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Economic Activity Associated with the Northeast Shelf Large Marine Ecosystem: Application of an Input-Output Approach

P. Hoagland, D. Jin, E. Thunberg, and S. Steinback

ABSTRACT

The industries linked to the uses of a large marine ecosystem (LME) have a substantial influence on contiguous coastal economies. We estimate the economic activity of U.S. marine sectors associated with the Northeast Shelf LME. Our best *upper bound* estimate of total output impact is $339 billion, including a total "value-added" impact of $209 billion. Total employment impacts are estimated on the order of 3.6 million persons. The estimate of total value-added impact is approximately 10% of the $2.2 trillion total gross state product for the region. In the future, critical interactions between industrial sectors and the ecological health of the Northeast Shelf will affect economic activity in opposing ways.

INTRODUCTION

Ecosystem Valuation

Measuring the economic value[1] of a large marine ecosystem (LME) is straightforward at a conceptual level. Where an LME is defined on the basis of its relevant ecological features, its economic value is equivalent to the net present value of goods and services that flow from uses and "non-uses" of the resources and the environment. A calculation of this kind is only descriptive, and it is necessarily anthropocentric. To undertake such a calculation, one estimates the sum of consumer and producer surpluses associated with identifiable uses of the ocean, such as recreation, commercial fishing, marine transportation, or plausible non-uses, such as preservation or species protection. These surpluses must be forecasted into the future and discounted back to the present.

Although the estimation of economic value is descriptive, its purpose may be normative. Ideally, we would compare such an estimate with the economic value that obtains when uses and resources of the ecosystem are allocated differently. A comparison of the values associated with alternative feasible allocations would measure the opportunity costs of policy interventions or could be used to characterize the most economically efficient allocation.

[1]We refer here to "social value," or the value to society--not to specific firms or individuals.

In practice, ecosystem valuation can be very problematic.[2] Few studies include calculations of surpluses from specific uses of the ocean. The results of studies that make such calculations may not be readily transferable to other areas where no studies have been conducted.[3] Resource depletion, pollution, ecological interactions, or irreversibilities further complicate the valuation process. If the effects of these phenomena are lagged, it may be difficult to forecast surpluses into the future. Some species or ecosystem characteristics may be difficult to value because their services are not traded in established markets. If user costs, externalities, or non-use values are ignored, then valuations become incomplete and less useful for normative comparisons. Finally, there may be substantial sources of uncertainty about uses, their markets, and even wholesale data gaps that limit the usefulness of valuation exercises.

The Input-Output Approach

A different analytical approach to understanding the economic characteristics of an LME exists. This approach involves the use of an economic input-output model to estimate the economic activity (or "impact") of marine sectors in coastal economies. The input-output approach was developed by economists to provide a snapshot of the universe of linkages between the economic sectors of an economy. The input-output approach estimates the value of goods and services produced (*i.e*., gross revenues) in different economic sectors that are linked to a marine sector, such as commercial fishing.

It is important to understand that the input-output approach is not a substitute for the calculation of surpluses. In particular, it does not provide an estimate of net benefits. As such, input-output analysis cannot be used as a normative tool to determine an efficient pattern of resource allocations in a large marine ecosystem (*cf.* Probst and Gavrilis 1987). Moreover, the conventional input-output approach does not capture the effects of resource depletion and environmental degradation in a way that would fully reflect the costs of such phenomena to society.[4]

Although the input-output approach is not useful in making normative decisions, it does have several useful features. First, and most importantly, an input-output model gives us an understanding of the direct and indirect effects of activity in a particular sector on all other sectors from which it purchases and to which it sells goods or services. Thus we can use the model to identify patterns of transactions and to understand the economic "influence" of a large marine ecosystem on all sectors of the relevant economy to which it is linked. Second, the model quantifies this influence in terms of sectoral outputs (in dollars), employment, and other economic measures. The employment measure is important because the level of employment often is a central issue in public management debates. Third, the model may be used to explain economic growth in a region by showing how all linked sectors grow (or decline) as one sector grows (or declines).

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[2] A small body of literature on the valuation of ecosystems exists and is growing. We do not review the literature in this paper. The interested reader is referred to Bingham *et al*. (1995) for some of the central issues.

[3] The results of some recent meta-analyses have made careless transfers of benefits from small-scale, resource-specific valuation studies to large areas of the ocean. These studies often lack credibility.

[4] For example, some activities, such as responses to an oil spill, may lead to higher dollar estimates of economic impacts--even though oil spills should be regarded as involving a net loss to society.

Input-output models are used widely in regional economic impact analyses (Loomis 1993). Importantly, the input-output model can be used to estimate the economic impacts of different management alternatives. For example, the output levels and labor or supplier requirements associated with regulatory alternatives can be used as inputs to the model to estimate economic impacts such as changes in jobs (by industry), county income, or population. The input-output approach is now being developed by the US National Marine Fisheries Service to estimate the economic impacts of fisheries regulations for federally managed fisheries. A small number of studies examine the economic impact of fisheries and marine-related activities (Steinback 1999; Radtke and Davis 1998; Storey and Allen 1993; Andrews and Rossi 1986; Briggs, Townsend and Wilson 1982; Grigalunas and Ascari 1982).

In this article, we utilize the commercial software program IMPLAN Professional® (IMPLAN) and its associated data package to estimate the economic activity of marine-related industries and sectors associated with the Northeast Shelf LME. We generate state and coastal county level economic impact results for the US coastal states from Maine to North Carolina. This exercise is motivated by two considerations. First, while realizing its limits, we believe that the input-output approach currently provides one of the most practical ways to assemble essential economic information associated with a wide range of economic activities related to an LME. This quantification of economic activities could provide information useful for estimating economic value, including the identification of sectors and problems where the application of costly valuation methodologies might be worthwhile. Second, the IMPLAN data package, which combines key data from all major surveys at the federal, state, and local levels, is so far the most comprehensive database assembled for input-output analysis.

We focus on the Northeast Shelf LME. The Northeast Shelf has been the subject of several oceanographic studies, and it is thought to be a well-defined LME (see generally Sherman, Jaworski and Smayda 1996). The Northeast Shelf extends over approximately 260,000 km^2 (Figure 7-1), supporting a coastal county population of over 40 million within a coastal state population of about 71 million. There have been few attempts to quantify economic activity specifically for this LME.[5] We analyze state and coastal county level data for the Northeast Shelf to estimate associated economic activity. Because the input-output model aggregates data from many industries, it is sometimes difficult to factor out marine-related industries from aggregate industry sectors. Thus, we believe that data from coastal counties results in a better estimate of marine-related economic activity, although this estimate still may represent an upper bound.

