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# A Review of Regional Economic Models for Fisheries Management in the U.S.

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**Abstract** *In 1986, Andrews and Rossi reviewed input-output (IO) studies of U.S. fisheries. Since then, many more fisheries studies have appeared using IO and other types of regional economic models, such as Fishery Economic Assessment Models, Social Accounting Matrices, and Computable General Equilibrium models. However, to our knowledge no updated summary of these studies or models has appeared since 1986. This paper attempts to fill this gap by briefly reviewing the types of regional economic models that have been applied to fisheries, reviewing studies using these models that have been conducted for U.S. fisheries, and identifying data and modeling issues associated with regional economic analysis of fisheries in the U.S. The authors conclude that although economic impact analysis of fisheries policy is required under federal law, development of more representative regional economic models for this purpose is not likely to be forthcoming without increased information obtained through some type of comprehensive data collection program.*

**Key words** Review, regional economic models, fisheries, IO, FEAM, SAM, CGE, IMPLAN, data.

JEL Classification Codes R1, R13, R15.

## Introduction

Regional or community economic analysis of proposed fishery management policies is required by the Magnuson-Stevens Fishery Conservation and Management Act (MSA), National Environmental Policy Act (NEPA), and Executive Order 12866, among others. For example, National Standard 8 (MSA Section 301[a][8]) explicitly requires that, to the extent practicable, fishery management actions minimize economic impacts on fishing communities. To satisfy these mandates and inform policymakers and the public of the likely regional economic impacts associated with fishery management policies, economists need appropriate economic models. There are many regional economic models in the literature. Several studies have assessed the community economic impacts of fishery management policies in the U.S. using various regional economic models. Andrews and Rossi (1986) provided an in-depth review of six input-output (IO) studies of fisheries. However, their review is limited to those IO studies for northeastern regions conducted prior to 1986. Many more re-

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gional economic studies of fisheries have been published since 1986, and regional economic models other than traditional IO models have also been used.

To fill this gap, this paper first provides a short theoretical overview of the types of regional economic models, and offers a review of the studies that have been conducted for various fisheries throughout the U.S. (including the six studies reviewed in Andrews and Rossi). While many of these studies used conventional IO models, a broader range of regional economic models has been utilized, such as Fishery Economic Assessment Models (FEAMs), Social Accounting Matrix (SAM) models, and Computable General Equilibrium (CGE) models.

In the next section, we provide a short overview and comparative discussion of various regional economic models available for analysis of fisheries impacts, and review studies assessing the regional economic effects of fishery management actions in the U.S. Next, we compare the fishery regional economic models reviewed in this paper and discuss data issues associated with conducting economic impact studies for fisheries in the U.S. Finally, we conclude by highlighting some key issues (data and modeling issues) that must be carefully considered in conducting economic impact analyses for fisheries.

## Overview of Economic Impact Studies for U.S. Fisheries

### *Review of Regional Economic Models*

Several types of economic impact models have been used to analyze regional economic issues. These include IO models, SAM models, integrated econometric-input-output (EC-IO) models, and CGE models.[1] Table 1 summarizes the major features of these models, including data requirements, and compares their strengths and weaknesses for modeling regional economic impacts.

IO models have been a fundamental tool for regional economic analysis for the past half century. The SAM model represents a more recent extension of IO analysis arising from dissatisfaction with the nature of IO analysis and its limitations in assessing income distribution impacts. In both models, the effects of changes in exogenous final demand are calculated using multipliers. The SAM model shares certain limitations with IO. Specifically, in both types of models, prices are assumed to be fixed, and no substitution is allowed between factors in production or commodities in consumption. As a result, in cases where the fixed-price assumption may not be realistic, these models tend to overestimate impacts. Miller and Blair (1985) and Hewings (1985) provide detail on the IO model. Hewings and Jensen (1986) discuss interregional and multiregional IO models. Schaffer (1999) provides a more recent description of basic IO model construction and implementation. A survey of IO studies is found in Richardson (1985). Discussion of SAM models is found in King (1985), Pyatt and Round (1985), Adelman and Robinson (1986), and Holland and Wyeth (1993).

[1] Another model, the export base or economic base (EB) model is the conceptually simplest type of regional economic impact model. The EB model aggregates a regional economy into two sectors: a basic sector, demand for which drives the economy; and a non-basic sector, which endogenously adjusts to the level of basic sector activity. IO extends the EB model by disaggregating the basic and non-basic sectors. More detailed discussion of EB theory is found in Tiebout (1956) and Richardson (1973). Excellent critical reviews of theoretical and empirical studies of EB models may be found in Krikelas (1991, 1992). EB models were frequently used for regional economic impact analysis in the past. However use of EB models has declined, especially with the arrival of standard IO packages such as IMPLAN. The recent development of time-series modeling, such as vector autoregression and co-integration techniques, has made it possible to estimate the dynamic relationship between basic and nonbasic sectors. These dynamic EB models may have promise for future applications (LeSage and Reed 1989; LeSage 1990).

**Table 1**
Characteristics of Regional Economic Models

| | IO | SAM | Supply-determined Models | EC-IO | CGE |
|---|---|---|---|---|---|
| Equilibrium Conditions | Value added expenditure = value added receipts<br><br>Industry expenditure = industry receipts<br><br>Household expenditure = household receipts | Value added expenditure = value added receipts<br><br>Industry expenditure = industry receipts<br><br>Household expenditure = household receipts<br><br>Institutional expenditure = institutional receipts | The equilibrium conditions for SDIO are the same as for IO<br><br>The equilibrium conditions for SDSAM are the same as those given for SAM model | Value added expenditure = value added receipts<br><br>Industry expenditure = industry receipts<br><br>Household expenditure = household receipts<br><br>Short-term disequilibria may be observed in some markets before a long-term equilibrium across markets is obtained | Goods supplied = goods produced (quantity)<br><br>Factors supplied = factors demanded (quantity)<br><br>Household expenditure = household receipts<br><br>Government expenditure = government receipts<br><br>Savings = investment<br><br>Leakages to rest of the world (ROW) = injections from ROW |
| Producer Behavior | Intermediate and primary input demands are determined by Leontief function<br><br>Substitution effects are not allowed | Intermediate and primary input demands are determined by Leontief function<br><br>Substitution effects are not allowed | Intermediate and primary input demands are determined by Leontief function<br><br>Substitution effects are not allowed | Intermediate input demands are determined by Leontief function<br><br>Primary input demands are determined by econometric estimation<br><br>Substitution effects are allowed | Intermediate demand is determined by Leontief function<br><br>Primary input demand is determined endogenously via optimization<br><br>Substitution effects are allowed |

