision to define the preferred ecosystem state(s)
  - Methods of evaluation and adaptation
  - Ocean governance frameworks (*e.g.*, property right assignments)
  - Successful examples

The Economic-Ecological Framework

An Integrated Economic and Ecological Framework



Some Possible Economic Models

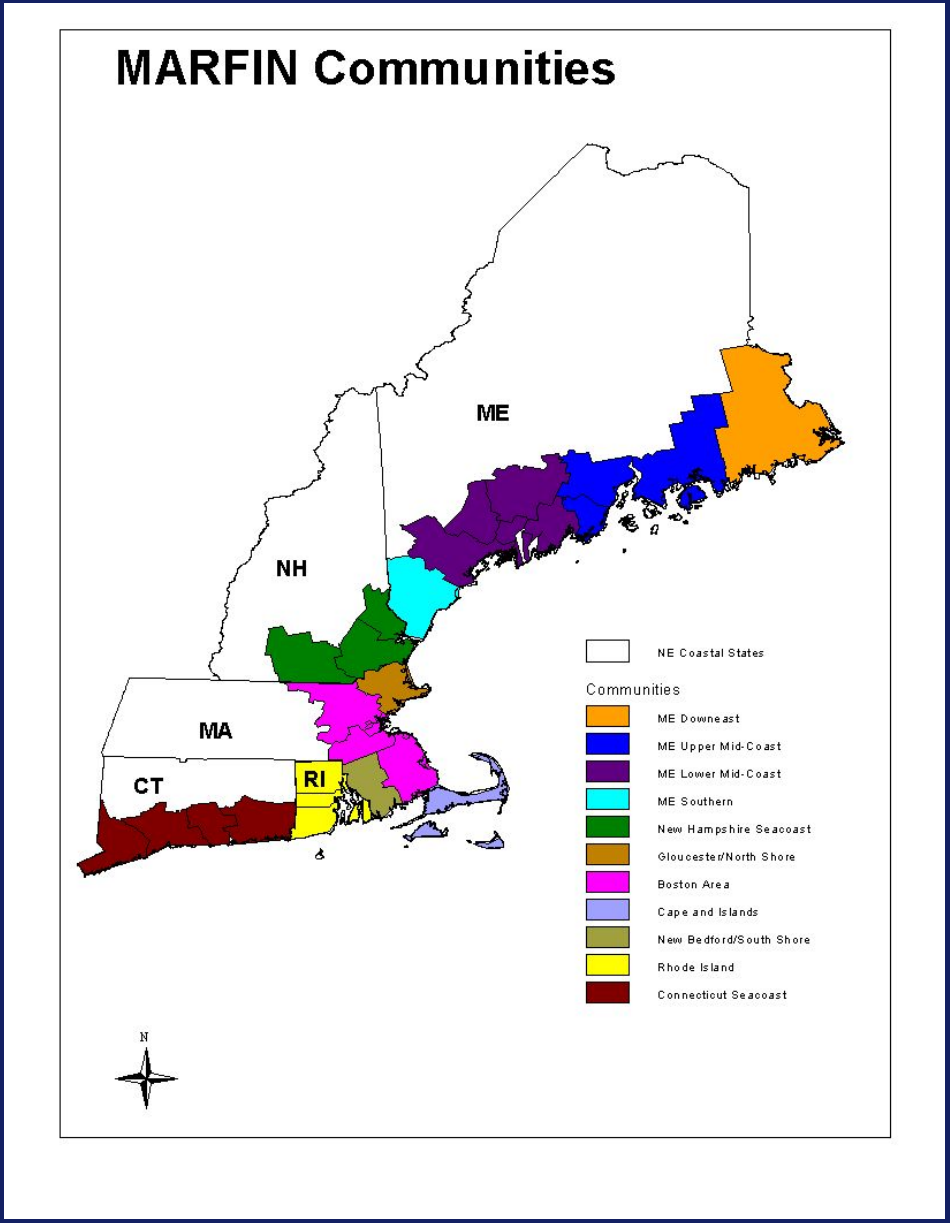
Bio-economic: captures the complexity of non-linear systems but incorporates only 1-2 species and 1-2 industry impacts

Input-output (I-O): includes numerous species and industries, but all coefficients (e.g., prices) are fixed

Computable General Equilibrium (CGE): captures key non-linear interactions and develops estimates of welfare changes

Input-Output Model Applications

- Evaluation of economic impacts:
  - Fishery management alternatives
  - Distribution across fishing communities
  - Distribution across industry sectors
  - Fleet rationalization efforts:
    - American lobster
    - Sea scallops