The article is organized as follows. In the next section, we outline the input-output methodology. In the subsequent sections, we describe the data, present the results of the model runs, and provide a brief discussion of the results. In the last section, we describe limitations of the model and future research directions.

[5] One example is referred to in the prologue to Sherman, Jaworski and Smayda (1996: ix). The editors state that "[t]he coastal states from Maine to North Carolina currently realize $ 1 billion of economic benefits annually from the fisheries of the ecosystem." Note that this figure is likely to be the value of commercial fisheries landings (*i.e.*, gross sales) at that time. The figure is not really an estimate of economic "benefits," but of impacts. It is comparable to the "output impacts" figure we report below. Some other, more specific, examples include economic analyses conducted for specific fishery management plans.

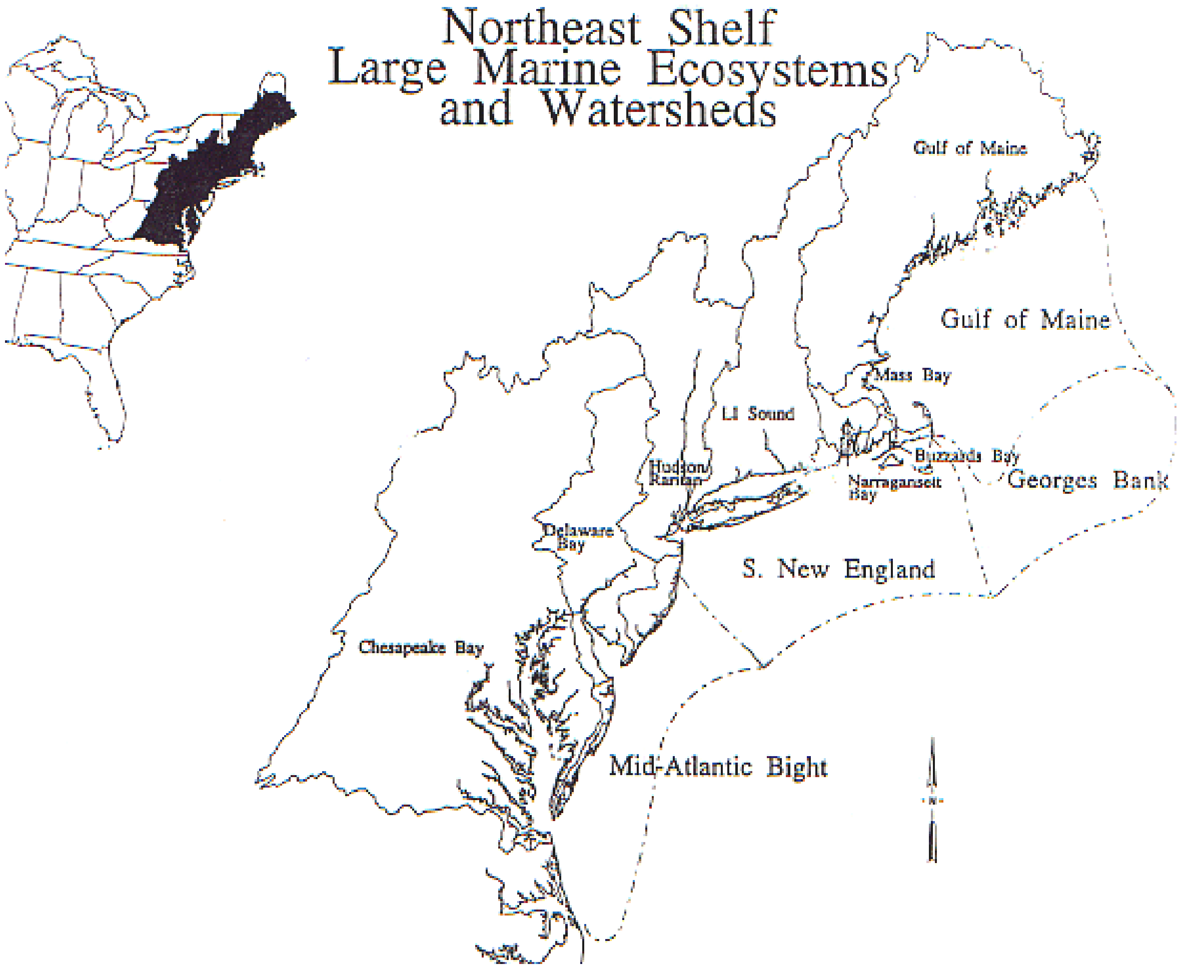

Figure 1. Northeast Shelf Ecosystem

METHODOLOGY

A static[6] Leontief input-output model is a system of linear equations:

$$(\mathbf{I} - \mathbf{A})\mathbf{X} = \mathbf{Y}$$

where **I** is a *n x n* identity matrix; **A** is a *n x n* technical coefficient (input-coefficient) matrix; **X** is a *n x 1* column vector denoting output; and **Y** is a *n x 1* column vector denoting final demand. The idea behind the model is that the output of any industry (x_i, an element of **X**) is needed as an input in many other industries, or even in that industry itself. Therefore, the correct level of x_i depends on the input requirements of all the *n* industries as well as final demand.

[6] The static analysis has its limitations, because it is not able to address when and what may happen along the adjustment process, which may take a long time to complete. Also, using a static analysis, we cannot determine whether the solution is stable. When certain additional economic considerations are incorporated into the static model, it can take on a dynamic character.

The standard input-output model is based on three assumptions: (i) each industry produces only one homogeneous commodity (broadly interpreted); (ii) each industry uses a fixed input ratio (factor combination) for production of its output; and (iii) production in every industry is subject to constant returns to scale (Chiang 1974).

The elements of **A**, a_{ij}, are called technical coefficients and are defined as:

$$a_{ij} = \frac{z_{ij}}{x_j}$$

where z_{ij} is the monetary value of the flow from sector i to sector j; and x_j is the total output of sector j.