**Table 1 continued**

| | IO | SAM | Supply-determined Models | EC-IO | CGE |
|---|---|---|---|---|---|
| Consumer Behavior | Household demand is given by average expenditure patterns | Household demand is given by average expenditure patterns | Household demand is given by average expenditure patterns | Household demand is determined by dynamic consumption function | Household demand is derived endogenously from optimization |
| | Substitution effects are not allowed | Substitution effects are not allowed | Substitution effects are not allowed | Substitution effects are allowed | Substitution effects are allowed |
| Functional Forms | Linear | Linear | Linear | Both linear and nonlinear | Both linear and nonlinear |
| Output Determination | Demand-driven | Demand-driven | Demand-driven | Demand-driven with some supply constraints | Determined by interaction of demand and supply |
| | Perfectly elastic supply | Perfectly elastic supply | Some sectors are supply-driven | | |
| Static or Dynamic | Static | Static | Static | Dynamic | Static and dynamic |
| Interregional and Intersectoral Factor Mobility | Perfect mobility implied | Perfect mobility implied | Perfect mobility implied | Imperfect mobility is typically assumed | Depends on specification of labor & capital behavior |
| Single-region or Multi-region | Both single- and multi-region models | Both single- and multi-region models | Both single- and multi-region models | Single-region models | Both single- and multi-region models |
| Policy Instruments | Final demand | Final demand | Final demand | Final demand | Final demand |
| | Transfer payments | Transfer payments | Transfer payments | Transfer payments | Transfer payments |
| | | | Outputs | | Input use |
| | | | | | Taxes, savings, subsidy |
| | | | | | ROW Prices |

**Table 1 continued**

| | IO | SAM | Supply-determined Models | EC-IO | CGE |
|---|---|---|---|---|---|
| Welfare Evaluation | No | No | No | Yes | Yes |
| Data Requirements | For each industry, need data on output, employment, value added, final demand, imports, make table, and use table (Note: IMPLAN provides estimates of all of these) | Same as IO plus more detailed inter-institutional accounts | Same as IO | Same as IO plus regional data for econometric estimation are needed | Same as SAM plus estimates of supply, demand, and trade elasticities |
| Strengths | Captures interindustry linkages<br><br>Easy to implement with IMPLAN | Measures impacts on distribution of income across institutions | Useful for analyzing impacts of reduction in productive capacity (supply shock) | Improved forecasting performance over econometric models<br><br>Capable of generating the time paths of policy impacts | Endogenous prices determine economic response<br><br>Substitution effects are allowed<br><br>Welfare implications can be easily derived |
| Weaknesses | Prices are fixed<br><br>Substitution effects are not allowed<br><br>Tends to overestimate policy impacts | Prices are fixed<br><br>Substitution effects are not allowed<br><br>Tends to overestimate policy impacts | Prices are fixed<br><br>Substitution effects are not allowed<br><br>Tends to overestimate policy impacts<br><br>Has mixed endogenous/ exogenous variable problem<br><br>Relatively more costly to implement than IO | Implementing costs are high<br><br>Framework for statistical inference is not yet developed<br><br>Some difficulties associated with specifying multiregional framework | Implementing costs are relatively high<br><br>Estimates of some parameters and elasticities may be hard to find |

Note: This table is based on Kraybill (1994), West (1995), and Rey (2000).

Regional economists have also used supply-determined IO (SD-IO) and supply-determined SAM (SD-SAM) models in which final demands for some sectors and gross outputs for the remaining sectors are specified exogenously (Miller and Blair 1985, Chapter 9). SD-IO models were used in situations where the productive capacity of a sector is exogenously reduced. Examples of studies that used SD-IO model are Johnson and Kulshreshtah (1982) and Papadas and Dahl (1999). SD-SAM models have been used to examine the impact of a change in industry productive capacity on income distribution. Examples of studies using SD-SAM models include Marcouiller, Schreiner, and Lewis (1995) and Seung, Harris, and MacDiarmid (1997). Although SD-type models can be more useful for analyzing the impact of a reduction in productive capacity than conventional IO or SAM models, SD-IO and SD-SAM models share the same general limitations of IO models discussed above. In addition, the SD models have a theoretical weakness in that the final demand for certain sectors is assumed to be endogenous.

One of the attempts to address the weaknesses of IO-type models is to combine an econometric model with an IO model. The combination is often called an integrated econometric-input-output (EC-IO) model. There are two motivations for developing EC-IO models: theoretical and practical (Rey 2000). One of the most important theoretical motivations is that prices are fixed in IO models, while they can vary in most econometric models. Thus, the weakness of price rigidity in IO models can be somewhat reduced by combining them with econometric models. There are also several practical reasons why the two different approaches are integrated. First, with detailed inter-industry relationships specified in the IO portion of the integrated model, the EC-IO has better forecasting performance compared with traditional structural econometric models. Second, with dynamic features present in econometric models, integrated models have improved impact analysis capabilities and can generate the time paths of the effects of policy impacts. Third, since the econometric portion in the integrated model is usually estimated based on regional data, the integrated model can be used to reduce the bias of secondary data-type IO models resulting from the regionalization of a national IO model (Rey 2000). Although there are some important advantages from integration of econometric and IO models, there are also complications. First, there is the difficulty of interpreting statistical inference in the integrated model, which consists of a deterministic portion and a stochastic portion. Second, while multiregional linkages can be specified in both IO and econometric models, there are difficulties associated with implementing the integrated model in a multiregional framework due to the scarcity of region-specific time-series data (Rey 2000). Examples of EC-IO models in use include the regional economic modeling incorporated (REMI) model (Treyz 1993) and research by Hewings, Okuyama, and Sonis (2001). Rey (2000) provides an excellent review of recent research on EC-IO, including discussion of modeling issues and opportunities. Loveridge (2004) provides a short summary and review of the EC-IO approach.