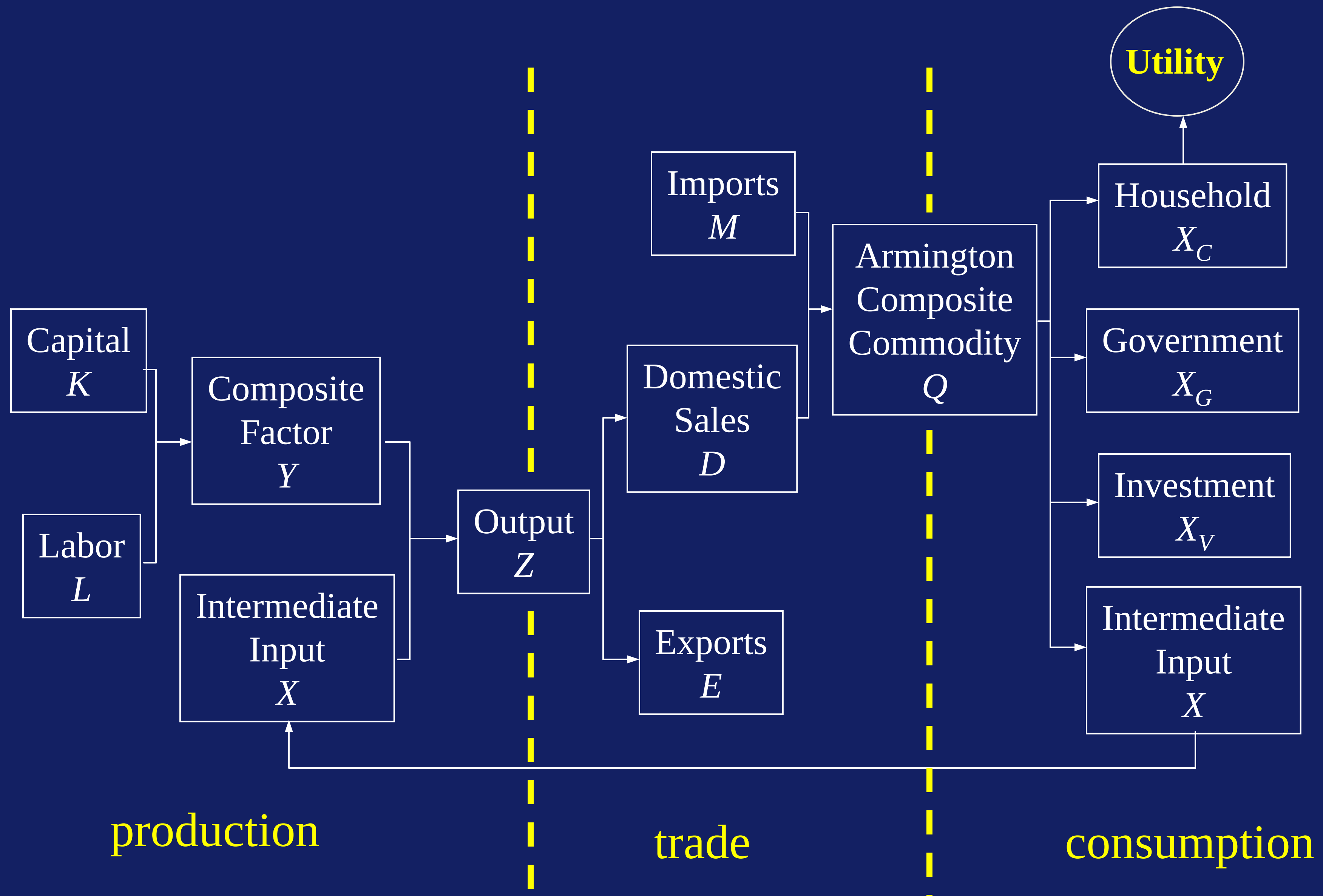
Major Features of a CGE Model

1. Multiple sectors, nonlinear, subject to resource constraints.

2. Supply and demand are derived from the behavior of profit-maximizing producers and utility-maximizing consumers.

3. Supply and demand for goods and production factors are equated by adjusting prices so that markets clear in equilibrium.