The matrix (**I-A**) is called the technology matrix. If the technology matrix is not singular, the impact of changes in final demand (**Y**) on output (**X**) can be estimated as

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y}$$

where $(\mathbf{I}\text{-}\mathbf{A})^{-1}$ is called the Leontief inverse. For a comparative static analysis, we define

$$\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$$

and the partial derivative gives us the matrix of multipliers

$$\frac{\partial \mathbf{X}}{\partial \mathbf{Y}} = \mathbf{B}$$

For empirical analysis, an input-output table (transactions table) includes all processing sectors (industries), final demand (including consumer/household purchases, private investment, government purchases, and exports), and the payments sector (value added including labor cost, capital cost, taxes, rental payments, and profit). Total industry outlays equal the value of total industry outputs. Outlays are payments made by firms for inputs and for other purposes in the payments sector. Inputs are purchased locally (within the region) or imported from outside the region.[7] Outputs are goods or services produced by the industry. They can be consumed directly by households and others as final demand within the region, or sold to other industries as intermediate demand.

The major advantage of the input-output model is its explicit capture of all the linkages in an economy. For example, suppose a fisheries management option requires a reduction of the number of fishing vessels in a fleet. This exit of vessels leads to a decline in the local fishing industry. To capture the full effect of an industry decline on the regional economy, we need to quantify the importance of the industry to the region. Fisheries contribute to employment and household incomes. Port buildings and equipment also provide a basis for tax revenues that support local and state government programs. Further, as purchasers of inputs, the fishing industry supports a number of other industries such as boat building and repairs. When all the

[7] For accurate estimations of regional economic impacts, one must carefully separate the local portion from the imported portion in every purchase/payment.

linkages within the economy are considered, income and employment generated by the fishing industry have ripple effects on the overall income and employment of the region.

Specifically, an industry's contribution to the overall regional economy consists of three components: direct, indirect, and induced effects. In the case of fisheries, if a vessel is taken out of service, the associated lost jobs and income are the direct effects. Indirect effects are additional jobs and income lost in other industries, such as boat repairing, that can be indirectly credited to the lost vessel. The more inputs produced and purchased within the region, the greater the magnitude of the indirect effect. Finally, lost jobs mean lower household income or a smaller number of households in the region. Lower income leads to reduced spending on food, housing, and cars. The latter are induced effects.

Using input-output analysis, we can compute multipliers[8] for a specific industry (*e.g.*, commercial fishing). The multipliers predict changes in regional output, income, value added, and employment[9] in each industry from a given change in its final demand.[10] Because neither environmental quality nor resource stocks have been included as data in the model, the specific impact of a change in final demand on these aspects cannot be quantified. Further, the static input-output model generates only annual economic impacts rather than a discounted sum of future impacts.

Development of an input-output model from primary data is a substantial undertaking. In most cases, management agencies do not have the resources needed to develop survey-based input-output models for a local economy. Instead, they adapt existing models to their purposes. A number of ready-made regional input-output models have been developed to perform economic impact analyses (Brucker *et al.* 1990). The best known is a software package for personal computers, IMPLAN.

IMPLAN was developed at the U.S. National Forest Service (Alward, and Palmer 1983). It is a modular input-output model that works down to the individual county level for any county in the United States.[11] The IMPLAN database consists of two major parts: (1) a national-level technology matrix and (2) estimates of sectoral activity for final demand, final payments, gross output, and employment for each county. This 528-sector (based on 4-digit SIC codes), gross-domestic-based model was derived from the Commerce Department's national input-output studies. In IMPLAN, national average technology coefficients are used to develop the direct coefficients for sectors at the local level (Loomis 1993; Minnesota IMPLAN Group 1997). IMPLAN data can be used as an initial set of technological relationships among regional industry sectors. The system allows the input-output model to be modified with better information (Minnesota IMPLAN Group 1997).

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[8] There are two types of multipliers. Type I multipliers capture direct and indirect effects; Type II capture direct, indirect and induced effects. The calculation of the Type II multipliers are realized by including households as a "processing sector."

[9] The employment multiplier is usually calculated using a direct employment coefficient that reflects the number of workers per dollar of output delivered to final demand.

[10] More specifically, we focus on the demand for output from within the region, excluding imports.

[11] The latest version of IMPLAN Pro allows input-output analysis at the national, state, county, or zip-code level.

DATA

A specific definition of the marine sector is provided by Pontecorvo *et al.* (1980) in their classic study of the contribution of the marine sector to the U.S. economy. In that study, the marine sector is defined to include those establishments in the national income accounting system that either utilize an ocean resource in a productive process, or exist because the demand for the establishment's final output is due to some attribute of the ocean. The 1980 study was updated for 1987 (Pontecorvo 1989).

We follow the Pontecorvo *et al.* approach in developing estimates of the impact of marine industries using the IMPLAN model. IMPLAN generates estimates of "value-added" effects that are directly comparable to the Pontecorvo *et al.* analysis, and we make such a comparison below. In addition to value-added, IMPLAN generates estimates of indirect and induced effects that were not estimated by Pontecorvo *et al*.

Using the IMPLAN database, we first divide the overall "marine sector" into six broad industry groups: fisheries, shipbuilding, shipping, water quality, tourism, and real estate. Several sectors in the IMPLAN database fall into these broad industry groups. These sectors are listed in Table 7-1, along with their corresponding IMPLAN sector codes.

The IMPLAN database has been constructed from several federal government databases. Each IMPLAN sector comprises data corresponding to one or more standard industrial classification (SIC) codes, which are the codes applied by the US Bureau of Economic Analysis to identify specific industrial sectors. Some of the IMPLAN sectors provide direct evidence of economic activity associated with the marine environment. These sectors include commercial fishing and processing, ship and boat building and repairing, and water transportation. We describe these sectors as the "primary tier," and we list the associated IMPLAN and SIC codes in Table 7-1.

We identify as "secondary tier" sectors all other industries that are arguably marine-related. These include IMPLAN sectors that combine marine-related SIC industries with non-marine industries, such as miscellaneous livestock (includes aquaculture), fishery services (includes fish hatcheries), and amusement and recreation services (includes public beaches, headboats, and scuba diving). In addition, we include cases in which SIC sectors combine both marine and non-marine industries. For example, SIC 7999 (amusement and recreation services, not elsewhere classified) includes a large number of small industries, only some of which are marine-related.[12] SIC sector 3812 (IMPLAN sector 400), search and navigation equipment, includes the manufacture of aeronautical, space, and defense equipment as well as marine equipment. Finally, some IMPLAN sectors are marine-related only when they are located in the coastal zone, such as water supply and sewerage systems, eating and drinking, hotels and lodging places, and real estate.

