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# Trade: A Driver of Present and Future Ecosystems

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## Abstract

Growing trade among nations is globalizing economies and driving environmental change. As a consequence, trade affects ecosystems, but trade is not currently a major topic in ecosystem research based on a survey of ecological journals. This survey reveals trade is rarely a title word or topic except for studies considering the movement of species or sustainability. However, when trade is considered at large scales, ecosystem mass balances are significantly influenced by traded products such as the nitrogen and phosphorus in fertilizers and livestock feeds. Trade also depletes resource species leading to ecosystem alterations such as the elimination of large predators and filter feeders in aquatic ecosystems and landscape conversion with attendant changes in biogeochemistry and biodiversity in terrestrial ecosystems. Trade is a source of alien species introductions. Trade also creates telecouplings among distant locations that cause changes in ecosystems including changes that may affect whether an ecosystem is a source or sink in relation to atmospheric carbon dioxide. There is a need for improved data tracing traded products, understanding the linkages of trade between ecosystem sources and sinks, and developing new methods and models to analyze trade impacts. Studies of trade impacts in relation to questions about changing ecological processes and the trajectory of ecosystems represent an important frontier.

**Key words:** trade; ecosystems; mass balance; alien species; telecoupling; resource depletion.

## Introduction

The consequences of global environmental change are a central theme of contemporary ecosystem science. These global changes are the result of anthropogenic drivers such as climate change, species introductions, extinctions, pollution, habitat loss, eutrophication, and shifts in biogeochemical cycling. These drivers are critical to present and future ecosystem states and their services (Millennium Ecosystem Assessment 2005). Trade is not commonly included in the list of key drivers but has impacts on ecosystems and often interacts with other drivers. For example, trade is a vector for alien species introductions (Hulme 2009). Furthermore, perceptions of future food and resource limitation are causing transformations of contemporary ecosystems to produce products for trade. Corporations and nations seeking to gain production capacity are acquiring land, obtaining water rights, and purchasing fishing access often from poor communities and nations (Gagern and van den Bergh 2013; Rulli and others 2013; Davis and others 2014).

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We define trade as the exchange of products that are (1) produced by ecosystems such as food, (2) mined and extracted resources such as fossil fuels, and (3) manufactured goods and services. Trade is increasingly global in scope with ever greater exchanges among nations. The annual trade of cereals, seafood, and forestry products have all increased from 1960 to 2012 (Figure 1). As an example, cereal trade has approximately doubled over the last 35 years. This growth is a consequence of increased production as well as increased trade among nations (Dalin and others 2012; Gephart and Pace 2015).

There are many benefits to trade. Ecosystem services that can be monetized (for example, fish catch or timber production) are often traded increasing their value. Although these commodities can be over-exploited, economic and other societal interests can also align to sustain production of ecosystem services and promote effective management (Birkes and Folke 1998). Trade may reduce environmental impacts by increasing the efficiency of resource use (Yang and others 2006). Trade may also stimulate economic growth increasing wealth and spending on environmental protection (Vernberg and others 2009). However, because of widening scope and intensification, trade is a key driver of environmental change that affects ecosystems now and the impacts of globalized trade are likely to increase in the future (World Trade Organization 2013).

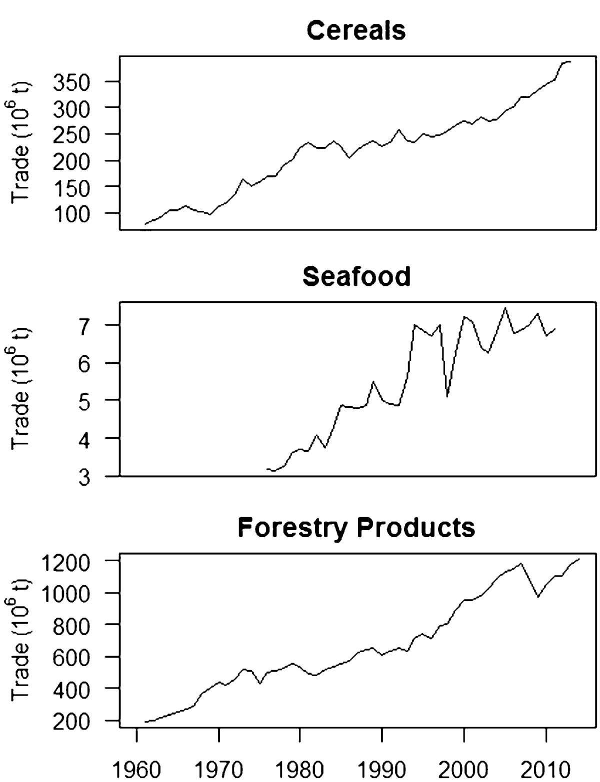


**Fig. 1.** Global annual trade of cereals, seafood, and forestry products from 1961 to 2014 in millions of metric tons. Trade data are plotted for available years in FAOSTAT (2014) and UN Comtrade (2010).

