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TECHNICAL ARTICLE

Short-term economic impacts of ecological restoration in estuarine and coastal environments: a case study of Lone Cabbage Reef

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Increasing demand for ecological restoration in the pursuit of long-term persistence of resource benefits has resulted in the development of a "restoration economy" in the United States, which has provided opportunity for business growth associated with ecological sustainability. Nearly all the restoration monitoring and evaluation efforts focus on the ecological outcomes of restoration, although the social and economic outcomes have received far less attention. One type of economic outcome that is often overlooked includes short-term economic impacts, which measure the market activity associated with the implementation of an ecological restoration project. This paper will provide an overview of how input–output analysis can be used as a method to quantify the short-term economic impacts of ecological restoration projects. Using the Lone Cabbage Reef restoration project in Florida as a case study and IMPLAN regional economic modeling software, we found that the implementation phase of the project supported 44 full-time and part-time jobs earning $1.01 million in labor income and generated $5.08 million in total industry output, including $3.02 million in total value added within the regional economy. These findings support the notion that short-term economic impacts are an important component when evaluating ecological restoration projects and can provide stakeholders with immediate and tangible, albeit short-term results.

Key words: coastal restoration, input–output analysis, oyster restoration, restoration economy

Implications for Practice

- Short-term economic impacts of ecological restoration are tangible outcomes that can often be seen immediately and should be included in the decision-making process for restoration efforts.
- Data requirements are not extensive, and will usually only require detailed project expenditures, which are readily available during the preplanning and planning phases of restoration.
- Total economic impacts of coastal and estuarine restoration activities are not limited to the industries that were directly involved in the restoration process but are distributed across a wide variety of industries within a regional economic system.
- Short-term economic impact analysis provides a method that can evaluate certain restoration outcomes and should be used as one component of a multicriteria analysis to evaluate the overall economic outcomes of a restoration project.

Introduction

Estuarine and coastal ecosystems are expected to face exacerbated environmental perturbations and an increased likelihood of adverse human-environment interactions under the ongoing climate crisis (Scavia et al. 2002; Harley et al. 2006; Halpern et al. 2007). Recognition of the resulting or potentially forthcoming degradation, damage, or destruction has motivated significant ecological restoration efforts, such as restoring tidal wetlands, oyster reefs, or seagrasses, to ensure long-term persistence of resource benefits (NAS 2017). In the United States, these efforts support a "restoration economy," which is comprised of a variety of industries and activities involved in ecological restoration (Mohr & Metcalf 2018). Despite the growing restoration economy, nearly all the restoration, monitoring. and evaluation efforts, as well as the corresponding academic literature, focus on the ecological outcomes of restoration (NAS 2017; Browne et al. 2018; Bayraktarov et al. 2019).

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On the other hand, the social and economic outcomes associated with ecological restoration receive far less attention. The general importance of these related social and economic outcomes has fueled support for their inclusion when reporting on restoration outcomes (Worthley et al. 2013; Browne et al. 2018; Bayraktarov et al. 2019). Generally, economic studies of ecological restoration projects focus on the traditional, welfare-based economic value, which is based on the benefit to society, whether from the consumer or producer surplus perspective. In some instances, this value can only be estimated using nonmarket valuation methods. For example, many studies have described the nonmarket value of ecosystem services repaired or sustained via restoration through welfare value-based metrics.

The economic effects of restoration can also be assessed as the exchange-based value—measures of how market activity (sales, expenditures, revenue, etc.) is affected by the implementation of restoration. One common method for calculating exchange-based metrics is input–output (IO) analysis, which is used to describe the total economic activity (or value of exchanges) that results from rounds of spending (e.g. direct, indirect, and induced) associated with an ecological restoration effort. These exchange-based value assessments, such as calculations of short-term regional economic impact resulting from ecological restoration projects, are often overlooked but they remain an important consideration for local and regional decision-making.