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[12] Many of these industries may operate primarily in fresh-water environments. The relevant industries in SIC 7999 include: bath houses (independently operated), public bathing beaches, pleasure boat rentals, operation of party fishing boats, operation of fishing piers and lakes, houseboat rentals, lifeguard services, rental of beach chairs and accessories, rentals of rowboats and canoes, scuba and skin diving instruction, and swimming instruction. There is no clear way to separate out the marine component from these industries. In this report, we assume that they are marine-related.

Table 7-1: Broad Marine Industries and IMPLAN Sectors

BROAD INDUSTRY	TIER	IMPLAN SECTOR	IMPLAN CODE	SIC CODES	RELEVANT SUB-SECTOR
Fisheries	1°	Commercial Fishing	25	0912, 0913, 0919	
		Canned and Cured Seafoods	97	2091	
		Prepared Fresh or Frozen Fish and Seafoods	98	2092	
	2°	Miscellaneous Livestock	9	0273, others	Aquaculture
		Agricultural, Forestry, Fishery Services	26	0921, others	Fish Hatcheries
Shipbuilding	1°	Ship Building and Repairing	392	3731	
		Boat Building and Repairing	393	3732	
	2°	Search and Navigation Equipment	400	3812	
Shipping	1°	Water Transportation	436	4400	
Water Quality	2°	Water Supply and Sewerage Systems	445	4941, 4952	
Tourism	2°	Eating and Drinking	454	5800	
		Hotels and Lodging Places	463	7000	
		Amusement and Recreation Services	488	7999, others	Beaches, Headboats, Scuba
Real Estate	2°	Real Estate	462	6500	

We conduct the analysis at the state and coastal county levels. The state level analysis estimates economic activity associated with the Northeast Shelf LME using state data for Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, the District of Columbia, Virginia, and North Carolina. The coastal county level analysis focuses on economic activity using coastal county data for these same states. Coastal counties (Table 7-2) are those counties whose populations are used by NOAA to calculate funding under section 306 of the Coastal Zone Management Act (Uravitch 1998).

We expect that the use of coastal county data for the states bordering the Northeast Shelf LME provides a better estimate of economic activity associated with the marine ecosystem. Including the entire secondary tier in a state-level analysis of the marine-related economic activity associated with the Northeast Shelf LME clearly results in an overestimate of that activity. However, it is not simple or straightforward to separate the marine-related component from the more general IMPLAN second tier industry sectors. We handle this issue by running the IMPLAN model for (i) both tiers together and (ii) only the primary tier. This gives us upper and lower bounds on our estimate of economic activity.

Table 7-2: Coastal Counties, Population and Area (mi^2)

State Name	County Name	Population	Area
MAINE	CUMBERLAND	248855	836
	HANCOCK	49386	1589
	KENNEBEC	116945	867
	KNOX	37269	366
	LINCOLN	31423	456
	PENOBSCOT	145529	3396
	SAGADAHOC	34150	254
	WALDO	35454	730
	WASHINGTON	36229	2569
	YORK	169348	991
NEW HAMPSHIRE	ROCKINGHAM	258150	695
	STRAFFORD	106368	369
MASSACHUSETTS	BARNSTABLE	199232	396
	BRISTOL	513150	556
	DUKES	12821	104
	ESSEX	682232	498
	MIDDLESEX	1405798	824
	NANTUCKET	7034	48
	NORFOLK	633992	400
	PLYMOUTH	452773	661
	SUFFOLK	647570	59
RHODE ISLAND	BRISTOL	49122	25
	KENT	162326	170
	NEWPORT	82474	104
	PROVIDENCE	580784	413
	WASHINGTON	116995	333
CONNECTICUT	FAIRFIELD	830702	626
	MIDDLESEX	147306	369
	NEW HAVEN	795485	606
	NEW LONDON	250227	666
NEW YORK	ALBANY	297980	524
	BRONX	1196046	42
	COLUMBIA	63731	636
	DUTCHESS	261512	802
	GREENE	47446	648
	KINGS	2280493	71
	NEW YORK	1525387	28
	NASSAU	1303231	287
	ORANGE	322349	816
	PUTNAM	90138	232
	QUEENS	1974383	109
	RENSSELAER	155322	654
	RICHMOND	396748	59
	ROCKLAND	277034	174
	SUFFOLK	1351843	911
	ULSTER	167223	1127
	WESTCHESTER	891044	433
NEW JERSEY	ATLANTIC	233634	561
	BERGEN	843338	234
	BURLINGTON	407931	805
	CAMDEN	507089	222
	CAPE MAY	98133	255

State Name	County Name	Population	Area
	CUMBERLAND	137748	489
	ESSEX	760615	126
	GLOUCESTER	242924	325
	HUDSON	551198	47
	MERCER	330038	226
	MIDDLESEX	698029	311
	MONMOUTH	585218	472
	OCEAN	466142	636
	PASSAIC	463558	185
	SALEM	65226	338
	SOMERSET	265158	305
	UNION	496735	103
PENNSYLVANIA	BUCKS	573130	608
	DELAWARE	548043	184
	PHILADELPHIA	1499762	135
DELAWARE	KENT	121234	591
	NEW CASTLE	467755	426
	SUSSEX	128052	938
MARYLAND	ANNE ARUNDEL	461981	416
	BALTIMORE	714495	599
	CALVERT	64521	215
	CAROLINE	28983	320
	CECIL	78317	348
	CHARLES	111626	461
	DORCHESTER	29912	558
	HARFORD	205499	440
	KENT	18816	279
	PRINCE GEORGE'S	767006	486
	QUEEN ANNE'S	36876	372
	ST. MARY'S	80984	361
	SOMERSET	24268	327
	TALBOT	32411	269
	WICOMICO	79122	377
	WORCESTER	40101	473
	BALTIMORE CITY	689432	81
WASHINGTON D.C.	WASHINGTON	554528	61
VIRGINIA	ACCOMACK	32123	455
	ARLINGTON	175035	26
	CAROLINE	21083	533
	CHARLES CITY	6786	182
	CHESTERFIELD	239371	426
	ESSEX	9250	258
	FAIRFAX	889015	396
	HANOVER	74716	473
	GLOUCESTER	33250	217
	HENRICO	232176	238
	ISLE OF WIGHT	27839	316
	JAMES CITY	40478	143
	KING GEORGE	16357	180
	KING AND QUEEN	6417	316
	KING WILLIAM	12170	275
	LANCASTER	11267	133
	MATHEWS	8824	86
	MIDDLESEX	9330	130
	NEW KENT	11673	210
	NORTHAMPTON	12979	207