This paper considers the interaction of trade and ecosystems. We first explore how often trade is a topic in ecological journals. We then focus on the effects of four aspects of trade that influence ecosystems including alteration of mass balances, depletion of natural resources, introduction of alien species, and the creation of telecouplings. We also suggest research needs for better studying trade in relation to ecosystem science. We contend trade is an important direct and indirect driver of ecosystem dynamics and deserves increased attention in ecosystem science.

## Trade as a Subject in Ecological Journals

To what extent is trade currently considered in ecosystem research? Using the Web of Science (WOS), we searched for the word ''trade'' in titles, abstracts, and keywords in ecological journal articles over the last ten years (2006–2015). Ecologists frequently use ''trade off'' in a context unrelated to the trade of goods and services so we eliminated that term and its variants (for example, ''trade-offs''). We chose ecological journals (including *Ecosystems*) that covered the spectrum of the discipline and were among those with the highest impact factors. Seven of the 20 journals we surveyed had papers with trade in the title (Table 1). More articles within the journals used trade in the form of a WOS ''topic'' (that is, either in the title, abstract, or key words). Eight journals had no mention of trade in either title or topic. *Ecosystems* had one study that explicitly considered trade.

The three journals with the greatest use of the term trade were *Molecular Ecology*, *Ecology and Society*, and *Frontiers in Ecology and the Environment*. Because genetic and other biomarker chemicals can be used to track species, numerous papers in *Molecular Ecology* consider species in relation to pet trade, aquarium trade, nursery trade, and other similar activities. Many of these papers document the movement, spread, and sources of species but they do not typically address ecosystem impacts of traded species. Papers in *Ecology and Society* as well as *Frontiers in Ecology and the Environment* were more varied addressing topics ranging from wildlife harvest and trade to the sustainability of social-

**Table 1.** Use of ''Trade'' in the Title of Articles or as a ''Topic'' in Ecological Journals Based on Searches of the Web of Science (WOS) for the Years 2006 through 2015

| Journal | Title | Topic |
|---|---|---|
| Annual Reviews of Ecology Evolution and Systematics[1] | 0 | 1 |
| Ecology | 0 | 2 |
| Ecology and Society | 7 | 25 |
| Ecology Letters | 2 | 5 |
| Ecological Applications | 3 | 13 |
| Ecological Monographs | 0 | 0 |
| Ecosphere | 0 | 3 |
| Ecosystems | 1 | 1 |
| Frontiers in Ecology and the Environment[2] | 4 | 20 |
| Functional Ecology | 0 | 0 |
| Global Change Biology | 2 | 4 |
| Global Ecology and Biogeography | 0 | 0 |
| Journal of Animal Ecology | 0 | 0 |
| Journal of Ecology | 0 | 0 |
| Landscape Ecology | 0 | 1 |
| Microbial Ecology | 0 | 3 |
| Molecular Ecology | 8 | 46 |
| Oecologia | 0 | 0 |
| Oikos | 0 | 0 |
| Trends in Ecology and Evolution | 0 | 0 |

*In WOS, ''topic'' includes the use of ''trade'' in the title, abstract, or keywords. The term ''trade off'' and its variants were excluded from the search.*
*[1]Also searched Annual Reviews of Ecology and Systematics.*
*[2]Excluded news, letters, and editorial matters.*

ecological systems. Across journals few of the articles we identified were directly related to the interactions of trade and ecosystems.