CGE models overcome some of the limitations of fixed-price models. In CGE models, prices are allowed to vary, triggering substitution effects in production and consumption. Therefore, the CGE model enables analysts to easily examine the economic welfare implications of a policy change. Furthermore, the CGE approach is generally more appropriate than other regional economic models for analyzing the impacts of a change in productive capacity of resource-based industries.[2] Details on the structure of CGE models are found in De Melo and Tarr (1992) and Shoven and Whalley (1992) for national-level analysis, and Kraybill (1993) for regional-level analysis. Vargas *et al.* (1999) provide an excellent description of the basics of re-

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[2] While in practice CGE models tend to be more aggregated than IO models, with modern solvers and software packages such as GAMS, model complexity and dimensionality no longer necessarily limit CGE model size.

gional CGE models. A survey of national CGE models of tax and trade policies is available in Shoven and Whalley (1984). Partridge and Rickman (1998) provide an excellent survey of regional CGE models, including multiregional CGE models. Examples of application of regional CGE models are found in Kraybill, Johnson, and Orden (1992); Hoffmann, Robinson, and Subramanian (1996); Waters, Holland, and Weber (1997); and Seung *et al.* (2000).

Most of the regional economic impact models are static. Specification of factor supply elasticities determines whether the single adjustment period in a static model represents a short (up to one year), intermediate (one to five years), or long-run (greater than five years) adjustment. In the real world, dynamic elements abound and policy evaluations based on a single-period, static equilibrium may incompletely characterize the effects that certain policies have over time. Static models collapse the time dimension of adjustment in regional goods and factor markets into a single period. However, policymakers may want to know the time path of a regional economy with and without a certain policy in place.

Fundamental to modeling any dynamic regional economic process is the treatment of capital accumulation and interregional movement of labor. For a regional economy with these dynamic elements, it may be more appropriate to employ a dynamic specification of a regional economic model. Regional models commonly used that have dynamic elements include EC-IO models, discussed above, and dynamic CGE models. In a typical regional dynamic CGE model (*e.g.*, Seung and Kraybill 2001), it is assumed that adjustment of prices and quantities in the goods and services market occurs in the short run (one year), reducing excess demand to zero (Walrasian equilibrium), but that full adjustment in factor markets takes longer because of lagged factor supply response. This effect is controlled by model parameters (elasticities) in the labor migration and investment functions. Static equilibria are sequenced through time to reflect a gradually changing capital stock due to net investment, and labor stock due to net migration and population change. The sequence of equilibria generated without any policy shock is called the "continuous benchmark," while that generated with the shock is called a "continuous counterfactual." Policy impacts are calculated by comparing the continuous counterfactual with the continuous benchmark. Note that this type of model does not necessarily optimize over all periods at once ("forward-looking"), but produces a sequence of equilibria, each depending primarily on net investment in the prior period. Examples of regional dynamic CGE include Seung and Kraybill (1999, 2001).

## *Review of Economic Impact Studies for Fisheries*

### Introduction

Most regional economic impact studies in fisheries have used IO or IO-based models. Among these studies, only one (Butcher *et al.* 1981) employed a multiregional IO (MR-IO) model, and another (Leung and Pooley 2002) used a SD-IO model. A recent study employed a SAM model developed for Alaska fisheries (Seung and Waters 2006), but to date there have been no studies applying SD-SAM models to fisheries. There has been one regional CGE model developed for a U.S. fishery (Houston *et al.* 1997), but this is poorly documented. By reviewing the methods commonly employed to assess regional economic impacts, we intend to provide guidance on which models are likely to be most appropriate in certain instances, and which shortcomings are most crucial to overcome in developing future applications. Table 2 lists existing regional economic impact studies of U.S. fisheries and compares the main features of the models used in those studies.

**Table 2**
Characteristics of Previous Regional Economic Studies for Fisheries

| Author | Model | Region | Commercial or Sport Fishing | Industrial Sectors | Data |
|---|---|---|---|---|---|
| Rorholm *et al.* (1967) | IO | 11 counties in RI, CT, and MA | Commercial | 1 harvesting sector; 2 processing sectors; 1 fish wholesale sector; 7 other marine-related sectors; 1 sportfishing-related sector; and 1 non-fishery sector | 1965–66 survey of 420 marine establishments for sales and purchases data |
| King and Storey (1974) | IO | Barnstable County, MA | Commercial (coastal zone planning) | 2 harvesting sectors; 2 fish wholesale sectors; 6 other marine-related sectors; 2 sportfishing-related sectors; and 1 non-fishery sector | 1971 survey of waterfront firms and commercial vessels |
| Callaghan and Comerford (1978) | IO | Rhode Island | Commercial | 4 harvesting sectors (including 1 non-Rhode Island vessel sector); 1 fish handling, packaging, and processing sector; and 1 non-fishery sector | 1976 survey of 72 firms engaged in commercial fishing (exempting retailers) |
| Harris and Norton (1978) | IO | United States | Commercial | 1 harvesting sector (domestic fishing industry); 1 processing sector (canned and frozen food products); and 1 non-fishery sector | Almon *et al.* (1974) and U.S. Dept. of Labor (1977) |
| King and Shellhammer (1981) | IO (CIF model) | California | Commercial | 19 harvesting sectors; 9 processing sectors; 1 other marine-related sector; and 34 non-fishery sectors | Published sources, interviews, and mail survey |