State Name	County Name	Population	Area
	NORTHUMBERLAND	11151	192
	PRINCE GEORGE	28270	266
	PRINCE WILLIAM	243458	338
	RICHMOND	8475	191
	SPOTSYLVANIA	71806	401
	STAFFORD	79921	270
	SURRY	6412	279
	WESTMORELAND	16492	229
	YORK	53891	106
	ALEXANDRIA	115838	15
	CHESAPEAKE	187904	341
	COLONIAL HEIGHTS	16916	7
	FREDERICKSBURG	21899	11
	HAMPTON	138783	52
	HOPEWELL	22458	10
	NEWPORT NEWS	179163	68
	NORFOLK	236129	54
	PETERSBURG	37704	23
	POQUOSON	11680	16
	PORTSMOUTH	102100	33
	RICHMOND	197744	60
	SUFFOLK	56655	400
	VIRGINIA BEACH	429760	248
	WILLIAMSBURG	12642	9
NORTH CAROLINA	BEAUFORT	43998	828
	BERTIE	20745	699
	BRUNSWICK	60697	855
	CAMDEN	6399	241
	CARTERET	57690	531
	CHOWAN	13958	173
	CRAVEN	85163	696
	CURRITUCK	16285	262
	DARE	26074	382
	GATES	9784	341
	HERTFORD	22555	354
	HYDE	5362	613
	NEW HANOVER	139906	199
	ONSLOW	144259	767
	PAMLICO	12064	337
	PASQUOTANK	33759	227
	PENDER	35208	871
	PERQUIMANS	10737	247
	TYRRELL	3846	390
	WASHINGTON	14138	348

RESULTS

Table 7-3 presents the results from the state-level run for the Northeast Shelf LME. Both annual industrial output (1995 $ millions) and employment (thousands of employees) are shown across all industrial sectors. Industry output is the value of an industry's total production, which includes purchases by all other industries, and by consumers and government agencies for final demand

and exports. Both output and employment for these industries represent between 9 and 10 percent of their respective total economy levels in the region. Although not shown explicitly in Table 7-3, for the *primary tier* marine industries *only*, both output and employment represent less than one-half of one percent of their respective state economy totals.

Table 7-3. Northeast Shelf LME: State Level Sectoral Output, Employment, and Type II Multipliers

BROAD INDUSTRY	TIER	IMPLAN SECTOR	OUTPUT†	TYPE II MULT	EMPLOY-MENT‡	TYPE II MULT
Fisheries	1°	Commercial Fishing	880	1.87	19	1.46
		Canned and Cured Seafoods	236	1.65	2	1.76
		Prepared Fresh or Frozen Fish and Seafoods	1,294	1.63	9	2.29
	2°	Miscellaneous Livestock	638	1.64	29	1.18
		Agricultural, Forestry, Fishery Services	1,961	1.78	71	1.27
Shipbuilding	1°	Ship Building and Repairing	4,952	1.87	51	2.00
		Boat Building and Repairing	932	2.00	9	2.08
	2°	Search and Navigation Equipment	10,013	1.97	53	3.02
Shipping	1°	Water Transportation	9,394	1.95	45	3.22
Water Quality	2°	Water Supply and Sewerage Systems	1,474	1.85	7	3.22
Tourism	2°	Eating and Drinking	67,875	1.92	1,905	1.37
		Hotels and Lodging Places	26,869	1.91	427	1.73
		Amusement and Recreation Services	8,439	1.91	278	1.34
Real Estate	2°	Real Estate	200,665	1.52	927	2.36
TOTALS			335,622		3,832	
% of State Total			9.25%		9.44%	

† $U.S. millions (1995)
‡Thousands of employees

In Table 7-3, we show also the "Type II" multipliers for output and employment for each industry. Type II multipliers measure the effect of changes in final demand[13] for one industry on output in

[13] Final demand represents purchases by end users (consumers or firms), government agencies, and exports for consumption. Once final consumption occurs, goods and services disappear from the economy and are not available to generate further output. Final demand is *not* shown in the tables in this article.

all other linked industries and on the income of people employed in those industries. For example, for each $1.00 of final demand for boat building and repairing, $2.00 in industrial output and household income is generated in the Northeast Shelf LME "economic region." Employment multipliers are interpreted in much the same way. For example, each job in water transportation generates about three (3.22) jobs in the regional economy.

We present in Table 7-4 the same type of information as Table 7-3, focusing on the coastal county levels for the Northeast Shelf LME. Output and employment are reported in the same terms. Coastal county level output and employment are around 10 percent of the total for the coastal counties. Although not shown explicitly in Table 7-4, the primary tier output (0.7%) and employment (0.5%) percentages of the total coastal counties-level economy are fairly low.

The Type II multipliers for sectoral output are all in the same general range (between 1.48 and 2.00). There appears to be little difference between the state and coastal county level multipliers. At the coastal county level, the water transportation, search and navigation equipment, amusement and recreation, commercial fishing, and hotel and lodging place sectors have the largest output multipliers. Real estate has the lowest multiplier. At the county level, water supply and sewerage, water transportation, and search and navigation equipment have the largest employment multipliers. The miscellaneous livestock, amusement and recreation services, and eating and drinking sectors have the smallest multipliers.

Because multipliers are important for impact analyses, one must be careful not to misinterpret them. The Type II multipliers reported in Table 7-3 and Table 7-4 may be used directly to generate total impacts in a regional economy when changes in final demands are strictly limited to products made within the region. While this use is appropriate when we assess the contribution of an industry to the regional economy, an adjustment must be made to the multipliers when one wants to estimate the impact associated with changes in final demands for *local* as well as *imported* products. Generally, to assess the impact of an increase in final demand in a region, one must adjust the multiplier with a regional purchase coefficient (RPC) that reflects the percentage of demand met by local producers. The balance is provided by imports.[14] If the RPC is not applied, the total impacts will be exaggerated.