## Trade Alters Mass Balance

One of the hallmark concepts used to organize ecosystem studies is mass balance. For small ecosystems like most lakes, fields, or watersheds, trade often has little consequence for mass balance questions, but as the size of ecosystems under study increases the effects of trade are harder to ignore. Consider the inputs of ''new'' nitrogen to major river watersheds on the eastern coast of the United States. New nitrogen refers to inputs from outside the watershed including biological fixation of nitrogen. Boyer and others (2002) categorized the dominant nitrogen inputs as atmospheric deposition, fixation in forests, fixation in agricultural lands, fertilizer inputs, and food for humans plus feed for animals. The last two categories, fertilizer and food plus feed, are traded commodities that are mainly imported to these watersheds. The contribution of these two categories to total new nitrogen varies, but ranges from a low of 12 % for the Saco River watershed to a high of 67% for the Charles River with an average across all watersheds of 35%

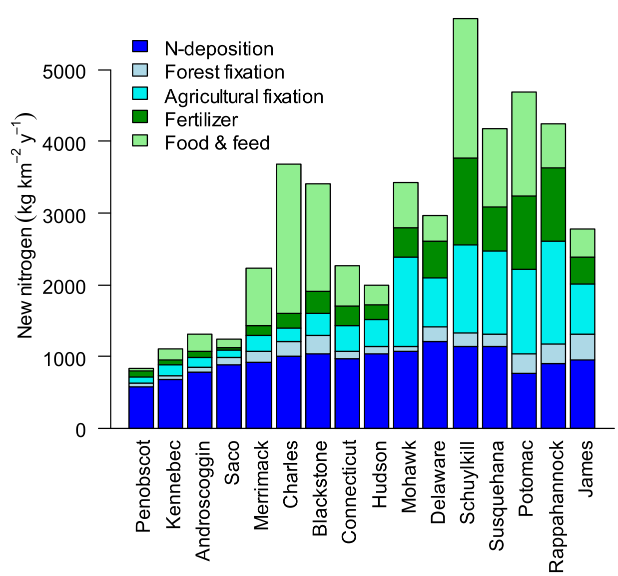


**Fig. 2.** Inputs of new nitrogen to watersheds of 16 eastern U.S. rivers. Traded commodities are fertilizer and food plus feed. Plot based on data in Boyer and others (2002).

(Figure 2). The nitrogen budgets of these systems are strongly influenced by traded goods. Further much of the variability in nitrogen inputs is related to the variability in the traded nitrogen (Figure 2) reflecting variability in agriculture and urbanization among these watersheds (Boyer and others 2002).

Although trade has benefits as noted above, analyses of regional and global mass balance indicate trade can change ecosystem stocks and flows over large scales with consequent environmental degradation. Schipanski and Bennett (2012)—the single paper identified in *Ecosystems* in our search of trade—illustrate this point with their analysis of phosphorus (P) and trade. P-inputs to agricultural systems include fertilizers and manure (recycled from livestock), while P-losses are exports of crops and livestock plus erosion. Based on agricultural production and consumption, some countries are net importers and others net exporters of phosphorus (Schipanski and Bennett 2012). Exporters that fertilize risk increased accumulation of phosphorus in soils with the possibility of increased loss of P to inland and coastal waters. Exporters that do not fertilize risk decline of soil fertility as phosphorus taken up by plants is removed in agricultural products and lost from the system. Importers do not bear the phosphorus risks associated with production (for example, phosphorus accumulation in soils), but importers release embodied phosphorus contained in traded products to the environment. Schipanski and Bennett (2012) conclude that agricultural trade is disrupting the global phosphorus cycle—concentrating phosphorus additions in fertilized agricultural soils causing accumulations in a subset of nations while causing phosphorus losses elsewhere. Trade should improve the efficiency of resource utilization, which in this example, are the resources supporting agricultural production. However, the costs of environmental degradation associated with phosphorus are not accounted for and have differential impacts around the world (Schipanski and Bennett 2012).

As in the examples above, nitrogen and phosphorus from fertilizers are the elements most commonly identified as disrupting mass balances. Does trade also impact other mass balances? This may occur for both uncommon and common elements. Rare earth metals such as lithium are used in batteries for many products and create waste both at mining sites as well as after disposal. These fluxes of lithium are typically evaluated as pollution (Wong and others 2007; Wanger 2011) and poorly documented in terms of mass balance. Water balances are also affected by trade where water intensive agricultural products are produced in one area and consumed elsewhere (that is, virtual water) which may improve large-scale water efficiency but risk local water scarcity (Lenzen and others 2013; Martinez-Melendez and Bennett 2016). For more common elements such as carbon, mass balances are indirectly affected by trade through processes like land-use change (for example, deforestation and eutrophication) as we discuss further below.