**Table 2 continued**

| Author | Model | Region | Commercial or Sport Fishing | Industrial Sectors | Data |
|---|---|---|---|---|---|
| Butcher *et al.* (1981) | Multiregional IO | Alaska and Washington | Commercial (Shellfish) | 3 harvesting sectors in AK and 3 harvesting sectors in WA; 3 processing sectors in AK, 1 processing sector in WA; and 12 non-fishery sectors in AK, 11 non-fishery sectors in WA | Bourque and Conway (1977) for WA; Logsdon and Casavant (1977) for AK; U.S. Army Corps of Engineers (various years); and other published data |
| Grigalunas and Ascari (1982) | IO | 11 counties in RI, CT, and MA | Commercial | 3 harvesting sectors; 1 processing sector and 1 seafood trade sector; 9 other marine-related sectors; 1 sportfishing-related sector; and 1 non-fishery sector | 1976 survey of 390 marine establishments |
| Briggs, Townsend, and Wilson (1982) | IO | Maine | Commercial | 5 harvesting sectors; 4 processing sectors; and 28 non-fishery sectors | 1963 U.S. Multiregional input-output model, Polenske, Anderson, and Shirley (1972), and interviews |
| Rossi, Andrews, and Persaud (1985) | IO | Ocean County, NJ | Commercial | 2 harvesting sectors; 1 fish wholesale sector; 3 other marine-related sectors; and 1 non-fishery sector | 1981 survey of 41 fishermen, 8 dock operators, and other marine-related establishments |
| Carter and Radtke (1986) | FEAM | Three communities on the Oregon coast | Commercial and sport fishing | 1 commercial fishing sector in IMPLAN and unknown number of disaggregated commercial fishing subsectors in the FEAM submodel; 2 processing sectors in IMPLAN and unknown number of disaggregated processing subsectors in the FEAM submodel; and the other 525 IMPLAN sectors | IMPLAN and survey/interview data |

**Table 2 continued**

| Author | Model | Region | Commercial or Sport Fishing | Industrial Sectors | Data |
|---|---|---|---|---|---|
| Hushak, Morse, and Apraku (1986) | IO | 17 counties in northern Ohio | Commercial and sport fishing | 1 harvesting sector; 1 processing sector; 2 other marine-related sectors; 1 charter fishing sector; and 38 non-fishery sectors | King and Shellhammer (1981) for commercial fishing sector's data, primary data surveys for charter fishing sector and marina and boat sales sector; and 1972 U.S. national IO model for the other 40 sectors |
| Martin (1987) | Keynesian-type model | Bay of Quinte, Lake Ontario, Canada | Sport fishing | N.A. | Survey on angler expenditures, business expenditure survey; angler accommodations survey; and household expenditure survey |
| Houston *et al*. (1997) | CGE | A costal Oregon region | Commercial | 5 harvesting sectors; 5 processing sectors; 24 other industry sectors; 3 household sectors; and 2 government sectors | IMPLAN, FEAM, and regional fishery industry data |
| Herrick and Huppert (1988) | IO | California | Commercial | 19 harvesting sectors; 9 processing sectors; 1 other marine-related sector; and 34 non-fishery sectors | Used multipliers from CIF model (King and Shellhammer, 1982) |
| Storey and Allen (1993) | IO | Massachusetts | Sport fishing | 494 sectors in Regional Science Research Institute's IO model | Survey on angler expenditures and annual NMFS marine recreational fishing survey |
| Schorr *et al*. (1995) | IO | Seven contiguous counties in OK and TX | Sport fishing | 1 commercial fishing sector in IMPLAN; 2 processing sectors in IMPLAN; and the other 525 IMPLAN sectors | IMPLAN data and angler expenditure data from mail, telephone, and roving creel surveys |

**Table 2 continued**

| Author | Model | Region | Commercial or Sport Fishing | Industrial Sectors | Data |
|---|---|---|---|---|---|
| Steinback (1999) | IO | Maine | Sport fishing | 1 commercial fishing sector in IMPLAN; 2 processing sectors in IMPLAN; 1 for-hire recreational fishery sector; and the other 525 IMPLAN sectors | Angler expenditures data, operating expenses of the marine for-hire fishing businesses; U.S. Fish and Wildlife Service angler expenditure information; and IMPLAN data |
| Natcher, Greenburg, and Herrmann (1999) | FEAM | 1 census district in AK (Nome) | Commercial | 1 commercial fishing sector in IMPLAN and 4 harvesting sectors (vessel categories) in FEAM; 2 processing sectors in IMPLAN and 1 processing sector in FEAM; and the other 525 IMPLAN sectors | IMPLAN, interviews, and surveys |
| Woods Hole Oceanographic Institution (2000) | IO | 10 northeast coastal regions | Commercial | 5 harvesting sectors (by gear type); 2 seafood processing sectors as in IMPLAN and 1 seafood dealer sector; and the other 525 IMPLAN sectors | IMPLAN data, dealer weigh-out slips data, and survey data for harvesters' cost |
| Hamel *et al*. (2002) | IO/FEAM combined with recreation demand model | Lower and Central Cook Inlet, western Kenai Peninsula, AK | Sport fishing | 1 commercial fishing sector in IMPLAN; 2 processing sectors in IMPLAN; 1 charter boat sector created and internalized in the model; and the other 525 IMPLAN sectors | Mail survey of anglers on expenditures, operating cost data, data on stated preferences for hypothetical trips, and zip-code area level IMPLAN data corrected with primary data |
| Leung and Pooley (2002) | SDIO | Hawaii | Commercial | 2 harvesting sectors; no processing sector (fish processing is included in "construction and manufacturing" sector); 2 sportfishing-related sectors; and 6 non-fishery sectors | 1992 Hawaii state IO model (Sharma *et al*., 1999) |