The short-term impacts of a restoration project include the market activity associated with project implementation, which includes preplanning, planning, and construction activities. Although different restoration types involve different amounts and types of planning and construction activities, all types of restoration involve investments or capital expenditures that result in the purchase of goods and services within the local economy. For example, oyster restoration can require substrate installation, tidal wetland restoration can require sediment deposition on subsiding marshes, and seagrass restoration can require replanting efforts (NAS 2017). These activities might involve purchases from local contractors, support local jobs, and can lead to increased rounds of spending in other sectors of the regional economy (Prato & Hey 2006; Kellon & Hesselgrave 2014). Additionally, employment opportunities associated with these restoration activities can be localized and relatively well-paying (BenDor et al. 2015). Although economic impacts have been assessed for other ecosystems (Nielsen-Pincus & Mosely 2013; Kellon & Hesselgrave 2014; Hjerpe & Mottek-Lucas 2018; Newton et al. 2021), the economic impacts of coastal and estuarine restoration projects have been assessed by few studies (Kroeger 2012; Samonte et al. 2017; Knoche et al. 2020).

There has been an increased attention toward oyster restoration as global oyster reefs continue to decline on a global scale (Beck et al. 2011; Camp et al. 2015). Despite this, there is a lack of studies assessing the short-term economic impacts of oyster restoration (Bendick et al. 2018; Bloomberg 2018). Oyster restoration often requires a substantial investment in both material and labor, such as substrate material to provide reef elevation and suitable habitat (Hernandez et al. 2018). Apart from very small projects, the addition of substrate requires investment amounts typical of major construction projects, which can generate economic activity (Baggett et al. 2015; Colden et al. 2017). This can be seen in the restoration of the Lone Cabbage Reef (LCR) complex located in Levy County, Florida (Fig. 1). From June to November 2018, the historically productive LCR complex was restored through a multi-million-dollar effort that restored 22 discrete oyster reefs across nearly 5 km. These efforts create an opportunity for substantial short-term economic impacts. As such, this restoration provides an ideal case study for estimating the short-term regional economic impacts of a restoration project which can be applied to other restoration projects of varying scope and spatial scale. As restoration efforts increase around the country, so too does the need to account for the full scope of potential effects that ecological restoration activities have on the regional economy through a variety of economic approaches. Estimation of the short-term economic impacts associated with the implementation of ecological restoration should be a necessary component of a multicriteria analysis that includes ecological, economic, and social components when evaluating restoration success and determining priorities for future efforts. When more than one method is used within such a multicriteria analysis, care should be taken to ensure fidelity and consistency in measurement, comparison, and evaluation. This paper estimates the potential short-term exchange-based economic impacts associated with ecological restoration, specifically using the restoration of the LCR complex in Florida.

Methods

Data

Economic effects can extend beyond the obvious industries and to a broader geographic region. Therefore, a functional economic region must be defined for the economic analysis using the boundaries of an integrated system of socioeconomic interactions (Karlsson et al. 2009; Karlsson & Olsson 2015). Although the restoration of the LCR complex was completed entirely in Levy County, United States, products and labor were sourced throughout the surrounding counties and beyond. The North Central Florida Economic Development District (NCF-EDD) was selected as the functional economic region for this analysis (Fig. 1; NCFRP 2017). EDDs are pre-defined by the U.S. Economic Development Administration (U.S. EDA), and described as multijurisdictional entities, composed of multiple counties that help lead the locally based, regionally driven economic development planning process (EDA 2020).

The short-term economic impacts of the construction of the LCR complex were evaluated using data on the structure of the NCF-EDD economy along with project expenditure data. Regional economic data were constructed using the Impact Analysis for Planning (IMPLAN) regional economic modeling software and associated data for 2018 (IMPLAN Group, LLC 2019). IMPLAN software is a trusted source for county-level economic data that include the value of production of goods and services by industry, intermediate and final