## Trade Depletes Resources Derived from Ecosystems

Humans alter ecosystems by depleting resources and transforming land. While this occurs due to local pressures, international trade loosens feedbacks between users and the environment and can shift or intensify resource depletion. Both direct removal of species and products from ecosystems and clearing or converting habitats to produce market goods connect trade to ecosystem impacts.

Sea cucumber harvest provides an example of how international trade proliferates and promotes resource depletion. Sea cucumbers are marine benthic invertebrates used as food and supplied to seafood markets in China. The exploitation of these animals has rapidly expanded geographically, and they are now sourced from an estimated 90% of the world's tropical shorelines (Ericksson and others 2015). The expansion of sea cucumber sources is not related to distance from the primary market (Hong Kong) or capacity for governance of fisheries. Instead, sources of sea cucumber have expanded contagiously facilitated by global connectivity related to improvements in shipping, communication, and technology as well as the presence of Chinese communities in many areas around the world (Ericksson and others 2015). Previously, fisheries and forestry have provided examples of serial depletion where a resource is exploited to low levels in one area, followed by depletion in a second area, and so-on. However, the sea cucumber example is more like parallel depletion where exploitation ramps up rapidly in new areas nearly simultaneously.

There may be effects on shallow marine ecosystems of sea cucumber harvest, because these animals influence calcium cycling and other biogeochemical processes through deposit feeding (Ericksson and others 2015). There are examples from other fisheries, agricultural expansion, and forestry of substantial ecosystem consequences from resource exploitation. Selective fishing changes the balance of predators and prey, while overall reductions in fish biomass reduce available resources for marine birds and mammals (Hilborn and Hilborn 2012). The ecosystem impacts of selective fishing are apparent in coral reefs where suppressed herbivore populations allow algae to dominate the reefs and in kelp systems where removing predators allows sea urchin populations to dominate the ecosystem (Estes and others 2011). Other cases are more complex, with resource use serving as one of several drivers of ecosystem change. For example, oyster catches were reduced to a few percent of peak values after mechanical harvesting of oysters was introduced in the Chesapeake Bay in the 1870s (Jackson and others 2001). Without oysters filtering the water column every few days, nutrient runoff led to eutrophication. The resulting hypoxia, along with continued dredging, and increases in parasites and disease have limited recovery of oyster reefs and the Chesapeake Bay ecosystem (Jackson and others 2001).

Whereas the globalization of seafood trade impacts many marine ecosystems, terrestrial ecosystems have been heavily impacted by increasing trade of food and timber. Agriculture is a proximate driver estimated to account for 80% of global deforestation, and agricultural exports are a primary driver of deforestation across the tropics (Kissinger and others 2012; De Fries and others 2010; Rudel and others 2009). Notably, a surge in Brazilian deforestation from 2002 to 2004 has been attributed to a combination of increased cattle exports and increased soybean production for the European Union and Chinese markets (Nepstad and others 2006). In other areas, trade of forest products accelerated harvests and intensified the removal of tress by clearcutting. For example, commercial timber extraction and logging accounts for more than 70% of forest degradation in Latin America and subtropical Asia (Kissinger and others 2012). The resulting impacts of deforestation and degradation on ecosystems are dramatic, altering biogeochemistry, hydrology, fire regime, and species composition (Foley and others 2005; Davidson and others 2012).

Overall, international trade can drive resource use in order to meet demand and higher price opportunities on the global market or through leakage, whereby resource harvesting restrictions in one geographic region lead to increased resource use elsewhere. International trade can also enable overexploitation of resources when there are weak feedbacks between global market actors and local ecosystems (Crona and others 2015). There is an obvious need to transition trade-based systems from depletion of resources to sustainable removal. Some markets sectors have sustainable management along with certification systems such as those for wood from forests (Rametsteineer and Simula 2003), but sustainable production systems represent a relatively low portion of international trade. Further, analysis of production systems must take into account losses and costs of the entire production cycle. For example, in the case of wood products, the carbon emissions associated with wood such as transportation, milling, and utilization need to be considered (Gower 2003).