**Table 2 continued**

| Author | Model | Region | Commercial or Sport Fishing | Industrial Sectors | Data |
|---|---|---|---|---|---|
| The Research Group (2000); Pacific Fishery Management Council (2004) | FEAM | Various regions in AK, CA, OR, and WA | Depends on topic and study region (either commercial or recreational) | 1 commercial fishing sector and 2 processing sectors in IMPLAN (The numbers of harvesting and processing sectors in the FEAM submodel depends on topic and study region), and the other 525 IMPLAN sectors | IMPLAN data and survey/ interview data<br><br>Primary data vary depending on study region and topic |
| Seung and Waters (2006) | SAM | State of Alaska | Commercial | 1 commercial fishing sector, 1 processing sector, and 27 non-fishery sectors | IMPLAN data, nonresident employment and earnings data, permanent fund dividend data, and Census 2000 data |

In the remainder of this subsection, we review previous IO studies for fisheries, including the SD-IO model and the SAM model. Then we briefly discuss two regional impact models which are not well documented elsewhere, the FEAM and a regional CGE model developed for fisheries. Finally, we compare these different regional economic models.

## Review of Fishery IO Studies

Most fisheries economic impact studies used IO models or IO-based models. There are several reasons why the IO models have been extensively used. First, within the IO framework, it is possible to investigate the detailed inter-industry relationships in a regional economy. Second, the models are relatively easy to implement with available software and data. Third, IO-based models have less extensive data requirements than CGE models. There have been a number of IO studies analyzing fisheries in the U.S. However, these are a small proportion of the number of regional IO studies examining non-fishery issues. Probably the main reason that IO models have not been more commonly utilized for fisheries is the extreme sparseness of regional economic data for fisheries-related sectors.

IO studies for fisheries can be divided into three categories: those that analyze commercial fishing (*e.g.*, Herrick and Huppert 1988), sport fishing (*e.g.*, Steinback 1999), or both (*e.g.*, Hushak, Morse, and Apraku 1986). To estimate the potential impacts of fishery management actions on individual harvesting and processing sectors, it is necessary to disaggregate the fishery-related sectors into several different subsectors by vessel and processor type. There are two approaches commonly used to model disaggregated sectors. The first approach is to directly incorporate the disaggregated fishery-related sectors into the IO framework. The second approach is to estimate changes in revenues (incomes) and expenditures (costs) in disaggregated fishery-related sectors, allocate these changes to the sectors in an aggregated IO model, and calculate impacts by multiplying the changes in the disaggregated fishery-related sectors by the multipliers given by the IO model. Most IO models for fisheries, including King and Shellhammer (1981) and the Northeast Fisheries Science Center (NEFSC)[3] model (Woods Hole Oceanographic Institution 2000), have used the first approach. The second approach was used by Natcher, Greenburg, and Herrmann (1999), and in models such as FEAM. Hamel *et al.* (2002) employed both approaches.

## The Fisheries Economic Assessment Model (FEAM)[4]

FEAM has been the major analytical tool employed to calculate regional impacts from commercial and recreational fisheries in Alaska and the West Coast. Compared

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[3] The NEFSC model was developed to assess the economic impacts of groundfish fisheries regulations in New England for 10 northeast coastal regions.

[4] FEAM was developed in early 1980s by William Jensen and Hans Radtke to estimate the contributions of the commercial and recreational fishing industries to the economies of West Coast regions. Although FEAM has been the major analytical tool employed for calculating regional impacts from fisheries in Alaska and the West Coast, an organized document describing the model has not been published. The Pacific Fishery Management Council's Scientific and Statistical Committee began a review of the West Coast FEAM in 1994; however, no definitive recommendation was made regarding use of the model. One of the review's findings called for increased documentation of FEAM data and model assumptions. It is unclear whether this call was followed up. As part of this study, we prepared an appendix detailing the model structure and explaining how economic impacts are calculated in FEAM. A copy of this appendix is available upon request.

with IMPLAN (IMpact analysis for PLANning)[5], which provides fishery-related data for only a few very aggregated sectors, FEAM provides much more detailed information at a disaggregated level. However, FEAM does not include any information on final demands for processed products. FEAM is a production-oriented model designed to estimate the impacts of supply-side (harvesting sectors) changes assuming perfectly elastic demand for outputs. Because the fishery sectors are specified in a highly disaggregated manner, one is able to calculate the economic impacts resulting from a change in landings of a particular species, by a specific vessel type, and in a particular location. FEAM consists of two sub-models. The first sub-model calculates the revenues and expenditures of harvesting and processing industries.[6] The second sub-model is derived from IMPLAN. Regional economic impacts are calculated by multiplying changes in fishery-related revenues (incomes) and expenditures by income multipliers from an IMPLAN model.

For each of the harvesting and processing subsectors, FEAM includes data on output by species, use of intermediate inputs, and value-added components. Value-added components include: labor income (crew share, processing workers' income, and administrative salaries), capital income (operating income), and indirect business taxes (fish taxes and business/property taxes). Intermediate input categories in FEAM include vessel and engine repair, fuel and lubricants, ice and bait, supplies, insurance, and other goods and services. The first sub-model allocates fishery sector expenditures to the FEAM expenditure categories. The second sub-model maps each FEAM expenditure category onto several different IMPLAN sectors. The multiplier for each FEAM expenditure category is calculated as the weighted average of the underlying IMPLAN multipliers. Weights are calculated as the share of expenditure allocated to a given IMPLAN sector compared to total expenditures in that category. The FEAM multipliers thus calculated are used to estimate changes in regional income resulting from a change in fishery sector harvest or output levels.