Basic Components of a CGE Model



Economic Interactions between Commercial Fishing and Aquaculture

Example: An increase in fish biomass

New England Coastal Regional Economy

Baseline Economic Value

Sector/ Commodity	Output	Total Supply*	Imports**	Exports**
Agriculture	2,428	7,107	5,305	626
Aquaculture	127	684	565	7
Fishing	870	653	42	259
Fish Processing	1,124	543	126	708
Manufacturing	194,703	247,123	90,029	37,608
Other	750,325	673,199	131,211	208,336

Millions of 2006 $

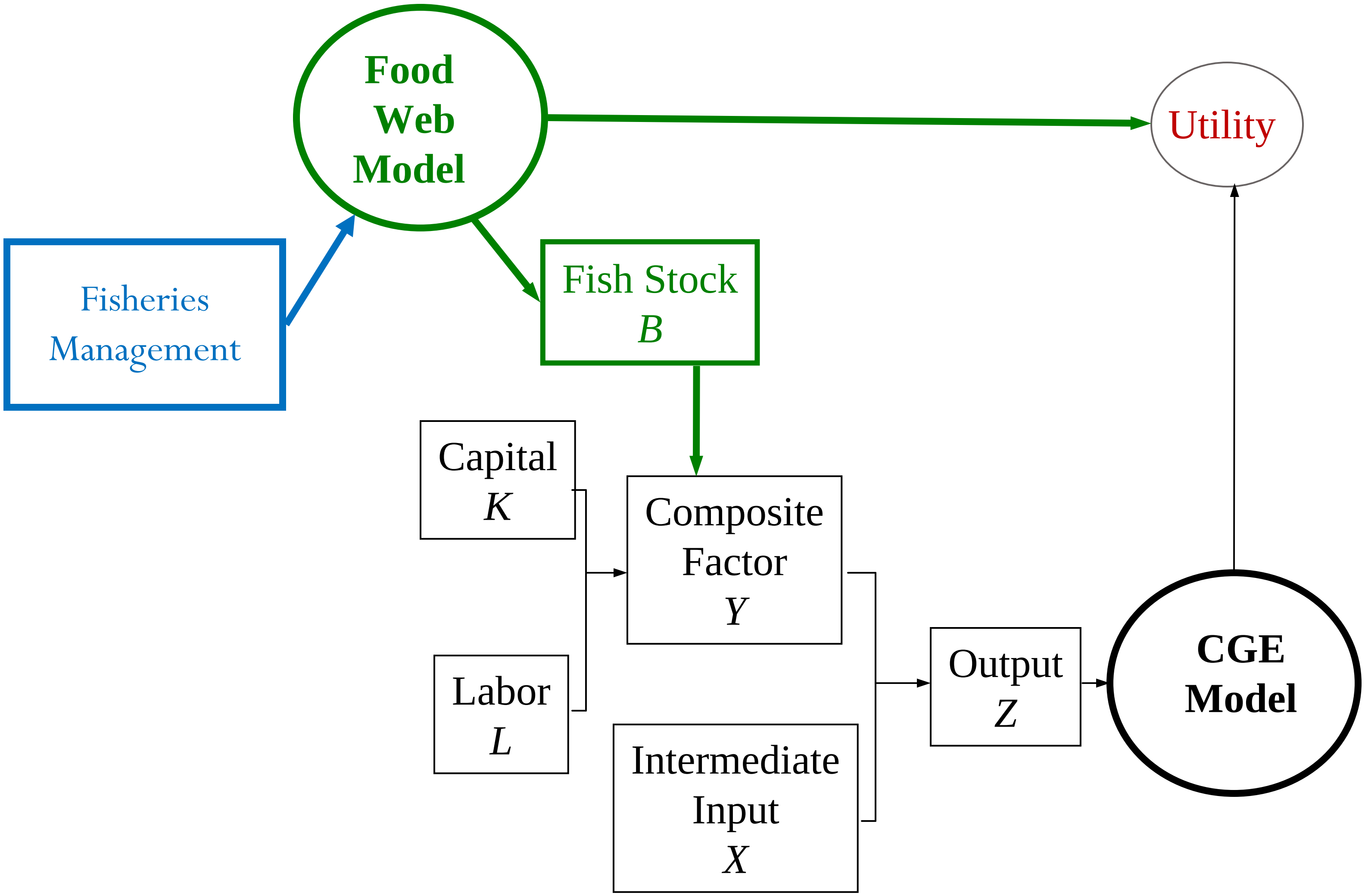
* Composite Commodity

** Including both domestic and foreign trade

Foreign and domestic imports and exports
(2006 $ millions)

Sector/ Commodity	Foreign Imports	Domestic Imports	Foreign Exports	Domestic Exports
Agriculture	1,118	4,187	161	465
Aquaculture	99	466	7	0
Fishing	42	0	259	0
Fish Processing	28	98	66	643
Manufacturing	30,537	59,491	37,608	0
Other	341	130,870	15,532	192,804