## Trade Introduces Alien Species

Although trade depletes resource species, it also transports and introduces new species. Both directly traded alien species (for example, wildlife, pets, nursery plants) that escape as well as ''hitchhiking'' species accompanying traded commodities are important sources of invaders. The number of alien species and the patterns in their distributions are related to trade. For example, the current distributions of naturalized plants (=successful invaders) in countries are predictable from models using the value of bilateral trade (Seebens and others 2015). Furthermore, based on future projections countries with emerging economies are likely to experience the greatest increase in naturalized plants according to modeled links between trade and invasions (Seebens and others 2015). In other words, there is an ''invasion debt'' associated with trade. Diseases are also introduced by trade particularly via the transport of vectors (for example, mosquitoes) harboring pathogens novel to the recipient region (Tatem and others 2006; Kilpatrick 2011). Risks of invasion can be assessed though knowledge of potentially invasive species and by evaluating attributes of trade such as volume and patterns of connectivity (Hulme 2009).

Because of the prominence of alien species introduction as well as shifts in species associated with climate change, novel biological communities are developing globally. It has long been hypothesized that positive interactions among alien species may increase their abundance and impacts on ecosystems—a phenomenon dubbed invasional meltdown (Simberloff and Von Holle 1999). Recent reviews of interactions among pairs of invaders indicate that interactions are mainly neutral or negative (Kuebbing and Nunez 2015; Jackson 2015), whereas the cumulative impacts of invaders on ecosystems are antagonistic (Jackson 2015). Thus, although there are examples of facilitation, multiple invaders do not tend to act synergistically. However, because of trade, invasions are increasing in ecosystems where the history of alien introductions is documented, as for example in the Laurentian Great Lakes (Ricciardi 2006). Hence, ongoing, new, and possibly increased impacts are likely as are a few synergistic interactions. Although the ecosystem impacts of some alien species are understood, the duration of these effects as well as their changes over time is poorly known (Strayer and others 2006). One well-documented example indicates some invader impacts are persistent, whereas others change through time. The zebra mussel (*Dreissena polymorpha*) invaded the Hudson River of New York State (USA) and rapidly reduced phytoplankton productivity and biomass (Caraco and others 1997). This shift has endured for over two decades (Strayer and others 2014). Other effects like declines in zooplankton, certain benthic groups, and fish have moderated (Pace and others 2010; Strayer and others 2014).

Like many other invasions, the entry of zebra mussels into North America was an indirect consequence of trade resulting from the release of shipping ballast water. Could a better understanding of trade and its environmental consequences along with appropriate policy have forestalled this invasion? This type of question brings trade, species ecology, ecosystem science, and management together and remains a topic of continuing research emphasis.

## Trade Creates Telecouplings

As used in atmospheric science, teleconnections are linkages over a large distance that are related to climate anomalies. For example, variations in the North Atlantic Oscillation, a large-scale atmospheric pressure pattern influences climate in eastern North America and western and central Europe far from the oceanic locations where the atmospheric conditions occur (Wanner and others 2001). These climatic teleconnections are an important topic in ecosystem research and there are many examples of how teleconnections influence ecological dynamics (Stenseth and others 2003). A similar concept arises in considering distant interactions among social-environmental systems. These are referred to as telecouplings as defined by Liu and others (2013). These authors also articulated a framework for considering telecoupling which consists of sending systems, receiving systems, and spillover systems that are connected by flows. Within each of these systems, there are causes and effects that are influenced by agents. A key feature of this conceptual framework for telecouplings is the recognition of feedbacks, information flow, and other linkages. Like teleconnections, ecosystems are affected by telecouplings to and/or from distant locations. These effects in some cases spill over to other distant systems.

Trade is a potent force in creating telecouplings via the movements of products that link distant ecosystems. One example is the effect of trade on land-use change. Kastner and others (2015) document a large increase in the net trade balance of human appropriated net primary production from Latin America to the European Union (EU) over the period 1987–2007. Human appropriated net primary production is the total human use of net primary production in the form of products like food, paper, wood, and fiber derived for a given area (for example, country, region, globe) (Imhoff and others 2004). This transfer of production in the form of traded products has caused changes in forest and agricultural land cover. For example, in Brazil, deforestation has occurred and agricultural land has increased. In France, agricultural land has been abandoned and converted back to forest (Meyfroidt and others 2010). Following the scheme of Liu and others (2013), Brazil is the sending system, whereas France (or the EU) is the receiving system, and flows are in traded commodities (Figure 3). One effect of this telecoupling is that European forests are an increasing carbon sink (Naudt and others 2016), but this may occur at the cost of a loss of carbon storage in places such as Brazil. Trade couples these land-use changes, although it is important to recognize that this coupling is layered on other trends such a long-term recovery and management of forests for ecosystem services and economic goods in the EU (Naudt and others 2016). There are other effects of this example of telecoupling between Brazil and the EU including changes in fertilizer applications and movements of invasive species as discussed above. Spillover effects from telecouplings may also include the spread of disease.