### The CGE Model

There are few examples of regional CGE models applied to fisheries. Houston *et al.* (1997) developed a regional CGE model of coastal Oregon to evaluate the impacts associated with different policies for reducing groundfish harvest.[7] The authors used the Oregon coast CGE model to examine regional impacts under several different policy scenarios, including reduced groundfish catch assuming current capacity lev-

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[5] IMPLAN (IMpact analysis for PLANning) was originally developed by the U.S. Forest Service to assist in land and resource management planning. Beginning in 1993, development of IMPLAN was privatized under the Minnesota IMPLAN Group, Inc. (MIG). IMPLAN has two components: database and software. The IMPLAN database includes 21 economic and demographic variables for 509 NAICS-based industry sectors for every county (borough) and state in the United States. The economic variables include: employment, value-added components, government purchases, and household consumption. IMPLAN software includes a linear algebra algorithm for solving the IO model and calculating impacts.

[6] In the first FEAM sub-model, revenues from the harvesting and processing sectors are allocated to expenditures for intermediate inputs and factor inputs according to ratios estimated based on interviews of harvesters and processors. The first sub-model is an accounting framework used to track expenditures by fishery sectors and map them to the correct IMPLAN industry categories in the second FEAM sub-model.

[7] A similar model was also constructed for the New England groundfish fishery based on Bristol County Massachusetts regional data. However details of the Bristol County model were never documented. Regional SAM models of the Oregon Coast and Bristol County were also constructed as part of the same project. The SAM models were used to analyze economic dependency on fisheries and other industries in the two regional economies.

els, and reductions in fishing capacity with and without a vessel buyback program.

The Oregon coast CGE model was built around IMPLAN data augmented with additional regional and fisheries data. The core of the model is a 1995 IMPLAN SAM. The coastal region was defined as all Oregon counties bordering the Pacific Ocean, except Lane and Douglas Counties, which lie mostly inland. Additional data on industry income and employment were taken from the Bureau of Economic Analysis (BEA) Regional Economic Information System (REIS) economic data reports. PacFIN data were used to calibrate the ex-vessel value of landings by species and by vessel type. Estimates for the production functions and output mix of regional vessels and processors were developed from the industry expenditure patterns in the Oregon FEAM.

To examine differential impacts on individual fishing sectors, the single IMPLAN commercial fishing sector was replaced by five fishing sectors based on FEAM vessel types. Each vessel type harvests several different species. For example, a groundfish trawler catches bottom groundfish, shrimp, scallops, salmon, Pacific whiting, and crab. The authors specified five processing sectors, each associated with the corresponding harvesting sector's landings. The model contained 24 other aggregated industry and commodity sectors, three household income categories, two government expenditure accounts, three factor income accounts, a trade account, and an investment expenditure account.

Allocation of resources and commodities in a CGE model is a function of economic scarcity as indicated by the relative prices of goods, services, and productive factors. Key determinants of relative prices include: (*i*) constraints on factor supply and production; (*ii*) ability of regional consumers to substitute between alternative sources of commodity supply (*i.e.*, regional supply versus imported supply); (*iii*) ability of regional producers to supply alternative markets (*i.e.*, local markets versus "export"); and (*iv*) demand conditions affecting local markets and export markets.

Behavioral assumptions ensure that producers maximize economic returns by equating marginal factor cost with the value of each factor's contribution to marginal product. Total supply supports intermediate demand for producer inputs, endogenous demand for consumer goods, and exogenous demand represented by business investment, government purchases, and exports. Household consumption is driven by changes in endogenous factor incomes and relative commodity prices.

Recently there has been work linking models of the feedback between fishery stocks and fishing activity with CGE models to show the dynamic impacts of changes in harvest on regional economies over time. While not examined here, we feel this approach called "bioeconomic modeling" has particular promise for further development.[8]

## Comparison of Regional Economic Models for Fisheries

Table 2 summarizes the main characteristics of the models used for regional economic impact studies of U.S. fisheries. The following discussion highlights these characteristics, focusing on the key differences between the model types.

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[8] For example, Finnoff and Tschirhart (2003, 2005) developed an integrated regional dynamic CGE – ecosystem model for Alaska fisheries. In their work, an Alaska CGE model is combined with a general equilibrium ecosystem model (GEEM) which links multiple species in complex food webs. Floros and Failler (2004) used a similar approach to model the fishery economy in Salerno, Italy.

### *NEFSC-type vs. FEAM-type Models*

The NEFSC-type IO model internalizes the disaggregated fishery-related sectors and explicitly details the relationships between these and other industrial sectors. As a result, this type of model explicitly captures the feedback effects of non-fishery sectors on fishery sectors. However, developing a NEFSC-type model requires a large amount of data and time to augment the default IMPLAN accounts with other data. Additional data needed to develop an NEFSC-type model include: (*i*) output, employment, value added, intermediate inputs, final demands, and import and export estimates for each of the disaggregated fishery sectors; (*ii*) a use matrix showing the flows of intermediate inputs between industries; and (*iii*) a make matrix describing the outputs produced by each industry. Since this data is not generally available for most U.S. fisheries, developing intersectoral and interregional IO coefficients for these sectors is a daunting task. However, the time and funding required for such an endeavor vary depending on the number of fishery-related sectors and regions that are specified.

Developing a FEAM-type model requires relatively less effort in that the modeler does not need to: (*i*) derive a technical coefficient matrix of the transactions between industrial sectors and disaggregated fishery sectors; (*ii*) develop final demand vectors for the disaggregated fishery sectors; and (*iii*) construct and balance the SAM including the added fishery sectors. Also, a FEAM-type model is somewhat more flexible in that changes in parameters, such as ex-vessel or wholesale prices, can be accommodated. Thus, if a management action results in both a change in harvesting and processing of certain species and a change in their prices, a FEAM-type model can incorporate those changes to calculate economic impacts. Unlike an NEFSC-type model, this type of model has an important theoretical weakness, in that it does not internalize the disaggregated fishery sectors within the IO model framework, so it does not explicitly capture feedback effects from non-fishery sectors on the fishery sectors. Ignoring feedback from non-fishery sectors would tend to underestimate indirect and induced impacts if fisheries were important suppliers of intermediate inputs to non-fishery sectors. However, this is probably not the case in most fisheries, so the degree of bias should generally be low.