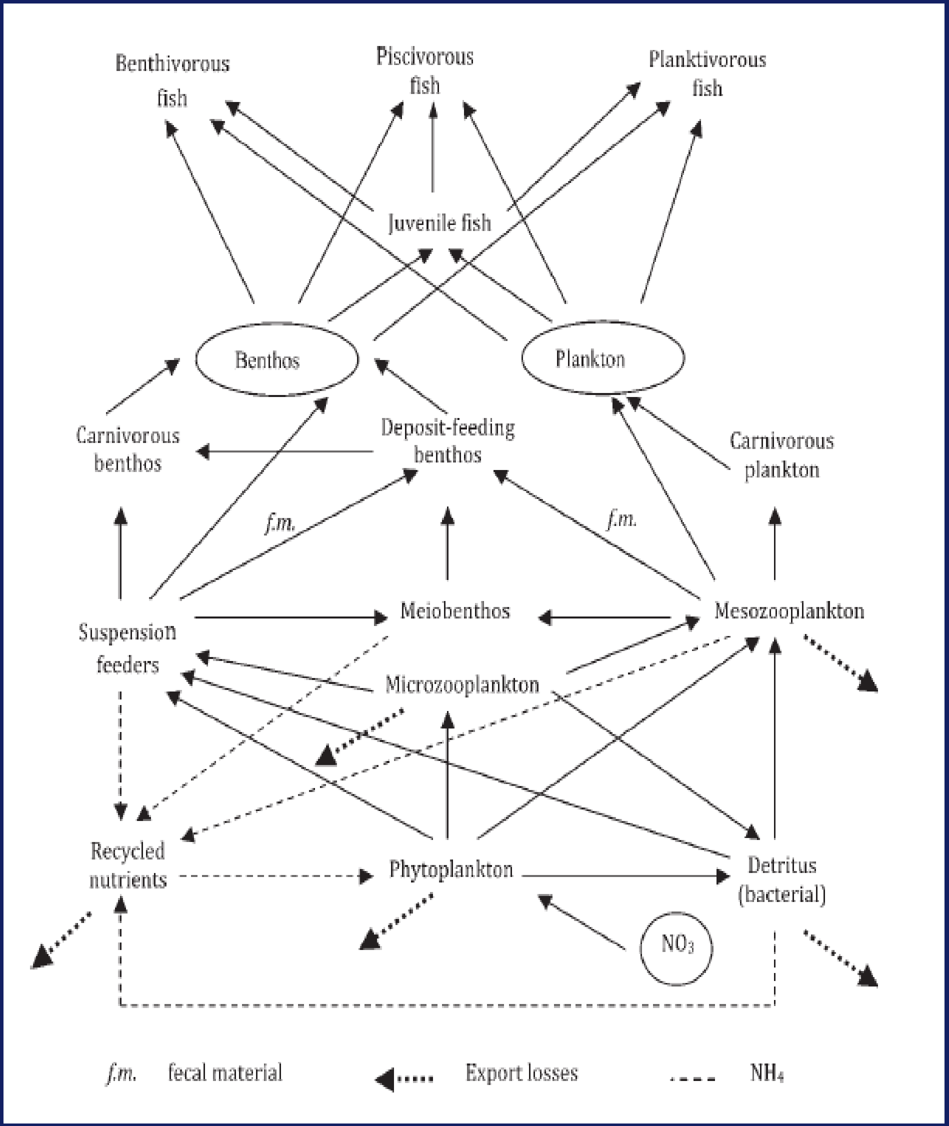
Linking of a CGE model with a marine ecosystem model for fisheries policy analysis



Ecosystem Productivity Scenarios

Collie *et al*. (2009); Steele *et al*. (2007)

- Baseline: 1993-2002 foodweb configuration
- P_{III} = reduce the role of invertebrate pelagic predators → increases the abundance of all fish guilds (1971-1990 foodweb)



Feeding Guilds (Steele *et al.* 2007)

Piscivores

Spiny dogfish
Winter skate
Silver hake
Atlantic cod
Pollock
White hake
Spotted hake
Atlantic halibut
Summer flounder
Bluefish
Sea raven
Goosefish

Planktivores

Smooth dogfish
Barndoor skate
Little skate
Thorny skate
Haddock
Red hake
American plaice
Yellowtail flounder
Winter flounder
Witch flounder
Longhorn sculpin
Cunner
Ocean pout
Fourspot flounder

Benthivores

Atlantic herring
Butterfish
Acadian redfish
Northern sandlance
Atlantic mackerel
Windowpane
Loligo squid
Illex squid
Smooth skate