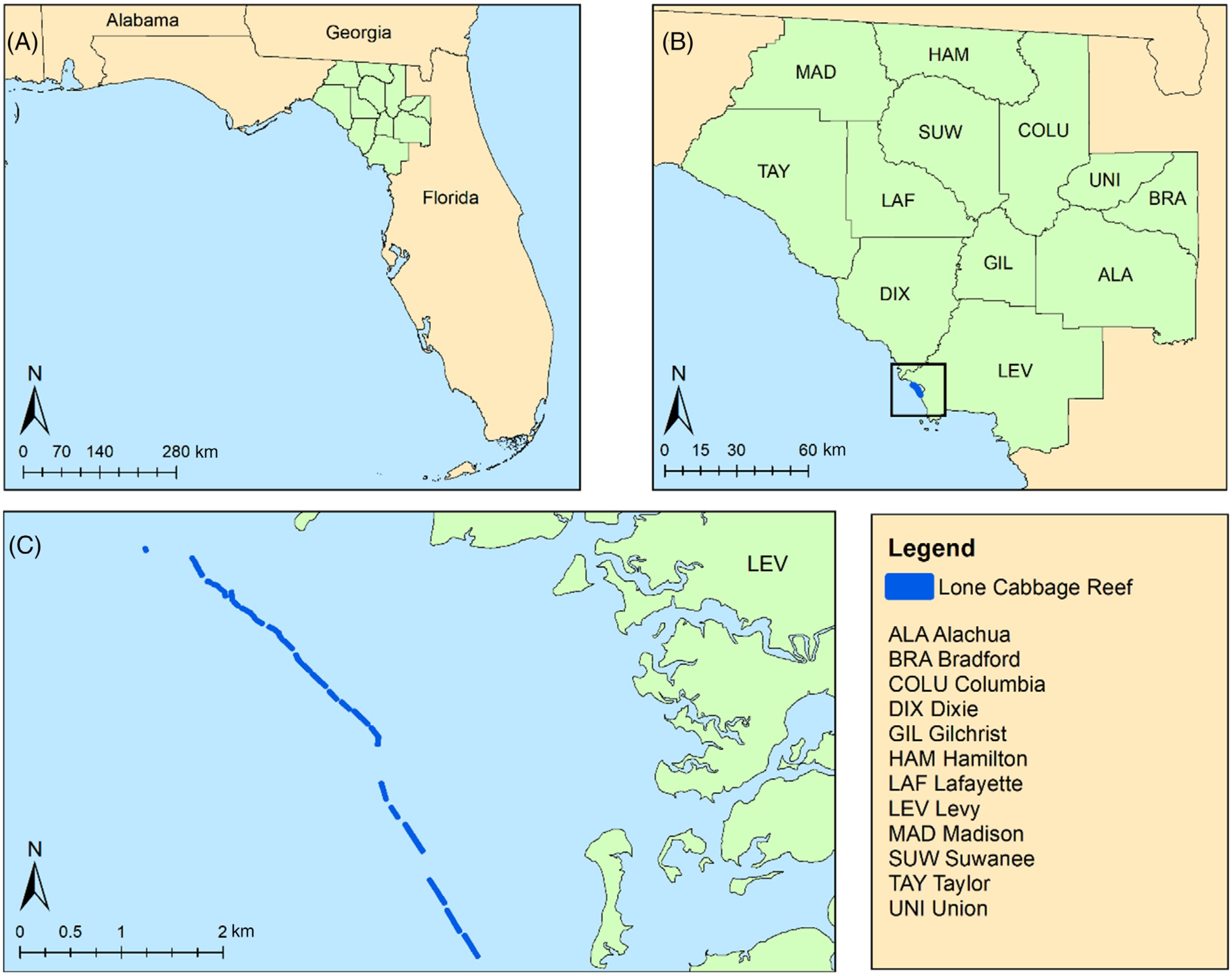

Figure 1. Location of the LCR Restoration Project and the NCF-EDD, where (A) shows the NCF-EDD in relation to the state of Florida, (B) shows each county in the NCF-EDD and the relative location of the LCR, and (C) shows a closer look at the LCR in relation to Levy County's coastline (created through ArcGIS software by Esri, M. Moreno 2021, personal communication).

consumption of these goods and services, interregional trade flows, capital investment, taxes, and transfer payments such as social security, welfare, retirement pensions, and savings by households. The data for each county within the NCF-EDD are combined to create a multiregional model that is representative of the NCF-EDD economy. This model was constructed with the IMPLAN trade flows specification and social accounts for households internalized (Type II multipliers) (Thorvaldson 2018).