### *Demand-driven vs. Supply-driven Models*

IO studies of fisheries typically use a traditional demand-driven approach. However, fishery management actions typically involve supply constraints, such as changes in Total Allowable Catch (TAC) or season or area closures. In this case, demand-driven IO models (or demand-driven SAM models) may not adequately capture the chain of effects, especially if, as is likely the case, it is not known how much final demand for processed seafood would change as a result of the change in supply. Leung and Pooley (2002) employed SD-IO to model an exogenous change in productive capacity, asserting that a demand-driven model was not appropriate for modeling a supply-side shock (*i.e.*, change in landings of fish). Although this might be true from a theoretical point of view, in practice a demand-driven IO model can often be adapted for analyzing fisheries situations. For example, suppose that landings are reduced due to closure of a fishing area. Unless there are alternative sources of supply, it is likely that the processing sector will reduce its purchase of raw fish accordingly. These processors will then process smaller amounts of fish and export smaller amounts of processed products. In other words, at least in the short term, reduced harvest leads to a proportionally reduced output for final demand (*e.g.*, exports). In a demand-driven IO model in which fish harvesting and seafood processing are separate sectors, the reduction in final demand for processed seafood will lead to reduced harvesting via backward linkage to the harvesting sector. Therefore, if the relationship between final demand and production is known, a reduction in the harvesting sector can be effectively treated using a demand-driven IO model, and the results will correctly measure the short-term impacts from the supply-side disturbance.

### *Single-region vs. Multi-region Models*

In the fisheries impact literature, we are aware of only one study (Butcher *et al.* 1981) that employed an interregional or multiregional model. All other examples are single-region models that do not endogenously capture the interregional flows of goods and services. Single-region models do not estimate economic impacts transmitted outside the study region, nor are they designed to estimate spillover effects in the study region resulting from events occurring outside. In some cases, it may be important to develop interregional (or multiregional) models to fully measure the impacts of a region's fisheries, including those impacts in regions that supply goods and/or factors of production to the study region or that demand goods and services produced there. An interregional model would be especially useful for Alaska, where most intermediate goods are imported and much of the factor income leaks out of the region. Developing an interregional model invokes the formidable task of estimating interregional flows of goods and services, including those used as intermediate inputs by production sectors.[9]

### *Fixed-price vs. Flexible-price Models*

IO, SAM, and SD-SAM models assume exogenous prices and, therefore, share the same limitations faced by all fixed-price models. Conversely in a CGE model, endogenously determined relative prices trigger substitution effects in production and consumption. A CGE model allows calculation of the change in economic welfare resulting from a policy change, by comparing the value of real consumption in the counterfactual scenario against the baseline level. CGE models will be also more appropriate in cases where management actions have significant indirect effects on prices or where productive inputs are limited in supply.

The extent that model assumptions embody actual regional economic constraints will likely affect the quality of model results. The appropriateness of using fixed-price or flexible-price models for analysis of economic impacts often centers on the length of run or magnitude of the shock involved. In general, in the long run, say at least five years after the initial economic shock, there are no fixed factors, so the fixed-price model assumption of perfectly elastic supply of productive factors may be appropriate. Likewise, in the very near term (up to one year), or if the shock is relatively small or the economy is very open, factor supply constraints may prove not to be binding, so price response would be minimal. In the intermediate term (between one and five years), especially in a relatively closed or remote regional economy, binding supply constraints would retard the rate of response to an eco-

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[9] Developing this type of information for an interregional model has traditionally been very challenging due to an absence of interregional trade flow statistics. However this task should soon become much easier upon release of IMPLAN Version 3.0, which will reportedly include an interregional trade modeling capability.

nomic stimulus, and depending on the magnitude of the shock, relative factor prices would adjust to reflect this factor scarcity. Especially in cases where input factors are in limited supply, a flexible price model, such as a CGE model, may be most appropriate.

Developing a CGE or EC-IO model has a higher computational cost than an IO model. Generally speaking, it takes less time and money to implement an IO model. The additional effort required to construct a CGE or EC-IO model arises from the need to specify economic agents' behavior (*i.e.*, production technology, consumer preferences, and export and import behavior), obtain or estimate the associated parameters, and then fully calibrate these relationships. Although some of these relationships have been estimated for other resource-dependent sectors, such as agriculture, they have not generally been well specified for fishery-related sectors.

## Data Issues in Economic Impact Studies of Fisheries

IMPLAN is widely used by economists for implementing regional economic models, including IO, SAM, supply-determined models, and CGE models. However, it is not advisable to use unrevised IMPLAN data for analyzing fishery industries in the U.S. for several reasons. First, IMPLAN applies national-level production functions to regional industries, including fisheries. While this assumption may not be problematic for many regional industries, use of average production relationships may not accurately depict regional harvesting and processing technologies. Therefore, to correctly specify industry production functions, it seems necessary to obtain primary data on harvesting and processing sector earnings and costs through detailed surveys. Second, the employment and earnings of many crew members in the commercial fishing sector are not included in the IMPLAN data because IMPLAN is based on state unemployment insurance program data which excludes "uncovered" employees such as self-employed and casual or part-time workers. Therefore, IMPLAN understates employment in the commercial fishing sectors. Processing sector data is also problematic stemming from the nature of the industry. Geographical separation between processing plants and company headquarters often leads to confusion as to the actual location of reported employment. Finally, fishery sector data in IMPLAN are highly aggregated. Models using aggregate data cannot estimate the potential impacts of fishery management actions on individual harvesting and processing sectors. To estimate these types of impacts, IMPLAN commercial fishery-related sectors must be disaggregated into subsectors by vessel and processor type. This requires data on employment, revenues and expenditures (intermediate inputs) by vessels and processors. Currently, collection of such data depends on voluntary reporting. However, reluctance to provide these data, primarily for business confidentiality reasons, makes it very hard to obtain useful regional economic information through a voluntary data collection program.

