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Mapping the global distribution of locally-generated marine ecosystem services: The case of the West and Central Pacific Ocean tuna fisheries

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ABSTRACT

Ecosystem service (ES) maps are instrumental for the assessment and communication of the costs and benefits of human-nature interactions. Yet, despite the increased understanding that we live a globalized tele-coupled world where such interactions extend globally, ES maps are usually place-based and fail to depict the global flows of locally produced ES. We aim to shift the way ES maps are developed by bringing global value chains into ES assessments. We propose and apply a conceptual framework that integrates ES provision principles, with value chain analysis and human well-being assessment methods, while considering the spatial dimension of these components in ES mapping. We apply this framework to the case of seafood provision from purse seine tuna fishery in the Western and Central Pacific Ocean. The ES maps produced demonstrate the flow of a marine ES to a series of global beneficiaries via different trade and mobility pathways. We identify three types of flows – one to one, closed loop and open loop. We emphasize the need to consider a series of intermediate beneficiaries in ES mapping despite the lack of data. We highlight the need for a shift in ES mapping, to better include global commodity flows, across spatial scales.

1. Introduction

We live in the era of globalization, on a planet in which distances and boundaries are increasingly irrelevant, and mobility and trade facilitate connections among different parts of the world. These connections support a growing demand for the flow of goods and services around the globe. Within this global system of flows, a local or regional-scale natural resource can become a global commodity whose benefits are widely distributed (Challies, 2008; Grilly et al., 2015; Nelson et al., 2009). This local to global flow has an impact on the way natural resources are managed by local, national and global decision-makers although the effects of this multiplicity of scales are rarely taken into account.

Oceans are systems in which such local to global flows comprise a dynamic, complex adaptive social-ecological system (Liu et al., 2013), shaped through trade, maritime mobility (Österblom and Folke, 2015; United Nations, 2016) and a series of natural processes (e.g., migration of fish species or carbon sequestration by coastal vegetation). Within such a telecoupled system (Liu et al., 2013) socioeconomic and environmental interactions occur over large distances and across scales. Actions taken by humans locally impact an ecosystem's state and associated human well-being (Drakou et al., 2017a), but also other social-ecological systems that connect with this system either through mobility and trade (in the case of provisioning and cultural ecosystem services (ES)) or through a series of natural processes and biogeochemical cycles (in the case of regulating ES). For instance for cultural ES, the deterioration on water quality of a pristine beach will impact the ecological state of adjacent areas, the quality of life of people living nearby, but also the number of tourists arriving from distant locations to enjoy this beach. For regulating ES, the reduction in mangrove cover in the coastline e.g., of Indonesia, will impact the climate regulation capacity of these in a larger than the country scale, with impacts to the global population.

Seafood provided by marine social-ecological systems is one of the most prominent examples of such flows. Seafood contributes significantly to the global food supply, constituting almost 20% of the average per capita intake of animal protein for more than 3.1 billion people, and representing one of the most-traded segments of the world food sector (Smith et al., 2010). Particularly in Small Island Developing States (SIDS) and coastal states, seafood provides critical societal benefits which help reduce poverty and support the local and regional economy – for example providing 50–90% of animal protein for coastal

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communities in many Pacific Island countries and territories (Bell et al., 2018; Merino et al., 2011). For these states, such marine resources are considered a source of economic growth, in some cases in the form of fishing licences paid by foreign fleet operators. A number of efforts (e.g., Erisman et al., 2017) have focused on measuring the size of the economic benefits provided by services such as seafood that are generated from ocean ecosystems, defined here as marine ecosystem services (ES). However the attribution of these benefits, notably between residents of coastal and island states controlling access to the resources and foreign beneficiaries consuming the end products remains under debate (Micheli et al., 2014).

Several management measures have been introduced in recent years to tackle issues arising from these global flows of locally-produced marine ES and particularly on how benefits are shared among local, regional and global beneficiaries. At the global level for example, in October 2014 the United Nations launched the Nagoya Protocol on Access and Benefit Sharing (ABS), to safeguard a fair and equitable access to genetic and natural resources, and attribute ownership rights to societally vulnerable population groups of the developing world (United Nations, 2010). In October 2015, the Sustainable Development Goals (SDGs) for 2030 were adopted by the United Nations General Assembly (United Nations, 2016) focusing on the sustainable use of the oceans and the ES they provide (SDG14), while at the same time raising the need to address the equitable distribution of these services, in order to help end poverty (SDG1) and hunger (SDG2). At a more regional level, the Nauru Agreement concerning the Cooperation in the Management of Fisheries of Common Interest is an example of a cross-country cooperation to manage tuna fisheries. The Agreement was signed in 1982 by eight countries that collectively control access to some 25–30% of the world's tuna supply and approximately 60% of the tuna supplied from the Western and Central Pacific ocean (WCPO). As these examples illustrate, managing marine social-ecological systems and the ES they provide requires a coordination of all these different policy objectives, across multiple spatial scales.