Although trade is a flow that creates telecoupling between distant ecosystems, trade may also drive other types of telecouplings. Grasshopper swarms (that is, locusts) damage crops and pastures over vast areas affecting food security in many regions. In northern China, overgrazing of grasslands changes nitrogen cycling and promotes outbreaks of the Mongolian locust, *Oedaleus asiaticus* (Cease and others 2016). These outbreaks are a telecoupling with locusts as the ecological agent. During outbreaks, locust spread over large areas of land (over thousands of square kilometers according to news reports). Production for markets and associated trade drives the overgrazing, and shifts in

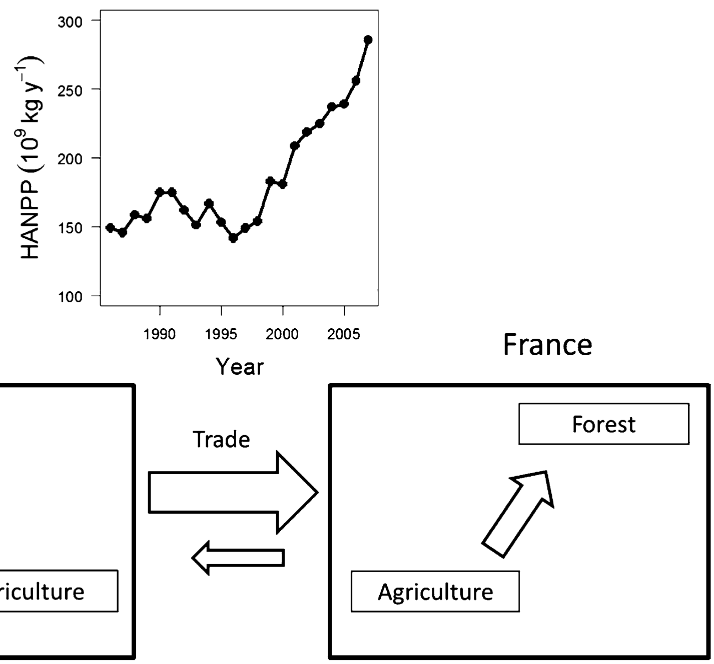


**Fig. 3.** Telecoupling of Latin America/Brazil with Europe/France. Latin America exports of human appropriated net primary production (HANPP) to Europe (graph) were stable from 1986 to 1998 but increased rapidly thereafter (plotted from data provided by Kastner and others 2015). This change has caused a shift in land use from forest to agriculture in Brazil, whereas in France agricultural land has changed to forest. These shifts are driven by trade in agricultural products and have consequences for ecosystems and carbon sinks.

nitrogen cycling lead to altered locust dynamics. Whether there are feedbacks between market prices and decisions farmers make about selling livestock in the presence or absence of locust outbreaks is not known (Cease and others 2016), but represents an intriguing problem for future study.

Although the impacts of trade on an ecosystem or ecosystem service may be apparent, linking these changes to distant systems and processes may not be apparent. Furthermore, the causes, effects, and the agents that mediate interactions are dynamic and, as in the case of locusts, may be external to the market. Further, market mechanisms such as commodity derivatives, which often take the form of future agreements to pay for a quantity of a commodity at specified price, may promote telecoupling because price shifts and volatility may drive changes in crop production (Galaz and others 2015). Hence, telecouplings are a likely source of surprise and may become more common in a world of globalized and shifting trade as well complex financial markets (Galaz and others 2015). Future studies in ecosystem science need to move beyond identifying external drivers such as trade and incorporate the potential of multi-causality and feedback interactions represented in the telecoupling framework (Liu and others 2013). This framework is one way to integrate the study of ecosystems within research on the dynamics, resilience, and sustainability of social-ecological systems.