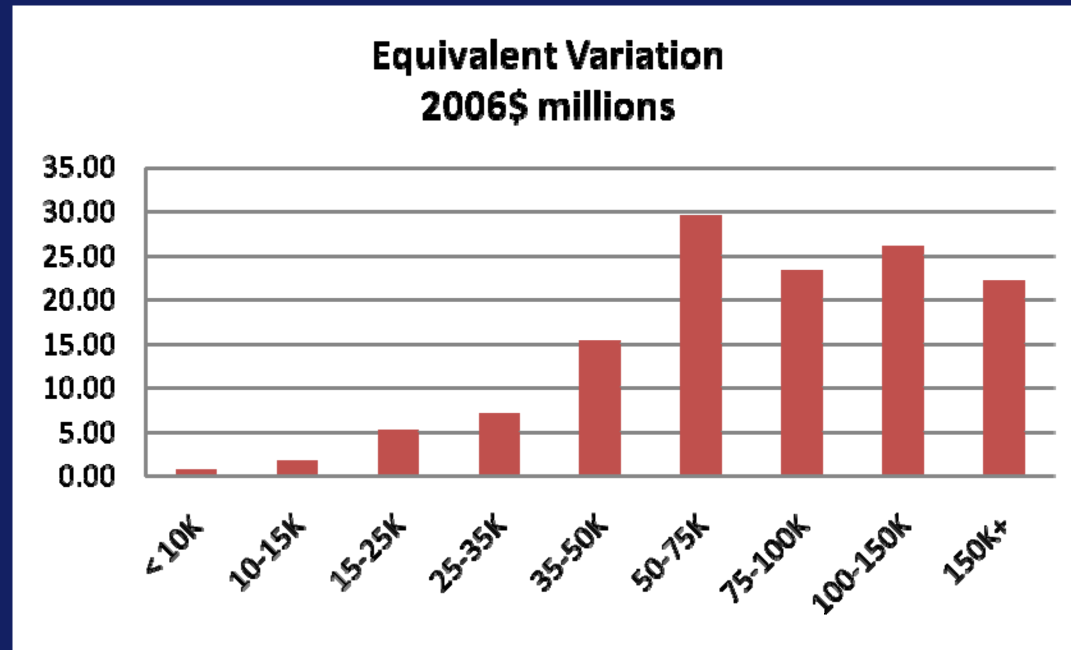
Percent changes associated with ecosystem changes
An increase in fish biomass

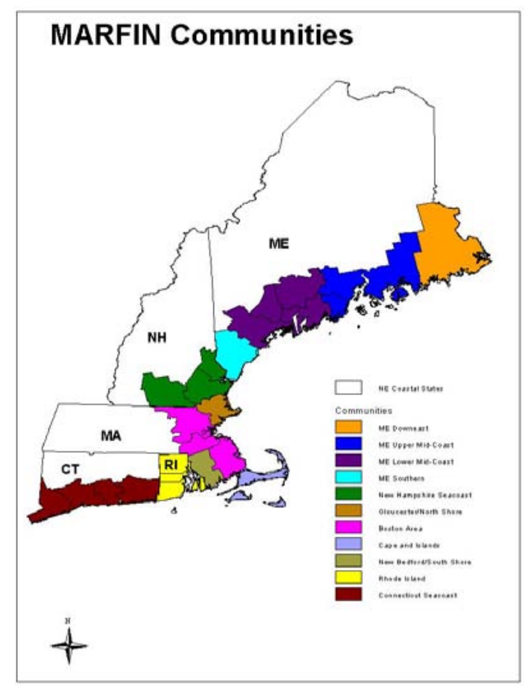
Sector/ Commodity	Output	Supply	Imports	Exports	Price
Agriculture	0.00	0.02	0.03	-0.01	0.01
Aquaculture	-1.25	0.86	1.28	-3.34	0.21
Fishing	10.33	6.35	-3.43	17.87	-4.70
Fish Processing	9.96	2.27	-4.35	13.21	-3.28
Manufacturing	0.03	0.04	0.04	0.01	0.01
Other	0.04	0.04	0.05	0.03	0.01

Millions of 2006 $

Distributional Effects

- Productivity scenario: P_{III}
- Region comprises the New England coastal fishing communities
- Benefits are EV surplus gains ($) per household
- Distribution is skewed, reflecting seafood consumption habits
- Could map across communities