There are a number of emerging ES methods and concepts can be used to address such different policy objectives simultaneously in the shared space of the marine social-ecological systems, across a range of scales (Drakou et al., 2017a). Although to date most marine ES assessments mainly inform rather than influence or shape decision-making (Drakou et al., 2017a; Ruckelshaus et al., 2015), mapping of marine ES has proved to be a powerful tool which facilitates the sharing of scientific evidence to inform policy decision-making (e.g., Liquete et al., 2016). However, most cases of ES mapping focus on aggregate supply or total benefits, and rarely emphasize ES flow and the distribution of benefits across different spatial scales (Drakou et al., 2017b). Proxies and indicators are often used to quantify the total benefits generated by marine ES from a given area, such as total fish landings or total employment in the case of the seafood provision ES (Liquete et al., 2013). Rodríguez-Garcia and Villasante, (2016) are among the few that used Value Chain Analysis (VCA) methods to account for the flow or distribution of benefits from marine ecosystems in addition to the total benefits, but to our knowledge such methods have never been incorporated in ES mapping.

Our work aims to highlight the need to adopt a global view on the way we map, quantify and assess the benefits generated by marine ES at the local or regional level. To achieve this, we develop and apply a conceptual framework for mapping the size and distribution of benefit flows generated by marine ES, which integrates the principles of VCA and ES mapping. We map the flow of marine ES benefits along a global food commodity chain, using the case of purse seine tuna fishery of the West and Central Pacific Ocean (WCPO) region. The ultimate goal of integrating these two analytical methods is to improve the quality of information given in maps of marine ES, while highlighting the differences in spatial scale and extent among the ES supply, flows and benefits. By quantifying and mapping the size and distribution of marine ES with this method, we aim to emphasize on the difference in the quality of information that can be used for sustainable management of marine ecosystems, enhancing the supply chains they support and their impacts on human well-being.

2. Methodological approach and concepts applied

ES mapping and modeling has been widely used in the last two decades to measure not only the potential and actual size of the benefits provided by ecosystems to society, but also their flow and distribution (Balmford et al., 2008; de Groot et al., 2010; Schirpke et al., 2014). The spatial representation of ES through maps facilitates the way we share information about ES to support planning and decision-making. In many cases, what is represented in traditional ES maps is relatively static and largely focused on mapping ES at the case study level (Egoh et al., 2012), which is not always suitable for marine social-ecological systems. Efforts to date to simultaneously assess and map ES provision, flow and demand, were mostly applied to account for spatial mismatches of ES supply and demand in specific locations (Zhao and Sander, 2015), typically at local or sub-national levels. The ES beneficiaries are usually taken into account for the quantification, modelling and economic valuation of ES, and their role has been explicitly addressed in several studies (Bagstad et al., 2014; Rodríguez-Garcia and Villasante, 2016). However, the different ES dimensions of supply, flow, demand and benefit are usually assessed and mapped separately, and are rarely found in one single map. As a result, many analyses have only provided a partial visualization of the spatial extent of an ES supply chain, and hence the distribution of the benefits.

Efforts to address this gap in understanding the distribution of benefits from ES have accelerated recently. A newly introduced framework was proposed by Drakou et al. (2017b) to improve the way we map ES whose benefits are captured in different locations from the geographic area where they were generated. This framework integrates the basic principles of ES mapping with Value Chain Analysis (VCA) methods. VCA has been widely used in economics, energy and social sciences to capture and analyze the way benefits are distributed along supply chains from the source or point of provision to the point of use or consumption (Mitchell, 2012). Typically a VCA deconstructs the stages that a product follows from the very beginning of its production to its final sale, and even beyond. Some analyses include suppliers or distributers of the product, especially where there are critically important linkages between the various organizations in the chain. The value added in each step of the chain is assessed, from production until final consumption. VCA was initially used to study international trade in the context of a political economy framework, applied to the field of business management as a decision support tool (Porter, 1985). VCA has become increasingly popular and has been applied to various domains from transportation to telecommunications, within the fields of economics, industry, market, information technology (Bolwig et al., 2010; Ketchen et al., 2008; Singer and Donoso, 2008; Swoboda et al., 2008).

The integrated framework proposed by Drakou et al. (2017b) accounts for the spatial distribution of ES flow from the point of harvest to the end beneficiaries. To our knowledge, these two approaches have not been integrated before to add a spatial dimension to value chains, and to show the spatial distribution of the benefits generated through an ES provision chain. The potential of global supply chains based on agricultural food commodities to contribute simultaneously to the objectives of both poverty reduction and food security has been widely studied over the years, and the role of global supply chains based on food commodities generated from marine ecosystems (often located in the jurisdiction of developing countries) has been highlighted as well (Barr and Mourato, 2009).

To better assess nature's contribution to human well-being, Daw et al. (2016) developed a framework that analyzes how this relationship affects ecosystem resilience and elasticity to changes. In that framework the links between ES and well-being are explicitly addressed, and the