Project expenditure data are itemized in Table 1. Cost items were assigned to one of three separate construction activities (preplanning, project management, and sitework) and to a specific industry sector. Industry sectors were assigned using the Northern American Industry Classification System (NAICS), which base their sector groupings on the primary product produced or serviced provided. NAICS assignments for each cost item were then assigned to the appropriate IMPLAN sector for a total of 12 sectors. The total expenditures for each IMPLAN sector define the direct economic impacts of the LCR complex restoration, which are then used to drive the economic impact analysis.

Analysis

The regional economic impacts associated with and project expenditure data for the LCR complex restoration were analyzed within the IMPLAN software (IMPLAN Group, LLC 2019). IMPLAN provides a user interface for IO analysis, which has been used by economists and regional scientists for decades, providing a transparent method for deriving the broader regional economic impacts of an event or change in economic activity through the estimation and use of economic multipliers. These multipliers describe how the broader regional economy might be affected by direct expenditures that occur

Table 1. Breakdown of IMPLAN inputs and their associated costs. Because project expenditure data reported just one value for all utility-related expenditures, IMPLAN sectors 39–49 were aggregated to form one aggregated utility sector, as opposed to allocating project expenditures to individual utility sectors (unique power generation types, water/sewage provision, and natural gas provision, etc.). Transportation and maintenance costs for this project were largely comprised of fuel expenditures. As it was determined that these expenditures were reported in purchaser prices, adjustments were made within the model to properly account for the producer price of the fuel as well as associated transportation, wholesale, and retail margins (Clouse 2020).

Activity	*Cost breakdown*	*Expenditure ($)*	*NAICS code*	*IMPLAN code*	*IMPLAN sector name*
Preplanning	PI	$51,658.42	92	5001	Employee compensation
	PI	$14,187.70	92	5001	Employee compensation
	Co-PI	$33,596.52	92	5001	Employee compensation
	Co-PI	$9,274.71	92	5001	Employee compensation
	BioScientist I	$39,615.05	92	5001	Employee compensation
	BioScientist I	$15,002.03	92	5001	Employee compensation
	Engineering services	$60,000.00	541330	457	Architectural, engineering, and related services
	Surveying services	$14,400.00	541370	457	Architectural, engineering, and related services
	Total expenditures	$237,734.43			
Project Management	Contract manager fee	$241,807.11	237990	56	Construction of other new nonresidential structures
	Bonds and insurance	$26,918.69	524126	445	Insurance agencies, brokerages, and related activities
	General liability insurance	$19,660.48	524126	445	Insurance agencies, brokerages, and related activities
	Final clean-up	$6.41	23	60	Maintenance and repair construction of nonresidential structures
	Temp utilities/facilities	$1,076.30	221112	39	Utilities
	Reproduction of documents	$252.15	323111	152	Printing
	Total expenditures	$289,721.14			
Sitework	Transport. and maint. costs/travel	$11,725.68	447110	408	Retail - Gasoline Stores
	Transport. and maint. costs/marine	$20,030.22	447110	408	Retail - Gasoline Stores
	Project manager	$34,011.82	237990	5001	Employee compensation
	Project engineer	$5,343.94	237990	5001	Employee compensation
	Project verification assistance	$5,983.02	237990	5001	Employee compensation
	Superintendent 1	$35,511.43	237990	5001	Employee compensation
	Superintendent 2	$15,817.22	237990	5001	Employee compensation
	Limestone boulders: materials and placement	$2,403,900.00	212310	28	Stone mining and quarrying
	Shell materials and placement	$363,829.27	311710	92	Seafood product preparation and packaging
	Shellfish relocation	$393,750.00	114112	17	Commercial fishing
	Aids to navigation, installation, and materials	$49,020.00	311710	92	Seafood product preparation and packaging
	Survey/maintenance of survey	$74,759.39	541370	457	Architectural, engineering, and related services
	Temp signage/MOT	$2,908.78	339950	385	Sign manufacturing
	Costs to correct elements	$50,000.00	212310	28	Stone mining and quarrying
	Total expenditures	$3,466,590.77			