Table 7-5 presents county output and employment as a percent of state output and employment. Note that the primary tier industries exceed 80 percent of the state levels in all cases except for boat building and repairing (which is close at 79% of output; 78% of employment). This result suggests that, at the *state level*, the primary tier industries provide a good estimate of economic activity, but only for the primary tier industries. Among the secondary tier industries, coastal county outputs for all other sectors, except for miscellaneous livestock (39%), represent more than 50 percent of the state outputs. This result implies that, while these sectors are important contributors to economic activity associated with the Northeast Shelf LME, including the second tier industries in a state level analysis results in an overestimate of the influence of the Gulf of Maine ecosystem on the region.

[14] For example, if the change in demand is $1 million, the Type II multiplier is 2.00, and the RPC is 0.75, then the adjusted multiplier is 1.50 (0.75 times 2.00), and the impact on the local economy is $1.5 million (not $2 million).

Table 7-4: Northeast Shelf LME: Coastal County Level Sectoral Output, Employment, and Type II Multipliers

BROAD INDUSTRY	TIER	IMPLAN SECTOR	OUTPUT†	TYPE II MULT	EMPLOYMENT ‡	TYPE II MULT
Fisheries	1°	Commercial Fishing	855	1.83	18	1.42
		Canned and Cured Seafoods	234	1.65	2	1.73
		Prepared Fresh or Frozen Fish and Seafoods	1,187	1.61	8	2.18
	2°	Miscellaneous Livestock	250	1.53	11	1.14
		Agricultural, Forestry, Fishery Services	1,457	1.68	45	1.27
Shipbuilding	1°	Ship Building and Repairing	4,872	1.77	50	1.86
		Boat Building and Repairing	735	1.71	7	1.79
	2°	Search and Navigation Equipment	6,554	1.85	35	2.71
Shipping	1°	Water Transportation	7,694	1.96	37	3.12
Water Quality	2°	Water Supply and Sewerage Systems	878	1.78	4	3.23
Tourism	2°	Eating and Drinking	38,993	1.80	1,042	1.33
		Hotels and Lodging Places	18,563	1.83	265	1.71
		Amusement and Recreation Services	5,413	1.84	171	1.31
Real Estate	2°	Real Estate	146,250	1.48	619	2.30
TOTALS			233,935		2,314	
% of Coastal County Total			10.65%		9.81%	

† $U.S. millions (1995)
‡ Thousands of employees

Table 7-5: Northeast Shelf LME: Coastal County Level Sectoral Output and Employment as a % of State Level

BROAD INDUSTRY	TIER	IMPLAN SECTOR	OUTPUT†	EMPLOY-MENT‡
Fisheries	1°	Commercial Fishing	97	95
		Canned and Cured Seafoods	99	100
		Prepared Fresh or Frozen Fish and Seafoods	92	89
	2°	Miscellaneous Livestock	39	38
		Agricultural, Forestry, Fishery Services	74	63
Shipbuilding	1°	Ship Building and Repairing	98	98
		Boat Building and Repairing	79	78
	2°	Search and Navigation Equipment	65	66
Shipping	1°	Water Transportation	82	82
Water Quality	2°	Water Supply and Sewerage Systems	60	57
Tourism	2°	Eating and Drinking	57	55
		Hotels and Lodging Places	69	62
		Amusement and Recreation Services	64	62
Real Estate	2°	Real Estate	73	67

† $U.S. millions (1995)
‡Thousands of employees

We present in Table 7-6 the state-level output and employment impacts for the Northeast Shelf LME. These estimates are broken down into direct, indirect, and induced impacts.[15] Our upper bound estimate (primary and secondary tiers) of the marine-related economic activity due to the LME is $507 billion, employing 5.9 million persons. Our lower bound estimate (primary tier only) is $31 billion, employing 296 thousand. We examine too the impacts that result from broad industry groupings (including both tiers, where applicable). For example, the fisheries industry group has an $8 billion impact, employing 170,000 persons.

[15] Since industry sectors (*e.g.*, fishing and seafood processing) are linked in an input-output model, there would be a problem of double counting which leads to over-estimating the indirect and induced impacts, when we calculate multi-sector cumulative impact. To avoid double counting, we cut the linkages among sectors in a specific industry group by setting RPC = 0 for these sectors using IMPLAN editing functions. We construct separate models for each of the five sector groups (*e.g.*, Fisheries) shown in tables 6, 7, 9, and 10.

Table 7-6: Northeast Shelf LME: State Level Output and Employment Impacts Ascribed to Aggregated Marine Sectors

	OUTPUT IMPACT†				EMPLOYMENT IMPACT‡			
	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total
Tiers 1&2	335,621	94,510	77,263	507,394	3,834	1,112	984	5,929
Tier 1	17,687	5,863	7,380	30,931	135	64	96	296
Fisheries*	5,009	1,150	2,249	8,407	130	11	29	170
Ship-building* & Shipping	25,290	9,695	11,585	46,570	159	97	151	406
Water Quality, Tourism & Real Estate	305,322	85,086	66,728	457,136	3,545	1,018	849	5,413

† $U.S. millions (1995)
‡Thousands of employees
*Includes tiers 1 and 2

In Table 7-7, we present the same kind of information as in Table 7-6, focusing on coastal county impacts. Our upper bound estimate (primary and secondary tiers) of the marine-related economic activity in coastal counties due to the LME is $339 billion, employing 3.6 million persons. Our lower bound estimate (primary tier only) is $26 billion, employing 245,000 persons. The fisheries sector represents about $6 billion in output impacts at the coastal county level, with 112,000 employees.

Table 7-8 examines the coastal county output and employment impacts as a percent of the state level impacts. Again, the tier 1 coastal county impacts are a large proportion of the state level impacts. The combined water quality, tourism, and real estate sectors have the smallest percentages.

In Table 7-9 and Table 7-10, we present the state and coastal county level *value-added* estimates. These tables are organized exactly like those preceding, showing direct, indirect, induced, and total value-added impacts. In the IMPLAN model, total value-added is defined as industry output less the sum of inter-industry sales and imports, [16] and it is equivalent to the measure used to estimate gross state product (GSP). Thus the last columns in Table 7-9 and Table 7-10 can be used to compare to the estimate of GSP for the region (about $2.2 trillion in 1995). The total for tiers 1 and 2 can be thought of as an upper bound on marine-related value-added, and the total for tier 1 only can be thought of as a lower bound. Table 7-11 shows coastal county value-added impacts as a percentage of state level impacts.