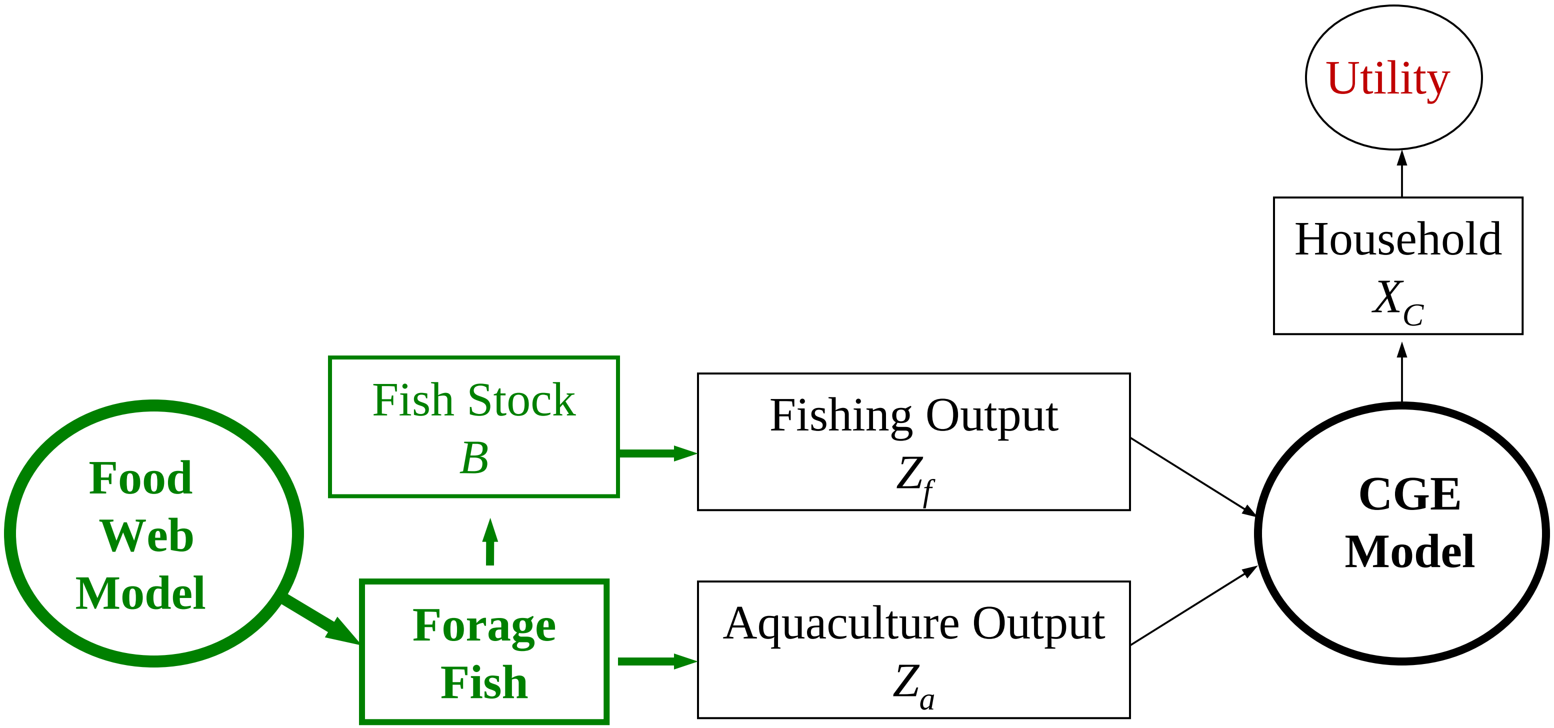
Welfare changes (equivalent variations) associated with changes in fishery stock (2006 $ millions) by household Income categories

Total 131.02

Ecological Interactions between Commercial Fishing and Aquaculture

Example: The management of forage fish

An integrated economic-ecological analysis of forage fish management



A framework by Hannesson *et al*. (2009)

Let species *j* be the commercially harvested small pelagic species, and species *i* be a predator of species *j*.

$$\Delta B_i = \frac{a_i}{C_i / P_i} \Delta B_j$$

Capture fisheries

Aquaculture

where ΔB is the change in biomass,

ai is the share of ΔBj eaten by species *i*,

C is consumption, and *P* is production.