It is also necessary to identify the place of residence of the owners of harvesting vessels and processing facilities. The amount of net returns to capital that remain within the study region depend on the residency of these owners. For example, many of the harvesting vessels operating off Alaska are owned by residents of Washington and Oregon, so it is likely that most of the capital income earned by these vessels will leave Alaska. Similarly, the residence of crew members and processing workers needs to be identified to estimate the leakage of labor income. Some labor income will stay in the study region, since nonresident workers may spend some of their income there. However, most of nonresidents' labor income will likely leave the region. In general, it is difficult to identify the residence of economic agents using existing data. Additionally since many of the intermediate inputs used in fishery industries are imported, detailed information on regional trade flows is also needed. It is important to estimate how much of the goods and services used as intermediate inputs in fishery industries are imported from other regions. In the case of Alaska, most of the intermediate inputs used in fishery industries are imported, mainly from Washington State. If economic impacts are calculated assuming that these goods and services are supplied by local industries, then regional impacts will be significantly overestimated (Hushak 1987). Only expenditures made within the study region will generate positive economic impacts for the region.

Published regional economic data generally do not provide the detailed and reliable information needed for regional economic analysis of fisheries. The absence of important regional economic variables, and deficiencies of the data that is available have severely limited the development of regional economic fisheries models.

## Conclusion

This paper has reviewed the models used to analyze regional economic impacts resulting from fisheries activities or policies that affect fisheries and local economies. By reviewing the methods commonly employed to assess regional economic impacts, we tried to provide guidance on appropriate model choice in certain instances and point out which shortcomings, especially data deficiencies, are most crucial to overcome in developing future modeling applications.

There are important data problems associated with fishery-related IMPLAN data. These problems include: (*i*) the national-average production function used in IMPLAN may not correctly represent the production technology of fishing and seafood industries in a given region; (*ii*) IMPLAN understates employment and payroll in the harvesting sector; and (*iii*) the IMPLAN fishery sector data are too highly aggregated for detailed analysis. Two other important data issues are that it is: (*i*) important to correctly estimate what proportion of the goods and services used as intermediate inputs in seafood industries are imported from other regions, and (*ii*) necessary to correctly identify the place of residence of factor owners in the harvesting and processing sectors. Published data for these variables are not sufficiently detailed to be used for regional economic analysis of fisheries. The absence and/or deficiencies of these data have severely limited development of viable regional economic models for fisheries. Therefore, to support accurate regional economic analysis of fisheries, it is critical to have a comprehensive data collection program.

This paper also identified four important model choice issues. Model choice hinges on factors such as: (*i*) the nature of fishery management issues at hand, (*ii*) information needs of the decision-makers, (*iii*) the time and financial cost of implementing the model, and (*iv*) available data. There is no universal regional economic model that can be used for analyzing all kinds of fishery management policies. All these factors need to be weighed when choosing a model.

First, if fishery management actions involve change in supply, then demand-driven models, such as IO and SAM, may not be appropriate unless it is known by how much final demand for processed seafood will change in response to the change in harvest. In cases where the initial policy directly affects the supply of factors or resource inputs, a more theoretically sound approach is to use a CGE model. Recently developed bioeconomic models, in which the economic system interacts with elements of the natural system, may have particular promise for fisheries-related applications (*e.g.*, Finnoff and Tschirhart 2003).

Second, model choice also depends on the information needs of policymakers. If policymakers wish to know the impacts of management actions on more than one region, an interregional or multiregional model is needed. If they are interested in the detailed time path of impacts, then a single-period static model may not be adequate. In this case, a model with dynamic elements (such as a dynamic CGE or EC-IO model) may be more appropriate. However, keep in mind that developing a dynamic regional economic model requires the specification of the investment behavior of fishery-related industries and the rest of the economy, as well as the migration behavior of factors of production.

Third, the time and financial cost of implementing a model must be considered. If an analysis requires a high degree of sectoral disaggregation, developing a CGE model may have a higher computational cost than an IO model, although modern solvers and software packages are making this less of a constraint. If the choice is between an integrated NEFSC-type IO model and a two-step FEAM-type model, while the latter requires relatively less data and effort, the resulting analysis provides much less detail than can be obtained with the NEFSC-type model.

Finally, the availability of data is the most significant constraint on model development. For example, to develop an interregional model, in addition to the “core” region data needs, the modeler will need to specify interregional flows of goods and services and factors of production. To develop a CGE model, the modeler needs point estimates of the values of all parameters (elasticities) used in the model equations. Since estimates of these parameters are generally not available, it may be necessary to econometrically estimate these values, especially for the fishery-related sectors. In this way, the data requirements of the CGE model would be more like an EC-IO model, requiring extensive cross-section and or time-series data to estimate model parameters. On top of these requirements, developing a dynamic model requires the modeler to specify the investment behavior of regional industries and the rate of temporal change in labor and capital supplies. Integrated bioeconomic models not only have the same extensive data requirements as a dynamic CGE or EC-IO model, but also demand specification of the parameters of the natural capital stock (the fishery resource), and the impact of human activity on these natural dynamics. Very often these processes are only poorly understood.

In sum, while regional economic models for analysis of fisheries do exist, examples are relatively few largely because reliable data on fisheries-related economic sectors necessary to implement the models is lacking. Without reliable data obtained through a comprehensive data collection program, it will continue to be very difficult to develop viable economic models. One remedy would be to include a mandatory data collection program in the reauthorization of the MSA or its implementation standards and guidelines. In the absence of accurate information on the economic conditions facing our regional fishing fleets and processing facilities, we will continue to fall short of our obligations to maximize economic benefits of fisheries to the nation while minimizing negative impacts on fishing communities.

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