[16] Value-added includes employment compensation, proprietary income, other property type income, and business taxes.

Table 7-7: Northeast Shelf LME: Coastal County Level Output and Employment Impacts Ascribed to Aggregated Marine Sectors

	OUTPUT IMPACT†				EMPLOYMENT IMPACT‡			
	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total
Tiers 1&2	233,935	58,662	46,599	339,196	2,313	679	569	3,561
Tier 1	15,577	4,656	5,878	26,110	123	49	74	245
Fisheries*	3,983	886	1,566	6,435	84	8	20	112
Shipbuilding* & Shipping	19,855	6,639	8,093	34,587	129	65	101	295
Water Quality, Tourism & Real Estate	210,096	52,172	39,192	301,461	2,100	615	478	3,193

† $U.S. millions (1995)
‡Thousands of employees
*Includes tiers 1 and 2

Table 7-8: Northeast Shelf LME: Coastal County Level Output and Employment Impacts as a % of State Level Impacts

	OUTPUT IMPACT (%)				EMPLOYMENT IMPACT (%)			
	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total
Tiers 1&2	70	62	60	67	60	61	58	60
Tier 1	88	79	80	84	91	77	77	83
Fisheries*	80	77	70	77	65	73	69	66
Shipbuilding* & Shipping	79	68	70	74	81	67	67	73
Water Quality, Tourism & Real Estate	69	61	59	66	59	60	56	59

*Includes tiers 1 and 2

Table 7- 9: Northeast Shelf LME: State Level Value-Added Impacts Ascribed to Aggregated Marine Sectors

	VALUE-ADDED IMPACT†			
	Direct	Indirect	Induced	Total
Tiers 1&2	204,802	53,541	48,848	307,192
Tier 1	6,548	3,375	4,609	14,532
Fisheries*	2,712	614	1,403	4,729
Shipbuilding* & Shipping	9,480	5,445	7,234	22,159
Water Quality, Tourism & Real Estate	192,610	48,285	42,127	283,022

† $U.S. millions (1995)
*Includes tiers 1 and 2

Table 7-10: Northeast Shelf LME: Coastal County Level Value-Added Impacts Ascribed to Aggregated Marine Sectors

	VALUE-ADDED IMPACT†			
	Direct	Indirect	Induced	Total
Tiers 1&2	144,536	34,611	30,005	209,151
Tier 1	5,966	2,755	3,741	12,462
Fisheries*	2,115	480	995	3,590
Shipbuilding* & Shipping	7,630	3,878	5,150	16,658
Water Quality, Tourism & Real Estate	134,791	30,852	25,188	190,831

† $U.S. millions (1995)
*Includes tiers 1 and 2

Table 7-11: Northeast Shelf LME: Coastal County Level Value-Added Impacts Ascribed to Aggregated Marine Sectors as a % of State Level Impacts

	VALUE-ADDED IMPACT†			
	Direct	Indirect	Induced	Total
Tiers 1&2	71	65	61	68
Tier 1	91	82	81	86
Fisheries*	78	78	71	76
Shipbuilding* & Shipping	80	71	71	75
Water Quality, Tourism & Real Estate	70	64	60	67

† $U.S. millions (1995)
*Includes tiers 1 and 2

DISCUSSION

The industries that are directly related to the use of the Northeast Shelf LME and its resources have a substantial influence on the economies of the states of New England and the mid-Atlantic. Coastal county level data are more useful than state level data to estimate the regional economic influence of the marine environment. Our best upper bound estimates for economic activities associated with the Northeast Shelf LME are $339 billion in total output impacts, 3.6 million persons, and $209 billion in value-added impacts. This latter estimate is 9.5% of the total GSP for the coastal states ($2.2 trillion in 1995).[17] A lower bound estimate, using value-added impacts from the first tier only, is less than one percent of the total GSP for the region.

[17] Gross *county* product (GCP) for the counties bordering the Northeast Shelf LME is $1.4 trillion. Our upper bound estimate is 14.9% of GCP.

Our upper bound estimate is considerably larger than the Pontecorvo (1987) estimate (2.6%) of the ocean sector as a percentage of total industry contribution to GNP at the national level. There are at least three reasons for this discrepancy. First, the IMPLAN sectors include some SIC sectors that arguably are non-marine. Inclusion of these sectors would inflate our estimate relative to that obtained by Pontecorvo *et al*.[18] However, examination of coastal county level data should ameliorate this problem, because second tier industries are more likely to have a marine connection when located in coastal counties. Second, Pontecorvo *et al*. estimate marine production as a direct value-added impact. Our upper bound direct value-added impact (Table 7-10) is $145 billion, accounting for roughly 6.5 percent of the regional GSP. Third, Pontecorvo *et al*. examine marine-related production as a proportion of national value-added. National value-added necessarily includes production from industries in areas of the country that have no marine connections, thereby reducing the relative marine contribution. We would expect to find a higher proportion of marine-related value-added in coastal states. The true level of economic activity probably lies somewhere in between our estimate and that of Pontecorvo *et al*. Further research, involving the disaggregation of both IMPLAN and SIC sectors, is required to resolve this issue.

Fisheries are often thought to be the most important use of the marine environment. However, our estimates show that, including the secondary tier industries, fisheries account for only 2 percent of total output impacts, 3 percent of employment impacts, and 2 percent of value-added impacts. Note also that seafood processing, defined here to be a tier 1 industry sector, may involve significant amounts of imports when local fish stocks are overexploited. Although the processing activity itself generates important economic impacts, if the fish being processed do not derive from the Northeast Shelf LME, then it is inappropriate to attribute those impacts to the LME. More work needs to be done to discover what proportion of the New England and mid-Atlantic processing sector depends specifically upon the Northeast Shelf.