EMAX model of Georges Bank by Link *et al.* (2008)

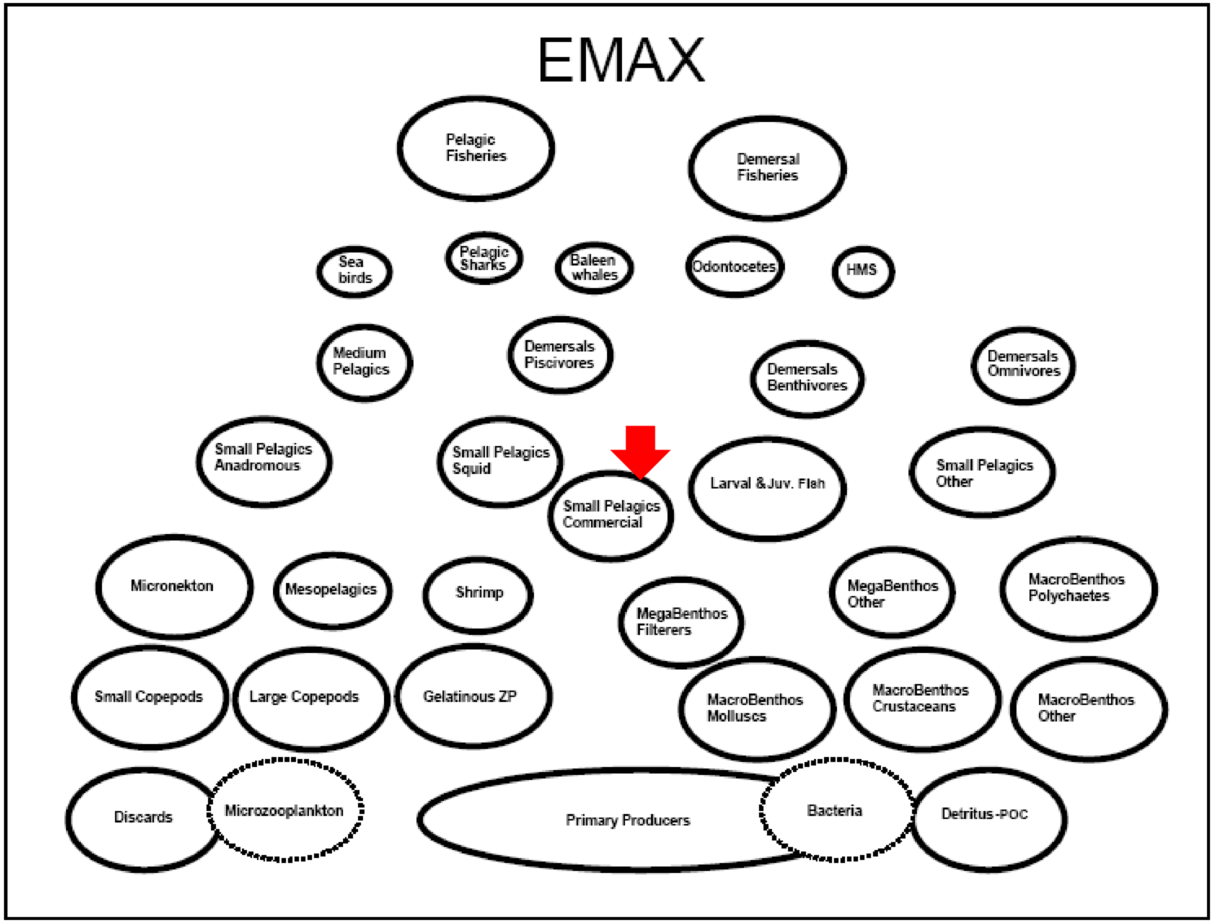


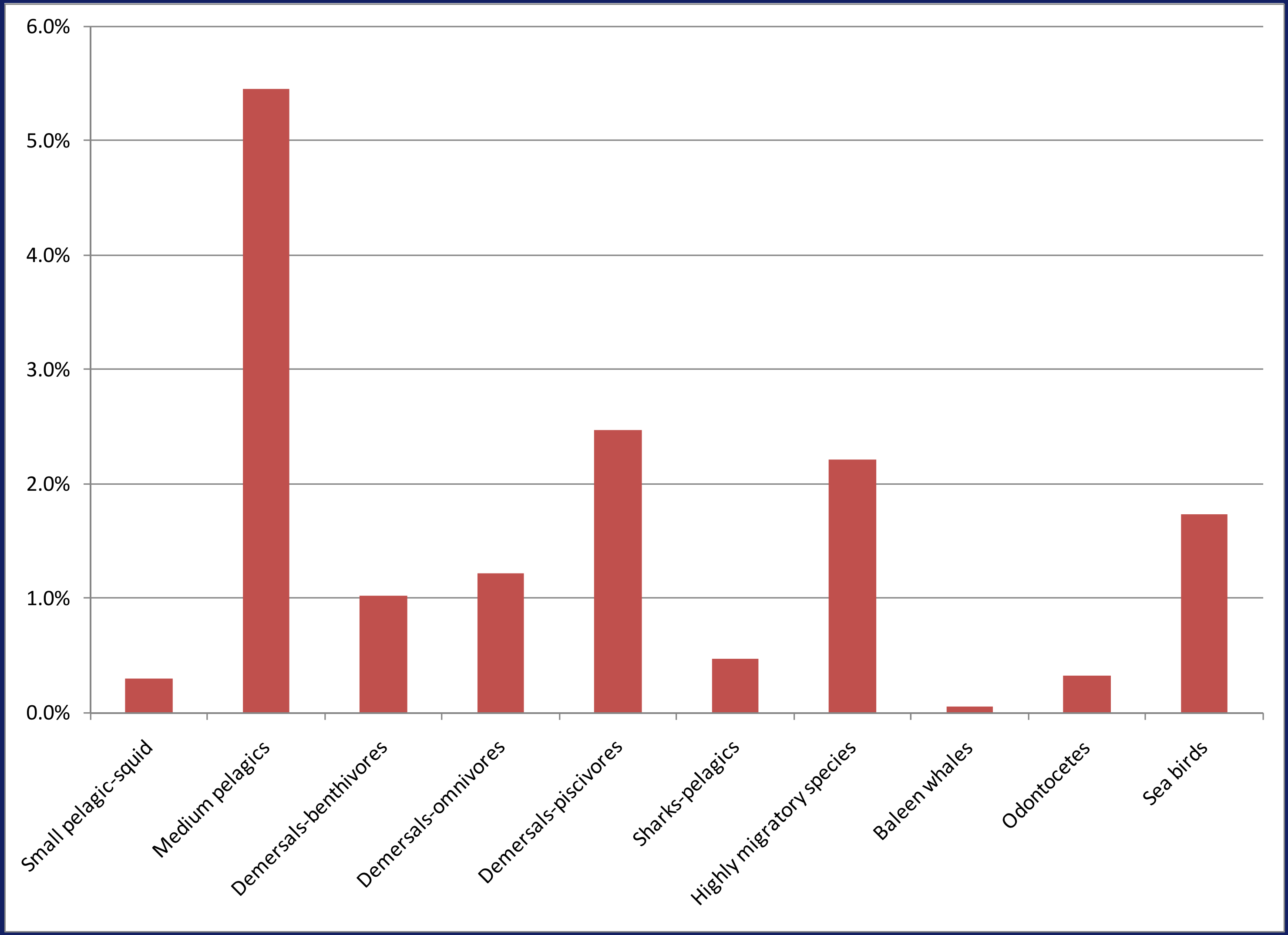
Fig. 3. Network diagram from EMAX. The two fishery nodes are not modeled directly as nodes in this network analysis; rather they are treated as direct (landings) and indirect (bycatch and discards) removals of other nodes. The dashed lines indicate that those nodes are part of the microbial loop.

Ecosystem effects of a change in small commercial pelagic stock*

Compartment	*B*	*P/B*	*D*	*C/P*	*a*	*s*
Small pelagic-squid	0.962	0.95	1.4	2.89	0.0084	0.0029
Medium pelagic	0.1928	0.45	53.5	5.4	0.0568	0.0105
Demersals-benthivores	5.02	0.45	10.1	2.04	0.1054	0.0517
Demersals-omnivores	3.779	0.45	12	1.84	0.0850	0.0462
Demersals-piscivores	4.254	0.45	24.3	5.42	0.5710	0.1054
Sharks-pelagics	0.0244	0.1	21	5.55	0.0006	0.0001
Highly migratory species	0.0352	0.68	14.4	3.01	0.0023	0.0008
Baleen whales	0.4167	0.04	5.8	118.36	0.0259	0.0002
Odontocetes	0.122	0.04	35.2	360	0.1401	0.0004
Sea birds	0.0144	0.28	27.3	15.92	0.0040	0.0002

* Ecological parameters are from Link *et al*. (2008). Units for biomass (*B*) are in g m^{-2}; and units for production (*P*) and consumption (*C*) are in g m^{-2} yr^{-1}.

Percent changes in predator biomass resulting from one unit (g m^{-2}) change in prey biomass (small commercial pelagic species)



Next Step

- To develop an integrated model that is useful for analyzing policies related to aquaculture development
- To improve the resolution of fishing and aquaculture related sectors in the CGE model
- To develop model links between the ecosystem (e.g., forage fish biomass) and relevant aquaculture productions

Summary

- EBM involves understanding intra-system linkages and the feedbacks between natural and human systems
- Aquaculture and commercial fisheries may interact in a complex way throughout economic system (e.g., may compete in downstream markets).
- The culturing of one species could affect the status of a range of species or the characteristics of an entire ecosystem.
- The economic-ecological framework is a useful tool in EBM implementation.