## Needs

We suggest three needs for the study of trade-ecosystem interactions. First, there should be a greater emphasis on the study of trade as a driver and as a feedback process in relation to ecosystems, including ecosystem services, biogeochemical cycling, productivity, and temporal dynamics. Second, there is a need for better data tracing trade among and within countries to identify potential effects on ecosystems. Third, methods and models are needed for incorporating trade information and analyzing trade in relation to ecosystem research. Meeting these needs will require new approaches, but there are examples that indicate fruitful directions.

Emphasis on trade in ecosystem science is already occurring particularly in research on ecosystem services (for example, Koellner 2011). Trade-offs in uses of ecosystems for service production, the impacts of importers and exporters on ecosystems, methods of payment for ecosystem services, and governance of ecosystem services are among the many active topics (Rodríguez and others 2006; Carpenter and others 2009; Farley and Costanza 2010). Martinez-Melendez and Bennett (2016) provide an example in determining that agricultural trade between the United States and Mexico reduces the environmental impact of food production. These authors also identified additional reductions in land, fertilizer, and water use that could occur if production with subsequent trade shifted to the most efficient country for a given crop (Martinez-Melendez and Bennett 2016). Beyond ecosystem services, we contend that inclusion of trade must be a more routine part of ecosystem science as reflected, for example, in ecological journals such as the ones we surveyed for Table 1. This will require considering trade in studies of mass balance, biogeochemical cycling, energy flow, food web interactions, and other topics. As the scale at which ecosystem studies are conducted is expanding to larger and larger areas, the need to consider trade is of growing significance, because trade will likely be a key factor determining the status and trends of ecosystems in the future.

Global trade data are available for various commodities through sources like the United Nations Comtrade database and for food from the Food and Agriculture Organization's FAOSTAT (Comtrade 2010; FAO 2014). Most analyses of the interaction of global trade with the environment rely on these data. Volumes and flows of trade are tracked by a coding system called the Harmonized System (HS) administered by the World Customs Organization. The specificity of this coding is limited as pointed out for wildlife trade by Chan and others (2015). Of the $2.8 billion of animal (excluding fisheries) trade in 2012, 68% was not taxonomically classified, 25% was designated at the class level, and the remaining at the order or family level. Fisheries labeling is more developed but only 10% of the 2012 trade was tracked at the species level. The lack of resolution makes it difficult to determine species level impacts of trade in the case of endangered wildlife and fisheries. Chan and others (2015) argue that the HS system could be improved by more specific labeling which would be relatively easy to implement at least in developed countries with well-organized customs authorities. More accurate assessment of trade is critical for better resolution of interactions and potential telecouplings. In this context, trade data within countries are also needed to better evaluate local and regional ecosystems. There are few such trade monitoring systems in place.

Flows of traded goods are typically depicted for nations and global regions. These can be analyzed using network approaches as we have recently used for global seafood trade (Gephart and Pace 2015). Network analysis allows evaluation of many aspects of structure, temporal change, trade dependence, and inequalities. Further, network models can be analyzed for vulnerability to shocks (Gephart and others 2016) and other changes (Dalin and others 2012; D'Odorico and others 2012; Carr and others 2013). These analyses identify patterns and dynamics that may be useful for ecosystem studies, but because networks are most often resolved at the national level, there is a gap between the scale of most ecosystem studies and the scale of trade information. Economic models, including computable general equilibrium, input-output, and multimarket models, can be used to connect resource use in distant locations and project changes in trade patterns under future scenarios. For example, the Global Trade Analysis Project (GTAP) is a computable general equilibrium model which has been used to estimate the market-mediated greenhouse gas and land-use changes associated with biofuel production in the US (Hertel and others 2010). The GTAP database has also been used with an input–output model to estimate the flows of virtual carbon implicit in domestic production (Atkinson and others 2011). Additionally, the International Food Policy Research Institute's International Model for Policy Analysis of Agricultural Commodities and Trade is a multimarket model linked to modules to incorporate climate, water resources, and land use (Robinson and others 2015). Extensions of such models provide opportunities to connect international trade to ecosystem impacts.

## Conclusions

Globalizing trade is a sentinel feature of the human activity that is transforming the planet. While the proximate impacts such as species invasions are considered, trade is often treated as external to ecosystem science. Nonetheless, analyses are emerging especially at the global scale that document how the distributions of species and biogeochemical cycles are related to trade. Understanding differences among current ecosystems, and importantly, the trajectory of future ecosystems will benefit from the integration of trade studies into ecosystem research.

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