Shipbuilding and shipping represent about 10 percent of total output impacts, 8 percent of employment impacts, and 8 percent of value-added impacts. This grouping represents important industries that are almost completely reliant[19] upon the existence of the ocean as an economical transportation medium. It is important to note, however, that the reliance of these industries upon an ecosystem, per se, is more tenuous. In fact, the growth of the shipping and shipbuilding industries may be limited because of interactions with the ecosystem. For example, the occurrence of oil and hazardous waste spills, waste disposal, transport of non-indigenous species, and ship strikes of marine mammals, among others have all contributed to the development of a more stringent regulatory environment. While many of these regulations are worthwhile and act to protect important ecosystem features, they may limit the potential economic impacts from this industry sector. In future work, it will be important to identify those industry sectors that contribute to marine environmental protection vis-à-vis the shipbuilding and shipping sectors,

[18] Note that Pontecorvo *et al*. (1980) include additional sectors, such as offshore oil and gas and naval expenditures, that are not included in our analysis. Removal of these sectors from the Pontecorvo *et al*. model would lower their estimate of the contribution of the marine sector to the national economy.

[19] Note that only the marine component of the search and navigation equipment sector depends upon the adjacent LME. However, even if we are able to disaggregate the marine business from this sector, it would represent an overestimate of economic activity associated with the Northeast Shelf LME because some of the manufactures are sold to firms or consumers operating in regions other than the Northeast Shelf.

such as oil spill prevention or electronic charting.[20] Of course, the recreational boating industry is dependent upon a healthy ecosystem.

Most impacts occur in the water quality, tourism and real estate sectors: 89 percent of output impacts, 90 percent of employment impacts, and 91 percent of value added impacts. These industry groupings are all second tier. The tourism industries tend to aggregate many different kinds of activities, and it is difficult to separate those activities that are distinctly marine-related from those that are not. However, a case can be made that the marine environment and its associated coastal zone represent important attributes of a multifaceted tourism "experience," whose output and employment impacts would be much diminished in their absence. Nevertheless, more work needs to be done to identify the components of these industries that are directly related to the marine environment. Water quality and real estate are much easier to categorize as primary tier industries when located in the coastal zone.

In the future, critical interactions between industrial sectors and the ecological health of the Northeast Shelf will affect associated economic activity in opposing ways. A better managed and healthier large marine ecosystem leads to higher levels of output, value added, and employment impacts in industries such as fisheries, tourism, boat building, water quality, and real estate. On the other hand, actions taken to improve the health of the ecosystem may limit the growth of the shipbuilding and shipping sectors. A possible restriction on the disposal of dredged materials from New York Harbor is an excellent case in point. Too, restrictions imposed on the commercial fishing industry may limit or reduce output and employment from that sector—at least until stocks recover. These interactions and the range of possible effects on economic activity in the Northeast Shelf region need to be examined more closely in future efforts.

LIMITATION OF THE MODEL AND FUTURE RESEARCH

In this paper, we have presented a positive description of the economic activities associated with the Northeast Shelf LME. Although the information generated from the IMPLAN model can be useful for policymakers in understanding the economic impacts of marine-related sectors on the coastal economy, due to a number of limitations, the model is not directly useful for making ecosystem management decisions. Instead, we believe the model could be an important building block for the development of an integrated ecological-economic analytical framework.

As noted, a major limitation of a conventional input-output model (*e.g.*, IMPLAN) is its exclusion of the effects of environmental degradation and resource depletion. In order to address this issue, economists have taken some initial steps toward expanding the input-output model by including environmental sectors explicitly (Leontief 1970). Progress in developing resource and environmental accounting and some important issues have been summarized in recent work by Nordhaus and Kokkenlenberg (1999).

Other limitations of the input-output approach relate to its underlying assumptions. For example, naive impact analyses assume that labor and resources have no alternative uses. An increase in factor demand will be met by local supplies or imports at fixed costs (*e.g.*, wage rate is constant).

[20] We expect that many of these sectors are already embedded in the shipbuilding and shipping industries.

However, with full employment, an increase in wage payments and an increase in output in one sector comes largely at the cost of relative reductions in wages and output in other sectors.

Finally, conventional input-output models are static and deterministic. However, ecosystem management involves decision-making under uncertainty and possibly irreversibility (Chavas 2000) and in a dynamic context (*e.g.*, inter-temporal resource allocation). For example, the economic benefits of resource conservation efforts may not be realized all at once. The selection of a discount rate may be critical in comparing benefits and costs in different periods (Starrett 2000).

For LME management, there exists a need for development of an integrated economic-ecological framework (Arrow *et al*. 1995). Such a framework would extend the traditional bioeconomic approach (Clark 1990). It would consist of two major components that model, respectively, the economic system and the ecosystem. It should capture two general types of linkages between the two systems. The first linkage represents the supply of ecosystem resources, goods, and services to a coastal economy (*e.g.,* fish stocks as inputs to the fish harvesting industry), and the second describes the impacts of economic activities on the ecosystem (*e.g.,* marine pollution, bycatch, and destruction of fish habitat).

The integrated model could be designed to be used to describe existing economic and ecological conditions and to demonstrate the potential wealth to society that may be derived from the consumption of marine resources, goods, and services associated with a well-managed marine ecosystem (*cf.,* Edwards and Murawski 1993). The model could be useful for assessing the change in wealth associated with changes in the quality and quantity of natural and environmental resources in the ecosystem. Further, the integrated model would be useful for exploring a variety of policy-relevant research questions. For example, a change in final demand for the output of a particular industry could be traced back to determine its impact on the structure of the ecosystem. On the other hand, a change in the structure of the ecosystem could be followed through to determine its economic impacts. Because there may be more than one feasible ecosystem state, the economic impacts of alternative states might be compared.

Although the concept of a dynamic general equilibrium model is clear, it is difficult to construct such a model to capture the many interactions between ecological and economic systems. Most classical bioeconomic models involve the dynamic control of nonlinear biosystems (see Clark 1990). Because of complexity, these models include a small number of variables (*e.g.,* biomass and either fishery yield or fishing effort). Starrett (2000) has argued that we are still far away from the capability of constructing a dynamic general equilibrium model, much less analyzing it.

Realizing the tradeoff between the number of variables and nonlinear dynamics in modeling, we believe an interesting area for future research is to explore the possibility of merging a regional input-output model of a coastal economy with a model of a marine food web (*viz*. Jin *et al.* 2003). This type of analysis reprises the seminal work conducted by Walter Isard and his colleagues more than three decades ago (Isard *et al*. 1968). It makes sense to revisit this approach now because of the improved input-output framework (*e.g.*, the IMPLAN model) and the development of marine ecosystem models for New England. Given these developments, creating a linear version of the integrated economic-ecological model enhances the potential for making sound public policy decisions, and could serve as a foundation for the development of dynamic analysis.

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