in an industry. The multipliers can then be used to calculate the total economic impacts that result from the direct expenditures (i.e. multiplier effects). Readers interested in the basic tenants and mathematical derivations of IO analysis should refer to Miller and Blair (2009). Because these models are essentially static snapshots of the regional economy, they are most appropriate for analyzing marginal impacts that are unlikely to result in significant changes in prices, labor markets, or in the underlying economic structure of the region. Although we argue that the short-term impacts of ecological restoration are significant, it is unlikely that they are large enough to violate the assumptions of IO analysis.

Economic multipliers measure the total amount of economic activity within an economy that results from an initial (direct) change in economic activity. There are three components or multiplier effects that comprise the estimated total change: direct effects, indirect effects, and induced effects. Direct effects measure the value and distribution of the initial change in economic activity associated with the scenario of interest, in this case, the expenditures associated with the LCR complex restoration project. Indirect effects measure the interindustry transactions that take place through multiple rounds of supply chain spending. In our case study, indirect effects might include the purchase of input goods and services by the construction company hired for LCR complex restoration tasks. Induced effects measure the respending of employee wages paid because of both direct and indirect effects (i.e. payments spent on goods and services for their households by individual employees involved in the LCR complex restoration project as well as employees supported in indirectly impacted industries). Total economic impacts represent the total of these three effects and are measured by several metrics including employment (full-time and part-time jobs), labor income (wages, salaries, and benefits), value added (Gross Regional Product), and industry output (sales revenue). Sector-level expenditures associated with each activity within the LCR complex restoration project were entered into IMPLAN to estimate the short-term economic impacts of the project.

Results

Regional Economic Impacts

Economic impacts for each activity involved in the construction on the LCR complex are summarized in Table 2. Results suggest that the overall LCR complex project generated $5.08 million in total industry output or sales revenue within the NCF-EDD, $1.01 million in total labor income, $3.02 million in total value added or gross regional product, and generated 44 total job-years (full-time and part-time). The breakdown of these estimated total impacts for each restoration implementation activity is shown in Figure 2, which suggests that most of the activity is associated with sitework (85% of total industry output impacts). Notably, preplanning activities generated 2 job-years and $232,000 in total industry output; project management activities generated 5 job-years and $536,000 in total industry output; and sitework activities generated 37 job-years and $4.32 million in total industry output. The overall LCR complex project had an imputed output multiplier of 1.45, estimated as the ratio of total industry output impacts to direct industry output impacts, suggesting that for every $100,000 spent on the LCR complex project, an additional $45,000 of economic activity was generated throughout the NCF-EDD. Imputed multipliers estimated for each type of activity involved in the LCR complex project suggest there are larger multiplier effects for preplanning

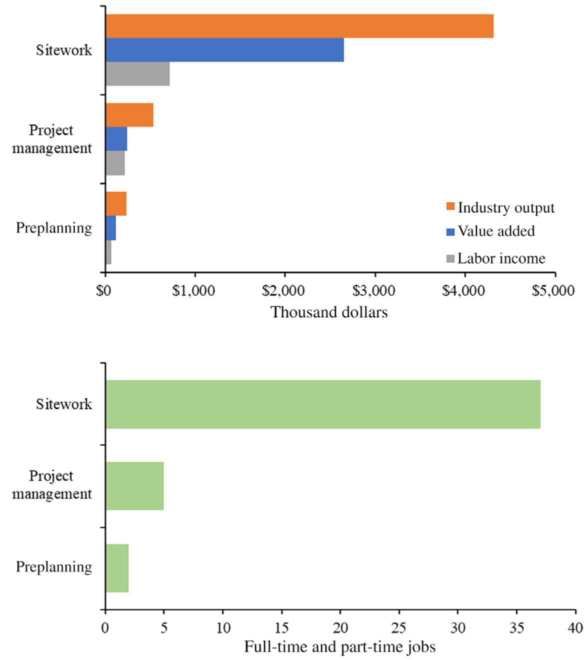

Figure 2. Total economic impacts for each construction activity during the LCR complex restoration in 2018.

Table 2. Summary of economic impacts of oyster reef construction activities, 2018. Total effects might not equal column sums due to rounding. Employment impacts are measured in jobs or total full-time and part-time positions. Dollar values are measured in thousands of 2020 dollars.

Industry activity	*Impact type*	*Employment (jobs)*	*Labor income (thousand $)*	*Value added (thousand $)*	*Industry output (thousand $)*
Preplanning	Direct effect	1	$28	$36	$78
	Indirect effect	0	$8	$12	$25
	Induced effect	1	$35	$73	$130
	Total effect	2	$71	$121	$232
Project management	Direct effect	3	$152	$123	$300
	Indirect effect	1	$32	$52	$118
	Induced effect	1	$32	$66	$118
	Total effect	5	$216	$242	$536
Sitework	Direct effect	30	$391	$2,062	$3,128
	Indirect effect	5	$206	$343	$741
	Induced effect	3	$120	$251	$447
	Total effect	37	$717	$2,656	$4,316
Total all activities	Direct effect	34	$572	$2,221	$3,506
	Indirect effect	5	$246	$407	$883
	Induced effect	5	$186	$391	$695
	Total effect	44	$1,005	$3,019	$5,084

activities (2.97) and project management activities (1.79), with slightly smaller multiplier effects for sitework activities (1.38), indicating stronger regional linkages associated with consumption-induced, service-type activities rather than resource-based or construction activities.

Economic Impacts by Industry Group

Although most of the direct expenditures associated with the LCR complex restoration took place in only a few sectors, the indirect and induced effects occur throughout the entire economy as input goods and services are purchased and employee households spend their incomes. The total economic impacts by major industry group are shown in Table 3. The largest total impacts in terms of value added occurred in the "mining" ($1.61 million) and "agriculture, forestry, fishing & hunting" ($450,000) industry groups (Fig. 3). These were primarily driven by large expenditures associated with the procurement and placement of limestone boulders and oyster relocation (Table 3). The "transportation & warehousing," "wholesale trade," and "administrative & waste services" industry groups have large indirect impacts in terms of output, because these services are purchased by both "mining" and "agriculture, forestry, fishing, & hunting" industries. Additionally, "real estate & rental," "health & social services," and "retail trade" industry groups show large induced effects in terms of output, which are typical of employee household expenditures. Total employment impacts were highest in the "agriculture, forestry, fishing & hunting" (22 job-years) industry group, which is an artifact of the low output per employee in this sector, followed by "mining" (8 job-years), "construction" (3 job-years), and "professional, scientific, and technical services" (2 job-years). Job-years supported in the latter two sectors, representing roughly 11% of the jobs supported throughout the project, have labor income per employee values that are higher than the average for the NCF-EDD, supporting the notion that employment opportunities associated with restoration implementation can be relatively well-paying (BenDor et al. 2015).

Discussion

Often, the economic benefits/effects of ecological restoration take time to materialize and can be difficult to assess in a timely manner. For example, nonmarket ecosystem service values are often measured, but these services or their recognized value might take years or more to become noticeable, if at all. Similarly, increases in harvest from spillover effects of eventual augmented harvestable populations might take a long time to materialize and are uncertain, both because populations might not recover and because if they do, harvest might need to be greatly constrained to ensure sustainability. Although the importance of the traditional economic welfare-based benefits of restoration should not be overlooked in a multicriteria analysis, exchange-based metrics can also be used to demonstrate tangible and immediate impacts of restoration projects in the short term that might be extremely important to local stakeholders. As seen with the 6-month implementation phase of the LCR complex, short-term economic impacts of restoration can be substantial. These results can be easily quantified, making them a useful component of a multicriteria analysis to evaluate the outcomes of restoration.

Table 3. Total economic impacts of the construction of the LCR complex by industry group 2018. Industries are grouped together based on the 2-digit NAICS sector codes.

Industry group	*Employment (jobs)*	*Labor income (thousand $)*	*Value added (thousand $)*	*Industry output (thousand $)*
11. Agriculture, forestry, fishing and hunting	22	$84	$450	$460
21. Mining	8	$283	$1,606	$2,645
22. Utilities	0	$4	$25	$63
23. Construction	3	$151	$124	$307
31–33. Manufacturing	0	$8	$18	$81
42. Wholesale trade	0	$22	$66	$105
44–45. Retail trade	1	$35	$61	$102
48–49. Transportation and warehousing	1	$83	$94	$199
51. Information	0	$7	$17	$42
52. Finance and insurance	1	$47	$70	$196
53. Real estate and rental	0	$9	$144	$215
54. Professional, scientific, and technical services	2	$118	$152	$311
55. Management of companies	0	$10	$12	$30
56. Administrative and waste services	1	$31	$37	$71
61. Educational services	0	$3	$3	$5
62. Health and social services	1	$58	$67	$115
71. Arts, entertainment, and recreation	0	$2	$4	$10
72. Accommodation and food services	1	$20	$32	$63
81. Other services	1	$22	$27	$42
92. Government and non-NAICs	0	$2	$6	$10
Total	44	$1,000	$2,982	$5,072

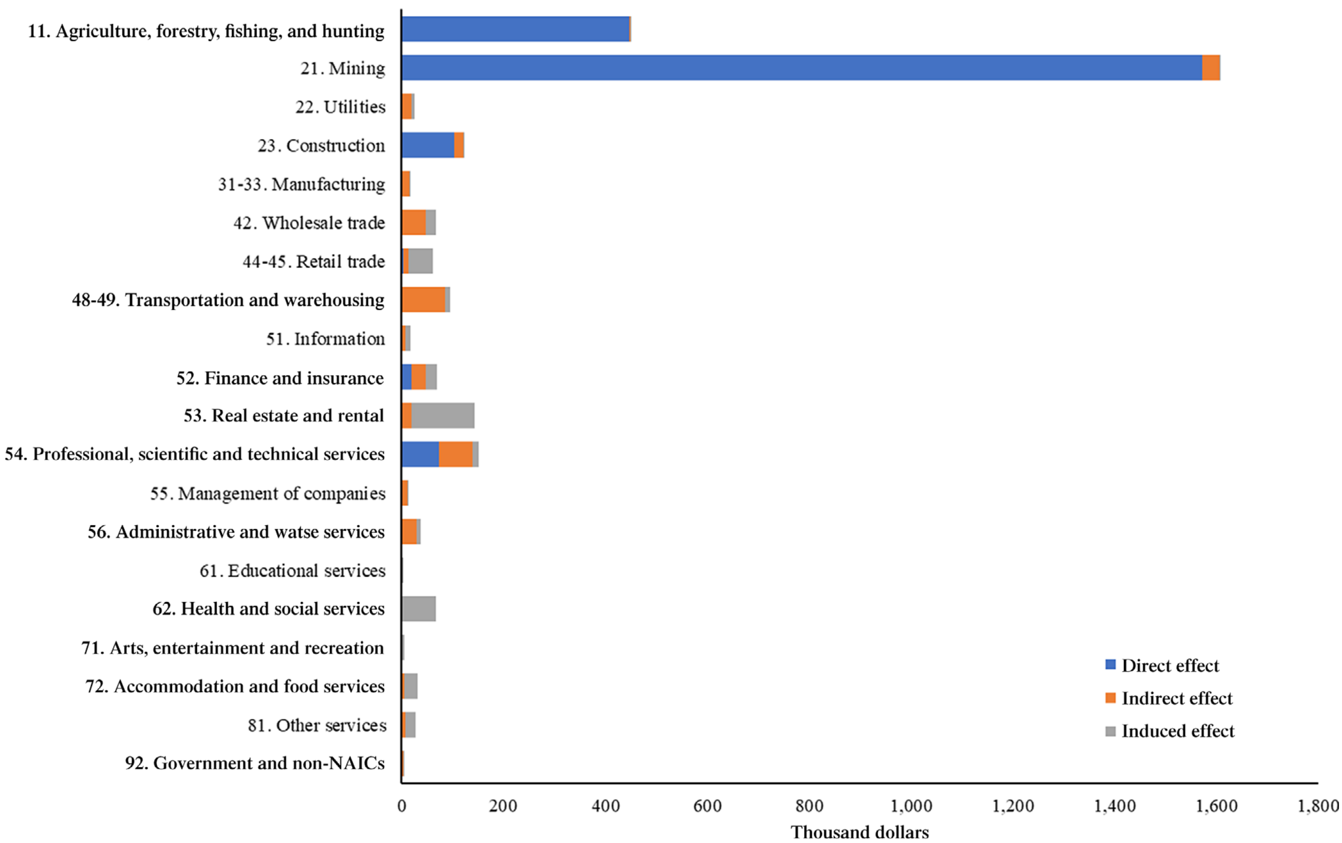

Figure 3. Value added impacts for each major industry group during the LCR complex restoration in 2018.

Assessing these short-term impacts provides further information about how a region's economy might be affected by restoration activities, aiding in management decisions. Similar to the few studies that have included the economic impacts of construction (Kroeger 2012; Kellon & Hesselgrave 2014; BenDor et al. 2015), our results find positive economic impacts in a variety of industries that arise from the direct expenditures associated with restoration implementation. In this case study, the direct expenditures were distributed across 12 sectors, but impacts were experienced in nearly 300 additional sectors. Although many of these additional sectors experienced only minor changes in activity levels, the distribution of impacts provides useful insights into the scope of economic impacts. The scale and distribution of indirect and induced impacts are largely a factor of the economic structure of the local region (i.e. industry size and interdependence) and will vary by region. Thus, although scenario- and region-specific data will differ, IO-based economic impact analysis is a useful tool that is generalizable across restoration types and geography. This method can provide insights on the size and scope of broader economic impacts that can occur beyond those directly associated with restoration implementation efforts. While direct effects occur wholly within the restoration project implementation period, the multiple rounds of spending associated with indirect and induced effects can occur over a more prolonged period and potentially support regional economic activity beyond the restoration project timeline; however, the mathematical derivation of multiplier effects ensures that larger effects occur in earlier rounds of spending (Miller & Blair 2009). These impacts are overlooked when an analysis of the short-term economic impacts is not conducted either prior to or after the implementation of a restoration project. This type of additional information could also garner public and political support for restoration projects.

Such an analysis can also provide an opportunity to evaluate alternative approaches for restoration. A variety of construction approaches can be used in restoration activities, which can lead to different impacts depending on the type of material and labor used, as well as their source. Evaluating short-term economic tradeoffs as one component of a multicriteria analysis would provide a valuable decision-support tool in the planning stage of restoration projects. For example, a restoration project's budget for construction might not include the exact materials used, where they are sourced, how they will be deployed, or who will be hired. Different decisions can be analyzed with an economic impact analysis approach to calculate which alternative might have the largest and most widespread short-term, regional economic impact. Although the case study presented does not provide an explicit comparison of the possible outcomes based on alternative investments, such analyses are possible and could be particularly useful on projects with the potential for using different approaches.

Quantification of the short-term economic impacts is perfectly situated to complement estimations of welfare- or exchanged-based measures of longer-term economic activity generated by restoration and other sociological and human dimensions studies to better understand stakeholders. Additionally, restoration efforts have been shown to be tied to stakeholder perceptions, in which stakeholders' attitudes and understanding of ecological restoration can affect decision-making (Gamborg et al. 2019). Seafood workers might not always support restoration activities, especially if the activities are believed to reduce harvesting (Paolisso & Dery 2010; Camp et al. 2015). It is possible that purposeful involvement of local beneficiaries, accompanied by actual accounting of the short-term economic impact, as was done here, might be used to reduce conflict and even build the social capacity necessary for restoration (Pretty & Smith 2004; Aronson et al. 2006). This would be quite compatible with the broader understanding that local participation in resource management and governance can foster a sense of stewardship and compliance among primary stakeholders (Walker et al. 2002; Arlinghaus et al. 2017). However, there was no assessment of how stakeholder perceptions changed following the restoration of the LCR complex, so these changes are unknown in this study.

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